FLOODING IN AUSTRALIA - PERSPECTIVES AND PROSPECTS

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1. INTRODUCTION

Australia ranks as both the driest inhabited continent and the continent with the greatest variability of rainfall and runoff. It is sunburnt agricultural country in which flood and drought are recurring themes. In the vast flat interior plains floods can inundate areas in excess of 100,000 km². However, the dominant focus, and that of this account, is upon urban flooding which effects all of the state capitals, all of which are located on coastal estuaries, and many of the smaller rural centres.

The Commonwealth of Australia is a federation of eight states and territories. Constitutionally the states are responsible for water resources and legislation and approaches to floodplain management vary throughout the nation. However, the federal (Commonwealth) government has, for many years, exercised an influence over policy. This takes several forms. The provision of federal funding, on a shared basis for agreed schemes, for a variety of flood studies and mitigation projects is a long established practice. The Bureau of Meteorology, federally funded, is the responsible body for the provision of flood forecasts on major rivers. In addition, disaster relief payments have been administered under the Natural Disaster Relief Arrangements (NDRA) since the late 1950's. The NDRA comprise formally agreed joint funding between the federal and state governments. Finally, the State Emergency Services are partly funded from federal sources and the Natural Disaster Organization (NDO) is a federal body designed to oversee any natural disaster that is of national significance, eg the destruction of Darwin by Cyclone Tracey in 1975. It is also the agency which coordinates Australian assistance to overseas disasters, especially those in the Pacific region.

Often, in reviewing the roles of federal and state governments, the significance of local government authorities (LGA's) is omitted. Notwithstanding federal and state funding, legislation and guidelines, what happens at community level depends heavily on the attitudes of local government. There are some 800 LGA's in Australia with populations varying from less than five hundred to in excess of a million. The importance of LGA's also applied to many of the major cities where many of the planning powers are vested with local councils. For example the Sydney conurbation has some 30 LGA's.

In attempting a national account of flooding it is inappropriate to describe the detailed differences between states and territories. Despite the diversity of governmental arrangements and the vast areal extent of the country it is possible to distinguish overall national trends. This account attempts to outline topics in which Australia experience may be of value to flood managers from other countries.

2. THE PHYSICAL BACKGROUND

Australians have long subscribed to the view that the continent has a variability of rainfall and runoff that is greater than that for other continental landmasses.

Researchers at the University of Melbourne have built up rainfall and runoff data bases for Australia and for the rest of the world. These are described in Finlayson et al (1986). The results of the analysis of the data sets are that Australian variability is, in fact, greater than comparable regions elsewhere. The only exception is South Africa. The variability exists regardless of overall similarity of climatic type. As an example, a comparison of climatic influences and variability between southeastern Australia and southeastern USA is presented in Kuhnel et al (1990).

Mean annual flood discharge is strongly correlated with area and is remarkably similar for all continents. However, if the variability of flood behaviour is assessed, Australia and South Africa are distinctly different to all other regions. The variability is not only very much greater but, especially for Australia, increases with size of catchment. This is in complete contrast to the pattern for other continents. For large catchments (in excess of 10^6 km^2) the coefficient of variation for peak flows is four times greater than in north America or Europe.

The aberrant pattern for Australia (and South African) is also apparent when the q_{100} value (the discharge from the 1 in 100 year flood) is compared to that of $\overline{q}$ (the mean annual flood). For Australia the ratio of q_{100} to $\overline{q}$ for large basins ($10.^6$ km^2) is about 7.5 while for north America and Europe the ratio is close to 2.5. Thus, the discharge for rarer floods from large catchments in Australia is, compared to other regions, significantly greater than the mean annual flood. Details of the methods of analysis and results are presented in Finlayson and McMahon (1988).

For parts of Australia the length of the rivers and the flatness of the central regions of the continent lead to extremely long travel times for flood waves. For example, floods that are generated in the Darling River in Queensland can take several weeks to reach riverine settlements sited on the lower parts of the Murray/Darling system. As the overall climate is semi-arid this makes it possible to give extremely long warning times for downstream communities. Indeed, for some small towns tenders are placed in the local newspapers for bids to use sandbags to custom-build the levees to the forecast flood stage. This apparent advantage is countered by the length of time for the flood peaks to pass. Individual farms can be isolated for periods of several weeks. It is not unknown for such downstream localities to be eligible for both drought and flood disaster relief payments at the same time.

In terms of overall flood policy and expenditure it is floods in urban areas, with relatively short lead times, that are of major concern. Approximately two thirds of the total Australian population is located in coastal settlements along the eastern and southern coasts from central Queensland to the west of Melbourne. All of these communities are at risk from flooding although in any given town only a small proportion of the population is located on flood liable land. The basic physical problem is that all of these coastal settlements are to the east or south of the Great Dividing Range. This is located relatively close to the coast and the time between rainfall and flood is relatively short. The lag is typically less than 12 hours and for minor catchments within the floodprone metropolitan areas of Brisbane, Sydney and Melbourne it can be less than 1 hour.

It is this concentration of population in coastal settlements that historically, at present and for the future provides the impetus for floodplain management in Australia. A problem exacerbated by the occurrence of tropical cyclones for the more northerly parts of this elongate concentration of population.

The Bureau of Meteorology is not only responsible for the national floodwarning system but also provides the official statistics for all aspects of climate. In the mid-1980's (Aust Bureau of Meteorology, 1985) it revised the estimates for probable maximum precipitation (PMP). The review was based upon the methodology used by agencies in the USA and recommended by the World Meteorological Organization. The outcome was that for most parts of Australia, certainly the populous coastal areas, there was an increase in the PMP and thereby in the probable maximum flood (PMF). This has had significant implications for flood studies. Currently concern is dominantly with the safety of hazardous dams but it is equally important for rare floods under natural conditions.

It would be remiss to omit mention of *Australian Rainfall and Runoff* (Institution of Engineers, Australia, 1987) This is the basic reference for the design of hydrological structures. A comparison of the current edition with its forerunners provides an excellent example of the progressive adaptation of design to the unusual features of Australian rainfall and runoff rather than uncritical acceptance of overseas studies.

GOVERNMENT AND GENERAL ORDERS

GOVERNMENT HOUSE, SYDNEY, WEDNESDAY, 5th MARCH, 1817

CIVIL DEPARTMENT

The GOVERNOR's official Communications from the Interior within the last few Days have excited in HIS EXCELLENCY's Mind the most sincere Concern and Regret for the recent Calamities in which the unfortunate Settlers on the Banks of the Nepean and Hawkesbury have been once more involved, by the late dreadful Inundations of those Rivers.

WHILST is does not fall within the Reach of human Foresight or Precaution to be able to guard effectually against the baneful Recurrence of such awful Visitations, or to avoid being more or less involved therein, yet when the too fatal Experience of Years has shown the Sufferers the inevitable Consequences of their wilful and wayward Habit of placing their Residences and Stock-yards within the Reach of the Floods (as if putting at Defiance that impetuous Element which it is not for Man to contend with); and whilst it must still be had in Remembrance that many of the deplorable Losses which have been sustained within the last few Years at least, might have been in great Measure averted, had the Settlers paid due Consideration to their own Interests, and to the frequent Admonitions they had received, by removing their Residences from within the Flood Marks to the TOWNSHIPS assigned for them on the HIGHLANDS, it must be confessed that the Compassion excited by their Misfortunes mingles with Sentiments of Astonishment and Surprise that any People can be found so totally insensible to their true Interests, as the Settlers have in this Instance themselves.

HIS EXCELLENCY, however, still cherishes the Hope that the Calamities which have befallen the Settlers will produce at least the good Effect of stimulating them to the highly expedient and indispensable Measure of proceeding to establish their FUTURE RESIDENCES in the TOWNSHIPS allotted for the Preservation of themselves, their Families, and heir Property, and that they will, one and all, adopt the firm Resolution of forthwith erecting their habitations on the High Lands, cheered with the animating Hope and fair Prospect of retrieving, at no very distant Day, their late Losses, and securing themselves from their further Recurrence.

THESE ORDERS are to be read during the Time of DIVINE SERVICE at each of the CHURCHES and CHAPELS throughout the Colony, on the three next ensuing SUNDAYS.

"LACHLAN MACQUARIE"

BY COMMAND OF HIS EXCELLENCY,

JOHN THOMAS CAMPBELL, SECRETARY

Figure 1 Governor Macquarie's proclamation of 1817.

3. THE HISTORY OF FLOOD ADAPTATION

Aboriginal habitation in the continent extends back for at least 100,000 years. However, for the European colonists, who first arrived in 1788 it was terra nova. None of the accumulated flood experience of the native peoples was utilised by the new culture. A completely new settlement pattern was superimposed without any understanding of the nature and variability of the climate. In order to take advantage of water transport the original settlements were frequently sited on creeks and estuaries. Indeed expansion of settlement inland was delayed to the physical barrier posed by the Great Dividing Range. Strangely, for a nation dependant on primary products the Australian population has, since First Settlement, been highly urbanised. This legacy of inappropriately sited coastal communities has been the curse of Australian floodplain management.

Within 25 years of the founding of the colony of New South Wales massive floods inundated the farms and settlements of the Hawkesbury River, now a western suburb of Sydney. Lives, crops and homes were lost. This led to Governor Macquarie, in 1810, moving five new townships to flood-free high ground. After further floods the same Governor issued a proclamation that can be regarded as the state's first policy for flood liable land. It is reproduced here as Figure 1. The Hawkesbury Valley is still a recurring theme of media and political conflict discussing the need for improved floodplain management.

Major calamities to the towns of Gundagai (with the loss of 89 lives out of a population of 250 in 1852), Nowra and Moama (in the 1870's) caused these towns to be moved to adjacent flood-free sites. The subsequent history of flood hazard in Australia is similar to that for comparable nations. Little of substance was accomplished until post-World War II.

Political and management response were reactive to major disasters. Major floods in the late 1940's and 1950's provided the impetus for the beginnings of present policy. For example, Maitland was very badly damaged in 1955. This it should be noted, was one of the townships relocated by Governor Macquarie but his new town site remains as a heritage monument overlooking the expanded city of Maitland surrounded by a complex and largely ineffective system of levees. This first phase of modern floodplain management was dominated by the construction of structural works dominantly funded by federal and state governments.

Any lingering complacency on the flood risk ceased in 1974. This was a 'disaster' year with widespread flooding in January that inundation vast areas of eastern Australia with severe flooding in Brisbane. The year ended with the devastation of Darwin, on Christmas Day 1974, from tropical cyclone Tracey.

The events of the mid-1970's prompted widespread reviews of flooding, particularly for the communities that suffered most. Major studies were undertaken for Brisbane (Cities Commission, 1975) and Lismore (Smith et al, 1979). Prompted by federal government, reviews were undertaken of all capital cities. Adelaide was found to have a severe flood threat, flood maps were produced and mitigation measures undertaken (SMEC, 1980). This was noteworthy in that the study and measures were *not* prompted by a flood disaster.

4. FLOOD MAPS, STANDARDS, RISKS AND DAMAGES

Prior to the studies of the late 1970's there were no good quality maps of floodplain risk for urban areas in Australia. A key response was to produce such maps in order to define the size and nature of the problem. The responses of the states and territories differed. NSW introduced an extensive mapping program, with the published maps freely available to the public. In Queensland excellent maps were produced for the Brisbane region but few for other parts of the state. Victoria incorporated assessment of risk into community based flood plans, the situation for Adelaide is described above. These programs were encouraged, and partly funded, by federal government. However, it is important to note that there were no specific national program or standards for map production.

The maps, with very few exceptions, employed the 1 in 100 year flood as the standard (or design) flood. This decision is now seen to be have been a mistake. Flood range is site specific and the increases in depth and velocity with major floods varies from place to place. The situation is illustrated in Figure 2. For case A, the 1 in 100 year standard is sensible but for case B it is not. The extra depth of inundation for rare floods in Case B poses very real problems for safety. This is because the combinations of depth and velocity can cause widespread building failure. The hydrological data necessary to produce the 1 in 100 year flood maps should have been extended to provide additional information for more extreme events.

By 1982 NSW government agencies had produced high quality flood maps for some 80 flood liable urban communities within the state. However as the mapping moved into the suburbs of Sydney opposition became more strident. Unfortunately this coincided with a state election and the floodplain mapping program was abandoned and the existing maps withdrawn, an account is given in Handmer (1985). The leaflet shown in Figure 3 indicates the level of the debate. Despite the election hype there were substantial reasons for a change of policy although not for the withdrawal of the maps. The original mapping and floodplain management regulations were superimposed upon local government who were responsible for local planning.

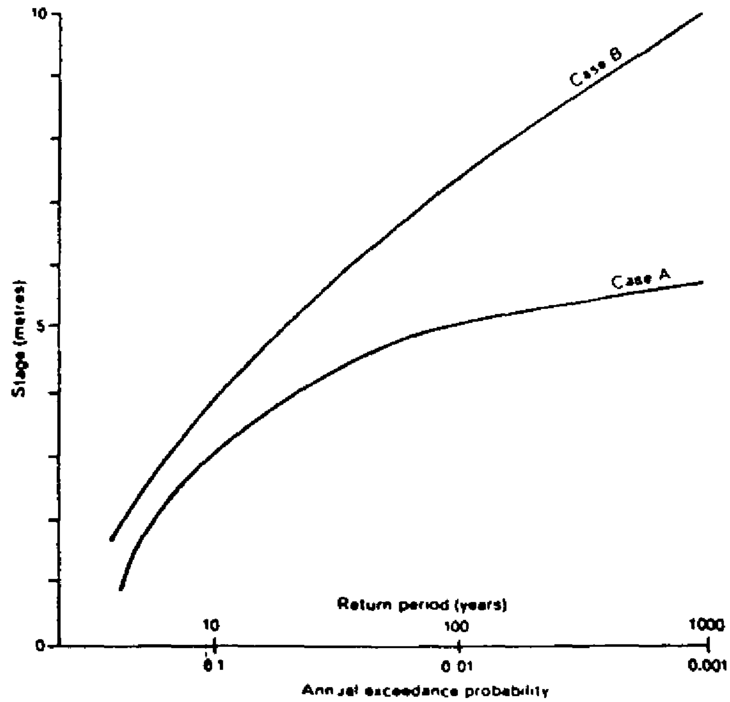

Figure 2 Increase in flood depth with varity of flood.

HAS YOUR HOME BEEN FLOODED IN THE LAST 100 YEARS?

As a result of Labor Government policy introduced last year, your home may be declared "flood prone" if the Government thinks it may be subject to flooding once in every hundred years.

In areas affected by the "one-in-a-hundred-year" flood policy, development will be severely restricted and property values will pluminet with serious impact on insurance and finance.

A LIBERAL GOVERNMENT WILL:

- Abolish the concept of the one-in-a-hundred-year flood
- Enable you to sell your home at full value.

  A Liberal Government will limit the definition of flood prone lands to actual flood channels (derived on the basis of a flood once every 20 years), and progressively acquire such land at full market values.
- Allow local councils to approve extensions to homes in these areas.
- Begin effective flood mitigation works to reduce the flood risk to all properties.

A vote for Nick Greiner on March 24 will stop Labor's Flood Prone Lands Policy washing the value of your home down the drain.

NSW LIBERALS

LET'S CLEAN UP N.S.W.

Authorised by S.G. Litchfield, The Liberal Party of Australia, N.S.W. Division 234 George Street, Sydney 2000. Printed by Dashing Printing, 6 Bridge Street Sydney

By 1984 a new Flood Prone Land Policy was established. The philosophy changed from a (state) prescriptive to a (local) merit approach. The overall floodplain management systems is shown diagrammatically in Figure 4. Each flood prone council is required to produce a Floodplain Management Plan which, when complete, is approved by the Minister. An initial step in this process is to decide upon the 'flood standard'. Once agreed this is used with the state's Floodplain Development Manual (NSW Govt, 1986) to produce local plans which include regulations for zoning. Despite the objections to the original flood maps virtually all councils have selected the 1 in 100 year as the flood standard. Overall the merit approach has improved floodplain management and removed much of the conflict between state and local government. The quality of the new mapping has been greatly improved but there is little doubt that the availability of the maps to the community and the emergency services has been reduced.

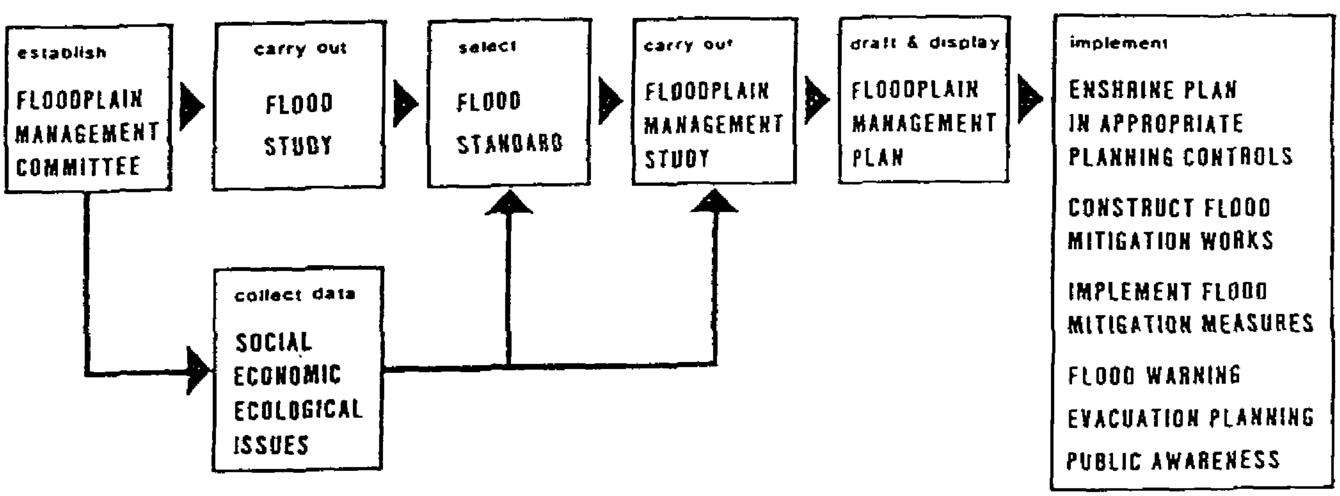

Figure 4 The NSW floodplain management system (NSW Govt., 1985).

What is the Urban Flood Risk?

The magnitude and location of urban flood risk is basic to any form of comprehensive management. How do we define such risks? These deceptively simple questions are difficult to answer. The problems can be described as:

- Definition of flood prone
- Number of properties
- Damage estimates
- Safety.

Definition of Flood prone. As discussed above, the widely accepted design flood is that for the 1 in 100 year event. Normally some form of flood map is available that shows this limit. However, only in the last two or three years has any serious consideration been given to estimating the level of rarer floods. By their very nature the necessary hydrological calculations are more difficult. The paucity of information for these rarer floods has seriously affected the overall estimation of all other forms of flood risk.

Further, the definition of the 1 in 100 year flood only applies to 'mainstream' inundation. That is for rivers and creeks that are suitable for analysis by established hydrological techniques. 'Urban flooding' due to surcharge from urban drainage systems presents an additional flood problem. Historically, such systems are designed to meet the 10% or 20% annual frequency of exceedance - limits commonly used in Europe or north America. The current concern is that damages from urban drainage surcharge are thought to be substantial. Contributing reasons are:

i the inappropriateness of adopting overseas standards for design levels in Australia

ii increasing urbanisation which increases flood runoff,

iii the temporary blocking of urban channels in larger floods due to debris (cars, trees etc).

The areas at risk to the level of the 1 in 100 year flood are relatively well known but information for rarer floods and for urban surcharge are essentially unknown.

Number of Properties. In urban areas damage, potential or actual, is dominantly concerned with losses to buildings and their contents. Estimates of the numbers of such buildings has been widely used to indicate the size of the urban flood problem.

The first serious attempt to define the extent of urban flooding in Australia was by Devin and Purcell (1983). They recognised 285 urban areas subject to mainstream flooding within Australia, a total of 61,000 individual buildings at risk from mainstream flooding up to the level of the 1 in 100 year event. No attempt was made to distinguish between residential and commercial/industrial buildings. These figures have been subject to subsequent revision. Smith (1986) revised the estimates, on the same basis, for NSW and suggested that the number of buildings for that state was close to 50,000.

The numbers of properties at risk between the 1 in 100 year and the probable maximum flood remains largely unknown. Recent estimates for three catchments in Sydney, subject to mainstream flooding, indicate that there are 3261 residential properties within the 1 in 100 year limit and a further 7402 between the 1 in 100 year and probable maximum flood. Data for Queanbeyan, a small regional centre, are 448 and 1505. These numbers are not thought to be atypical but comparable detailed estimates are not available. The total number of properties in NSW located between the 1 in 100 year and probable maximum flood are guesstimated to be 100,000 (NSW Govt, 1989). The figures for Sydney are from Smith et al (1990) and for Queanbeyan from Smith (1990).

The paucity of information is worse for urban drainage surcharge flooding. A recent government review (NSW Govt, 1989) states, '...it has been estimated that 100,000 properties in NSW are potentially subject to flooding from urban surcharge, although there has been no comprehensive investigation of the extent or severity of local drainage problems for the State'. The situation would be no different elsewhere in Australia

So despite large expenditure on urban flood studies our understanding of the extent of the risk is limited.

Damages. The study by Devin and Purcell (1983) used their information on numbers of properties to estimate average annual damages at the national scale. The value was $19m at 1983 prices. There is no doubt that this is a gross underestimate, in part because no attempt was made to assess commercial and industrial losses (see Smith and Handmer, 1984). Subsequent detailed analysis for NSW (Smith, 1986) estimated the average annual potential tangible damages to be some $38m but closer to $15m if allowance was made for measures to reduce losses during the actual flood, ie moving or lifting of contents. These estimates are only for floods up to the 1 in 100 year level.

Information on similar losses that take into account floods up to the probable maximum flood is sparse. For the three Sydney catchments such estimates total some $16m. This contrasts to about $8m for the AAD restricted to the level of the 1 in 100 year flood. It is of interest to note that for Sydney some 90% of the PMF losses are to the commercial and industrial sectors. Similar results were obtained for Queanbeyan, ie over half the AAD losses were contributed from floods that exceeded the 1 in 100 year level.

The damage estimates for Sydney and Queanbeyan make allowance for the collapse of building structures at the more extreme floods. The criteria for collapse are based on the combinations of depth and velocity proposed by Black (1975). Although his work was undertaken in the USA the building types are similar to those in Australia. The literature on flood damage has been slow to include the extra losses posed by building failure.

Official estimates of flood damage, as opposed to imprecise media accounts, are relatively few. NSW estimates that flood damage in the four years, 1986-1989, exceeded $100m. This figure includes both mainstream and urban surcharge flooding. In terms of event damage the official estimates suggest that PMF events for urban drainage would be some $2,000m and for mainstream flooding $50,000m.

Since the late 1970's detailed flood studies have been undertaken for a large proportion of the urban areas subject to mainstream flooding up to the 1 in 100 year level. Many of these studies use the ANUFLOOD computer program (Smith and Greenaway, 1988). This interactive package uses a data base that includes information on every individual building at risk and assesses damage by assigning building types to specific stage damage curves. In addition to its use to estimate flood damage it can also be employed to provide preliminary estimates for a range of mitigation options. It also provides a detailed data base which can be of value to the emergency services.

Safety. Flood risk can also be defined in terms of safety to the communities at risk. Depth and velocity are the key components. The starting point is a map showing flood limits although the ability of the public to convert such information into details on flood depth is extremely limited.

When an ANUFLOOD data base is available this can provide information for emergency services. The property data can be used in conjunction with flood height forecasts to provide real time output although, to date , this has not been used operationally. An alternative is to make available look-up tables with a print out of road names and numbers listed against depths of overfloor (or overground) flood depth. Where velocity figures are available ANUFLOOD can also indicate buildings that at risk from collapse. For the Queanbeyan example 1422, out of 1953, residential buildings would likely collapse for a PMF event. For the commercial sector the corresponding numbers are 343 collapse out of a total of 381.

Although the limits of safety, in terms of velocity and depth, have been known for some years it is still unusual for the velocities of flood discharge over the floodplain to be available. It is even more unusual for the emergency services to have this information in a usable form.

5. FLOODWARNINGS AND EFFECTIVENESS

In Australia and elsewhere there is a substantial legacy of established flood prone communities in areas of known flood risk. Only in exceptional cases can we expect such buildings to be removed or completely floodproofed. The need for the best possible floodwarning systems is undisputed. Unfortunately the history of the provision of such systems in Australia was, until the last few years, very poor. Basically the problem was jurisdictional, due to disputes over the funding roles of federal and state governments. The outcome was that the installation of floodwarning hardware was retarded. The detail of the development of floodwarnings in Australia is given in Smith and Handmer (1986).

These difficulties are now largely resolved and there is an upsurge in interest in modern floodwarning technology and floodwarning systems. In the current economic climate the installation of such systems requires analysis of their cost-effectiveness. The costs of installation and maintenance balanced against the likely additional savings in damage averted. This would appear to be a field of research that is relatively well developed in Australia. Detailed accounts are given in Smith (1986 and 1990).

In outline, the effectiveness of floodwarning systems arises from the provision of more reliable forecasts with longer warning times. The key questions are how does such information decrease tangible and intangible losses?

In terms of tangible damage the capacity of individuals to respond is a function of warning time and prior flood experience. To analyse the response it is necessary to have estimates of both potential and actual direct damage. 'Potential' relates to the loss of contents of buildings (residential and commercial) that would occur if no action was taken to remove or lift items. It is a worst case scenario. Information of this kind is sparse. Estimates of actual and potential damage for residential and commercial properties were first published for Lismore, in northern NSW (Smith, 1981). To assess the cost-effectiveness of floodwarning systems data are required on the ratio of actual to potential losses for differing lengths of warning time and for different levels of community experience. Diagrammatic representations of these effects are given in Figure 5. In a simplistic way these can be used to assess the likely increase in savings (changes in the ratio of actual to potential losses) due to the increase in warning time. They also indicate that if education could replace experience that the savings would be even greater! The problem with this approach is the difficulty of estimating the proportion of the community that would take advantage of the increased warning period.

The opportunity was taken to use the Sydney floods of August 1986 to gather additional information on this subject. Insurance loss adjustors were employed to survey 71 flooded households to ascertain the potential and the actual losses to contents (and thereby the damage averted) together with details of prior flood experience. An account this work is presented in Smith et al (1990).

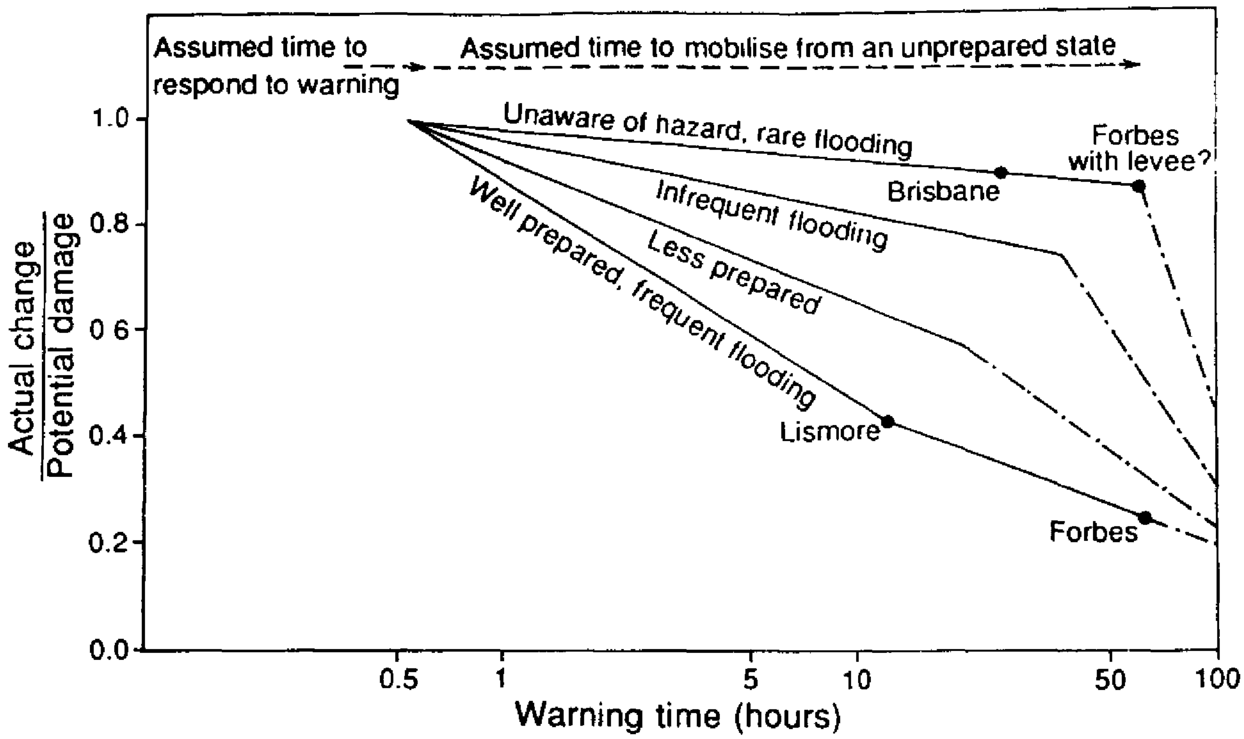

Figure 5 Relationship of direct damage to warning time and flood experience.

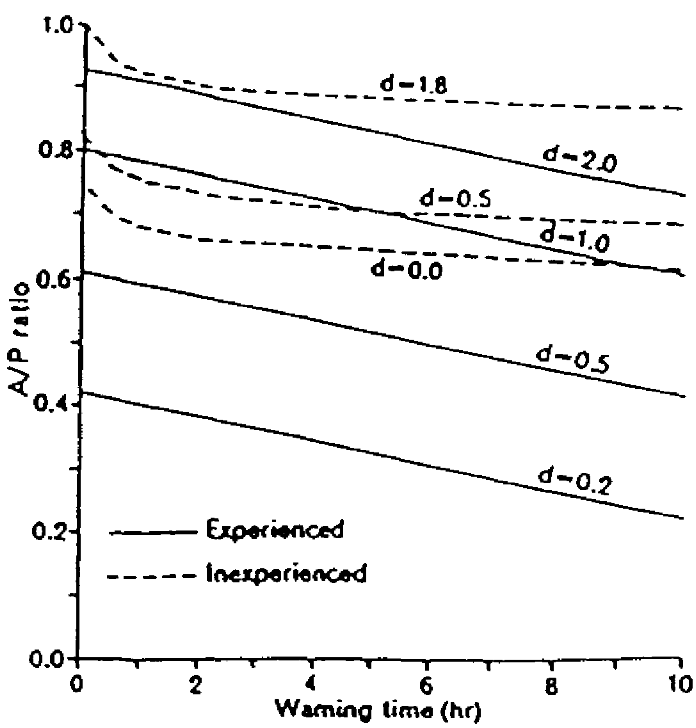

Figure 6 Relationship of actual to potential damage to overfloor flooding (in metres) and flood experience

For the Sydney flood in 1986 the warning system failed, virtually none of the households received an official warning. Surprisingly, households that had no prior flood experience (and no warning) still saved 25% of the value of household contents. This was mainly by lifting high value, electrical equipment above the flood level. Clearly with deeper overfloor flooding the savings would be less. A summary of the consolidated result is given in Figure 6. This shows the average actual to potential direct damage ratios for experienced and inexperienced households as well as the effects of depth of overfloor flooding.

The key elements to the effectiveness of floodwarning systems are the dissemination of the warning and the ability of those at risk to know how to respond. Worldwide it would appear that advances in forecasting technology are not translated into the savings that could theoretically be expected. Without doubt the greatest difficulty is to provide the warning in a form that is useful to the recipients. The forecast process ends with a value and time for a reference flood gauge. This information, especially for urban areas, has very little meaning for the inundated property owners. What is required is more attention to providing flood height forecasts in a form that is easy to understand. Where ANUFLOOD data are available it is an easy matter to provide, for every flood prone building, information on the floor (or ground) height in relation to the gauge used for the forecasts. The program converts building ground height to gauge height and allows for the slope of the flood surface. A height could be affixed to every building that would enable the residents to estimate the flood level for their building in relation to the gauge forecast. Thus a gauge height has relevance for the whole community. Despite offers to provide this information it has not yet been adopted anywhere in Australia.

In monetary terms our studies indicate that savings to the commercial and industrial sectors are larger than those for residential property. There are two reasons for this.

- total potential direct damages for the commercial sector are generally larger than those for residential property,

- the scope for savings in response to floodwarnings is greater for the commercial sector.

The first point is illustrated in Table 1 which presents values for the proportion of potential direct damages that are residential or commercial for a selection of Australian towns. An example of the second is an industrial estate at Tamworth, and inland town in NSW.

On Saturday 28 January 1984 a floodwarning was issued and some enterprises in the known flood prone area took actions to reduce loss. These mainly consisted of lifting stock and equipment to higher levels. The forecast flood however, did not occur and the owners departed for the weekend but left the flood reduction measures in place. In the early hours of Monday 30 January (the Australia Day public holiday) a flood inundated much of the estate. Warnings were issued but were of little value; the local radio station is under-powered at times of flood, road access to the industrial estate is cut and early morning radio messages have few listeners on a public holiday. This provided an ideal opportunity to evaluate the losses to the premises that had undertaken flood reduction measures and those that had not. Overfloor flooding affected 82 premises, of these 11 had undertaken reasonable levels of flood protection, a further 16 had taken limited action and 55 had done nothing. The depths of overfloor inundation varied from 0.0 - 0.9m, with a mean depth 0.3m. A questionnaire was administered, in an interview setting, to all 82 premises in order to assess direct damage to property and contents. These direct damages were compared to the likely potential damage obtained from earlier Australian studies. The results of the savings from enterprises that undertook flood reduction measures were large, they are presented in Table 2. A detailed account of the study is available in Smith and Greenaway (1984).

The problem with the commercial and industrial undertakings is that very few have specific 'flood action plans' to reduce damage. It is uncommon to inform such enterprises that they are flood liable and to give guidelines on how to prepare such a plan.

Flood forecasting technology has made impressive progress in the last decade. This is largely wasted if the information generated cannot be transmitted to those at risk in a form they can readily comprehend. Further, the dissemination must be accompanied by clear instructions on what to do in order to reduce damage. Extensive reviews of these topics are presented in Handmer and Ord (1986) and in Handmer and Penning-Rowsell (1990)

Where risk to life is significant the needs are even more apparent. In Australia lives lost from flooding are remarkably small, a mean annual loss in the range of 5-10. This is, in part, a tribute to emergency planning. Most fatalities are due to incidents involving foolhardy actions by motorists often ignoring warnings. However, there is the potential for severe loss of life from more extreme floods especially those that cause building failure. Dam safety emergency planning is currently an active issue, initiated by the revisions to the PMF in the late 1980's. Studies of direct damage from dam failure have been published (Smith, 1990). There is a resistance to providing inundation maps for dam failure flooding.

Table 1 Percentage of potential direct average annual damage to the residential and commercial sectors.

	Residential	**Commercial**
Denman	64	36
Lismore	34	66
Murwillumbah	22	78
Queanbeyan	38	62
South Grafton	31	69
Sydney	18	82

All based on CRES studies, damages are up to the level of the 1 in 100 year flood.

Table 2 Commercial contents flood damage with and without preparation, Tamworth NSW.

	Damages $/m²	
	Warehouses & retail	**Other uses**
No preparation	49.5 (7)	10.5 (37)
Limited preparation	3.7 (7)	1.0 (9)
Well prepared	3.1 (7)	5.2 (4)

Damages at 1984 prices, size of sample in brackets.

However this is slowly being overcome but it raises the interesting comparison to areas subject to PMF events on natural rivers. In many cases the risks to life and potential tangible losses are comparable to those for dam failure.

6. CONCLUSION

Laing (229: 1981), a senior water engineer in South Australia, reviewed the institutional aspects of floodplain management in the following terms.

> 'The progress in dealing with flooding problems has been slow and arduous. History reveals that the responses to the procession of floods that have occurred, has been a series of committees of enquiry, disputes, negotiations, reports not acted upon and further committees. Although many of the problems encountered have been the result of inappropriate institutional arrangements the physical nature of the flooding problem cannot be separated from institutional matters'.

This description, I am sure, could be applied to the majority of countries represented a the conference. What has Australia learned for its past experience and what are the likely thrusts for the future - the perspectives and prospects?

- What is flood prone land?

This is a complex but fundamental question. The selection of a flood standard that only applies to mainstream flooding is inadequate. The extent and velocities of floods up to the probable maximum flood should be estimated and be freely available. Similarly information on the extent of flooding from urban drainage surcharge.

- Who is responsible for zoning?

The necessity to zone floodprone land for appropriate use is widely accepted. Zoning can only be undertaken in a sensible manner when flood maps and velocity data are available. Experience suggest that zoning should be undertaken jointly with the local community (local councils) within guidelines produced by state or federal governments. Ideally this would lead to a choice of flood standard that is appropriate to local conditions such as the pattern of hydrological variables.

- Cost-effectiveness of mitigation measures.

These should include all flood liable land with serious consideration given to questions of rare floods and high velocities especially when building failure is involved. All structural mitigation schemes should include comprehensive emergency plans for failure or overtopping.

- Floodwarning systems

The three major components of floodwarning systems, namely forecast, dissemination and response, need to be clearly acknowledged. As forecasts improve it is clear that expertise and expenditure on the other two components should be greatly increased. When this is done floodwarning systems are extremely cost-effective.

- Rare events

Understanding and preparedness for rare flood events is poorly addressed. However in the last two to three years the subject has started to appear on the flood agenda in Australia, especially for urban locations. The recognition of the issues is only is only a first step but it is progress! The hope is that it will not require a major catastrophe to stimulate further action.

I suspect that these deficiencies are near universal. The International Decade for Natural Disaster Reduction has the potential to act as a focus for future progress. However, to date its profile is as flat as the central deserts of Australia. My University organised the only national event on October 10 1990, the inaugural National Disaster Day. The results of that seminar are available in Smith and Handmer (1991).

REFERENCES

Aust. Bureau of Meteorology, 1985.
The estimation of probable maximum precipitation in Australia for short durations and small areas. Melbourne: Bureau of Meteorology (Bulletin no. 51).

Black, R.D. 1975.
Flood proofing rural residences. Washington: Report to US Department of Commerce, Economic Development Administration.

Cities Commission, 1975.
Brisbane River flood investigations: final report. Canberra: Snowy Mountains Engineering Corporation for the Cities Commission.

Devin, L. and Purcell, D. 1983.
Flooding in Australia. Canberra: AGPS. (Water 2000. Consultants report no. 11).

Finlayson, B.L. and McMahon, T.A. 1988.
Australia versus the world: a comparative analysis of streamflow characteristics. In: Warner, R. (ed) *Fluvial geomorphology of Australia,* 17-40. San Diego: Academic.

Finlayson, B.L. McMahon, T.A., Srikanthan, R. and Haines A. 1986

World hydrology: a new data base for comparative analyses. *Proceedings Hydrology and Water Resources Symposium Brisbane, November, 1986.* Canberra: The Institution of Engineers Australia.

Handmer, J.W. 1985.
Flood policy reversal in New South Wales , Australia. *Disasters* 9(4) 279-285.

Handmer, J.W. and Ord, K.D. 1986.
Flood warning and response. In: Smith, D.I. and Handmer, J.W. (eds), *Flood warning in Australia,* Canberra: CRES, Australian National University, 235-51.

Handmer, J.W. and Penning-Rowsell, E.C. (eds) 1990.
Hazards and the communication of risk. Aldershot: Gower.

Institution of Engineers, Australia, 1987.
Australian rainfall and runoff - a guide to flood estimation. Canberra: the Institution of Engineers, Australia. Third edition, 2 vols.

Kuhnel, I., McMahon, T.A., Finlayson, B.L., Haines, A., Whetton, P.H. and Gibson, T.T. 1990.
Climatic influences on stream flow variability: a comparison between southeastern Australia and southeastern USA. *Water Resources Research,* 26(10), 2483-2496.

Laing, I. 1981.
The institutional aspects of flood management in South Australia. Proceedings of the Floodplain management. Conference, Canberra, May 1980. *Australian Water Resources Council, Conference Series,* n.4, 228-236.

NSW Government, 1986.
Floodplain development manual, Sydney: New South Wales Government.

NSW Government, 1989.
Review of floodplain management practice in New South Wales - *discussion paper.* Sydney: New South Wales , Government.

Oliver, J. (ed) 1983.
Insurance and natural disaster management. Townsville: Centre for Disaster Studies, James Cook University of North Queensland.

SMEC, 1980.
Assessment of potential flood damages, River Torrens, Adelaide. Adelaide: Engineering and Water Supply Department, South Australia. 2v.

SMEC, 1980.
Assessment of potential flood damages, River Torrens, Adelaide. Adelaide: Engineering and Water Supply Department, South Australia. 2v.

Smith, D.I. 1981.
Actual and potential flood damage: a case study for urban Lismore, NSW, Australia. *Applied Geography.* 1(1): 31-39.

Smith, D.I. 1986.
Cost effectiveness of flood warnings. In. Smith, D.I. and Handmer, J.W., eds. *Flood warnings in Australia.* Canberra: Centre for Resource and Environmental Studies, Australian National University.

Smith, D.I. 1990.
The worthwhileness of dam failure mitigation: an Australian example. *Applied Geography,* 10(1), 5-19.

Smith, D.I. 1990.
Floodwarnings, response and damage reduction: the Australian experience. In: *Proceeding Flood Management Conference.* Toronto: Ontario Ministry of Natural Resources.

Smith, D.I. and Greenaway, M.A. 1984.
Commercial and industrial flood damage: a case study for the Taminda Estate, Tamworth, NSW. Canberra: Centre for Resource and Environmental Studies, Australian National University (CRES working paper 1984/14).

Smith, D.I. and Greenaway, M.A. 1988.
The computer assessment of urban flood damages: ANUFLOOD. In. Newton, P.W., Sharpe, R. and Taylor, M.A.P., eds. *Desktop planning, advanced microcomputer applications for physical and social infrastructure planning.* Melbourne: Hargreen: 239-250.

Smith, D.I. and Handmer, J.W. 1984.
Urban flooding in Australia: policy development and implementation. *Disasters 8(2): 105-117.*

Smith, D.I. and Handmer, J.W. (eds). 1986.
Floodwarning in Australia: policies, institutions and technology. Canberra: Centre for Resource and Environmental Studies, Australian National University.

Smith, D.I. and Handmer, J.W. (eds) 1989.
Flood insurance and relief in Australia. Canberra: Centre for Resource and Environmental Studies, Australian National University.

Smith, D.I. and Handmer, T.W. (eds) 1991.
Australia's role in the International Decade for Natural Disaster Reduction. *Resource and Environmental Series,* n.4, Canberra: Centre for Resource and Environmental Studies, Australian National University.

Smith, D.I., Handmer, J.W., Greenaway, M.A. and Lustig, T.L. 1990.
Lessons and losses from the Sydney flood of August 1986. Canberra: Centre for Resource and Environmental Studies, Australian National University, 2 vols.

Smith, D.I., Den Exter, P., Dowling, M.A., Jelliffe, P.A., Munro, R.G. and Martin, W.C. 1979.
Flood damage in the Richmond River Valley, New South Wales . Canberra: Centre for Resource and Environmental Studies, Australian National University. (CRES report DIS/R1).