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

Commissions of Inquiry Order (No.1) 2011

Queensland Floods Commission of Inquiry

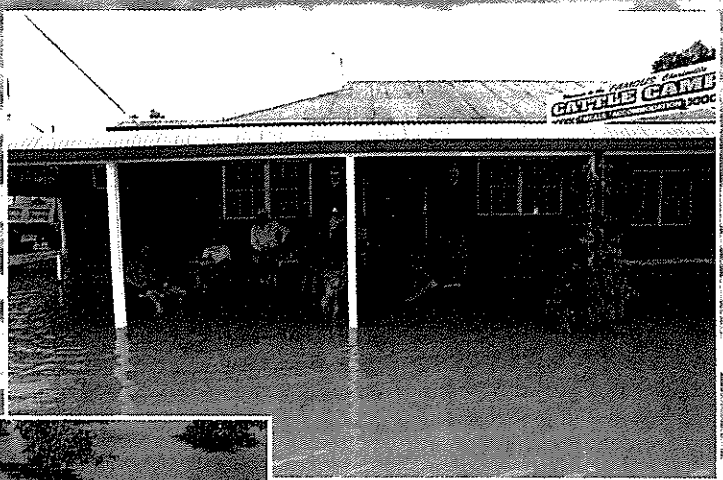
Second Witness Statement of Peter Baddiley

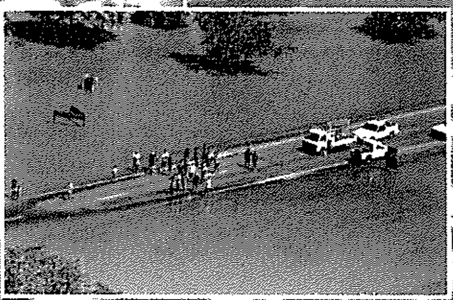
Annexure "PB2-5"

Hydrology Qld -
Peter Baddiley

URBAN FLOODING IN QUEENSLAND - A REVIEW

by David Ingle Smith, CRES, ANU, Canberra





Appendix 1 - Page 2

February 1998

LANDCARE QUEENSLAND

NATURAL RESOURCES Queensland

Hydrology Qld

URBAN FLOODING IN QUEENSLAND

A REVIEW

David Ingle SMITH

Prepared for the Department of Natural Resources, Queensland

February 1998

Centre for Resource and Environmental Studies
Australian National University
CANBERRA ACT 0200

ACKNOWLEGEMENTS

NHT Support
This Report is part of a Floodplain Management initiative of the Queensland Government which is jointly funded through the National Landcare Program of the Natural Heritage Trust.

Queensland Newspapers - Cover Photo's of Flooding in Queensland

Mr K Durham - Cover Photo's of Flooding in Queensland

Mr B Barchard - Cover Photo's of Flooding in Queensland

Additional information on this document is available from:

Regional Planning Group
Water Infrastructure Planning and Development

12th Floor, Mineral House
41 George Street
BRISBANE Q 4000

Telephone: (07) 322 42719
Fax: (07) 322 47999

DNRQ980129
ISBN 0 7242 7445 6

TABLE OF CONTENTS

List of Figures

List of Tables

Executive Summary

The aims of the study are to:

- assess the size of the urban flood problem in Queensland;
- to advise on deficiencies in floodplain management; and
- to recommend how to overcome the shortcomings.

The major source of information was from an extensive questionnaire circulated to all local councils in Queensland. The total number is 125 and questionnaires were returned from 103 of these. Discussions with State and federal agencies established that 18 of the non-respondents did not have an urban flood problem, defined as a minimum of ten buildings at risk from the 1 in 100 year flood event.

Visits were made to five councils, Brisbane, Cairns, Logan City, Carpentaria and the Gold Coast. The last of these, is thought to have more flood prone buildings than any other local authority in Australia. Detailed accounts are presented for Brisbane and the Gold Coast.

Size of the Problem

Assessment of the size of the problem, in terms of number of buildings at risk, is handicapped by the lack, for many councils, of reliable information on flood hydrology. The best estimate of the total number of buildings liable to flooding to the level of the 1 in 100 year flood event is 65,000. This is very similar to the number for New South Wales, estimated in Smith (1996) to also be 65,000. Queensland and New South Wales together account for over 80% of flood prone buildings in Australia. A ranked list of the 12 Queensland councils with the largest number of buildings at risk to the level of the 1 in 100 year flood event is presented below, these account for at least two-thirds of the State total. The poor quality of the data does not allow further sub-division into residential, commercial and industrial buildings.

Local Government Authority	Number of buildings
Gold Coast	16,650
Mackay	8, 500
Brisbane	8, 000
Dalby	3, 300
Ipswich	3, 000
Logan	2, 375
Hinchinbrook	2, 175
Charleville	1, 350
Rockhampton	1, 200
Burdekin	1, 000
Cairns	728
Caboolture	455
TOTAL	**48,733**

It is not possible to provide reliable estimates of those buildings at risk from floods that have recurrence interval between that for the 1 in 100 year event and the probable maximum flood, i.e., the worst flood that could occur. Only 11 councils in Queensland have such information and, of those, only 8 have the information in map form. The number of buildings liable to flooding at the level of the probable maximum flood could be in excess of 200,000.

The need for hydrological information to the level of the probable maximum flood is stressed throughout the report. This is necessary in order to assess potential flood damages, the risk of building failure and to provide a basis for effective emergency management at times of flood. For localities with a high flood range, a measure of the depth of flooding, there is a very real risk of the failure of lightweight structures (such as detached weatherboard dwellings) at time of extreme flood.

Damages

Because of the limited data on flood hydrology and vulnerability, ie. what is at risk from flooding, it is not possible to provide reliable estimates of flood losses. However, a guesstimate for the average annual actual damages (AAAD) for tangible losses to the residential, commercial and industrial sectors, to the level of the 1 in 100 year flood, is close to $100m (at 1990 values). The corresponding AAAD, if the damage estimates are extended to the level of the probable maximum flood, would be very much higher perhaps by a factor of two.

The report has established that Queensland has the highest AAAD for any State in Australia. The number of buildings at risk are comparable to those in New South Wales but there, the steadfast application of effective urban floodplain management has progressively reduced the AAAD for many flood prone urban localities and dramatically slowed the construction of new buildings in areas subject to the 1 in 100 year flood. In contrast, Queensland has not reduced flood vulnerability and for many urban flood prone communities the lack of land use controls or building regulations is such that potential damages increase year by year. A report, in 1978 by a National Committee investigating a National Scheme for Natural Disaster Insurance reached virtually the same conclusions.

It needs to be stressed that some of the major flood prone communities were greenfield sites at the time of the extensive floods of 1974. It is not possible from the questionnaires to give any firm data on the increase of the size of the urban flood problem since then, but there is no doubt that it is has been significant. The Gold Coast is a prime example but undoubtedly the expansion of developments, many of which are dominantly residential, onto flood prone sites has been a State-wide phenomenon.

Mitigation measures

The use of structural mitigation measures is limited. Although not necessarily a recommended procedure, only 13 councils in Queensland report the use of levees to reduce flood losses. Other strategies, some of which can be applied to individual buildings are rarely used. Examples are flood proofing, the raising of weatherboard dwellings above flood level or the purchase of especially hazardous buildings Compared to other states, this restricted use of structural measures is thought to reflect paucity of funds, lack of background information and of urban flood policy.

The provision of flood forecasts, in part based on local instrumentation, is of a comparatively high standard. Exceptions are for some remote inland communities, the coastal settlements of the Gulf of Carpentaria are examples. Analyses, provided by the Bureau of Meteorology, indicate that the warning times for flood forecasts for 100 flood prone urban locations (about 70% of the total) are less than 12 hours. Thus, the best possible preparedness and response are necessary if the benefits of the forecasts are to be fully captured. Improved information on flood hydrology and the availability of flood maps are required together with the provision of flood markers at the local level. Only 25% of councils report that such flood markers are in place, their use should be obligatory.

Need for a State Policy

Only 35 of the council responses indicated that they had an `urban flood policy' and in many cases these fall short of being `state of the art'. This number is unacceptably small and often, where such a policy exists, the information on which it is based in inadequate.

Queensland is unusual among the Australian States in that it does not have a State-wide policy for urban floodplain management. Action is left to individual councils and the 35 responses that provided information on the under-pinning legislation, demonstrate that the institutional arrangements are unclear. The burden of costs, both for the necessary flood studies and for possible subsequent mitigation, have been frequently borne solely by local councils. This is marked contrast to New South Wales, where the contribution of state funding is close to 40% of the total costs, normally matched by similar federal funding.

The need in Queensland is for a co-operative, locally-based approach to urban floodplain management that is formulated to accord with an established State policy. This would require the provision of technical advice and a contribution to council funding from State sources (especially for assistance with flood studies).

Steps towards these aims would be for the State government to produce a flood manual specifically designed for use by local governments. This should present guidance to all aspects of best practice floodplain management. It should include guidance to all relevant planning legislation in order that floodplain management by local government is integrated into the State's overall planning policy.

A clear statement on the legal liability of council decisions that allow building in flood prone areas may aid improved floodplain management. Indemnity from such liability for councils following accepted procedures (as indicated in the proposed manual) is a strategy that could be investigated.

Until Queensland adopts an acceptable policy for new urban developments in flood prone areas, the damage bill will continue to escalate. It is important to note that Commonwealth contributions to flood relief, under the Natural Disaster Relief Arrangements, have decreased over recent years. This places additional burdens on the State Treasury and it is surprising that this has not resulted in greater pressure to reduce future flood losses by way of improved planning. Many mitigation measures would have favourable benefit-cost ratios and would therefore indicate medium to long-term advantages. In addition, the Commonwealth government has indicated that future payments for flood relief will be evaluated against improvements in floodplain management.

Storm Surge

The questionnaire also provides background information of coastal inundation for storm surge (alternatively referred to as 'storm tide'). A total of 25 councils replied that they had a storm surge problem which equates to virtually all coastal LGAs in Queensland. These are listed below with the date of the last occasion on which buildings were damaged.

Local Government Authority	Location affected	Date of most recent damaging event
Bowen	(Queens Beach)	1980
Burnett	(Bundaberg Point)	1942
Caboolture	(Several locations)	
Cairns	(City and Northern Beaches)	1979
Calliope	(Tannum Sands, Boyne Is.)	
Caloundra	(Kawana Waters)	
Cardwell	(Tully Heads, South Mission Beach)	
Carpentaria	(Karumba)	1976
Cook	(Ayton, Cooktown)	
Douglas	(Port Douglas)	
Gladstone		
Gold Coast		1974
Hervey Bay		1992
Hinchinbrook	(L. Tully)	
Johnstone1996		
Livingstone		
Mackay	(City and North Mackay)	1918
Noosa		1992
Pine Rivers		1993
Redcliffe		1994
Redland	(Bay Island)	
Sarina	(Several locations)	1918
Thuringowa		1971
Tiaro		
Townsville	(City)	1971

Information on storm surge risk is generally poor, the study estimates that between 40,000 and 50,000 buildings may be at risk from extreme surge events. This problem is compounded by the fact that it is unusual for councils to have any restrictions on development in areas liable to the storm surge.

Unlike river flooding, the problem of surge is concentrated in Queensland and therefore, there is not the same opportunity for the transfer of methodologies and experience between States. Succinctly, inundation of urban areas from storm surge is a Queensland problem. Surge flooding requires similar land use planning regulations to those for river flooding, the major difference is that the occurrence of a major surge event could cause, at a single urban locality, the structural failure of several hundred dwellings.

The responses to this question indicate that to date effective development controls have been lacking and that there is an urgent need to better define the areas at risk, to introduce appropriate land use and building regulations and for improved arrangements for emergency management.

The Future

Actions to improve current practices are necessary to prevent the occurrence of major disasters with extensive damage and loss of life.

Section 11, *Towards Better Urban Floodplain Management*, outlines the steps that are required to improve urban floodplain management in Queensland. The essential first step is the provision of detailed studies, for flood hydrology and vulnerability, for all urban flood prone communities liable to flood. Without such information further progress is severely handicapped.

Overall, the current state of knowledge of flood risk in Queensland is poor and far below the standard of that elsewhere in Australia.

Conclusions

(i) Reliable estimates of the number of localities and the number of buildings subject to urban flooding in Queensland are severely hampered by the paucity of information on flood hydrology.

(ii) It is best estimated that the number of buildings (residential, commercial and industrial) at risk from the 1 in 100 year flood event is 65,000.

(iii) The majority of councils in Queensland have no information available on the risks associated with extreme floods, i.e. those in excess of the 1 in 100 year flood event. Only eight councils have such information available in map form.

(iv) The tangible annual average urban damage in Queensland, to the level of the 1 in 100 year flood event, is thought to be about $100m. The paucity of information on flood hydrology and vulnerability is such that that this estimate should be regarded as tentative; the data base for commercial and industrial losses is especially poor.

(v) Notwithstanding the quality of the background data, Queensland has the highest average annual urban flood damage of any State in Australia.

(vi) Continued development in flood-prone areas is of special concern, this leads to an ever-increasing escalation in vulnerability and flood damage.

(vii) The warning time that can be provided for some 70% of urban floodplain locations within Queensland is less than 12 hours.

(viii) In comparison to other Australian States, Queensland is unusual in that there is no clear or comprehensive State-wide policy to guide urban floodplain management.

(ix) Only thirty-five councils have a policy for urban floodplain management and, in many cases, these do not meet national or international best practice.

(x) Twenty-three councils report that they have urban areas at risk from storm surge (storm tide).

(xi) Overall, information available on liability for damage from storm surge, and the potential for catastrophic losses (including widespread building failure) are even less well developed than even those for riverine flooding. A guesstimate is that some 40-50,000 buildings in the State are at risk from the 1 in 100 year storm surge event.

(xii) Urban inundation from storm surge is essentially a Queensland problem, the risk likely exceeds that of the combined total for all other Australian States.

Recommendations

Flood studies

(i) There is an urgent need for information on flood hydrology for all flood-prone urban locations. The ranked list of flood liable locations could be used to prioritise such studies. Attention should also be given to providing information on flood hydrology for areas likely to be developed in future years.

(ii) Studies of flood hydrology should include information of the areal extent of the probable maximum flood and give, at least, a semi-quantitative assessment of over-floodplain velocities.

(iii) When studies of flood hydrology are complete they should be used to assess vulnerability, flood damage and be integrated into emergency management.

(iv) The resultant flood studies (combining hydrology, vulnerability and damage) should then be used as a basis for comprehensive urban floodplain management including evaluation of the full range of mitigation measures - structural and non-structural.

Forecasting and awareness

(v) There is a need to better use flood forecasts to capture the full benefits for all forms of loss reduction. One simple measure would be to make it obligatory for councils to install flood markers in order that forecasts of flood height could more readily used to give an indication of the extent and severity of flooding. Such measures are cheap and effective.

Policy and legislation

(vi) There is an urgent need for the Queensland government to clarify, and ideally to revise, legislation relevant to the implementation of effective urban floodplain management.

(vii) A clear statement of the legal liability of councils that allow development in flood-prone sites should be provided by the State government.

(viii) To assist with the recommendations outlined above, the State government should fund and distribute a comprehensive urban floodplain manual specifically designed for use by local councils in Queensland. This should provide guidance on how to undertake studies of flood hydrology, vulnerability and damage together with information on mitigation options and the appropriate legislative basis for locally-based flood policy.

(ix) Analysis of the risks of catastrophic damage in urban areas from storm surge (storm tide) should be a given a high priority. Policy for the planning, and for the reduction of damage to existing structures, in storm surge areas should be integrated into that for riverine flooding.

Introduction

The study was commissioned to review all aspects of the urban flood problem throughout Queensland.

Specific aims included:

- the design, distribution and analysis of a questionnaire survey to all local government authorities (LGAs) in the State;
- estimates of the size of the urban flood problem;
- a review of the current state of urban floodplain management, including flood warning systems, mitigation measures etc.
- a prioritised list of flood prone communities for future detailed study;
- a review of best practice methods to assess urban flood losses;
- recommendations on how State agencies can assist and encourage LGAs to attain more effective flood management.

An outline consideration of inundation from storm surge was also included, as this is considered to represent an extension of riverine flood policy.

It is clear that many of the respondents to the questionnaire expended valuable time to complete the extensive range of questions. The author would like to thank all those involved for their cooperation. Special thanks are also due to senior staff of the following councils: Brisbane, Cairns, Carpentaria, Gold Coast and Logan, who, in addition to completing the questionnaire, were willing to discuss urban flood problems face to face.

Peter Baddiley and Terry Malone of the Hydrological Section of the Brisbane Regional Office of the Bureau of Meteorology, and Doug Angus and the staff of Queensland Emergency Services, willingly gave advice at all stages of the project.

Dr Darryl Muller of the Department of Natural Resources was responsible for assembling the questionnaire while Russell Cuerel, and other staff at the Department were responsible for the circulation of the questionnaire and chasing up recalcitrant respondents. Their diligence resulted in a remarkably high rate of return from local government officials who are undoubtedly over-worked and over-questionnaired.

Finally, my personal thanks to Katie Ellis in CRES, who skills, assistance and good humour at all stages of the project have been exemplary. These ranged from organising the computer data base for replies to the questionnaire, to proof reading and lay-out of the final report.

1

Background and Definitions

1.1 Definitions

A key factor in assessing the susceptibility of urban areas to flooding is the number of buildings liable to inundation. However, in order that urban flood locations can be ranked in terms of need for further study or for flood mitigation priority, this simple statement requires further definition. Necessary definitions are:

- how to define flood prone?
- what is an urban locality?
- how to classify the buildings and infrastructure at risk?

1.2 How to define flood prone?

Theoretically, a building or installation would be classified as flood prone if it is at risk from inundation by the probable maximum flood, this can be regarded as statistically the largest possible flood. 'Inundation' also presents a definitional problem with a choice between water over-ground on the property block, or restricted to a flood that exceeds floor level. For the various forms of infrastructure, the definition is more complex with the choice between over-ground inundation or the flood level that corresponds to a critical level that interferes with normal service provision, i.e., over roadbed level, or at a critical height for an electricity transformer.

However, data on the magnitude of the probable maximum flood is rarely available and the number of flood prone buildings is usually reported in terms of over-ground inundation for the 1 in 100 year event. This convention will be followed in this report except that, wherever possible, additional data will be given for liability to the level of the probable maximum flood.

1.3 What is a flood prone urban locality?

For the purposes of this study it was necessary to define what constitutes a flood prone urban locality. The decision was made to include all urban localities for which at least 10 buildings were liable to flooding from the 1 in 100 year flood event or were inundated by the flood of record. In practice, this refers to buildings that would have over-ground inundation, i.e., not necessarily over-floor level.

Any definition of this kind is arbitrary but the selection of a lower limit of 10 buildings corresponds to the criterion used in the first national survey of urban flooding undertaken by Devin and Purcell (1983).

1.4 How to classify the buildings and infrastructure at risk?

It is common practice for urban flood studies to report risk in terms of the number of buildings liable to inundation. Many studies do not differentiate between residential buildings (in Australia normally detached dwellings) and those that are commercial or industrial. Other accounts sub-divide business enterprises into 'commercial and 'industrial'. In many Australian flood studies these are defined on the basis of likely flood damages and the commercial sector is restricted to the more commonly occurring buildings used for retail or office functions with 'industrial' used for larger enterprises (sometimes incorporating a number of individual buildings) often engaged in some form of manufacturing. An example that occurs relatively frequently in small urban centres is the regional milk factory. These finer divisions are usually related to studies that are designed to assess potential flood losses.

Thus the most frequently used definition of buildings in flood studies recognises residential and commercial sectors with a possible further sub-division to recognise large industrial concerns. Some flood damage surveys recognise an additional category, often termed 'public buildings'. Examples in this category are schools, hospitals and council offices.

In Australia and overseas, studies of urban flood risk are normally limited to the analysis of buildings, however defined. In recent years more emphasis has been placed upon the susceptibility of 'lifelines' to flooding. 'Lifelines' are usually restricted to services of which roads, bridges, water supplies, sewerage and electricity form critical elements. A limited number of surveys of actual floods give descriptions of such infrastructure damage and sometimes these are included in estimates of flood damage. Even more recent studies, often based on the use of Geographical Information Systems (GIS), have begun to analyse the significance of the potential damage to lifelines in order to better plan for emergency management.

However, such studies are relatively uncommon and it standard practice in Australia and overseas to evaluate urban risk in terms of building damage. This approach forms the main thrust of this report although additional descriptions are given to the problems of infrastructure where such information is available.

To a large extent the detail and definition of buildings used in flood studies reflects the purpose of the investigation. If the aim is to assess flood damage, often as a basis for cost benefit analysis of flood mitigation options, the classification of buildings into residential, commercial and industrial is necessary. If the aim is to provide the background for emergency management, the emphasis is upon the safety of the inhabitants and this focuses attention on the residential sector and upon lifelines.

1.5 What is a designated flood?

It is near universal practice for floodplain management, in Australia and overseas, to select the level of the 1 in 100 year event as the designated (or standard) flood. Once established the designated flood forms the basis for new developments which for residential buildings are usually related to the habitable floor level. This is usually set at the 1 in 100 year level plus extra 'freeboard' which is typically a foot or 300 mm. Some jurisdictions permit floor levels for commercial and industrial establishments at lower levels, with higher levels for especially vulnerable buildings such as hospitals, police stations etc.

The adoption of a designated flood is the key step in introducing land use zoning to control the growth of new developments on flood prone land. A detailed hydrological study is required in order to satisfactorily establish the position of the 1 in 100 year flood line, as a temporary measure LGAs sometimes substitute the flood of record for the design flood. It is common practice for the extent of the design flood to be shown on large scale maps or orthophotos. This however, is not universal and in New South Wales there is a reluctance to produce flood maps. The background to this unusual stance lies with community dissatisfaction with such maps in the mid-1980s, a detailed account of this hiatus is given in Handmer (1985).

The widespread adoption of the 1 in 100 year flood as the designated flood, however, represents an imperfect solution to the definition of 'flood prone'. There are three reasons why it is often unsatisfactory. They are:

- the large variation in flood height range between locations
- the possibility of building failure from extreme events
- the problems posed by the probable maximum flood.

Each of these is outlined below.

1.5.1 Flood height range

The flood height range (FHR) is a term frequently used in the USA to provide a measure of the difference in stage (height) between the 1 in 10 (or 1 in 20) and 1 in 100 year events. The FHR can differ markedly from one location to another, a range from a metre or so to ten metres is not unusual. Figure 1.1 demonstrates the variation in stage for two locations. In Case A the FHR is less than a metre and in case B is about four metres. Many inland locations in Queensland would be similar to Case A, this is because when the river exceeds bankfull there are extensive flat floodplains that provide very large natural storage's for the flood waters. Case B is commonly associated with sites upstream of river gorges so that flood flows back up to considerable depths during floods.

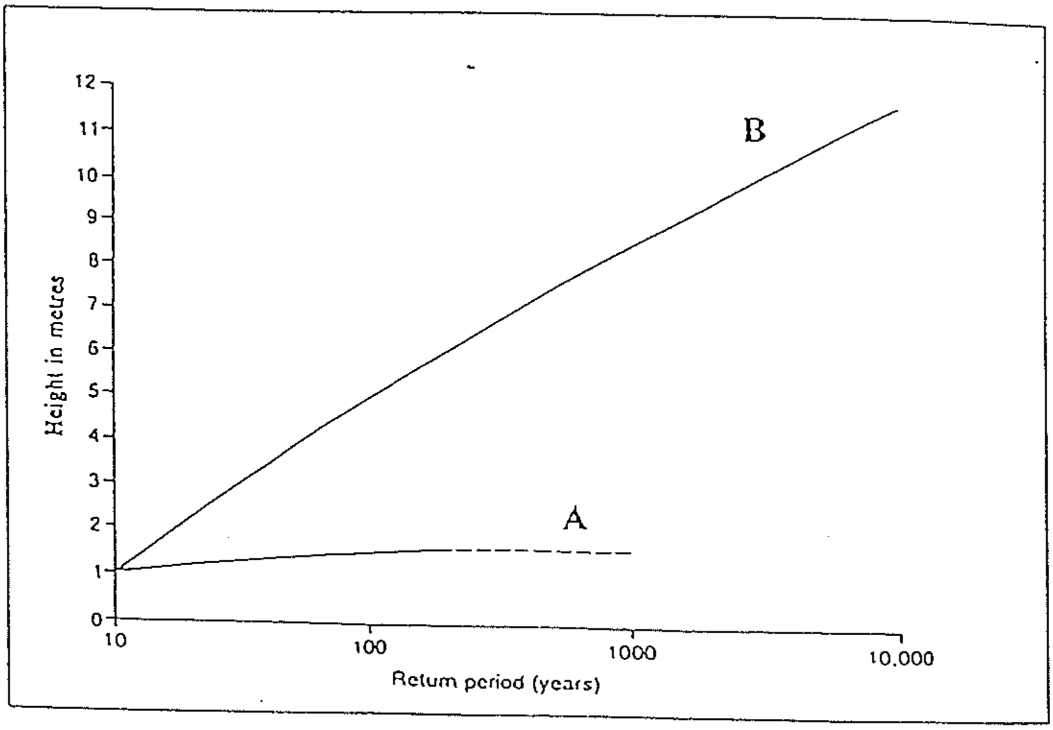


Figure 1.1 Low and high flood height range

The significance of the FHR is that buildings located close to the 1 in 100 year line in Case A would only experience limited over-floor inundation from floods greater than the 1 in 100 year, while for Case B water could be several metres over floor level. For locations similar to case B there is an additional risk of building failure (see below) and loss of life.

Data on flood height range is relatively poor for many locations in Queensland but there is little doubt that there is a wide range of values.

A surrogate for FHR can be obtained from the Flood classification for Queensland flood warning river height stations, compiled by the Hydrological Section of the Brisbane office of the Bureau of Meteorology. This lists flood warning heights for several hundred flood gauges distributed throughout the State. It is not designed to give FHR *per se* but it does report minor, moderate and major warning heights for each station. The classification of the level of risk is given as an aid to emergency management. For example, 'moderate' corresponds to '... inundation of low lying areas requiring the removal of livestock and the evacuation of isolated houses' and 'major' is defined as major disruption ... 'evacuation of many houses and business premises may be required'.

For many urban settlements the Bureau of Meteorology also produces booklets describing key aspects of the flood warning system, notes on the flood history etc. In the absence of detailed hydrological studies such information forms an invaluable guide to urban flooding. The major limitation is that the 'major' flood heights are often well below the level of the 1 in 100 year flood or the flood of record. Table 1.1 illustrates the problem of FHR for a selection of flood prone urban communities.

Table 1.1 Flood height range and flood warning levels for a selection of Queensland towns, all heights are in metres

	Flood warning levels			Flood height range	Flood of record
	Minor	Moderate	Major		
Brisbane City gauge	1.7	2.6	3.5	4.0	5.45 (1974)
Ipswich City gauge	7.0	13.0	15.5	10.0	20.73 (1974)
Rockhampton City gauge	5.0	6.0	7.0	1.75	10.1 (1918)
Ingham City gauge	10.0	11.0	15.0	1.5	16.4 (1967)
Logan River, Macleans Bridge	10.0	13.5	16.0	8.0	21.67 (1974)

All values in metres. Estimate based on limited information

The data demonstrate both the variations in the FHR and the relationship of the flood of record to the warning levels. The flood height ranges given in Table 1.1 are the best estimates of the range between the 1 in 10 and 1 in 100 year flood events; the minor, and major flood warning levels are related to the effects upon those at risk and not to flood recurrence intervals.

Interpretation is further blurred by local factors. For instance for Ingham the height difference between the 1 in 2 and the 1 in 10 year floods is 4.5 m but only a further 2.0 m between the 1 in 10 and 1 in 100 year. In many cases the hydrology is imperfectly known and the data given in Table 1.1. should be regarded as indicative of high or low flood height ranges rather as precise estimates.

1.5.2 Building failure

Data that present critical combinations of flood depth and velocity that lead to building failure are available. These are based on studies from the USA, for instance Black (1975), but the results are also relevant to a range of Australian building styles. A more accessible review of these relationships and their importance for damage and emergency management is given in Smith (1991). Examples of these relationships are reproduced here as Figure 1.2.

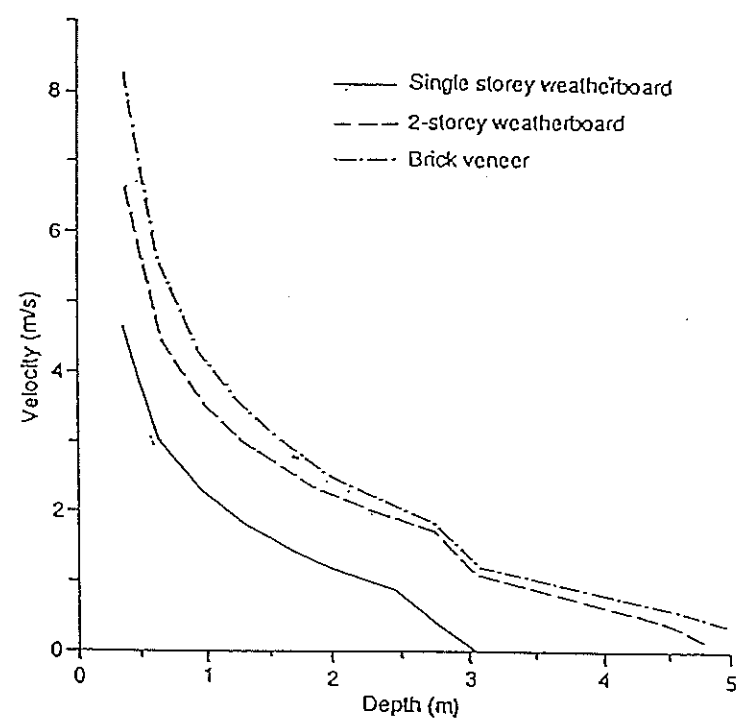


Figure 1.2 Critical flood velocity and depth for residential building failure

Detached, single storey weatherboard houses, a style common throughout Queensland, are particularly susceptible to failure which is often related to their buoyancy in flood water causing the building to 'float off its stumps'.

To use these failure relationships it is necessary not only to know the flood depth but to also have reliable estimates of the velocity of the flood waters. The velocities are those for over-floodplain discharges, not in-channel flows. Such data are rarely available in Queensland.

It should be obligatory for any future hydrological flood studies to estimate over-floodplain velocities for flood flows. This should not be difficult to achieve as many contemporary computer-based hydrological models have the capacity to estimate such velocities. In many areas, especially where the FHR is small, the chances of building failure are remote. However, for other sites the risk can be considerable and may well be judged to be unacceptable. The significance of potential building failure for emergency management and for damage estimation is large. The possibility of building failure should be a key factor in the selection of the designated flood.

1.5.3 Less frequent floods including the probable maximum flood (PMF)

The worst flood that could occur is termed the probable maximum flood (PMF). This is clearly a very rare and extreme event and it could be replaced by estimates of the 1 in 5,000 or 1 in 10,000 year flood. In any new hydrological study it should be obligatory to provide estimates of the full range of floods including the PMF although it is accepted that, for the less frequent events, the estimation error bands will always be large.

The major reason for estimating the PMF is to use it in conjunction with Figure 1.2 in order to assess the potential for building failure from rare events. All too often the perception of the 1 in 100 year (or other) design flood is that this divides areas that are considered as flood prone from those (erroneously) thought to be flood free. However, residual risk from the PMF (and the other large events) is not only due to building failure. An additional reason for assessing the less frequent events is to ensure that emergency measures to deal with the residual flood risk (like access for evacuation and refuge points) can be implemented as part of a flood disaster response plan

It would be economically unacceptable to prohibit all new development below the level of PMF but if there would be widespread building failure from such extreme events this should be recognised in any land use zoning restraints. Knowledge of this worst case flood should be fully understood by the emergency services, the problem of isolation of flooded areas as islands is of special concern.

Such risks of failure are generally greatest for locations where the flood height range is large. Although precise hydrological data are not available, dwellings close to the 1 in 100 year at Ipswich would have several metres of water over floor level for a near PMF which, in many cases, would result in widespread building collapse.

The risk of failure for existing developments below the level of the 1 in 100 year flood line can be very severe. For Ipswich, with the high FHR shown in Table 1.1, it is likely that several hundred buildings would be totally submerged by such extreme floods. The loss of more than thirty dwellings in the 1974 flood demonstrates that this risk is very real. The fact that similar houses were re-built on the sites is an example of very poor urban floodplain management.

1.6 Definitions – a summary

In this account a flood prone urban location is defined as a place at which at least 10 buildings would be subject to the 1 in 100 year flood event. Buildings are regarded as flood prone if their grounds are within the limits of the 1 in 100 year flood. Wherever possible the buildings are sub-divided into residential and commercial. For many localities hydrological studies that define the extent of the 1 in 100 year flood are lacking, in such cases the flood of record is substituted.

Such definitions are used because:

- they give comparability between places
- they represent the most commonly available data
- it is common practice for floodplain management to use the 1 in 100 year (or flood of record) flood line as the basis for building and land use controls

The questionnaires used in the study were designed to provide this basic information but also provided the opportunity to report more detailed information where it is available, ie properties liable to flooding from the probable maximum flood, susceptibility of infrastructure etc.

It needs to be stressed that, although the 1 in 100 year event is very widely used as the basis for floodplain management, it is far from an ideal standard for universal application. Further, for emergency management and flood damage assessments over-floor flooding is much more critical than over-ground inundation.

For the purposes of floodplain management it is necessary to select a designated flood which forms the basis for controls on new developments. Although the 1 in 100 year flood line is often used, this is not necessarily a good choice due to large variations in flood height range which have, in extreme cases, the potential to cause structural failure especially for lightweight buildings.

Hydrological studies of flood prone areas should always include estimates of the magnitude and extent across the full range of floods to the level of the probable maximum flood. This is especially important because of its implications for emergency response planning.

2

Urban Flooding in Queensland: Early Estimates of Size

2.1 Early estimates

Any estimates of the number of properties at risk from flooding made in Australia prior to the mid-1970s are little more than guesses. The impetus to flood studies from the widespread flooding of 1974 resulted in the first systematic attempts to assess the magnitude of the problem. These estimates were hampered by the lack of flood maps, which are essential to define the urban areas at risk. The first estimates based upon a growing data base were made by a Technical Committee of the Australian Government Actuary (AGA, 1978) which reported its findings in 1978. In 1976 Douglas, in a paper at the National Hazards Symposium held in Canberra (available as Douglas, 1979), presented a review of flooding in Australia. This suggested that some 5 per cent of dwellings in Australia were liable to river flooding, the information base for this estimate was derived from the information gathered by the Technical Committee.

Irish and Devin (1978) discussed methods to estimate mean annual damage to dwellings. Their account gave estimates of the number of dwellings exposed to damage from the 1 in 100 year flood for 135 urban areas throughout the Commonwealth. These included all major urban centres plus smaller urban areas known to have a significant flood risk.

Irish and Devin, commented, in comparing the estimates for Queensland and New South Wales, that:

> ... Mean annual flood damage for New South Wales was estimated to be much less than for Queensland despite the disparity in State populations. This is thought to be due to the flood mitigation program which has been carried out in many NSW towns over the last two decades, the tighter town planning controls and the absence of major flood hazards in Sydney, Newcastle and Wollongong (Irish and Devin, 1978: 106).

A recent review of urban flooding in Australia is also given in Smith (1996).

2.2 Estimates by Australian Water Resources Council (AWRC)

The study undertaken by Water Studies Pty Ltd, and reported in *Floodplain management in Australia* (AWRC, 1992), provides the most recent nationwide flood estimates. These include information on the numbers of buildings at risk, together with estimates of annual average damage (AAD) for rural and urban sectors for both mainstream and stormwater flooding. The background data were assembled after discussions with the responsible agencies in each State and Territory. The survey is comprehensive but reflects the deficiencies outlined in Section 1.

The major limitation is that all the estimates are restricted to the 1 in 100 year flood event, the additional losses that could be expected from extreme floods and building failure are omitted. To an extent the two are linked, building failure would be a much larger factor for the rarer extreme events. The reasons for these omissions are the paucity of available data and the restricted approach taken by most State agencies to the definition of flood.

2.2.1 Number of properties at risk in Queensland

A convenient starting point for the present study is to consider the data on the number of properties at risk in Australia from the 1 in 100 year flood as reported in Appendix D of the AWRC (1992) report. These are given in Table 2.1.

Table 2.1 Number of properties, by State, at risk from 1 in 100 year mainstream flooding, from AWRC, see Appendix D (1992)

	Protected	Unprotected	Total
New South Wales	21,800	36,100	57,900
Northern Territory		2,000	2,000
Queensland			21,000
South Australia	1,350	1,350	1,350
Tasmania		715	715
Victoria	3,600	10,600	14,200
West Australia	4,440	1,350	5,750
Total	**29,800**	**73,115**	**102,915**

Table 2.1 also divided properties into 'protected' and 'unprotected'. The protected are those where structural mitigation measures lessen the impacts of the flood events, such protection is dominantly provided by levee systems. These are of major significance in New South Wales, Victoria and Western Australia, but much less so for Queensland. Protected residences pose problems for damage estimation, this is because the levees have a design limit and when this is exceeded, severe flooding can result. An additional complication is that such levees can fail at heights below the design (i.e. overtopping) level.

The AWRC report (1992) gives the official estimates of flood prone properties, as provided by the former Queensland Water Resources Commission (now part of the Department of Natural Resources) as 17,000. Of these 14,600 were urban and 2,400 rural. These were known to be under-estimates and they were revised in the AWRC report to a state-wide total of 21,000. This too, was undoubtedly a major under-estimate. Reliable estimates of the numbers will not be available until the areas subject to flood are delimited on the basis of good quality flood studies.

2.3 The Insurance Council of Australia (ICA)

A more recent unpublished study was undertaken for the Insurance Council of Australia (ICA), this included estimates of the number of residential buildings at risk from flooding for each State and Territory (Smith, 1996). The results are summarised in Table 2.3, with the exception of Queensland, the numbers of residential buildings are similar to those in AWRC (1992), given in Table 2.2.

Table 2.2 **Revised State estimates of residential buildings at risk from 1 in 100 year mainstream flooding, from Smith (1996)**

	Inland	Coastal	Protected	Total
New South Wales	9,700	27,800	27,500	65,000
Northern Territory	2,000	0	0	2,000
Queensland	10,000	40,000	0	50,000
South Australia	0	1,500	0	1,500
Tasmania	375	375	1,000	1,750
Victoria	4,150	7,200	3,650	15,000
Western Australia	0	1,350	4,440	5,750
Total	**26,225**	**78,225**	**36,550**	**141,000**

NOTE: The Queensland data reported in AWRC (1992) does not differentiate between 'protected' and 'unprotected' buildings, however the number of protected buildings is small.

The ICA report acknowledged that the data base for Queensland is poor but suggested a working estimate of 50,000 residential buildings, i.e. those subject to over-ground inundation from the 1 in 100 year flood event.

2.4 Summary

Regardless of the imperfections of the estimates the overall conclusion of the existing surveys is that the combined buildings at risk in New South Wales and Queensland account for over 80% of the national total. In terms of both buildings and damage (assessed in terms of average annual loss) the magnitude is similar in both States.

These earlier accounts are all restricted to inundation from mainstream flooding, ie urban storm drainage surcharge is excluded, although the AWRC (1992) report separately assessed flood risk from storm water drainage. These earlier studies also excluded inundation from storm surge which is limited to those areas of northern Australia exposed to risk from tropical cyclones.

In practice, storm surge inundation is dominantly a Queensland problem, this is because there are only a few small urban settlements in Western Australian and the Northern Territory that are at risk from major surge events. The major urban surge locality in these other northern States is Darwin but zoning to exclude new developments from areas liable to surge was undertaken in the late 1970s, ie after Cyclone Tracey. Although the current study is focussed on urban mainstream flooding in Queensland a preliminary account of urban exposure to storm surge will be included.

Detailed studies of flood hydrology, vulnerability and loss are well-advanced in New South Wales but are only known with any precision for a few localities within Queensland. The risk of urban flood in Queensland is undoubtedly large but how large, and which localities have the major risks, provides the impetus for the present study.

3

The Questionnaire: The Size of the Problem

3.1 Questionnaire distribution and response

The questionnaire, *Urban flood risk in Queensland*, was distributed to all LGAs throughout the State over the period September to November 1996. The number of LGAs totalled 125, a list is given in Table 3.1. Responsibility for circulation, the collection of returns and contacting recalcitrant respondents was undertaken by staff of the DNR. By April 1997 completed questionnaires had been received from 102 LGAs, 15 of which provided information for more than one flood prone location within their area of jurisdiction, these are also indicated on Table 3.1. Of the completed forms, 15 LGAs did not meet the criteria used to define a flood prone community, i.e. more than 10 flood prone buildings at a single locality. These are also shown on Table 3.1.

The areal coverage of LGAs who responded, also including those with an insignificant urban flood problem, are given in Figure 3.1.

In order to obtain this degree of participation, the DNR repeatedly contacted those LGAs who had not sent in completed questionnaires. In reviewing progress in early 1997, it was decided not to further harry those non-responding LGAs who were considered not to have an urban flood problem. The decision on LGAs in this category was based upon discussions with the Hydrological Section of the Bureau of Meteorology and with staff of Queensland Emergency Services. The 18 LGAs in this category are indicated on Table 3.1 and as a result of their elimination, there were only 4 LGAs of interest who did not respond.

In total, responses were received from 102 LGAs covering 133 localities.

A further modification to the original intention of the questionnaire, that it should be completed for each flood prone location within single LGAs, was for Brisbane and Gold Coast City Councils. This is because for both of these the size of the urban flood problem, in terms of numbers of buildings at risk, was especially large and because flood prone buildings were distributed over a number of catchments. The detail for Brisbane and the Gold Coast are outlined in Section 4.

Overall, the level of response and detail given by those LGAs that have a risk of urban flooding was good. Where known, separate estimates of the size of the urban flood problem for these, and for respondents who did not complete individual questions, are included in the discussion of the results.

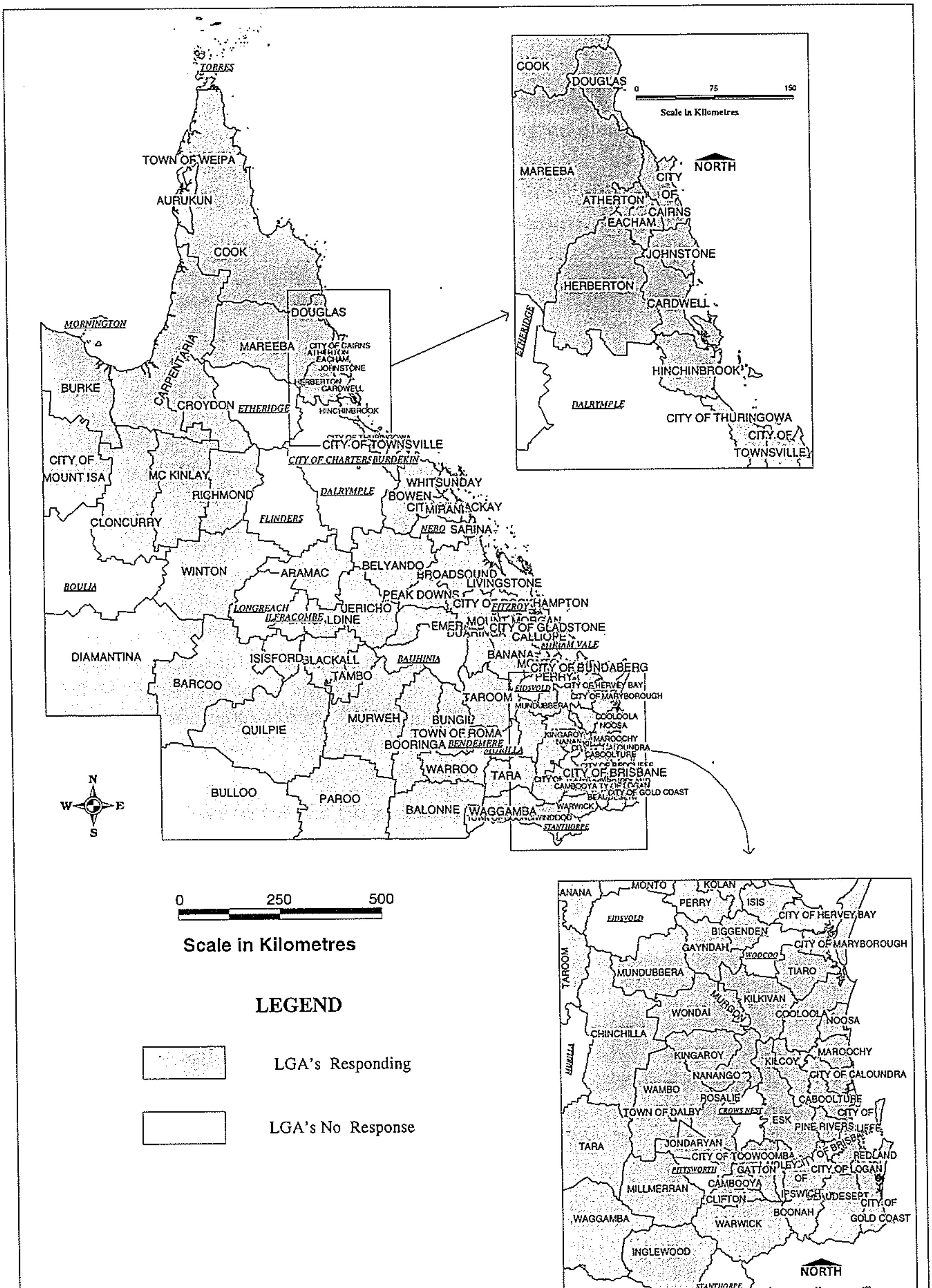


Figure 3.1
Areal Distribution of Responding LGA's

Table 3.1. Queensland LGAs, responses to the questionnaire

No.	LGA	
1.	**Aramac Shire**	
2.	**Atherton Shire**	*
3.	**Aurukun Shire**	
4.	**Balonne Shire**	(5)
5.	**Banana Shire**	(4)
6.	**Barcaldine Shire**	
7.	**Barcoo Shire**	(3)
8.	*Bauhinia Shire*	[1]
9.	**Beaudesert Shire**	
10.	**Belyando Shire**	*
11.	*Bendemere Shire*	[1]
12.	**Biggenden Shire**	
13.	**Blackall Shire**	
14.	**Boonah Shire**	
15.	**Booringa Shire**	
16.	*Boulia Shire*	[1]
17.	**Bowen Shire**	
18.	**Brisbane City**	
19.	**Broadsound Shire**	*
20.	**Bulloo Shire**	
21.	**Bundaberg City**	
22.	**Bungil Shire**	*
23.	*Burdekin Shire*	
24.	*Burke Shire - received but not included*	
25.	**Burnett Shire**	
26.	**Caboolture Shire**	(8)
27.	**Cairns City**	(2)
28.	**Calliope Shire**	
29.	**Caloundra City**	
30.	**Cambooya Shire**	
31.	**Cardwell Shire**	
32.	**Carpentaria Shire**	(2)
33.	*Charters Towers City*	[1]
34.	**Chinchilla Shire**	
35.	**Clifton Shire**	*
36.	**Cloncurry Shire**	*
37.	**Cook Shire**	(3)
38.	**Cooloola Shire**	
39.	*Crows Nest Shire*	[1]
40.	**Croydon Shire**	
41.	**Dalby Town**	
42.	**Dalrymple Shire**	[1]
43.	**Diamantina Shire**	*(2)
44.	**Douglas Shire**	
45.	**Duaringa Shire**	*
46.	**Eacham Shire**	
47.	*Eidsvold Shire*	[1]
48.	**Emerald Shire**	
49.	**Esk Shire**	
50.	*Etheridge Shire*	[1]
51.	*Fitzroy Shire*	
52.	*Flinders Shire*	[1]
53.	**Gatton Shire**	
54.	**Gayndah Shire**	
55.	**Gladstone City**	
56.	**Gold Coast City**	
57.	**Goondiwindi Town**	
58.	**Herberton Shire**	
59.	**Hervey Bay Shire**	(2)
60.	**Hinchinbrook Shire**	
61.	*Ilfracombe Shire*	[1]
62.	**Inglewood Shire**	
63.	**Ipswich City**	
64.	**Isis Shire**	*
65.	**Isisford Shire**	
66.	**Jericho Shire**	(2)
67.	**Johnstone Shire**	
68.	**Jondaryan Shire**	(2)
69.	**Kilcoy Shire**	
70.	**Kilkivan Shire**	*
71.	**Kingaroy Shire**	
72.	**Kolan Shire**	*
73.	**Laidley Shire**	
74.	**Livingstone Shire**	
75.	**Logan City**	
76.	*Longreach Shire*	[1]
77.	**Mackay City**	
78.	*Mareeba Shire*	
79.	**Maroochy Shire**	
80.	**Maryborough City**	
81.	**McKinlay Shire**	
82.	**Millmerran Shire**	*
83.	**Mirani Shire**	
84.	*Miriam Vale Shire*	
85.	**Monto Shire**	*
86.	*Mornington Shire*	[1]
87.	**Mount Isa City**	
88.	**Mt Morgan Shire**	
89.	**Mundubbera Shire**	
90.	**Murgon Shire**	*
91.	*Murilla Shire*	[1]
92.	**Murweh Shire**	(2)
93.	**Nanango Shire**	
94.	*Nebo Shire*	[1]
95.	**Noosa Shire**	
96.	**Paroo Shire**	
97.	**Peak Downs Shire**	*
98.	**Perry Shire**	*
99.	**Pine Rivers Shire**	
100.	*Pittsworth Shire*	[1]
101.	**Quilpie Shire**	
102.	**Redcliffe City**	
103.	**Redland Shire**	(2)
104.	**Richmond Shire**	
105.	**Rockhampton City**	
106.	**Roma Town**	
107.	**Rosalie Shire**	(2)
108.	**Sarina Shire**	(5)
109.	*Stanthorpe Shire*	[1]
110.	**Tambo Shire**	
111.	**Tara Shire**	
112.	**Taroom Shire**	
113.	**Thuringowa City**	
114.	**Tiaro Shire**	
115.	**Toowoomba City**	
116.	*Torres Shire*	[1]
117.	**Townsville City**	
118.	**Waggamba Shire**	
119.	**Wambo Shire**	
120.	**Warroo Shire**	
121.	**Warwick Shire**	
122.	**Whitsunday Shire**	*
123.	**Winton Shire**	
124.	**Wondai Shire**	*
125.	*Woocoo Shire*	[1]

Italic = no response received
[1] = not chased up - believed to have no problem
Bold = response received
* = no obvious problem
(#) = multiple responses received

3.2 Discussion of the questionnaire

Responses to the questionnaire are used as a basis for discussion throughout the remainder of this report.

This Section (Section 3) concentrates on the size of the problem, Section 5 *on Hydrological information, mapping, damage studies, mitigation and policy, Section 6 on Flood warning systems and counter disaster plans and Section 7 on The largest known flood - the effects on lifelines.*

An overall summary to the questionnaire results is given in Section 10.

Appendix 1 provides detail on responses from each LGA. This omits qualifying comments. The original forms and a spreadsheet of responses with included comments are held by the Department of Natural Resources.

Appendix 2 is a copy of the questionnaire with, where appropriate, indications of the responses to each question.

3.3 Interpreting questionnaire responses

Before presenting an analysis of the responses it is important to the note difficulties in designing a questionnaire to cover LGAs that differ in size from Brisbane City Council to remote locations in the north and west of the State that cover areas of several thousand square kilometres but have populations of only a few hundred. There are also difficulties in that the questions were designed to obtain information from LGAs that had undertaken hydrological and vulnerability studies as well as those that had no detailed information whatsoever.

The analysis presented below does not give detailed quantitative information for each section of each question on the questionnaire. However, Appendices 1 and 2 to the report present a summary of all questions from each questionnaire received.

Because of the comprehensive nature of the questionnaire, it was not possible for all respondents to provide answers to each question and sub-question. Therefore, the number of answers to each question varies. This is indicated by presenting the results to individual questions in the form of '55 of the 101 respondents'.

A limited number of questions were included that allowed LGAs to comment on whether they had a risk from storm (tide) surge. This was not intended to be a detailed survey but to gain some overall indication of the perceived size of the storm surge problem which has much in common with overland mainstream river flooding. The results for storm surge are discussed in Section 9.

3.4 Size of the urban flood problem

Ideally the first step in analysing the size of the urban flood problem in Queensland would be to present data on the numbers of buildings at risk from overground (or over-floor) inundation from both the designated flood (usually that associated with the 1 in 100 year event) and the probable maximum flood. The latter is rarely available in Australia or elsewhere and it is standard practice to use the 1 in 100 year flood to define numbers of buildings, see Section 1.2. However, in Queensland only a limited number of LGAs have undertaken the detailed hydrological studies necessary to define this level, in such circumstances the best estimate (although far from ideal) can sometimes be obtained by considering the flood of record.

3.4.1 Definitions used to define the number of flood prone buildings

The questionnaire was designed to obtain information on numbers of buildings for both the *Largest recorded event* (Questions 4.4 to 4.7) and the *Total number of buildings flooded by the adopted designated event* (Questions 6.8 to 6.11). Where possible the respondents were requested to classify the number of buildings into residential, commercial, industrial and caravans (including mobile homes). In both cases information was requested from the best available data. In a limited number of cases this aspect of vulnerability was known in detail, eg. for Mackay and Charleville both based on detailed GIS studies of individual buildings, but for many other locations the size is often that of an educated guess.

In order to preserve comparability, the number of flood prone buildings are in terms of over ground flooding. This is because it is the simplest, and most commonly used procedure, to estimate the number of buildings located below the level of the 1 in 100 year flood. The numbers of buildings that would experience over-floor inundation would be considerably less. The importance of this distinction will be illustrated in section 4 with data from the Gold Coast.

There are also difficulties in whether the data are expressed in terms of 'buildings' or 'properties'. The questionnaire was quite deliberately worded in terms of 'buildings'. This was because the use of the word 'property' is often interpreted at local government level to represent a building block, with or without a building on it. The other problem is that in the residential sector a 'building' can sometimes contain more than one dwelling unit, for example when the building is divided into flats or apartments. For much of Queensland this is a not a serious problem. However, for some localities (the Gold Coast is a prime example), they can be a significant difference between the number of residential buildings and dwelling units. The difference is important both for assessment of potential flood losses and for the emergency services, i.e. in converting residential buildings to numbers of people in order to plan for emergency evacuation.

For consistency, the numbers below are expressed in terms of flood prone buildings liable to over-ground flooding and with no allowance for the conversion of residential buildings into dwelling units. Similar assumptions are made in comparable flood studies in Australia and elsewhere, and in the AWRC (1992) report. For floodplain and emergency management at local level the details of numbers of buildings flooded over-floor and the number of individual dwelling units are however, important.

To provide even a provisional estimate of the numbers of flood prone buildings in Queensland is a difficult task. Using the survey responses to arrive at a total figure involved assessing the following components :

- numbers of buildings given in direct response to Questions 6.8 to 6.11, i.e. where the flood problem was relatively easily described by a number in the questionnaire answer box (these are described in Section 3.4.2 and summarised in Table 3.2)

- numbers of buildings for LGAs that did not provide a direct answer to Questions 6.8 to 6.11; these were in two groups:

  a) more complex responses where the flood problem was large or involved numerous catchments - typically the larger LGAs (responses for these are included in Section 3.4.3 and summarised in Table 3.4)

  b) estimates for councils known to have large numbers of buildings at risk that did not respond to Questions 6.8 to 6.11, these are also given in Section 3.4.3 and summarised in Table 3.4,

- allowance for missing data (i.e. those not considered in Sections 3.4.2 and 3.4.3), these are given in Section 3.4.4.

For many of the authorities with a small number of flood prone buildings the estimates are taken directly from the questionnaire, the totals for these are given in Table 3.2. The detail can be obtained from the precis of the individual questionnaires given in Appendix 1. Those with a larger number of buildings at risk fall into two categories. Some have information based on detailed hydrological and vulnerability studies, others base their estimates on very poor quality data. The councils with larger numbers of buildings at risk, with either poor or good quality data, are listed in Table 3.4.

Thus, Table 3.4 lists those authorities with a substantial urban flood problem for which the numbers of buildings at risk were not given directly in response to Question 6.8 to 6.11. For many of the authorities in this category, numbers were not given because the information was too complex for a simple answer. For the two councils with the largest numbers of flood prone buildings, Brisbane and the Gold Coast, the problems of providing estimates are described in detail in Section 4. Where the number of flood prone buildings is poorly known this is indicated in Table 3.4. For these larger authorities a short description is given for each in Section 3.4.3.

Care has been taken not to double count estimates from the responses, given in Table 3.2, with those listed in Table 3.4. Attention however, is drawn to the number of flood prone buildings in the Nerang catchment of the Gold Coast. Initial, and provisional, Council estimates were given on the questionnaire but more detailed information was made available to the study at a later stage. In this instance, the initial estimate of 5,000 flood prone buildings given on the questionnaire has been omitted from the totals in Table 3.2 and the new estimate (of 16,650) added to Table 3.4.

Table 3.5 presents a consolidated ranked list, based on the information given in the questionnaire responses and from the data in Table 3.4. Of the twelve councils in Queensland that have the largest number of buildings at risk from urban flooding to the level of the 1 in 100 year flood event.

3.4.2 Numbers of flood prone buildings – reported in the questionnaire

The response to Questions 6.8 to 6.11, which requested the best estimates of the number of buildings at risk from flooding to the level of the designated flood, provided direct information for 34 urban locations from 23 LGAs. The totals for these locations are given in Table 3.2.

Table 3.2 **Total number of buildings at risk from flooding to the level of the designated flood, direct responses to Questions 6.8 to 6.11**

Number of buildings				
Residential	**Commercial**	**Industrial**	**Caravans (mobile homes)**	**Total**
7,189	345	217	474	8225

The provisional estimate for the Nerang Catchment given in the questionnaire response by the Gold Coast City Council has been omitted from Table 3.2.

The poor number of direct responses to this question is perhaps not surprising, this is because only 43 out of the 108 locations reporting to have carried out a 'flood' study in the questionnaire (Question 6.1), have designated flood levels.

There is also a difficulty in converting these data to number of buildings liable to flood from the 1 in 100 year event. This is because there are variations between the locations in the definition used for the designated flood. These variations are summarised in Table 3.3.

Table 3.3 **Definitions of the designated flood, based on Question 6.5**

Designated floods (numbers of LGAs)			
1 in 100 year	**1 in 50 year**	**Below 1 in 50 year**	**Flood of record**
27	11	4	2

The four locations that used a value below that of the 1 in 50 year have a variety of levels for the designated flood. For example, Ipswich uses the 1 in 20, Mt Isa the 1 in 15, Townsville the 1 in 10 and Hinchinbrook the 1 in 3 year level. Such criteria would not be acceptable by those States and nations that have urban floodplain management guidelines or regulations. Beaudesert and Mirani use the flood of record.

A further complication is that for some councils the designated flood level varies, for instance different criteria for mainstream and creek flooding. Examples of this kind are provided by Laidley and Logan.

There is also a problem in distinguishing between 'commercial' and 'industrial' buildings and for the overall State summary it is recommended that the two are combined into a single class. Any subsequent survey should aim to list major flood prone industrial complexes.

An example from Gladstone indicates that much of the large port complex is at risk from flooding, and for Brisbane industrial flood damage would be large.

3.4.3 Estimates of the number of buildings NOT included in the direct responses to Questions 6.8 to 6.11 and for which information is known to exist

The most significant feature of the response to the questions that describe the number of buildings at risk from the designated flood is that many of the LGAs with a known flood risk provided no information (ie did not complete Question 6.8 to 6.11, by reporting the number of buildings flooded to the level of the adopted designated flood). Table 3.4 lists estimates from other sources for many of the missing LGAs known to have a significant number of buildings at risk.

Also included in Table 3.4 are figures for those LGAs, such as Gold Coast and Brisbane, which were unable to provide a response by simply entering a number in answer to Question 6.8 to 6.11 but did however provide detailed data.

Table 3.4 Estimates of the number of buildings at risk for LGAs not completing Question 6.8 to 6.11

Local Government Authority	Number of buildings to 1 in 100 year level
Mackay	8, 500
Brisbane (Brisbane River and Creeks)	8, 000
Gold Coast	
Nerang catchment	14,650
Other catchments	2,000 ± 1,000
Dalby	3, 300
Ipswich (All catchments)	*3, 000
Charleville	1, 350
Rockhampton	1, 200
Burdekin	*1, 000
Total	**43,000**

* Poor quality estimates

An outline to the sources for each of the locations listed in table 3.4 is given below.

Gold Coast

Revised estimates for the Gold Coast based on detailed studies for the Nerang catchment (available after the questionnaire was completed) are discussed in detail in Section 4. The figure used in the estimates of numbers of buildings at risk in Table 3.4 (i.e. 14,650) is for 400 commercial and 14,250 'residential properties'. The Gold Coast is unusual in the large number of 'residential properties' (this equates to buildings) that contain a number of individual 'dwellings', i.e. multi-occupancy as flats or apartments, are relatively common. The number of 'dwellings' is estimated to be 28,600 ±-2,000. For reasons of consistency, the figure of 14,650 has been used in Table 3.4.

Other catchments in the area administered by the Gold Coast City Council also contain urban flood prone land, studies for these is less complete than for the Nerang catchment The Council provisionally estimates a combined total of 2,000 ±-1,000 flood prone buildings for the remaining catchments.

Mackay

A study of storm surge for south and north Mackay (the latter was then in the Pioneer Shire) also provided a building by building data base that could be used to estimate the numbers liable to flood from the Pioneer River, see Smith and Greenaway (1994). The problem for the estimation of mainstream flooding is that precise definition of the 1 in 100 year flood is not available (i.e. extent and slope). Despite this limitation, the combined estimate for south and north Mackay for residential, commercial and industrial buildings is 8,500 (to the level of the 1 n 100 year flood).

Brisbane

Details of the estimates for the main Brisbane River (post-Wivenhoe Dam) and for the various creek catchments in the area administered by the Brisbane City Council are given in Section 4. The favoured official figure is about 8,000 (all types of buildings) although there are reasons to consider that this may be an under-estimate. There is no doubt that some very large industrial enterprises are included. With the completion of a revised hydrological study, currently in progress, for the Brisbane River and the impending AGSO Cities Project study of vulnerability these estimates will be greatly improved.

Ipswich

Information for Ipswich is poor, although detail is known for Bundamba Creek, one of the sub-catchments. Based on the 1974 flood, 2,500 buildings were flooded. Although this would come close to a 1 in 100 year event such data are over twenty years old and with a 1 in 20 year designated flood level it is certain that the current number of buildings at risk would be larger, hence an estimated total of 3000 has been adopted.

Dalby

A Flood Management Study was commissioned by Dalby Town Council, after a series of major floods in the early 1980s. That study forms the basis for the estimation of the number of urban buildings at risk. Of the total of 3,300, about 400 are used for commercial or industrial purposes.

Charleville

Extreme floods occurred over a wide area of western Queensland in April 1990 and this led to detailed studies of the flood hydrology and of the vulnerability of the community affected. The study is reported in the *Western Queensland Flood Study*, Camp, Scott and Furphy (1991) The largest of the urban communities was Charleville which was estimated to have 1350 buildings within area subject to the 1 in 100 year flood. Of these, 1225 were residential and 125 commercial.

Rockhampton

Detailed consultant studies are available for the City of Rockhampton and these include estimates of the number of buildings, see Camp, Scott and Furphy (1992). However, these were not reported in the questionnaire and a provisional figure of 1,200 is used. Further detail could be obtained from the flood studies available to the council.

Burdekin

Unfortunately questionnaire information from Burdekin is lacking. Urban locations within the area administered by the council are thought to have a significant flood problem, especially for low probability flood events. The number of 1,000 is merely indicative of the size of the problem.

Combining the questionnaire results, consolidated in Table 3.2, with those in Table 3.4 gives a provisional estimate for the number of flood prone urban buildings in Queensland at the 1 in 100 year flood level. The total is close to 51,000, this combines residential, commercial, industrial and mobile homes. A ranked list of the twelve most flood prone LGAs, based on the questionnaire and Table 3.4, is presented in Table 3.5.

Estimates of the number of buildings liable to inundation for floods of greater severity than the 1 in 100 year event are discussed in Section 3.5 and summarised in Section 3.6.

Table 3.5 A list of the twelve LGAs with the largest number of buildings at risk from the 1 in 100 year flood

Local Government Authority	Number of buildings[1]
Gold Coast	16,650
Mackay	8, 500
Brisbane	8, 000
Dalby	3, 300
Ipswich	3, 000
Logan	2, 375
Hinchinbrook	2, 175
Charleville	1, 350
Rockhampton	1, 200
Burdekin	1, 000
Cairns[2]	728
Caboolture	455
TOTAL	**48,733**

1 Includes residential, commercial, industrial and caravans

2 Limited to the extent of the former Mulgrave Shire, riverine flooding in the area of the former Cairns City is, in comparison, limited (refer Section 9 for surge inundation estimates for Cairns and other coastal centres)

3.4.4 Missing data

The total of 51,000 buildings at risk from flooding at the 1 in 100 year level is not fully inclusive. As indicated, some of the questionnaire responses are for a designated flood that is lower than the 1 in 100 year flood level (and as a consequence are an underestimate of the number of properties at risk from the 1 in 100 year flood). It should be noted however, that the estimates in Table 3.4 are for the 1 in 100 year flood.

There remains the problem of LGAs who did not complete Ques 6.8 - 6.11 (Table 3.2) and for which estimates are not given in Table 3.4. It is unlikely that, to the level of the 1 in 100 year flood, any of the missing LGAs have exceptionally large numbers of flood prone buildings, say more than 500 at any single location. Even this statement needs caution as the very large numbers for the Gold Coast were unknown until recently, the size of flood risk at Mackay was not appreciated until the storm surge study undertaken in 1991 and Charleville was not thought to have a serious flood risk until the floods of 1990.

Further, the floods of early 1997 drew attention to a number of relatively small urban locations that had previously been considered, erroneously, as flood free. It is also salutary to note that whenever detailed, building by building, surveys are undertaken, the size of the problem increases over that for earlier estimates! This certainly was the case for New South Wales as building by building surveys replaced the original estimates provided by Councils. Undoubtedly, future floods will provide similar surprises.

3.4.5 Overall estimate of the number of flood prone buildings in Queensland

The estimate, given above, of 51,000 buildings at risk from the 1 in 100 year flood need modification to account for the missing and incomplete data indicated above.

A cautious estimate would be 60,000 but it is considered more likely that, if and when local urban flood studies are complete, that the number could be nearer to 65,000. It is also pertinent, to stress that without basic hydrological information and designated floods for planning purposes that the number is increasing year by year.

3.5 Probable maximum flood

Comprehensive studies of urban flood damage should consider the potential impact of the probable maximum flood (PMF). This is not in order that the limits of the PMF should be used as a designated flood for planning purposes but it is necessary in order to evaluate potential flood damage, the risks of building failure and to provide the emergency services with information to enable reduction in flood losses, especially the risk to life. The need is to estimate PMF although it is stressed that for many localities the increased risks could be relatively small, the significance is that for other locations the risks could be high. The background to the need for PMF information is given in Section 1.5.3.

3.5.1 PMF and the questionnaire

The lack of hydrological studies for most prone locations in Queensland is such that data on the extent of extreme events are often lacking. Only about 20% of responses (23 out of 108) indicated that they have data on the discharge of the flood of record. Such information is of course, invaluable for the subsequent estimation of the PMF.

Ques 6.3 specifically asks '... *has the PMF discharge been estimated*', less than 10% of the respondents (11 out of 109 replies) indicate that they had; examples of those that have such information are St George, Bowen, Gladstone and Rockhampton. Only 8 of the 10 with PMF discharges have converted the data into map form, LGAs that have include Cairns (Mulgrave), Noosa, Pine Rivers and Redland.

The questionnaire did not ask whether hydrological studies had included estimates of over-floodplain velocities, but it is extremely unlikely that this has been undertaken by more than a handful of authorities. Logan is one example that has information on velocity which has been used to assess the likelihood of building failure.

It is clear that, with few exceptions, information on the PMF or extreme floods (i.e. those in excess of the 1 in 100 year event) is not normally available. To follow best practice, estimates of flood discharges up to and including the PMF, their areal extent and over-floodplain velocities should be incorporated into all hydrological studies for flood prone urban locations.

This applies to existing urban developments and, equally important, for those yet to be developed above the level of the designated flood. It is crucial that the community perception does not consider that areas above the designated flood, regardless of its annual recurrence interval, are flood free. The PMF and velocity information are of significance for the emergency services and are necessary to establish comprehensive flood loss data for use in any form of cost benefit analysis. Often insurance companies are one of the few institutions to take cognisance of the risks involved from such extreme events.

Although detailed data are uncommon, there is little doubt that a near PMF for locations with a high flood range would result in structural building failure especially for many existing residential developments. Ipswich is one such example, some 30 dwellings failed during the 1974 flood and an event of greater magnitude would dramatically increase the number of such failures. This would clearly, pose a very real risk for loss of life.

3.5.2 Probable maximum flood – buildings at risk

Precise estimates of the number of buildings at risk from flooding to the level of the PMF are rarely available in Australia or overseas. Such studies in Australia are restricted to a limited number of urban flood prone communities in New South Wales.

Currently there are no detailed estimates of the numbers of buildings at risk from PMF or extreme floods for any location in Queensland.

Thus, evaluation of the risk to buildings above the level of the 1 in 100 year flood is essentially unknown. The account below attempts to describe the problem and its likely significance.

3.5.3 Increases in the number of flood prone buildings at the level of the probable maximum flood

The AWRC (1992), and earlier reports, specifically limit the numbers of flood prone buildings to those at risk from the 1 in 100 year event. This is done for the very good reason that few maps exist that show flood lines for events that exceed the 1 in 100 year level. Indeed, the only examples that consider this problem in any detail have been produced by CRES at ANU, see Smith (1991). A detailed account of these studies is given in Appendix 3.

For the case studies discussed in Appendix 3, (the Hawkesbury-Nepean region of western Sydney, the Georges River and Prospect Creek in Sydney, Queanbeyan in inland New South Wales and Canberra) the number of buildings subject to inundation at the level of the PMF are three to six times greater than the number for the 1 in 100 year flood event. The increases in flood height from the 1 in 100 year flood to the PMF for these localities are in the range from about 3 metres to greater than 10 metres. The larger the flood height range, the larger the increase in the number of buildings at risk when compared to those for the 1 in 100 year flood event.

Table 3.6 lists a selection of flood prone locations in Queensland known to have large height ranges. Although local site factors are significant, it is likely that increases in the number of buildings subject to inundation from a PMF would be comparable to those for the examples listed above in New South Wales and the ACT.

Table 3.6 Increases in flood height from the 1 in 20 to 1 in 100 year flood for a selection of Queensland towns

Ipswich, Brisbane-Bremner River	15.0+m
Kenilworth, Mary River	7.0 m
Gympie, Mary River	12.0 m
Taroom, Fitzroy River	7.0 m

The increases are related to the valley topography but are exacerbated by development guidelines that use the 1 in 100 year event as the definition of flood prone. This is because once floods exceed the 1 in 100 year level a large number of buildings, located just above the 1 in 100 year line to conform with development regulations, are inundated.

Of significance for urban locations with large flood ranges is the depth of inundation experienced by buildings that are located at, say, the 1 in 50 year level. These will have water over their rooves for near PMF events. It is this factor which is largely responsible for structural failure.

It is important to stress that all the case studies in Appendix 3 and in Table 3.6 are for locations which have relatively high flood level ranges. Such effects are not universal or even widespread. For example, they would be insignificant for most inland locations in New South Wales, along the Murray, in Adelaide and for most of Tasmania and Western Australia. However, high flood ranges occur in Ipswich, much of Brisbane and for some of the coastal flood locations in New South Wales and Queensland.

Attempts to allow for the markedly increased damage for locations with high flood ranges will be made in Section 8. Suffice it to say that such effects must be considered if the aim is to obtain realistic damage estimates on which to base flood mitigation strategies and their cost benefit ratios.

3.6 Probable maximum flood – summary

The responses to the question 6.3 illustrate the paucity of PMF data for Queensland, less than 10% had estimates of the PMF discharge and even fewer had converted this to maps showing the extent of the PMF event. There is clearly, an urgent need to consider the impacts of extreme floods to the level of the PMF. This is necessary to improve both the effectiveness of the emergency services to reduce all forms of loss from such extreme events and as a basis for acceptable and comprehensive cost benefit analyses of flood mitigation measures to lessen the losses to existing flood prone developments, especially those below the level of the 1 in 100 year flood.

Background data from New South Wales for locations with moderate to high flood height ranges, have been used to illustrate the nature of the problem (see Appendix 3). As a preliminary (and conservative) value it is not unlikely that the number of buildings in Queensland liable to inundation from the PMF are up to three times the number at risk from the 1 in 100 year flood event, i.e. close to 200,000 buildings.

Given the overall lack of PMF data for Queensland, it would be necessary to prioritise those LGAs with the major risk, ie those with a moderate or high flood ranges. The most significant of these is Ipswich, other locations include Brisbane River, Logan River, Mary River, and Taroom with others selected in consultation with the Bureau of Meteorology. Once the discharge and areal limits of the PMF are available, ideally with estimates of over-floodplain flow velocities, the risk of building failure could be assessed.

The selection of designated flood levels for urban floodplain management should incorporate the analysis of the effects of extreme floods especially for those localities that are known to have a high flood range. In some cases it would be inadvisable, if only on the grounds of safety, to use the 1 in 100 year flood for such purposes.

4

Brisbane and the Gold Coast

4.1 Brisbane and the Gold Coast

Brisbane City and Gold Coast City Councils completed the questionnaire circulated to all Queensland LGAs. However, in both cases the responses were limited to individual river catchments, the main Brisbane River and (for the Gold Coast) the Nerang catchment. As both councils have particularly large and complex urban flood problems interviews were held with senior staff to gain further information on the other flood prone catchments in their areas of jurisdiction. This section reports on the overall problem for both councils, first for Brisbane and then for the Gold Coast.

For Brisbane, the current study had access to an extensive series of reports of flood studies undertaken for the Creek catchments over many years. The section below combines this information with that given in the questionnaire for the main Brisbane River.

The Gold Coast also has a number of separate catchments, many of which contain major flood prone urban developments. Until the last year or so information on flood risk and vulnerability was not known in any detail, however comprehensive studies for the Nerang catchment were made available after the completion of the questionnaires. For the other catchments similar studies are not yet fully complete and the information reported below is limited to an outline of the likely situation. The flood studies for the other Gold Coast catchments, have yet to be finalised.

4.2 The flood problem for Brisbane

The Brisbane floods of the Australia Day week-end of 1974 still represent the most severe example of urban flooding in Australia, with an estimated damage bill of at least $200m at 1974 values. It is important to note that this widely quoted figure, based upon the SMEC (1975) flood study does not include the severe flooding of the Bremer River or of the Brisbane creek catchments. Even before the 1974 flood, inundation maps were available for parts of Brisbane and subsequent to the event Brisbane City Council embarked on a major series of flood studies for the creek catchments followed, in many cases, by the construction of flood mitigation works. Flood information on flood hydrology for the Brisbane Creeks is likely the best for any major metropolitan area in Australia. From the late 1970s, the City Council has progressively imposed land use controls and building regulations for new developments in flood prone areas.

The flood problem in Brisbane has two major components, flooding along the main stream of the Brisbane River and flooding in the smaller catchments, many of which are tributaries to the Brisbane River. This second category is often referred to as 'Creek flooding', some 26 separate creek catchments are recognised although many of these are conveniently grouped into larger catchments. The relationships between the Brisbane River and the Creeks are illustrated in Figure 4.1.

The questionnaire completed by Brisbane City Council, and the data reported in the Tables in other sections, relate solely to flooding along the main channel of the Brisbane River. The Creek catchments that pose major flood threats to buildings and infrastructure are named on Figure 4.1.

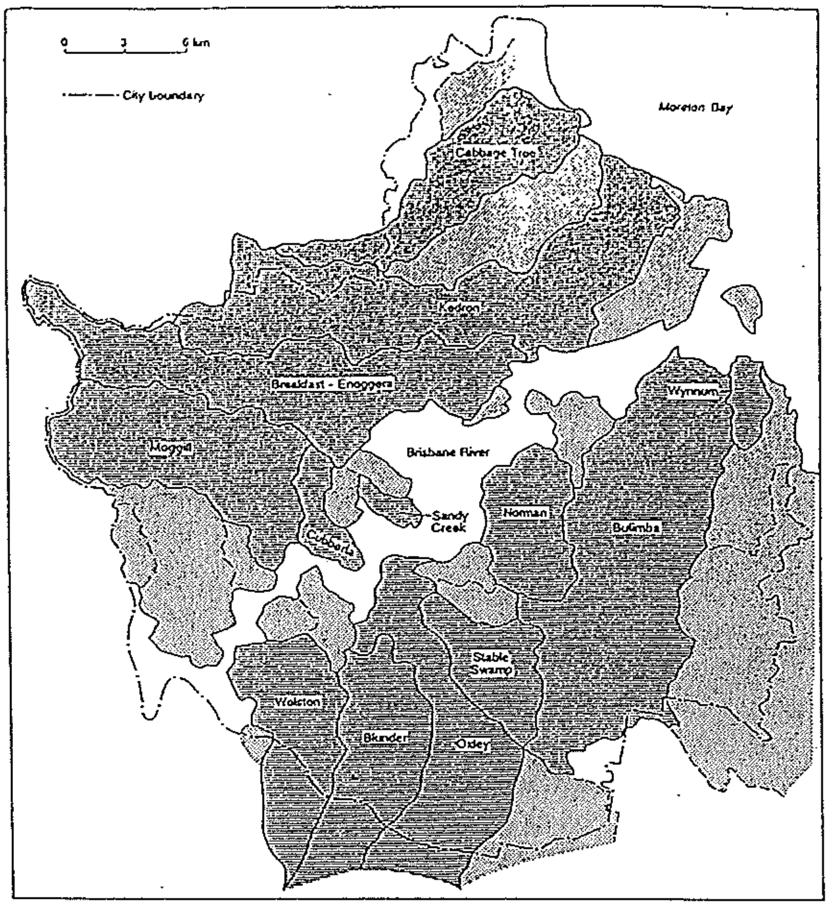


Figure 4.1 The Brisbane River and creek catchments in the area administered by Brisbane City Council

The nature of the flood risk differs markedly between the main river and the Creeks. The most significant difference is in the time interval between rainfall and downstream flooding. Oxley Creek is the largest of the Creek catchments with a length of about 53 km, the corresponding values for the other major Creeks are Bulimba at 41 km, Kedron 27 km, Breakfast/Enoggera 24 km, Cabbage Tree 23 km, Moggill 22 km and Norman 13 km. Carroll (1991), in a study of the warning times and flood forecasting in the Brisbane region, estimated that the time between rainfall and downstream flooding is about 18 h for Oxley Creek with all the other creek catchments having times of nine hours or less. Carroll estimates the effective warning time for Oxley Creek to be about 11 hours, for all the other catchments the effective warning times are 5 h or less. For Wynnum, one of the smaller creeks, the effective warning time is less than an hour.

These relatively short warning times contrast to the main Brisbane River where the warning times are in the range 12 - 24 h, for the 1974 floods the Creeks peaked more than 24 h before the main river. The differences between the times for the main Brisbane River and the Creeks is significant for measures designed to reduce risk of life and contents damage to dwellings and to commercial and industrial enterprises.

4.2.1 Problems with the assessment of flood vulnerability

Hydrological information for the Creeks is excellent and is used to define flood regulation lines on which land use and building controls are based. The only shortcoming is that detailed information on the number of buildings at risk from flooding is not known. This stems from the problem that, although both flood data and property boundaries are combined into a long established and well designed GIS for the whole of the region administered by the Brisbane City Council, there is no differentiation between those blocks on which there is a building and those that have not been developed. It is likely that this deficiency will be addressed in the near future as a part of the Australian Geological Survey Organisation (AGSO) Cities Project. Once such building information is incorporated into the GIS, the ability to use the data base for emergency management will be greatly enhanced.

This restriction on information on the type and number of flood prone buildings applies to both the Brisbane River floodplain and to the Creeks. For the main river, and for some of the Creeks, the earlier flood studies estimated the number of buildings at risk. For the main river these were based on the data collected by the SMEC (1975) study, those for the Creeks were much less precise although some have been revised on the basis of additional field studies. This is the case where economic assessments were undertaken in order to evaluate the costs and benefits of a range of floodplain mitigation options many of which were of a structural nature. To undertake such analyses it was necessary to assess flood damage under current conditions and this required data on the number and type of existing buildings. However, progressively the Creek studies were restricted to assessment (or re-assessment) of the flood hydrology and the evaluation did not include assessment of structural mitigation options.

Thus, information on the numbers of buildings at risk from flooding in Brisbane is not consistent across the catchments. This has been further complicated by other factors. These include:

- increases in upstream flood storage after the completion of the Wivenhoe Dam in 1985, this decreased downstream flood risk for the floodplain of the Brisbane River,
- in several of the Creek catchments structural works have lessened the flood risk
- the possibility of construction of new developments in flood prone locations.

Each of the factors is considered below.

4.2.2 The effects of the Wivenhoe Dam

The extra flood storage provided by the Wivenhoe Dam undoubtedly reduced downstream risk but the widespread community perception that it eliminated the flood problem is false. Data reported in CRCE Water Studies (1986), reproduced here as Table 4.1, provide estimates of the changes in risk for the Brisbane River floodplain due to enhanced upstream dam storage and compares the 1974 flood data to that for a re-run of that event under post-Wivenhoe conditions. These data suggest that the mainstream flooding for a 1974 event (close to the 1 in 60 year event) under current conditions would affect 4,900 dwellings and 1,600 commercial and industrial enterprise. It is estimated that the peak height of the 1974 flood in central Brisbane would be reduced by 1.45 m.

Table 4.1 Effects of Wivenhoe Dam on 1974 flood levels and damages for the Brisbane and Ipswich areas. From CRCE Water Studies (1986)

	1974 Flood Pre-Wivenhoe	1974 Flood Post-Wivenhoe
Flood height (AHD) Brisbane City gauge	5.45	4.00
Flooded houses	9,800	4,900
Flooded commercial/industrial enterprises	2,700	1,600
Total damage ($\$10^6$ at 1974 values)	180	80

A re-assessment of flood hydrology for the Brisbane River is listed as a priority by Brisbane City Council and is currently in progress. Studies are also in progress to re-assess the flood hydrology of Oxley and Wynnum Creeks. It is Council policy to re-assess the hydrology of the Brisbane Creeks on a 15-year cycle. This enables the effects of developments to be incorporated, offers the opportunity to utilise additional runoff and rainfall data and ensures that best practice techniques are employed. It needs to be stressed that developments that effect urban runoff are not restricted to buildings within the flood prone parts of the catchments but include a wide range of changes to land use modifications throughout the Creek catchments.

The policy of a 15-year rolling cycle of hydrological studies is to be commended and is not generally practised elsewhere in Australia or overseas.

4.2.3 Effects of structural works

The Creek catchments contain residential, commercial or industrial buildings constructed before floodplain management policies were introduced to regulate development in flood prone locations, in some cases before susceptibility to flood risk was known. Post-1974 flood mitigation studies were undertaken for these catchments, and where economic and physical factors allowed, a range of structural measures were undertaken to reduce flood risk. Thus, early estimates of the number of buildings at risk from a re-run of the 1974 event have now been reduced. Precise information on the numbers of buildings involved are not known but locally these could be substantial.

An evaluation of the reduction of flood risk due to structural mitigation works is available for the Norman Creek catchment. The initial study, entitled the *Norman Creek Flood Mitigation Report* was undertaken by Brisbane City Council (BCC, 1984). This noted that some 300 dwellings and 300 commercial enterprises were liable to flooding for a 1 in 100 year flood, the definition of flooding was over-ground level. On the basis of this study structural works were undertaken. A further study to assess the changes in hydrology due to the works was reported in the *Norman Creek Flood Study* (Connell Wagner, 1995). This study concluded that the estimated reductions in flood height due to the implementation of the works recommended in the BCC (1984) report were attained. The reductions in the height of the flood peaks vary throughout the catchment but in some locations achieved values in the range of 0.8 to 0.9 m. The 1995 study did not attempt to convert these changes in flood magnitude and frequency to economic gains but the original study in 1984 considers that these could amount to approximately half of the pre-works average annual damage.

Studies of this kind, i.e. that compare reality against original design, are unusual and this example for Brisbane is testimony to the high standard of the flood studies over the last twenty years.

4.2.4 Possibility of new flood prone buildings

The standard of flood hydrology in Brisbane is matched by the implementation of regulations to restrict development in areas of known flood risk. However, there is always the possibility that some developments have escaped enforcement of such regulations, particularly in the early years, if only because the limits of flooding were imperfectly known for the Creeks. Overall it is unlikely that there have been significant increases in the numbers of flood prone buildings in the area administered by the Brisbane City Council over the last twenty years or so. The reply to the questionnaire by Brisbane City Council, restricted to the main Brisbane River, lists a total of 6,027 buildings to the level of the designated flood (1 in 100 years) but comments, 'based on 1975 data – could be more houses affected now'.

4.3 Estimates of flood prone buildings in the floodplains of Brisbane river and creek catchments

The lack of information on the number of flood affected buildings and the problems of change with time, outlined above, restrict the provision of quantitative data on the size of the flood risk. A summary of the estimates is presented in Table 4.2, together with an indication of the date of the assessment. The details of the flood studies for the creek catchments are given in Appendix 4, they are not reported in the list of references. These present a complex picture which is discussed below.

First, Table 4.2 demonstrates the familiar problems associated with such estimates. They are limited to the risk from either the 1 in 100 year event or the flood of record (in this case the 1974 event) and it is not always clear if the numbers refer to above ground or above floor flooding. In recent years, the studies of flood hydrology commissioned by Brisbane City Council have included estimates of the magnitude of the probable maximum flood and over-floodplain velocities. Thus, when the data for the flood free buildings are fully combined with the City's GIS it will be a relatively simple matter to define precisely the vulnerability to flood in terms of ground or floor level and in terms of any flood frequency from 1 in 5 year to that for the probable maximum flood. It will also be possible to assess liability to potential structural failure of buildings in response to flood depth and velocity, information that is often lacking elsewhere. A listing of many of the major hydrological studies for the Brisbane Creek Catchments undertaken over the last 15 to 20 years is given in Appendix 4.

The official estimates supplied by the Brisbane City Council in the early 1990s, as a contribution to *Floodplain management in Australia* (AWRC, 1992, p.145), are described as follows:

> There are some 3,800 properties in Brisbane and Ipswich subject to flooding from the Brisbane River by the current 100 year ARI event. Brisbane City Council also estimate that there are some 6,000 properties in Brisbane (5,000 residential, 1,000 other) subject to major creek flooding. Some properties may be subject to both major creek flooding and Brisbane River flooding. It was assumed that 8,000 properties in the Brisbane metropolitan area were subject to 100 year flooding by either the Brisbane River or major creeks.

These data should be regarded as presenting a very general picture and are likely to be under-estimates.

Table 4.2 Estimates of number of flood prone buildings in the Brisbane region

	Residential	Commercial and Industrial	Total
Brisbane River* (SMEC, 1975)			
Pre-Wivenhoe			
4.0 m (1 in 28 yrs)	4941	1569 (+206)+	6716
6.0 m (1 in 60 yrs)	11614	3125 (+515)+	15284
Brisbane River* (Water Studies CRCE, 1986)			
Post-Wivenhoe	4900	1600	6500
Brisbane Creek catchments (BCC, 1977)			
Oxley	1500		1500
Enoggera/Breakfast	1100		1100
Kedron	1100		1100
Bulimba	50		50
Norman	50		50
Other creeks less than 50 buildings	-		-
Creek catchments from flood mitigation studies			
Oxley (BCC 1981)	1500		1500
Norman (BCC, 1987)	300	300	600
Cabbage Tree (Kinhill, 1991)	617	105	722
Bulimba (Connell Wagner, 1992	475	25	500
Brisbane (BCC estimates from AWRC 1992)			
Brisbane River (Post-Wivenhoe Dam)	3800		3800
Brisbane Creek catchments	5000	1000	6000
Brisbane overall (allowing for Brisbane Rivers and Creeks)	**8000**		**8000**

* Brisbane River and lower reaches of creeks, includes estimate for Ipswich
\+ Miscellaneous buildings

4.3.1 The SMEC flood study

The SMEC (1975) study of the Brisbane floods was the first study of its kind in Australia to accurately assess the number of buildings at risk from flooding and to combine this with stage-damage curves to provide an assessment of flood damage. A summary table from that report (SMEC, p.65, 1975) is reproduced here as Table 4.3. It is important to note that this relates only to flooding from the main Brisbane River although the numbers include buildings located in the lower reaches of the Creek catchments that would be flooded from the main river as well as from any separate floods from the upper reaches of the Creek catchments (at a slightly different time). The flood height (at the City gauge) for the 1974 flood was 5.5 m which gives approximately 15,000 buildings that experienced inundation over ground level, with most flooded above floor level. For an 8.0 m (1 in 110 year) flood the corresponding number is about 23,500.

Table 4.3 Numbers of buildings affected by various heights of flooding of the Brisbane River, from SMEC (p.65, 1975)

Flood height m	Recurrence interval	Commercial buildings	Industrial buildings	Residential buildings	Miscellaneous buildings	Total
2.0	1 in 11 yrs	165	64	208	32	469
4.0	1 in 28 yrs	708	861	4,941	206	6,716
6.0	1 in 60 yrs	1,230	1,925	11,614	515	15,284
8.0	1 in 110 yrs	1,664	2,615	18,461	786	23,526
9.0	1 in 150 yrs*	1,883	2,879	21,403	889	27,054

* Approximate, interpolated from data in SMEC (1975).
NOTE: Flood frequencies are post-Somerset Dam but pre-Wivenhoe Dam

The flood peaks correspond to the pre-Wivenhoe Dam situation although the flood peak was lower than under pre-1950s conditions due to the flood storage effects of the Somerset Dam. The data which correspond to a re-run of the 1974 event (post Wivenhoe dam), are a city gauge height of 4.0m,and total buildings of 6,716 (see Table 4.2).

There are other features of Table 4.2 which require additional comment. These include:

- all the estimates for flood prone buildings in the Creek catchments that have been updated with field studies show very significant increases from those based on earlier generalised information
- the problem of numbers of flood prone buildings for Ipswich

4.3.2 Increases with detailed field studies

Detailed field estimates of the number of buildings at risk for the Creek catchments are available for Norman (BBC, 1981), Cabbage Tree (Kinhill, 1991) and Bulimba (Connell Wagner, 1992). These all report significantly larger numbers that those in the provisional data of 1977. For example, the early estimates for Bulimba and Norman for the 1 in 100 year flood were both for 50 buildings but the detailed studies increase the listing to 600 and 500 buildings with over-ground flooding respectively. For Cabbage Tree the provisional estimate was for less than 50 buildings but with a field survey this increased to 722.

These discrepancies match experience elsewhere in Australia, that is provisional estimates seem always very much smaller than those found from field surveys of buildings.

Part of the discrepancy in Table 4.2 stems from the difficulty that the lower reaches of the Creek catchments are also subject to inundation from the main Brisbane River, further complicated by tidal and possibly storm surge associated with tropical cyclones which would, in many cases, be the trigger for severe rainfall and flooding. The effects of tides and surge have been incorporated into all recent hydrological studies commissioned by the Brisbane City Council but these rarely list the number of buildings at risk.

4.3.3 Numbers of buildings in Ipswich

Ipswich is inundated by floodwater from the Bremer River catchment but the flood height is effected by the height of the of the flood in the Brisbane River. The relationship between the two is complex and varies considerably from flood to flood, see SMEC (1975, p.25). For Ipswich, in contrast to Brisbane, there are no detailed hydrological studies or assessment of the number of flood prone buildings, although it is understood that such studies are currently in progress.

Chamberlain *et al.* (p. 9, 1981) report that for the flood of 1974:

> Ipswich City Council records show that over 1,800 buildings in that city, residential and commercial, were completely or partially inundated. Forty-one dwellings were swept away, 620 were completely submerged, and 974 partly submerged. Water entered about 200 other properties, though the buildings were not flooded [indicating over-ground but not over-floor flooding].

Thus, for the 1974 flood (close to a 1 in 100 year event for Ipswich) the number of buildings of all kinds flooded over ground was about 2,000.

These figures are now over twenty years old and, because Ipswich City Council regulations only prohibit new developments below the level of the 1 in 20 year flood event, the number of buildings currently at risk is likely to be much larger. The effect of Wivenhoe Dam at Ipswich would be restricted to the effects of the lowered tail water levels where the Bremer River joins the Brisbane River

4.4 Summary – number of flood prone buildings for Brisbane

Notwithstanding the generally excellent standard of the flood hydrology for both the Brisbane River and the Creek catchments, there are problems in providing detailed estimates for the number of buildings at risk from flooding. These are outlined above and include changes to flood risk due to mitigation works which vary in size from the Wivenhoe Dam to numerous minor structural works on many of the Creeks and lack of detail for developments described in section 4.2.4.

There are grounds for considering the official AWRC (1992) number of 8,000 buildings as given in Table 4.2 to be underestimates. The actual number could be considerably larger, based on supposition, perhaps by a factor of two.

The AGSO Cities Project, which commenced in late 1996, will focus on Brisbane as its major case study and will provide much improved information of the flood risks to buildings and infrastructure. As outlined above, the hydrological data base for the area administered by the Brisbane City Council is excellent but the need is to link this to GIS data for buildings and infrastructure. Such information will be of major value for emergency management and will also enable the further flood mitigation options, especially those of a non-structural nature, to be evaluated. The application of detailed regulations for the development of buildings and structures within the known flood prone areas have been in place for many years.

4.5 The flood problem for the Gold Coast

In this report the Gold Coast region equates to the area administered by the Gold Coast City Council and includes urban areas located in the catchments of the Logan, Albert, Coomera, Pimpama and Nerang Rivers together with a number of small catchments that drain directly into the Pacific Ocean. Prior to amalgamation in 1995 the region was under the jurisdiction of two local government authorities, namely Albert Shire and Gold Coast Council. As is commonly the case in Australia the river catchment boundaries are not coincident with those for local government and for the Logan and Albert Rivers upstream portions of the catchments remain the responsibility of other councils. For the Gold Coast region, this posed particular problems prior to recent amalgamation. An outline map of the major catchments and their relationship to the boundaries of the Gold Coast City Council are illustrated in Figure 4.2.

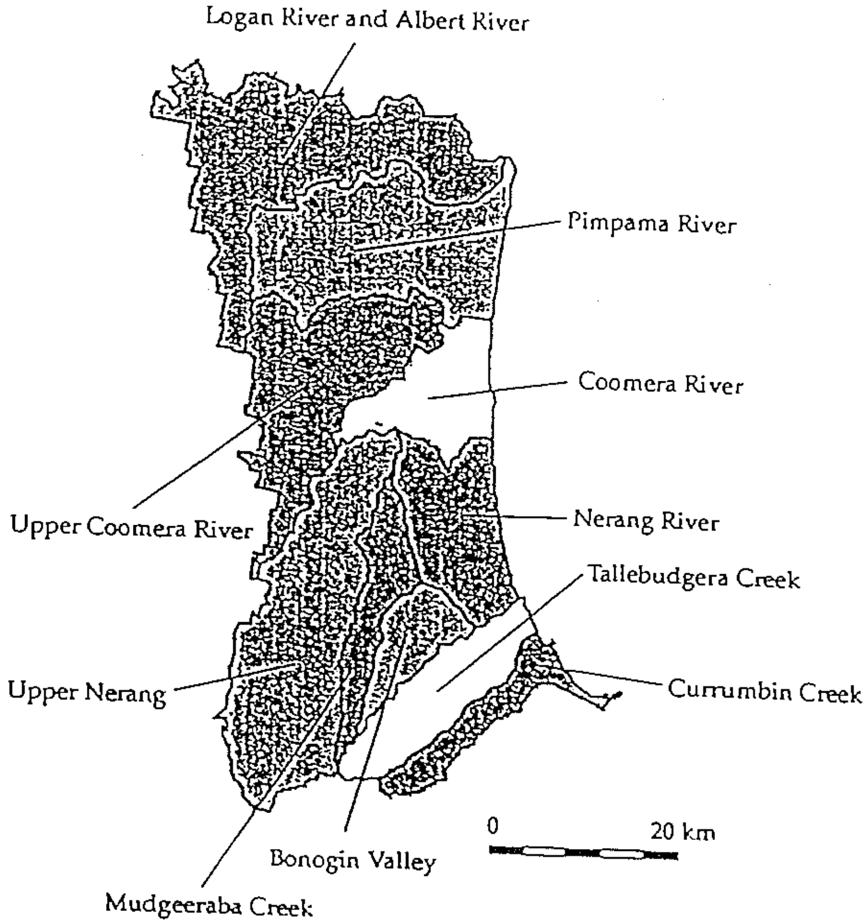


Figure 4.2 Gold Coast catchments

Based upon existing State government modelling, flooding for the Gold Coast region, in terms of the number of buildings, represents one of the largest single concentrations of urban flood risk in Australia. It is also noteworthy that the risk to the residential sector is exceptionally large.

There is abundant historical evidence of the stage height and extent of flooding in the Gold Coast region. A summary of these events is given in the *Logan and Albert Rivers Flood Warning System* (BOM, 1992). The floods of January 1887 and January 1974 represent the largest floods of record although for the former information is less detailed especially as regards the areal extent of inundation. The gauge height and extent of the 1974 flood, which was a major event throughout much of Queensland and New South Wales, is however well recorded and was subsequently mapped in detail for the Albert and Logan River floodplains by the Queensland Water Resources Commission. Maps of inundation for the 1974 flood also exist for the Pimpama, Coomera and Nerang Rivers as well as Tallebudgera and Currumbin Creeks, although the detail is less precise.

For the Nerang River system the January 1974 flood is estimated to have an annual recurrence interval of about 1 in 65-70 years. For the Coomera, Logan and Albert Rivers the 1974 flood is considered to be greater than the 1 in 100 year flood. It is pertinent to note that the 1887 flood was of greater magnitude and, although there is no available estimate of the annual recurrence interval, the gauge heights on the Logan River at Wakefield and Maclean's Bridge were between 0.6 and 0.8 m higher than for the peak of the 1974 flood.

Given this historical information of flood risk for the Gold Coast region it is surprising that data on the number of buildings at risk was not included in any of the earlier State surveys of flood risk; the numbers reported for Queensland are summarised in Section 2.2.1. Whilst there were land use controls provided by planning schemes which usually required compliance with a hydraulic study, individual developments have produced some afflux. It would appear that the cumulative effect of these developments would have significantly aggravated flooding problems if Council had not provided some additional flood mitigation benefit with the raising of Hinze Dam in the Nerang River catchment (the dam is primarily a reservoir to service the region's water supply needs). Developments had to show no adverse impacts in terms of afflux and floor levels were required to have either 150 mm or 300 mm freeboard above 1974 flood levels (former Albert Shire and Gold Coast City respectively). However, the last few years have witnessed major changes in the compilation of information on flooding and the implementation of land use and building regulations on the floodplains. An outline of these changes is given below.

4.6 Current status of Gold Coast urban floodplain management

The 1974 flood is estimated to have directly affected at least 1,000 dwellings in the Gold Coast region which at that time had a population of less than 100,000 people (today's population is about 350,000). Since that time major and widespread residential development has occurred in the area inundated by the 1974 event. The 1974 floods acted as a spur to undertake hydrological studies and, in addition to the map showing the 1974 flood limits, a physical model was developed for the Nerang River in the early 1980s. This was replaced, in 1989 by the production, of a one-dimensional computer model, by the Queensland Department of Primary Industries (now DNR).

In 1996 Council approved the development of two dimensional hydraulic and environmental models which have yet to be commenced. By 1997 a more sophisticated two-dimensional (MIKE 21) model which incorporated 130,000 grid points had been developed by a consultant acting for a landowner.

The overall situation in the Gold Coast region is similar to that described for the Brisbane City Council, i.e. there are a number of individual catchments each with their own hydrology. Each catchment requires detailed hydrological studies before reliable estimates of the number of buildings at risk, potential flood damages and possible flood mitigation options can be assessed. Projects to achieve these aims are actively in progress and the Gold Coast City Council in recent financial years has budgeted in excess of $1 m annually to meets these ends. The current status for the various catchments, provided by the City Council in response to the present study, is reproduced below.

Table 4.4 Localities affected by flooding in the Gold Coast Region

Catchment	Locality	Affected
Logan River	Waterford	Floodplain & Valley flooding
	Bethania	Floodplain & Valley flooding
	Beenleigh	Floodplain & Valley flooding
	Alberton	Floodplain & Valley flooding
	Woongoolba	Floodplain & Valley flooding
	Steiglitz	Floodplain & Valley flooding
Albert River		Valley flooding
Pimpama River	Norwell	Low lying areas and roads affected
Coomera River	Hope Island	Low lying areas flooding
	Upper Coomera	Valley flooding
Nerang River System	Area 65 sq km from Chevron Island in North to Burleigh Waters in South, West of Gold Coast Highway to Mudgeeraba in South West and to Nerang in North West.	Floodplain depths to 3.5 metres, residential areas affected
Nerang River	Upstream of Nerang	Valley flooding
Mudgeeraba-Bonogin Valley	No data available but some houses affected at Q5	Valley flooding
Tallebudgera Creek	Palm Beach	Floodplain
Currumbin Creek	Currumbin Waters	Floodplain

'Floodplain' indicates extensive inundation across the floodplain, 'Valley flooding' corresponds to flooding of more limited areal extent.

The current situation and stage of analysis is as follows:

Logan/Albert Rivers	Flood study by AWE for SOUTHROC has been recently completed. Flood inundation lines for various floods will be prepared and this data can be used to quiz Council's land use map and cadastre electronically.
Pimpama River	No flood study is available, however an approximate 1974 flood inundation line is available and an electronic quiz is possible.
Coomera River	Flood study by Kinhill Engineers has been undertaken, but inundation lines have not been prepared. An approximate 1974 flood inundation line is available for electronic quiz.
Nerang River System	Flood study is complete and inundation maps using early topographic data have been prepared by the Department of Natural Resources' Surface Water Assessment Group. New inundation maps are being prepared using photogrammetric data, and a flood damage study is in progress for Q20, Q50, Q100 and Q200 floods. At Q100 it is estimated there will be about 8,000 properties inundated and about 14,000 flood affected, with a private property damage bill of some $200 million.
Currumbin and Tallebudgera Creeks	Flood study is nearing completion and inundation maps will be prepared.

4.6.1 The hydrology

The hydrology of the of the catchments in the Gold Coast region poses particularly difficult problems: These include:

- the tidal nature of the rivers and creeks,
- the widespread changes to the catchment characteristics,
- surge associated with cyclonic conditions.

The lower sections of the larger rivers, namely the Logan and Albert, and the floodplains of the smaller rivers and creeks are all at low elevations and are therefore, affected by tidal influences. It is these areas that contain the major concentrations of residential growth, in part because of their appeal for water-based canal developments.

The construction of canal estates is but one example of the human-induced changes to the natural fluvial environment. Another is that the natural storage of the low-lying floodplains has been reduced due to fill to provide mounds on which dwellings are constructed. The network of canals for recreational vessels has also modified the original stream network. In addition to these problems the region shares the universal problem that there are very poor historic records of discharge and stage height for such small catchments.

One of the most probable scenarios for severe flooding in the Gold Coast region is linked to the effects of intense and heavy rain from tropical cyclones. This would be enhanced by the triggering effect of high ground that would cause heavy rainfall in the upper catchments of the rivers and creeks that flow across the floodplains in the Gold Coast. Such flooding could be compounded by the effects of storm surge (alternatively termed 'storm tide') associated with such cyclones. The direct effects of storm surge inundation are thought to be limited, ie in no way comparable with Cairns or Mackay, but the indirect effects could be considerable. These indirect effects would cause the rivers and creeks, especially in the tidal areas, to increase flood levels. The magnitude of the additional inundation depends on a range of meteorological factors and is also related to whether the peak surge and flood flows occur at high or low tide.

It is important to acknowledge the severe technical hydrological problems of the Gold Coast region. However, hydrological information now available, currently in progress and planned, is of a high order and attempts to incorporate the problems outlined above. In addition, the studies provide information on the magnitude of the very low probability floods (including estimates of the probable maximum flood), over-floodplain velocities and changes to flow paths. The Gold Coast Council is also aware of the possible changes (likely to be adverse) of greenhouse climate change.

The current stage of hydraulic information is described in the study undertaken by the DNR in 1992 (DNR, 1992). Such information is an essential first step to assess the vulnerability of existing floodplain developments. The approach is to use a geographical information system (GIS) to link the hydrology and land use (including the built environment). Flood maps showing the extent of flooding and the property boundaries are available in draft form for some of the catchments (the Nerang River catchment for example) and in progress for others. The amalgamation of Albert Shire and the Gold Coast Councils into a single authority has had positive outcomes in that it allows a more comprehensive whole of catchment planning but has also required the blending of two previously separate data sets.

4.6.2 Planning regulations and guidelines

The large number of residential flood prone buildings in the Gold Coast region, the majority of which have been built in the last twenty years, suggests that acceptable floodplain management regulations for land use, the floor height of habitable buildings, the use of fill etc, were poorly applied and enforced. However, the situation has, in the last few years, dramatically changed and comprehensive development assessment criteria for flood plain studies for developments in floodplains. For instance, the Nerang Hydraulic Master Plan was adopted in 1997.

Council requirements for inclusion in a Terms of Reference of any Environmental Impact Study usually include a statement along the following lines:

> 'The Environmental Impact Study shall include a hydraulic study investigating 10, 20, 50 and 100 year ARI, critical duration and the 1974 historical flood events, prepared by a suitably qualified consulting engineer at the applicant's

cost. The hydraulic study is to investigate the base case (undeveloped case) and the developed case. In relation to the design of the development, the following development objectives are desirable:

1. No net loss of floodplain storage – any increase in floodplain storage is an advantage.
2. No net increase in flood level except perhaps locally within the development site.
3. No significant change to flood flow direction.
4. No significant change in flood velocity unless it can be proven that either velocities are lower or will be to the advantage of neighbours. (A "neighbour" in this context is the owner of any property that can be demonstrated to be affected by this proposed development).
5. No net increase in inundation duration where inundation could damage private assets.
6. No loss or adverse change to emergency services access.
7. No net shortening of the warning time from declaration of emergency so as to maintain the ability of neighbours to provide protection to their assets or evacuation.

Should any of the above objectives not be achieved, then the applicant shall lodge a schedule of non-compliance with the design objectives together with an explanation of why the objectives cannot be achieved, and propose measures that would remedy any problems'.

The design flood will be the 1 in 100 year event or the largest recorded flood whichever is the higher. Developers are required to use approved hydrological modelling techniques and such analysis must extend to the level of the 1 in 200 year flood for reasons such as counter disaster planning.

Future floodplain management will be based on best practice hydrological assessment combined with GIS analysis of vulnerability and stringent regulations will be formulated and applied to any form of new development, building or other, that is proposed within the limits of the 1 in 100 year flood. Urban floodplain management will also include whole catchment planning and greater community involvement. An example of the former is the Joint Flood Plain Management Group for the Logan River, established in March 1996, which reports to the Logan River Management Co-ordinating Committee which has representatives from the Gold Coast, Beaudesert, Logan and Redland Councils. Community involvement is evident in such groups as the Merrimac/Carrara Floodplain Advisory Committee, established in August 1996 to consider the future of this portion of the Nerang River catchment. The Committee is composed of a wide range of stakeholders from community representatives to State government officials.

4.6.3 The problem of numbers of buildings and dwellings

Data from the 1997 Nerang River Flood Study, made available by the Gold Coast City Council in late 1997, provide an excellent illustration of the problem of basing flood assessment solely on the number of buildings (or properties). This is because many of the residential buildings in the Gold Coast region are designed for multi-occupancy, as flats or apartments. In such cases it is better to use the term ‘residential dwellings’, i.e. a residential dwelling unit is a single household in a multi-occupancy building. The data in the Nerang Study also illustrates the differences in the number of dwellings situated in the flood prone zone and the numbers liable to over-floor inundation. For example, for the 1% (1 in 100 year flood) there are 14,250 residential properties in the flooded area. These equate to 28,600 residential dwellings. Of these, only 8,000 would likely experience over-floor flooding for the 1 in 100 year flood. In part, the large difference in the number of dwellings in the flood zone with an without over-floor flooding is because many are multi-storey buildings.

The number of multi-occupancy and multi-storey residential properties in the Nerang River floodplain, in comparison to most other urban areas in Queensland, is exceptionally large. However, the data outlined above illustrate the necessity for detailed studies in order to adequately assess vulnerability, estimate flood damage or provide good quality information for emergency management. These aspects of the Nerang Flood Study could well be used as an example of how to undertake comparable detailed studies for urban floodplain management elsewhere in Queensland.

4.7 Summary

Notwithstanding the provisional nature of some of the estimates of the number of buildings, the size of the existing flood risk presents a massive problem. Estimates, supplied by the Gold Coast City Council, for direct damage (building structure, internal and external, contents) to residential developments for a re-run of the 1974 event in the Nerang catchment alone is of the order of $200m at current prices. In addition there would be direct and indirect losses in the commercial sector, widespread infrastructure damage and untold intangible losses due to the fall in tourist numbers.

The Gold Coast City Council is faced the management of the largest concentrations of flood prone residential buildings of any local government authority in Australia. The Council is currently addressing this issue by improving its flood information and modelling systems and by ensuring that flood risk forms a central component of its urban flooding policy. The Gold Coast situation provides a salutary lesson·for other Queensland councils..

5

Hydrological Information, Mapping, Damage Studies, Mitigation and Policy

5.1 Introduction

The design and implementation of acceptable urban floodplain management policy for flood prone LGAs requires a sound hydrological base. Information on the extent of inundation from floods of differing magnitudes and frequency is an essential step in this process. Normal practice is for such information to be obtained from rainfall/runoff modelling techniques but the accuracy of these depends on the availability of historical data. A less precise procedure is to base policy on information from the flood of record. Ideally, hydrological information is combined with damage studies in order to select effective flood mitigation options from which local policy is formulated.

An assessment of the current situation in Queensland can be obtained from the responses to the questionnaire, especially parts of Question 5, 6, 7 and 8.

Question 5 specifically addresses the information available on past flood events,

Question 6 asks for detail on hydrological studies,

Question 7 enquires if flood damage studies have been undertaken,

Question. 8 deals with the details of flood policy and mitigation measures.

The responses to each of these is addressed below.

5.2 Information on past flood events

Question. 5.1 asks '... *is historical flood data available?*' Two thirds (68 out of 102 responses) of localities reported that it was. The negative responses include those that do not consider they have a serious urban flood problem, but there are others that give the reasons for the lack of data as 'apathy', or 'no engineer' and a number replied that they considered that the responsibility lay with the DNR (or the former Water Resources Commission) or the Bureau of Meteorology. Those who consider that the responsibility lies elsewhere include LGAs who indicated (or thought) that the data were held by those agencies.

The responses on historical data closely match those locations which have a town flood gauge, a little over half of the localities (53 out of 101) are in this category. The length and quality of flood records are, of course, variable. For some locations the records extend back for over a hundred years, eg. Brisbane City 156 years, Rockhampton 137 years, Taroom 133 years, Gympie 128 years and Ipswich 100 years. Conversely, many LGAs have only short records, i.e. less than 10 years. ALERT flood warning installations provide an excellent opportunity to gather more precise rainfall and runoff data although there is a need for in-house LGA expertise to fully capture such information.

For the flood gauge records to be of real value, it is necessary for these to be expressed in terms of the areal extent of inundation. Question 5.10 asks if '*... flood limits for the largest known flood are available in map form*?' Exactly half (53 out of 106) of the localities have the records available in this form. Question 5.11 seeks further detail on the '*... historical flood mapping method.*' Most are available in paper map form but for 17 locations the information is also stored as GIS data and about 10 also have the flood limits superimposed on air photographs. The relatively high proportion who have converted the largest known flood into GIS format is encouraging and this will undoubtedly assist future flood policy design and implementation.

5.3 Hydrological flood studies

Question 6.1 asks if a '*... hydrological/hydraulic flood study has been carried out for this community*?' A positive response indicates that some form of modelling has been undertaken, using the historic flood data and regional rainfall statistics. The latter are much more numerous, and have longer records, than for flood or river discharge. Only 40 out of 108 of localities have undertaken hydrological studies although in some cases (i.e. Brisbane River) these are currently being re-assessed. Those with such studies include the majority of the major flood prone LGAs within the State although in some instances the data are of a relatively poor standard. Ipswich is in the process of undertaking such studies and the Gold Coast has recently completed studies for the Nerang catchment and is in the process of undertaking them for other catchments in their area of jurisdiction.

Question 6.2 invites LGAs with such flood studies to indicate the floods that '*... were studied*'. For the 40 responses the floods studied were to a variety of levels, in many cases the lowest probability flood also formed the designated flood. The lowest probability levels in the flood studies are summarised in Table 5.1.

Table 5.1 Flood studies, lowest probability event for which information is available, based on Question 6.2

Above 1 in 100	1 in 100	1 in 50	Below 1 in 50
4	24	6	6

In urban flood studies, it is common practice for the 1 in 100 year event to be the lowest probability event studied, although the recommended procedure is for such studies to extend to the probable maximum flood. In Table 5.1, the LGAs who extended the study to levels above that of the 1 in 100 year event include Brisbane (including the creek catchments), Logan (in part), Warwick and Rockhampton. An example which reported limits below the 1 in 50 year event was Mt. Isa. Studies at 1 in 50 and below are too limited to form the basis for acceptable urban floodplain policy. However, some of the LGAs with 1 in 50 year information do have other more limited data available, eg. for the flood of record. Some LGAs vary the level of study by catchment, examples are Laidley, Logan and Pine Rivers.

The situation for the probable maximum flood is separately assessed in Section 3.5. Only 8 localities have maps that show the extent of the PMF, among these are Gladstone, Redland, River, Rockhampton, Roma and Warwick.

Question. 6.5 requests information on the '... *adopted designated flood'*. The number of responses and level of adoption are given in Table 3.3. In summary, of the 44 responses 27 used the 1 in 100 year event, two the flood of record and the remainder the 1 in 50 year or even more frequent event.

Question 6.6 indicates that for 42 localities, a large proportion of those that answered Question. 6.5, have maps that show the designated flood line and nearly all of these also have the information in GIS format.

5.4 Damage studies

Question 6.12 enquires '... *has a damage study been carried out?*' There were only 11 (out of 98) positive replies. Such studies are not only critical to the assessment of the costs and benefits of floodplain mitigation options but, since they are based on field surveys of all buildings, provide an invaluable aid to all facets of emergency management.

Table 5.2 lists all the positive responses to this question. The majority are known to be of a high standard although for the Brisbane River the damage study is stated to be 'very old - 1976', i.e. after the 1974 flood. It is noteworthy that many of the damage studies were prompted by the occurrence of a major flood event that served to highlight the need for such information. Examples are given in Table 5.2 and include Rockhampton, Murweh (Charleville and Augathella) and Jericho. For the Gold Coast and Warwick such studies are actively in progress and Ipswich (omitted from the positive response data) has such information for the Bundamba catchment. The situation for the Brisbane Creeks is discussed separately, see Section 4.2, and not included in the questionnaire responses.

The poor coverage of flood damage studies for known flood prone urban locations in Queensland is regarded as a major barrier to the formulation of acceptable floodplain management policies.

5.5 Summary – past events, hydrological and flood damage studies

Historic data on flood events is available for a large number of flood prone locations but only about 40% have undertaken detailed hydrological studies. These include most of the major flood prone localities and 42 have the information available in map or GIS form. However, only 27 localities have used this information to define designated floods to the level of the 1 in 100 year event. Information on the PMF is rarely available and even rarer in map or GIS format. The greatest lack however, is for damage studies which only exist for 11 localities and are absent for many of the most flood prone LGAs.

5.6 Policy and mitigation

Question 7 specifically addresses LGA flood policy, and Question 8 flood mitigation measures. The analysis of responses to several of the questions on policy is reported by LGA and not by flood prone locality.

5.6.1 Policy

There were 79 responses, by LGA, to Question. 7.1 which asked '... *has a flooding policy been developed?*' Of these, 37 reported that there was such a policy and 42 that there was not. It is important to note that there are likely large variations in what is interpreted as constituting such a policy. However, it is thought that in all cases there are restrictions on new developments in areas below the level of the designated flood. Most of the LGAs with significant urban flood problems indicated that they had a flood policy, exceptions included Bundaberg, Dalby and Emerald.

Table 5.2 LGAs reporting that flood damage studies have been undertaken, based on Question 6.12

LGA and locality	Comment
Brisbane	For Brisbane River based on 1976 data.
Dalby	
Gold Coast	Completed for Nerang Catchment, in progress elsewhere.
Hinchinbrook (Ingham)	For Ingham.
Ipswich	Only for Bundamba catchment.
Jericho	After 1990 flood.
Mackay	
Murweh	Charleville and Augathella, After 1990 flood.
Noosa	
Rockhampton	After 1991 flood.
Roma	
Warwick	In progress.

Question 7.2 requested information on the '... *hydraulic basis for flooding policy.*' Two thirds (24 out of 79 LGAs) indicated that they use a designated flood with the remainder basing their policy on historic flood data. In some cases physical models had been employed to assist with flood policy, Caloundra and Mackay are examples. In many cases the policy is based on a combination of historic data and hydrological modelling.

However, attention is drawn to Section 5.2 which shows that for many locations, information on the extent of floods is limited.

Question 7.3 enquires '... *is the designated flood for residential buildings the same as the designated flood for commercial buildings?*' Of the 41 LGAs that replied, 36 used the same designated floods for both residential and commercial and 5 have different levels. There was only a single reply to Question. 7.4 which requested reasons for the differences. Gympie (Cooloola Shire) commented that it was '... deemed acceptable for commercial to flood', i.e. there were no restrictions for commercial developments in flood prone locations. Caboolture uses the 1 in 100 year as the designated flood for residential buildings and the 1 in 50 year for commercial.

Question 7.5 requests information on the '... *difference between allowable floor levels and designated flood levels*'. This is an example of obtaining more detailed information on the nature of the flood policy. A total of 22 LGAs provided data, the range was from zero to 1,000 mm. However, approximately half of the LGAs require a minimum difference of 300 mm (likely converted from earlier regulations of '1 foot'). Several LGAs vary the designated flood/floor level by location, e.g. Logan uses 150 mm for the main Logan River and 300 mm for the tributary creeks. Such variations usually reflect the quality of the available hydrological data which is invariably more precise for the main rivers than for the smaller tributary catchments. For this reason, Beaudesert requires a floor height of at least 1,000 mm above the designated flood in some locations.

5.6.2 Fill requirements

Some jurisdictions in Australia and overseas prohibit any new building within the flood prone area as delimited by the designated flood. Others use floor level restrictions, similar to those described above for Queensland, but have restrictions on the building methods employed to obtain the required level. In Queensland many of the regulations are related to fill, in order to form a mound on which to construct the buildings, elsewhere regulations often restrict 'raising' of the building to the use of columns or stumps, similar in form to the traditional high set Queensland dwelling. The reason for such restrictions is to avoid the afflux problems posed by using fill to produce the mound. In Queensland the use of fill is much more widespread and Question 7 was designed to gain further information on this.

Question. 7.6 asks '... if allowable filling requirements are:

a. ad hoc individual approvals,

b. filling policy determined on the basis of hydraulic studies,

c. individual approvals based on the developer demonstrating impacts,

d. other.

The 34 LGAs who responded indicated that there is variation both between LGAs and sometimes within the area administered by individual councils. Nine councils rely solely on the ad hoc approach, 4 on policies based on hydraulic studies and 13 on developers demonstrating impacts acceptable within the overall flood policy. The remainder use combinations of these requirements, often these differ in relation to the detail available from existing hydraulic studies. In such cases the developer is required to provide a detailed analysis to demonstrate whether the development is acceptable or not. The reply from Redcliffe to this question is noteworthy because the council does not allow fill under any circumstances.

If consistently applied, such variations are acceptable and there is often more consultation and detailed analysis where a major development is proposed. However, the continued use of ad hoc or poorly supervised requirements for fill can, and does, lead to significant increases in afflux and therefore, to increased flood risk.

There is a strong case for State guidelines and perhaps, regulation to clarify the arrangements for fill, if only to overcome the problems posed by differing requirements by councils in the same catchment.

Over-use of fill by one council can cause adverse effects for others on the floodplain. A Joint Flood Plain Management Group was established for the Logan River in March 1996 with elected and professional staff from the four LGAs that share the Logan River catchment. One of the terms of reference is to develop '... an agreed protocol to be followed by the each Local Government in assessing development applications'.

5.7 Legislative mechanisms

To achieve effective local floodplain management there is a need for the policy to have a sound institutional base. It is widely accepted that this is not the case for many Australian States, Queensland is no exception. The situation for the eastern mainland States is reviewed in National Landcare publication, *Issues in floodplain management – a discussion paper* (Smith *et al.*, 1996). To clarify the situation Question 7.7 sought information on the 'legislative mechanisms used' in Queensland.

LGAs were asked to indicate which of four Queensland Acts were used as a basis for their flood policy. The four were:

The Local Government Act (abbreviated to LG)
The Local Government (Planning and Environment) Act , hereafter LG (P & E)
The Water Resources Act (WR)
The River Improvement Trust Act (RIT)
Other

There were 37 responses, the results are given by LGA and not by locality. There was considerable variation between LGAs, some employing a single act and other combining one or more. A summary is given in Table 5.3.

Table 5.3 Legislative mechanisms used to underpin flood policy (Question 7.7)

	LG only	LG(P&E) only	LG/LG(P&E) combined	LG/WR combined	LG/LG(P&E)/WR combined
Number of LGAs	5	16	12	1	3

LG = Local Government Act
LG (P&E) = Local Government (Planning and Environment) Act
WR = Water Resources Act

The LGA and LG(P & E) Acts are the most widely used, either singly or in combination; 33 LGAs fell into this grouping. Neither the WR nor RIT Acts were used as the sole institutional underpinning but were used in combination with the two most frequently used Acts by six LGAs. Warwick is the only LGA to use all four Acts. There were no examples of the use of 'other' legislation as an institutional base for flood policy. From the survey results it would appear that the institutional arrangements are unclear.

5.8 Mitigation

It is standard practice to divide flood mitigation measures into two separate classes, namely structural and nonstructural. In detail there are definitional problems but the structural class normally involves engineering measures which are often costly. In contrast, non-structural measures generally have little direct cost (resumptions and rezoning compensations are two examples of expensive 'non-structural' measures) to LGAs and typically incorporate features such as zoning and building regulations. Question 8 invites LGAs to indicate any structural measures used for mitigation and Question 7 for non-structural. Although flood warning systems are included as a nonstructural measure (Question 8.2), much fuller information is requested in Question 10 with the results discussed in detail in Section 6. The flood mitigation options are discussed in terms of locality.

5.8.1 Structural mitigation measures

Question. 8.1 invites respondents to indicate '... *flood mitigation measures used to reduce [the] effects of flooding on [the] community*'. Four categories were given with the request to list any additional measures that had been used. The categories listed were:

Levees
Flood control dams
Retention basins
Flood proofing of buildings
Other

Structural measures, often of more than one type, were reported as used at 29 localities. Thirteen localities (out of the 29) use levees, in 6 instances in conjunction with one or more other structural measures. Although the respondents were not specifically asked, many report that the levees are only used locally, ie to protect a relatively small number of buildings or only apply to part of the flood prone locality, Brisbane and Balonne are examples. For two localities, Goondiwindi and Mackay, the levee systems are known to be extensive. At Goondiwindi the levee system has been in place for many years and affords a relatively high level of protection, that for Mackay is much more recent and has a level of protection for floods in the 1 in 30 to 1 in 40 year class.

A fuller list of localities reporting levees, excluding those already mentioned, includes Bundaberg, Emerald, Hinchinbrook (Ingham), Johnstone (Innisfail), Paroo (Cunnamulla) and Thuringowa. In comparison to New South Wales or Victoria, the number of major urban levee systems is relatively small.

Flood control dams are mentioned for only four locations. These are the Somerset and Wivenhoe Dams on the Brisbane River, the Ross River Dam upstream of Townsville and the Hinze Dam in the upper catchment of the Nerang in the Gold Coast. In all of these cases the primary purpose of the dams was water supply, irrigation or urban, with flood control as an additional feature.

Flood detention basins are smaller structures than flood control dams and are specifically designed to retard and decrease flood peaks that could cause downstream damage. They are usually constructed on small catchments in major urban areas. They are specifically mentioned for six localities, these include the Brisbane Creeks, Cairns, Maryborough and Townsville.

Flood proofing of buildings can be considered as a special case of structural mitigation, it differs from most other forms of structural mitigation as it can be undertaken for individual buildings (residential or commercial), only 8 localities report its use. These are Bowen, Dalby, Ingham, Maryborough, Logan, Murweh (Charleville) and Rosalie. This small number is perhaps surprising, in part because the traditional high Queensland detached dwelling provides a ready-made example of flood proofing. Although data are not requested of the numbers of buildings that are flood proofed, usually undertaken well after construction and in response to a known flood risk, the measure is only used in a minor way. This contrasts with some communities in New South Wales where house raising (the most common form of flood proofing) is widespread. For central Lismore over 1500 weatherboard houses have been raised, some to 3.0 m or more, over the last 60 years or so specifically to reduce flood losses.

'Other measures' are reported for a small number of locations. These include clearing vegetation from channels (Boonah), channel improvement and diversion (Bowen) and the use of flood gates (to lessen the tidal effects on river flooding) at Ingham. Logan also reports a program of acquisition for a small number of dwellings exposed to high velocity flood waters.

5.8.2 Non-structural mitigation measures

Question 8.2 lists three categories of non-structural measures, plus 'others', these are:

Building controls
Land use controls
Flood warning systems
Other

There are 66 responses, by locality, that list non-structural measures, that is more than double the number that report the use of structural measures (29). Some 55% of the localities (36 out of 66) combine building and land use controls. This indicates that some form of designated flood is used and that the buildings within the designated limits are subject to regulation which usually requires the floor levels to be at a specified height above that of the designated flood, see Question 7.5 (Section 6.1) for detail. Ten localities rely solely on building regulations and 8 on land use controls.

Exactly half (33 out of 66) list flood warning systems as a nonstructural measure, in 22 cases employed in conjunction with other measures.

'Other' measures are limited. Cairns reports that a program of acquisition for dwellings that are below the 1 in 10 year flood; interestingly Logan considers such a measure to be structural.

Two features of the replies need comment. The first is that only 36 localities have combined building and land use controls and the other is the relatively large number that report the use of flood warning systems. It was not possible from the survey to consider the details of the mitigation measures or, in the case of building and land controls, the degree of compliance.

5.9 Funding for flood studies and structural works

Flood studies are an essential prerequisite for the formulation of building and land use controls. Question 8.3 asks for information on the source of '... *funding for flood studies*' and Question 8.4 for the source of funding '.... *for structural works*'. In both questions the categories are given as:

Commonwealth government
State government
Local government
Other

It is important, for two reasons, to separate funding for flood studies and structural works. First because flood studies should be basic to any form of structural works and are comparatively, less expensive. Secondly, the various funding schemes between the three tiers of government vary for the two types of activity.

It is understood that State authorities in Queensland rarely provide financial assistance for studies (unless subsidisable capital works are involved). Commonwealth funding has traditionally been available for both studies and for works - indeed, without acceptable flood studies, assistance with funding for structural measures would not be provided. The difficulties of joint assistance from State and Commonwealth sources are outlined in Section 11.2.3.

5.9.1 Flood studies

Of the 52 responses, 49 indicate at least a contribution to the costs of flood studies from the appropriate LGA.

In some 60% of the localities (32 out of the 52 responses) funding for flood studies was borne solely by the LGAs.

Ten localities reported that funding was shared by all three tiers of government, examples are Logan, Paroo, Rockhampton and Mirani. Only 5 indicated that funding was shared between State and local government.

Assistance with funding from other (non-government) sources was limited. Cairns reports assistance from the Cairns Port Authority and in other cases the costs were partly re-couped from developers in the form of fee for service. Caloundra, Thuringowa and Caboolture specifically mention such contributions. For Caboolture, an LGA with a fast rate of growth and development, the costs of the flood study was recovered in two or three years by the sale of the appropriate part of the flood study (i.e. in the form of a computer model) to developers who were then required to demonstrate that their proposals were in accord with the council's flood policy.

5.9.2 Mitigation

In most cases the costs of structural works are very much greater than for flood studies. For example, levee schemes to protect even relatively small numbers of buildings often cost in excess of $1 m. They also require the LGA to take on substantial future costs for maintenance and repair. Thus, for many of the LGAs in Queensland, and elsewhere in Australia. The construction of such structural measures are dependent on assistance from higher tiers of government.

There were 30 responses, by locality, to the question of the funding for structural works. The combinations of funding are several and are summarised, with examples, in Table 5.4.

Table 5.4 Combination of funding sources for structural works (Question 8.4)

	C'wealth only	State only	LGA only	C'wealth/ State	C'wealth, State and LGA
Number of Locations	0	4	14	6	6
Examples		Blackall	Caboolture	Tara	Brisbane Logan Mackay Mirani Paroo Warwick

A small number of responses listed funding from other sources. For Mackay and Wambo these include local River Trusts and Thuringowa specifically mentions developer contributions. Again, the dominance of council contributions in funding is apparent. However, for many of the responses, which include those based solely on local funding, it is likely that the structural works were of a minor type. For example, the eight separate localities listed by Caboolture.

5.10 Summary – flood studies and mitigation measures

Councils play the major role in funding of both structural and non-structural mitigation measures, in many cases without any assistance from either State or Commonwealth sources. This contrasts to New South Wales where, for the early years of the 1990s, the combined annual expenditure on flood studies and works was well in excess of $20 m. The major difference between Queensland and New South Wales was that the latter was prepared to match, dollar for dollar, Commonwealth funding provided under FWRAP or, in later years, from the National Landcare Program. Queensland, with few exceptions was not prepared to match the Commonwealth contribution, exceptions involving major amounts of funding for capital works were Rockhampton and Mackay.

It is likely, although not subject to rigorous proof, that the relatively poor coverage of flood studies and mitigation measures in Queensland, in comparison to New South Wales, is a result of this difference in the approach to funding

Queensland has relatively few major structural flood mitigation works, although such works, (nearly all constructed to reduce flood damage to existing flood prone developments), are not in themselves a major plus for floodplain management. However, in New South Wales the construction of such mitigation measures was closely linked to the adoption of comprehensive land use and building controls usually related to a 1 in 100 year designated flood. This strategy has greatly reduced the potential for flood damage from new developments. For many parts of Queensland this has not been the case and the potential for future losses increases year by year.

6

Flood Warning Systems and Counter Disaster Plans

6.1 Introduction

A flood warning system encompasses the flood forecast, its dissemination and response by the emergency services and the community at risk. It is an essential component of urban flood mitigation both for communities with and without structural mitigation measures. For those with structural measures it is necessary because the majority of these are constructed to a specific design limit (often the 1 in 100 year flood or less) which can be exceeded. Structural measures also have some risk, albeit often small, of failure. If levee protection is used as an example, flood warning systems are necessary to cope with situations where the levee may be overtopped, i.e. the design limit exceeded, or is at risk from other forms of failure. In all cases, structural measures should be accompanied by an emergency plan. Although outside the direct scope of this study, this also applies to downstream inundation from the failure of all hazardous, i.e. large dams.

The Bureau of Meteorology, for Queensland this is the Brisbane Regional Office, has overall responsibility for the provision of flood warnings and forecasts of river heights. There is however, an important qualification which relates to 'flash' flooding. This is defined as flooding for which the time between rainfall and downstream inundation is less than six hours.

The responsibility for flash flooding lies elsewhere, in practice with local government.

With the exception of flash flooding, for those areas with the necessary field instrumentation to provide input data on rainfall and runoff the Bureau provides quantitative forecasts of flood height. This is normally presented as a forecast of river height and time for a specific flood gauge, often located in flood prone urban areas. The gauge heights are usually combined with a forecast expressed in terms of minor, moderate or major flood. These terms have agreed definitions and are available for several hundred gauges throughout the State. They are often related to the inundation of road crossings, overtopping of bridges, initial flooding of buildings etc. An extract from the Bureau's River height stations flood classifications is given in Table 6.1. The forecast to the public is issued after discussions between the Bureau staff and local agencies for key river height locations (towns, cities etc.) particularly those which involve urban flood inundation.

The Bureau is not primarily responsible for the dissemination of the forecast to the local community or for the response components of the flood warning system but in practice it works closely with LGAs and the emergency services to facilitate best warning practice and to give advice on response. Although Commonwealth policy affirms the Bureau's responsibility for flood warnings, it also calls on State and local governments to share in the upgrading and maintenance of monitoring networks. The Bureau is responsible for the rainfall network, and State/local governments for river height stations.

Table 6.1 An example of the Bureau of Meteorology river height stations flood classifications

Station Name	First report	Bridge height	Minor flood	Crops grazing	Moderate flood	Town houses	Major flood
Leichhardt							
The 16m waterhole TM			3.0		4.0		5.0
Floraville TM		3.0	3.0		5.0		7.0
Flinders							
Hughenden (SYN)	1.0 h	4.00	2.5	4.0	4.0 d/s	4.9	6.0 d/s
Marathon	2.0 h		6.0		8.0		9.0
Richmond (SYN)	3.0 h	5.80	5.0	6.0	6.0		8.0
Richmond TM			5.5		6.5		8.2
Hulberts Bridge	2.0 h	3.90	7.0	10.0	10.0	12.2	12.0
Cloncurry	2.0 h	10.30	3.0		5.0	11.0	7.0
Cloncurry TM		11.00	3.5		5.2	11.0	7.0
Carsland	1.0 h		2.0	2.0	3.0 d/s		5.0
Canobie	3.0 h		3.0		4.0		5.5
Walkers Bend	3.0 h	5.40	6.0	6.0	9.0		12.0
Walkers Bend		5.40	6.0	6.0	9.0		12.0
Norman							
Yappar River	1.6 h	0.60	1.6	2.0	2.5	3.8	3.8
Normanton	2.5 h	5.50	3.5	3.5	4.0	7.0	6.5

Queensland flood warning river height stations flood classifications

All lengths in metres

6.1.1 Flash flooding

Flash flooding is subject to different arrangements, by definition the time between rainfall and downstream flooding is limited. Thus, in order to provide forecasts with sufficient lead time to reduce losses to life and property, the analysis needs to be undertaken locally. For maximum effectiveness such systems require telemetric rainfall and river gauges that can transmit data to a locally based receiving station, ideally linked to a computer system that can convert the information into a forecast for downstream flood prone locations. A commercially available system, normally referred to as an ALERT system, fulfils these requirements. The funding and maintenance of such systems for flash flooding is usually the responsibility of LGAs, not the Bureau. However, the Bureau provides technical assistance with siting, installation, calibration and use and, in return, has access to the output. The majority of

ALERT systems used in Australia were based on a model tested and adapted by the Bureau. A few years ago Brisbane City Council installed a comprehensive flood warning system known as PROPHET, based on the ALERT concept, this is described by Carroll (1993).

6.1.2 Flood warning systems and flood mitigation

Until the late 1980s flood warning systems in Australia were handicapped by inter-governmental disagreement over the responsibility for future funding of the service. A background to this and to the general principles of flood warning systems is given in Smith and Handmer (1986). After that date it was agreed that the Bureau of Meteorology was responsible (with the exception of flash flooding) and additional staff and resources were allocated to the regional offices to provide the forecasting service. As a result there have been major improvements in the instrumentation, areal coverage and quality of the forecasts throughout Australia. The Brisbane Office of the Bureau has been to the fore of these developments.

Flood warning systems however, directly involve LGAs assisting with the process of data collection as an essential input into the forecasts, for interpretation of expected areas of inundation, for local dissemination and, together with the emergency services, for the appropriate response. Where the risk is from flash flooding they also have the responsibility for providing the forecast. This outline is necessary in order to understand the responses to the questions concerning flood warning systems in the questionnaire.

An understanding of flood warning systems is important as they assist with the definition of flood risk and thereby, assist with the prioritisation of future floodplain management needs of LGAs within Queensland. This is because the risk for all forms of damage is much greater for those LGAs that have only short warning times, say less than 12 hours, in contrast to others that have several days.

6.2 The questionnaire responses

The questionnaire responses are designed to obtain a picture of how LGAs contribute to, and gain from, the overall flood warning system.

Question 8.2 asks if LGAs use flood warning systems, assumed to be locally based, as a form of nonstructural flood mitigation measure. Approximately half (33 out of 67) of the responses report that flood warning systems are so used. As the total includes localities that do not have a significant urban flood risk this can be considered as a satisfactory result.

Four specific questions (10.1 to 10.4) were asked in the section of the questionnaire concerned solely with flood warning systems. These were:

> Question 10.1 requests information on the type of forecast provided by the Bureau.
>
> Question. 10.2 asks if the Bureau forecasts are further interpreted for use by specific local communities.
>
> Question. 10.3 enquires if the LGA maintains a local flood warning system.
>
> Question. 10.4 invites further detail on the methods used to disseminate the information to the community where a local system is maintained.

6.2.1 Question 10.1. Form of forecast supplied by the Bureau

Two thirds (65 out of 102) of localities receive quantitative forecasts from the Bureau in the form of river gauge heights and in terms of minor, moderate and major flooding. The majority of LGAs and localities that do not receive such forecasts are located in remote areas of the State and/or have only minor urban flood problems. The former, Carpentaria is an example, are in regions with a poor coverage of river gauges.

6.2.2 Question 10.2. Is the forecast further interpreted by the LGA?

Where quantitative forecasts are supplied by the Bureau, approximately 40% (28 out of 67) relay the information unchanged and 60% (38 replies) further interpret this for use by local communities.

6.2.3 Question 10.3. Does the LGA maintain a local flood warning system?

Forty-five localities have information based on local flood warning systems of the ALERT type. Such a high proportion is, to date, only found in Queensland. This is undoubtedly one of the major positive features of urban floodplain management in the State. However, it is worthy of note that the preliminary draft of the *Victorian flood strategy 1997 - 2007*, proposes 29 additional centres for flood warning systems for that State.

As noted, Brisbane City Council maintains its own comprehensive flood warning system and the south-east of Queensland now has a coverage of ALERT-type installations unmatched elsewhere in Australia. A number of systems originally designed for water resource management have been integrated into this coverage. One outcome of this detailed cover is that LGAs with ALERT systems for their local area have the capacity to interrogate or directly receive data from other systems in the region and thereby gain information on the approach of storm cells before they reach their catchments.

6.2.4 Question 10.4. How is the information from locally based systems relayed to the community at risk?

There were 49 replies to this question and the respondents could tick boxes to indicate door knocking, radio, television or loudspeakers as the method(s) used, respondents were also invited to add additional categories. Forty-two of the respondents (about 85%) indicated that they used more than one method to disseminate the forecast. This is particularly important as all analytical accounts of the effectiveness of flood warning systems stress the need for more than one method to be used in order to obtain community acceptance and thereby an effective response.

6.3 Flood warning time

The time that a community has between receiving a quantitative forecast and the inundation of buildings and infrastructure is an important element in defining susceptibility to flood. It ranks with the number of buildings and flood height range in outlining a priority list of communities in most urgent need of comprehensive floodplain management. However, it is difficult to define, with any precision, what is a flood warning time? There are a range of possible definitions, e.g. from the start of rainfall to time of flood rise, time of peak rainfall intensity to flood peak etc. In addition, the relationships between timing and intensity of rainfall to the subsequent downstream flood can vary considerably between events, e.g. it often depends on which sub-catchments received the maximum rainfall.

However, at a broad scale, there are clearly major recognisable differences in flood warning time between LGAs and localities in Queensland, the full range is from an hour or so to several weeks.

6.3.1 Flood warning time - questionnaire responses

LGAs were asked, in Question 4.15, for differing localities in their area, to give estimates for the flood warning time. In this case between '... *commencement of rainfall and initial inundation of the urban area*'. There were 71 responses and these are tabulated in Table 6.2.

Table 6.2 Flood warning time, responses to Question 4.15

	< 12 hours	12 to < 24 hours	24 hours to < 2 days	2 to 7 days	8 to < 14 days	> 14 days
Number of localities	26	14	18	6	3	4

Overall, 55% of the responses indicated a time of less than 24 hours.

At the other extreme 20% (13 replies) indicated a time of 2 days or more. A warning time of this length should be sufficient to enable maximum reduction of damage to take place and for the risk to life to be small.

6.3.2 Flood warning time — Bureau of Meteorology

A separate analysis was undertaken by the Brisbane Office of the Bureau as a specific contribution to the current study. This was to classify, for 143 (mainly urban) locations throughout the State, the flood warning time into three classes. These were less than 12 hours, 12 hours to less than 24 hours and greater than 24 hours. The information from the Bureau is presented in full in Appendix 5.

The analysis by the Bureau was based upon the lead times for the forecast of river flood heights that could be provided with reasonable accuracy for downstream locations using existing '... climatological factors and/or flood monitoring networks and prediction tools'. It is stressed that the classification represents an average case and lead times could vary for specific floods. The results are presented in Table 6.3.

Table 6.3 Flood warning times – the Bureau's analysis

	A < 12 hours	B 12 - 24 hours	C > 24 hours
Number of locations	100	25	18

Tables 6.4 Questionnaire and Bureau estimates of flood warning time for a selection of flood prone Queensland LGAs

Local Government/ Locality	No. of Buildings at Risk from 1/100yr Flood	Bureau of Meteorology A<12 hrs;B 12-24 hrs, C>24 hrs	Questionnaire Question 4.15
Gold Coast Overall total	16,650	A	24 hrs
Mackay	8,000	A	6 - 12 hrs
Brisbane	8,000		
Brisbane River		B	48 hrs
Brisbane Creeks		A	< 12 hrs
Dalby	3,300	A	7 hrs
Ipswich	3,000	A	24 hrs
Logan	2,375		
Logan River		B	48 hrs
Scrubby Creek		A	6-8 hrs
Hinchinbrook	2,175		
Ingham		A	36 hrs
Murweh	1,350		
Charleville		B	24 hrs
Augethella		A	< 24 hrs
Rockhampton	1,200	C	up to 14 days
Burdekin	1,000		
Hume Hill/Ayr		A	
Cairns	728		
City		A	2 hrs
Mulgrave		A	30 hrs
Caboolture	455		
Burpengary		A	6 hrs
Blackall	N/A	B	72 hrs
Cooloola	N/A		
Gympie		B	varies
Johnstone			
Innisfail	N/A	A	4 hrs
Carpentaria		C	10 days +
Normanton	N/A		
Mt Isa	70	A	

N/A Detailed estimates not available

Using the Bureau's definition, 87% of the localities fall into the '24 hours or less' category and 77% of the total have less than 12 hours between prediction and arrival of the flood.

The LGAs completing question 4.15 and the localities analysed by the Bureau are not identical and there are differences in the definition of flood warning time. However it is clear that a very high proportion of urban locations in Queensland have warning times of less than 24 hours.

Table 6.4 repeats the list of LGAs with the highest numbers of buildings at risk from the 1 in 100 year flood (see Table 3.5) together with the warning times from the Bureau and, where available, from the responses to the questionnaire. Table 6.4 is also extended to list a selection of other flood prone urban LGAs, for these detailed estimates of the number of properties at risk are not known but the numbers are relatively small.

6.3.3 Why are the flood warning times so short?

The relatively short leads given in Tables 6.2, 6.3 and 6.4 are perhaps surprising, given the length of many of the major rivers systems in Queensland. The reasons for the short times and forecasts include:

- many flood prone communities are liable to flooding from relatively small catchments that are tributaries to the major rivers. Examples are the Brisbane Creeks, the Scrubby Creek catchment in Logan, and Townsville.
- for locations situated on major rivers, damaging floods are often from rainfalls in the lower parts of the catchment, not necessarily in the more remote headwaters. Examples are Johnstone and Cairns (Mulgrave).
- often the Bureau's forecasts are, in part, based on river gauges which, for very good reasons, are not situated in the upper parts of major catchments.

Whatever the reasons, it is very clear that most of the major flood prone urban communities have lead times that are less, often very much less, than 24 hours. Given that rain and floods can occur at night, at week-ends or on public holidays, a time of even 24 hours requires best practice dissemination and response to significantly reduce flood losses.

6.4 Counter Disaster Plans

Counter disaster plans are a requirement for all LGAs in Queensland and throughout Australia. For many areas these include responses to flood events and therefore, are the component of the flood warning system most concerned with loss reduction, of which reduction to loss of life is predominant. Question 11 (11.1 to 11.6) was specifically designed to obtain information on the Counter Disaster Plans at LGA level. As the effectiveness of such plans is related to aspects of community awareness, the responses to Question 9 are also reported in this section.

6.4.1 Question 11. Counter Disaster Plans

Some of the component questions of Question 11 were difficult for respondents to answer. For example, 11.4 and 11.5 ask if the flood plan was activated during the last major flood and for comments on its effectiveness. The difficulties were that, in many cases, the 'last flood' was before the Counter Diaster Plan was developed and comments on effectiveness are subjective. In addition, it was not feasible for the questions to ask for details of the flood section of the Plan. It is suspected that often this is relatively meagre, if only because of the lack of hydrological information on the size and areal extent of the floods which should be basic to such a Plan. These caveats should be remembered in interpreting the responses summarised below.

Question 11.1. Is there a Counter Disaster (Flood) Plan for this community?

Approximately 90% (90 out of 101) of respondents report that there was a flood plan. All of the 10% with a negative response are for localities with only a small number of buildings at risk.

Question 11.2. Is the Counter Disaster (Flood) Plan linked to flood warning systems?

Some 60% (52 out of 88) replied that there was such a link. It would seem surprising that 40% (36) did not link the flood warning system to the disaster plan. Among these LGAs who did not have such a link were Caboolture, Goondiwindi and Mackay. Goondiwindi has levee protection from all but the most extreme flood events, it is therefore an example where a flood warning system should be required to deal with potential overtopping or failure. The recently constructed levee at Mackay, with a much lower level of protection, is a further instance.

Question 11.3. Was the Plan activated for the last major flood?

The responses were confused as the 'last major flood' could be before the plan was implemented. As this question was poorly worded discussion of the responses are omitted.

Question 11.4. Was the plan effective after the last major flood?

The answers were more satisfactory. Out of the 63 responses for localities that had experienced a flood since the Plan was implemented, 80% (51) replied that the plan was effective. Although this is often based on self-assessment, the level of favourable responses is good.

Question 11.5. Was the Plan revised after the last major flood?

Of the localities for which the question was applicable, 75% (50 out of 66) reported that a review had taken place.

Question 11.6. Does the Plan use or contain information from flood studies?

Approximately half of the replies (43 out of 83) are based on information from flood studies and half (40) are not. This confirms the overall lack of flood studies for much of Queensland.

Overall, for most localities with an urban flood problem, LGAs include a consideration of flooding within the Counter Disaster Plan. Although based on self assessments, most LGAs regard the Plans as effective and they are revised after flood events. It is disturbing however, that only half of the Plans are based on information from flood studies, taken to mean hydrological studies of the magnitude and extent of floods and the vulnerability of the flood prone communities. The frequent lack of links to flood warning procedures also warrants improvement and there are undoubtedly examples where flood studies have not been incorporated in the Counter Disaster Plan.

6.4.2 Awareness

Questions 9.1 to 9.5 requested information on the level of community awareness.

Notwithstanding that such responses are subjective, they form an important component of overall urban floodplain management.

Question 9.1. Is the community aware it is located on a floodplain?

Some 90% (91 out of 102) of locations are considered to have such awareness, exceptions include Biggenden, Caboolture and Herberton.

Question 9.2. Is the community aware that it can be flooded?

Approximately 98% (98 out of 102) replied that they were so aware. Toowoomba and Mt Morgan were examples of a negative response.

Question 9.3. Are past flood levels indicated locally (e.g. flood markers)?

About 25% (24 out of 102) replied that there were such flood markers. Among these were Brisbane, Dalby, Eacham, Emerald, Jericho, Isisford, Maryborough, Roma and Taroom.

It is especially significant that many of the communities with a larger number of buildings at risk do not have flood markers.

This is common throughout much of Australia, and although there are no national statistics it is likely that the situation reported for Queensland is better than for some other flood prone States. However, this may represent an over-optimistic interpretation of 'flood markers', for effectiveness in a large flood prone community there should be a series of such markers throughout the area at risk from inundation. It should be a requirement that flood markers are installed for all localities with a flood risk. This is because they are an essential and inexpensive mechanism which give meaning to the forecasts of river gauge heights for individual buildings. Although not requested in the questionnaire, the lack of markers is usually due to the perceived adverse effects on house prices or for future development.

Question 9.4. Are public awareness/education programs conducted?

Only a little over 20% (21 out of 96) communities would appear to have such programs. In a number of instances, especially for coastal communities, it was commented that such programs are associated with seasonal awareness campaigns for tropical cyclones rather than those solely related to flood. Among those LGAs with awareness programs are Brisbane, Ipswich (but qualified as 'limited'), Logan, Mirani, Rockhampton, Taroom, Townsville (linked to cyclone programs) and Warroo. Again there would seem to be a problem with the lack of such programs for many of the more flood prone communities. Finally, the effectiveness of such programs remains an unknown.

Question 9.5. Community awareness of counter disaster arrangements?

Approximately two thirds (64 out of 96) of localities replied that the community is aware of counter disaster arrangements. However, in retrospect this was not a well worded question.

In general, the level of awareness of flood threat would appear to be high among communities at risk. However, the use of flood markers and of programs to promote flood awareness would appear to be limited especially for many of the communities most at risk.

6.5 Summary

Flood forecasts, directly from the Bureau or from local systems, are widely available throughout the State. A notable feature is the growth in recent years of ALERT-type systems for locations liable to flash flooding. It is also clear that many of the LGAs with urban flood problems have developed a variety of methods to disseminate the forecast to the community at risk.

However, the lack of hydrological studies that define the extent of flooding for many LGAs poses problems for forecasting. Firstly, this limits the usefulness of the forecast as it is unclear what area is actually at risk for a forecast gauge height and secondly, the Bureau's staff can often only add to the list of flood prone locations after a major flood has occurred. There are also problems with the provision of installations in the remote and sparsely populated areas of the State.

A significant feature of flood warnings is that a very large proportion of flood prone communities have lead times that are less than 12 or 24 hours. This emphasises the need for locally based, ALERT-type, systems. The costs and expertise to install and maintain such systems pose very real problems, especially for those LGAs with small populations and thereby limited finance and technical resources. Overall, the provision of flood forecasts and their dissemination in Queensland, relative to the other States, is good. However, as these components of the flood warning system improve the spotlight turns to community response. The question then becomes how to capture the benefits offered by the forecasts and dissemination.

The majority of communities would appear to be aware of their flood risk but few of the Counter Disaster Plans specifically incorporate flood warnings. There is also a lack of flood markers and flood awareness programs, especially for many of the communities with large numbers of buildings at risk. Such issues should form a focus for future enhancement of the flood warning systems in Queensland.

7

The Largest Known Flood Events – The Effects on Lifelines

7.1 The largest known flood

The importance of the probable maximum flood, and the difficulties in its estimation, are discussed in Section 3.5. Questions 4.1 to 4.3 are concerned with the largest known flood event and this is used as a bench mark against which to evaluate the effect on lifelines. There remain two aspects that are worthy of comment, these are the duration of flood inundation and the date of its occurrence. Duration can be assessed in variety of ways and the term is not easy to define with any precision. However it can be used as an indication of the severity of the disruption to the community and is of significance for the provision of services and emergency management.

Analysis of the responses to the date of the largest event are not conducive to statistical analysis, in part because the length of records varies from well over a hundred years to less than five. But the pattern has interest for floodplain management.

7.1.1 Date of the largest known flood

Question 4.1 asks '*for the date of the largest known flood*', for the locality. There were 95 responses and the results are tabulated in Table 7.1. As would be expected the most recent decades have the larger numbers, this reflects the increasing number of flood gauges over time.

Table 7.1 shows that there is a tendency for some earlier decades to have a particularly high frequency of 'largest known events' and for others to be of low frequency. The 1890s and 1970s are examples of the former and the 1920s and 1930s of the latter. The significance of the data, with all their imperfections, is that major flooding would appear to be a sporadic event and therefore, there is a need for the collection of data over long periods. Massive floods, such as the Brisbane flood of February 1893 did not provide the stimulus for care in floodplain siting, however the floods of January 1974 (less severe than in 1893) resulted in Australia's most costly flood event. Despite such reluctance to learn from experience, knowledge of the levels of earlier floods is a key factor for the estimation of even greater floods and for emergency management. For some localities in inland Queensland the floods of early 1997, some reported in the questionnaire some not, achieved 'flood of record' status.

7.1.2 Duration

There were 69 replies to Question 4.3 which asked for estimates of the 'duration of flood inundation' for the largest known flood. The number of responses is less than for the date of the event (Question 4.1) as in a number of cases information on duration was not known. The duration estimates are tabulated in Table 7.2.

Overall, despite uncertainty over definition, duration's of 3 days or more are reported for approximately half of the locations (35 out of 69). It needs to be stressed that Table 7.2 refers to the largest known event, for lesser floods the duration would be considerably less. For example, the Brisbane River duration in 1974 was reported as 4 days.

Table 7.1 Year of the largest known flood by decade (Question 4.1)

Decade	Number+
1890 - 1900	10
1901 - 1910	0
1911 - 1920	4
1921 - 1930	1
1931 - 1940	0
1941 - 1950	9
1951 - 1960	10
1961 - 1970	4
1971 - 1980	29
1981 - 1990	10
1991 - early 1997	18

\+ Creek catchments for Brisbane are excluded.

Table 7.2 Duration of inundation for the largest known flood (Question 4.3)

	< 24 hours	1-2 days	3-7 days	8-14 days	> 15 days
Number of locations	20	14	23	7	5

As a guide, duration is related to warning time, i.e. the longer the warning time, the longer the period of inundation. Indications of duration of flood inundation can therefore, be obtained from Section 6 and Appendix 5. There are exceptions to this relationship and locally, low lying areas can remain inundated for much longer periods. However, such sites are usually of greater significance for agriculture rather than for urban flooding.

7.2 Lifelines

Questions 4.8 to 4.14 request information on the '... *effects of the largest known flood on lifelines*'. Individual questions address the following categories:

- Roads
- Rail
- Airports
- Water supply
- Sewerage
- Electricity
- Other (e.g. fire, ambulance, hospital)

There are variations in the degree of severity indicated for the various lifelines, e.g. for roads impacts are described as 'no access roads affected', 'some access roads cut' or 'all access roads cut'. The results are presented by locality.

7.2.1 Transport links

It is important to note that disruption, especially to transport links, can severely effect communities that do not experience inundation of buildings. This is especially true for remote settlements in the sparsely populated parts of the State. There were a number of replies to this question for localities that do not fulfil the study's definition for urban flooding, i.e. more than 10 flood prone buildings.

Road

Close to 75% (70 out of the 93 responses to this question) had all road access cut for the highest known flood, all but 2 of the remaining 23 had some access roads cut. The question did not ask for the length of disruption but for some remote localities this is measured in weeks, eg. Burke and Normanton.

Rail

For the largest known flood, over two thirds (40 out of the 59 reporting) indicated that all rail links were cut. For the larger urban centres, such as Brisbane, such closures were usually for a short duration, for remote localities with rail links the duration of disruption would be very much longer. There are also significant adverse effects on the handling of coal and minerals although these fall outside the scope of this report.

Airports

These vary in size from international airports to outback landing strips. The availability of air strips is especially important for emergency management in remote areas; for evacuation, for the supply of food and other assistance. Of the 56 replies, i.e. those with nearby air services, approximately half remain unaffected by even the largest known flood.

7.2.2 Water, sewerage and electricity

Major disruption to these services can have significant consequential indirect effects, for instance risks to health. These vary from the spread of disease due to contamination of drinking water to the lack of electricity for refrigeration and cold stores. It is also necessary to stress that key installations for water and sewerage are often located close to rivers and creeks and, if precautions are not taken, may be especially liable to disruption and damage by flood. A problem with the responses was that for many smaller communities there is, or was at the time of the largest known flood, no reticulated supply for these services!

Water

Perhaps surprisingly, close to 70% (62 out of 88) of the responses indicate that water supply was not affected by the largest flood.

Sewerage

Approximately 60% (38 out of 66) of localities with sewerage experienced disruption.

Electricity

About half (44 out of 87) of the responses indicate that electricity supplies were disrupted.

Other significant disruption to services

This question invited comment on disruption to other lifelines. A number of localities reported that the communities were isolated from fire, ambulance or hospitals, these include Blackall, the Gold Coast (fire and ambulance), Ingham (fire) and Laidley is isolated from its hospital. In some cases the service buildings are inundated and for others, access was cut. Many other responses commented that the disruption, especially to the road network, hampered the provision of the full range of emergency services.

7.3 Summary

As a general statement, it is not possible to flood proof the transport links. Indeed, a large proportion of the payments under the Natural Disaster Relief Arrangements are too small, but areally extensive, LGAs to repair their extensive road network, including bridges, culverts etc that are usually unsurfaced and therefore, particularly liable to flood damage. However, there is a case to locally provide upgraded transport links especially where these form evacuation routes for the communities at risk. This has special significance for those exposed to storm surge where evacuation is critical and also applies to the siting of all key emergency service installations and buildings, especially police, fire, ambulance, hospitals and communication buildings for emergency management. Special consideration should also be given to the siting of dwellings that house especially vulnerable groups such as the elderly and infirm.

For service provision, water etc, flood proofing of key installations is of importance. Throughout Australia, measures to flood proof especially vulnerable points of all infrastructure should have a high priority. This subject has been highlighted by Emergency Management Australia (EMA) and many of the corresponding State agencies for special attention in the coming years. It needs to be stressed that many individual service providers have well formulated emergency procedures although there is a need to integrate the individual services to take account of consequential effects. For instance, the supply of electricity is often critical to the provision of water and sewerage.

8

The Implication for Estimates of Flood Damage

8.1 Background to flood damage

The questionnaire circulated to all LGAs in Queensland did not include questions that asked for estimates of flood damage in dollar values. This was a conscious decision as such estimates are only of use if they are based on a consistent methodology and definitions of what constitutes damage. Contemporary estimates, say of the kind given in newspapers, are little more than anecdotal and do not represent any form of sound economic appraisal. In order to formulate best practice urban floodplain management it is necessary to undertake detailed assessment of flood losses for a community on a consistent basis. Such assessments require :

- detailed hydrological studies to define the risk
- data on what is at risk - the vulnerability.

This report has demonstrated that hydrological studies of this kind (with information on the magnitude, frequency and extent of all floods to the level of the PMF, with floodplain velocities for flood flows etc.) are only available for a limited number of localities in Queensland. Information on what is at risk (buildings, lifelines etc) is only known for a handful of these.

The paucity of the background information necessary to assess flood losses in economic terms is such that any attempt to evaluate these at the State level is little more than a guess. However, the data from the questionnaire on the number of buildings does enable some comment on losses relative to other States.

8.2 Queensland – estimates of urban flood damage

This section will comment on the likely size of the State's flood losses and is followed by discussion on how this could be improved.

8.2.1 AWRC (1992)

The AWRC report provided estimates at State level for urban damage in Australia. Following normal practice these are most usefully expressed for comparative purposes in terms of **average annual actual damage (AAAD)**. In this context, 'actual' refers to losses after allowance has been made for the reduction to contents loss by the actions of the residents, ie. by lifting or removing items so that they are not inundated. The estimates given below are for tangible losses, ie. they combine direct and indirect losses but do not include any allowance for intangible effects.

The AAAD values given in the AWRC report:

- are at 1990 values,
- only include damages to the level of the 1 in 100 year event,
- do not include losses to lifelines.

With these definitions and qualifications, the AWRC (1992) AAAD values for Queensland, and the number of buildings at risk used in their estimation, are given in Table 8.1.

Table 8.1. AWRC estimates for tangible annual average actual damage (AAAD) for Queensland (AWRC, 1992)

	AAAD in $m	Number of Properties to 1 in 100 year level
Residential	16.4	21,000
Commercial	6.0	2,000
Industrial	7.1	750
Public	4.5	750
Total	**34.0**	**24,500**

The AAAD estimates in Table 8.1, which total $34 m, are based on accepted practice for damage estimation. Indeed, in many respects the methodology ranks among the best available in the literature. The major shortcoming is the poor data base for the number of buildings at risk (to the 1 in 100 flood level), the estimates used by the AWRC were provided by Queensland State agencies.

8.2.2 Flood damage estimates Insurance Council of Australia (Smith, 1996)

In 1996 the Insurance Council of Australia (ICA) commissioned a study to provide estimates of residential flood damage for Australia. The report (Smith, 1996) is unpublished but the following extracts indicate the results for Queensland. The methodology, with the exceptions summarised below, followed that used in the AWRC study.

The major change to the AWRC report was that total number of residential buildings at risk to the level of the 1 in 100 year flood was increased to 50,000. The revised AAAD, restricted to the residential sector, was $31 m, at 1990 prices to allow direct comparisons to the AWRC value.

The ICA study also made a tentative attempt, based on extremely limited information, to estimate the AAAD to the level of the probable maximum flood. The AAAD value to the PMF for Queensland was given as $75 m for the residential sector alone. Most of this additional damage was due to the potential losses from building failure for such extreme events, for example for Ipswich.

8.2.3 Revised AAAD for Queensland.

The revised estimate for the total number of flood prone buildings in Queensland (residential, commercial and industrial etc) to the level of the 1 in 100 year flood is given in Section 3.4.4 as 65,000.

Thus, a very provisional guesstimate of the AAAD for tangible flood losses in Queensland, for all buildings to the level of the 1 in 100 year event, is of the order of $100 m. This is obtained by scaling up the 50,000 estimate given in Smith (1996) and making some estimate for commercial and industrial damage (for purposes of comparability the AAD is in 1990 values).

If the AAAD is extended to include events to the level of the probable maximum flood, these estimates would be very much higher, perhaps by a factor of two.

The possible doubling of AAAD, when estimated to the PMF, is due both to the increased number of buildings at risk and to the increased risk of failure under extreme flood conditions. The changes to the AAAD should not be confused with the increased number of buildings at risk, estimated to be a factor of three (see Section 3.8). This is because AAAD takes into account event damages and their frequency.

There are grounds for considering that the damages could still be underestimates. This is because there may still be flood prone communities that, on the basis of the questionnaire, are inadequately assessed in terms of the numbers of buildings at risk. Further, the ratio of residential to commercial/industrial buildings in the AWRC report and the inadequate questionnaire responses for building type suggest that the overall losses may be too small. This is because unit losses for commercial/industrial concerns are much higher than for residential buildings.

What is now certain is that the Queensland has the highest AAAD for any State in Australia. Numbers of buildings at risk in New South Wales are comparable but more than twenty years of steadfast application of urban floodplain management has reduced the AAAD for some communities and halted the increase in flood prone developments for the majority of LGAs. At State level, Queensland has not reduced the risk and for many major flood prone urban communities the lack of effective land use controls or building regulations is such that the potential damages increase year by year.

8.3 Assessment of urban flood damage

Need to define direct and indirect costs in this section

Hydrological techniques and models are widely available for the estimation of the magnitude, frequency and extent of flood events, this is now equally true for methods to assess urban flood damage. These are based on the use of stage-damage curves for differing classes of buildings, a technique first described in the USA by White (1945), these methods subsequently became the basis for the Federal Flood Insurance Program in the late 1960s. Refinements of the stage-damage technique, based on work in the UK, are given in Penning-Rowsell et al (1977). One of the first applications in Australia of such methods was to assess the damage after the Brisbane floods of 1974, see SMEC (1975). A study of the flood damages for Lismore in New South Wales (Smith et al, 1979), also prompted by the 1974 floods, led to the development of a commercially available computer package, ANUFLOOD, to assess urban flood losses and as a method to evaluate the costs and benefits of a range of flood mitigation measures.

ANUFLOOD is described in detail in the *User's manual* (Taylor *et al.*, 1983) and the accompanying *Field guide* (Smith and Greenaway, 1983), both have been revised on a number of occasions. The program combines spatial information on flood hydrology (magnitude, frequency and extent), a building data base and stage-damage curves appropriate for the classes of buildings. Together these can provide estimates of flood damage in a variety of forms, for example as event damages (say for the 1 in 70 year flood) or as average annual damage. Subsequent modifications to ANUFLOOD can (if flood velocity data are available) assess the additional costs due of building failure. The program has been modified, to ANUSURGE, for use to assess damage from storm surge (Smith and Greenaway, 1994). It is also possible to link ANUFLOOD (or ANUSURGE) to existing geographical information systems to produce output in terms in spatial information. This is essentially the basis of the AGSO Cities Program which is currently underway in Queensland.

Although ANUFLOOD and ANUSURGE are convenient packages, the principles are those accepted internationally as best practice for the assessment of flood damage, eg. White (1945), Penning-Rowsell *et al.* (1977). ANUFLOOD has been widely used by consultants and government agencies in New South Wales as a component of flood studies and as a foundation for floodplain management for well over fifteen years. More recently it has been used by consultants for studies in Queensland, for example the studies by Camp, Scott and Furphy for Rockhampton and Charleville, and ANUFLOOD is currently used as a basis by the DNR for flood studies in progress at Warwick.

In short, there are no technical barriers to the assessment of best practice flood damage estimates. A critical prerequisite however, is the availability of good quality hydrological data for the area under study.

The output of ANUFLOOD, and of similar computer-based programs, is usually in terms of direct, actual or potential, flood damage. The estimation of indirect damage is often undertaken outside the program. Indirect effects are much more difficult to define and are often assessed as a proportion of the direct losses. A more detailed discussion of the evaluation of indirect losses is given in Parker *et al.* (1986), a recent Australian account is available in Handmer and Thompson (1996).

Direct damage are those that result from the contact of flood water (and included sediment) with building structures and building contents. Indirect losses are essentially due to disruption caused by the flooding. For instance, a major category for the residential sector is the cost of alternative accommodation. For the commercial and industrial sectors indirect losses include loss of trading profit due to closure as a result of flooding. Indirect loses in the commercial and industrial sectors can be substantial and are relatively much larger than residential indirect losses.

Care is needed with the assessment of indirect losses to the commercial and industrial sectors. The choice is between financial losses (losses to individual firms comparable to insurance payments) and economic losses. The latter are usually less obvious and attempt to evaluate the losses to the regional, State or national economies. For example, if a beer bottle factory is inundated there are two possibilities to ensure continued production. One is that beer bottle production can be made up by other flood free beer bottle manufacturers, perhaps by working overtime, so that there is no overall loss to the economy; the other is that the lost capacity cannot be taken up elsewhere. In the former case the indirect losses, using economic criteria, are very small while in the latter case they are not. In the UK, the Treasury uses indirect losses defined on economic grounds, in Australia it has been the practice to use financial losses. Such questions are of significance in assessing flood damage, the differences in definition of indirect losses can have major effects on the cost benefit analysis of structural mitigation measures which are usually, in part, funded by State and/or national governments.

Direct and indirect damages are combined to give tangible losses. In many studies, especially overseas, these are usually in terms of potential losses and are not adjusted to allow for damage reduction to building contents by the residents, emergency services etc. In Australia such measures are often incorporated into the estimates, this is the case with damage data given in the earlier part of this section.

Consideration and weighting should also be given to intangible losses, which by definition, are not (easily) converted into dollar terms. It is recognised that such effects can be important and include all forms of stress, illness and, in the extreme case, death resulting from flooding. In the commercial sector the intangible losses can include loss of business confidence, future contracts etc.

8.4 Summary

Due to the paucity of hydrological studies it is not possible to give other than guesstimates for the magnitude of the State's flood damages.

It is however, likely that average annual damages are higher for Queensland than for any other Australian State, that the Brisbane floods of 1974 were the most damaging flood event ever to occur in Australia and that the Gold Coast has among the largest potential for flood losses of any LGA in Australia.

Techniques to assess flood hydrology and damages are available and expertise in their use is widely available in Australia. That this is the case is illustrated by Queensland LGAs that have undertaken such studies, for example Rockhampton and Murweh. However, the number is meagre especially in comparison with New South Wales. The problem becomes how to encourage such studies to be undertaken for all urban flood prone localities in Queensland.

The publication of a manual for use by LGAs in Queensland that describes methods to be used for hydrological studies and especially for damage evaluation, would be a invaluable aid to LGAs to achieve the aim of best practice urban floodplain management.

It is stressed that the available techniques to assess potential flood damage are based on the evaluation of direct losses to buildings and their contents, guidance on a consistent methods to estimate indirect and intangible losses is also required together with advice on how to assess the effects on lifelines.

The comments above apply to the assessment of losses from riverine flooding, the situation for losses from inundation by storm surge is even less satisfactory. In this case there is much less opportunity to learn from the experience of the other States as the risks of damaging storm surge are much greater in Queensland than elsewhere in Australia. State of the art studies in this field are from the southern eastern USA.

9

Surge Inundation

9.1 The background

Surge, alternatively termed storm tide, is associated with the low atmospheric pressure accompanying tropical cyclones. This causes a localised rise in sea level which is at a maximum immediately below the eye of the cyclone. When the cyclone moves into shallow coastal waters the increase in sea level can be enhanced due to wind and wave set-up. It is however, difficult to provide reliable forecasts of the height of the surge at, and landward of, the shoreline.

The magnitude of the surge near-shore is controlled by a variety of factors of which the off-shore bathymetry and the (in plan) shape of the coast are particularly significant. As a guide, extensive off-shore shallow water increases the height of the open sea surge and the effects can be further enhanced if the surge is funnelled into estuaries or embayments. Figure 9.1 taken from Hopley and Harvey (1979) provides an indication of the effects of bathometry, the diagram shows depth correction factors. The higher the correction factor the more likely that open ocean effects will be converted into enhanced coastal zone inundation. In broad terms a factor of 2.0 indicates a doubling of open ocean surge while 0.5 indicates that it would be halved. The Gulf of Carpentaria is noteworthy for its high correction factors, in contrast to the relatively low values for Brisbane, south to the Gold Coast and to the border with New South Wales.

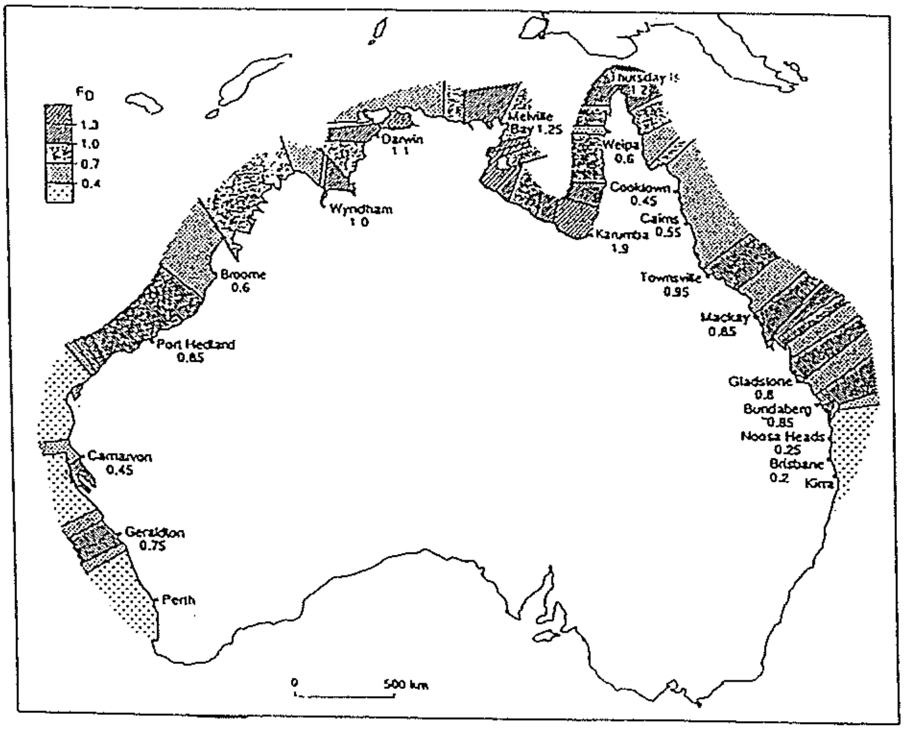


Figure 9.1 **Regional variations in depth correction factors, Fd, for the Australian coast, from Hopley and Harvey (1979)**

The need is for provision of estimates of surge height at specific locations but this requires detailed and complex calculations in order to translate the open sea surge into those that would apply at the coast. Such forecasts will never be precise because even small changes in the track of the approaching cyclone change the area at maximum risk. Over the last few years the Bureau of Meteorology, in part related to the Queensland-based Tropical Coastal Cyclone Impact Program (TCCIP), has undertaken 'state of the art' studies for storm surge at several east coast locations in Queensland. Such studies have included the major coastal low-lying urban areas of Cairns and Mackay. Notwithstanding this work, problems of forecasting surge are further complicated by the timing of the surge in relation to the prevailing tide and the problems of estimating wave height. During the course of a tropical cyclone, open sea wave height can be very large, but for most practical purposes (emergency management, damage estimation etc.) wave height needs to be added to the estimates of the height of storm surge which are normally reported in terms of 'still water'. The problem is especially important where surge inundates land and buildings beyond the landward limit of the highest astronomical tide. As a working rule wave height in inundated areas can be approximated to be half the still water depth, i.e. an inundation of 3.0 m of still water surge requires the addition of a further 1.5 m to allow for wave height.

Within the context of the present study, the focus is upon the risk of urban inundation from storm surge. To some degree, the whole Queensland coast is at risk from surge inundation associated with tropical cyclones and the urban risk applies to coastal settlements at low lying locations.

The inclusion of storm surge within a review of flooding is three-fold. This is because:

- the effects on buildings and services are similar to extreme river inundation,
- in many locations, urban areas subject to surge are also liable to river flooding,
- mitigation is best achieved by land use zoning and building regulations which are similar for riverine and surge flooding.

9.2 Surge inundation

A review of the effects of surge inundation on buildings with reference to Mackay is given in Tropical storm surge, damage assessment and emergency planning, Smith and Greenaway (1994). In summary, the effects of surge on buildings are much more severe than from river flooding, this is because of the power of wave impact on structures. In locations close to shore the best estimates, from the USA, indicate that for lightweight domestic or commercial structures there is a strong likelihood of complete failure if the depth of the surge (still water plus wave height) is in excess of 1.0 m over floor level. Severe damage could be expected for much more limited flooding over floor level. In addition, the salinity of sea water causes much greater damage to building contents than is the case for fresh water.

The implications for loss of life are therefore, extreme and far exceed those associated with river flooding.

Further, by definition, surge occurs in combination with extreme winds and rainfall associated with tropical cyclones. These factors are recognised by the emergency services in Queensland who, over the last five years or so, have been actively engaged in improving emergency response for areas liable to surge. A problem for the emergency services is that for the wind effects of cyclones, the preferred strategy is for those at risk to stay indoors, while for surge the need is for evacuation before the wind reaches velocities in excess of about 70 kph.

9.2.1 Surge and river flooding

Many coastal settlements in Queensland were originally sited on river estuaries and subsequent growth has often led to further urban development in low lying, near-coastal locations. Such sites are often, therefore, vulnerable to both river flood and surge. The problem with such sites is that a cyclone landfall in the vicinity of an estuarine town can cause inundation by surge followed, with a variable lag time, by river flooding resulting from intense rainfall in the upstream river catchment.

Mackay, on the Pioneer River, is a prime example for which information is available. In 1918, much of the settlement was destroyed by a surge event which was followed, some 12 - 24 hours later, by the flood of record. Indeed, it is difficult to distinguish from the contemporary accounts of the disaster which buildings were destroyed by wind, surge or river flood!

The conjunction of vulnerability to surge and flood in such locations emphasises the need for mitigation to consider both hazards in an integrated fashion.

9.2.2 Land use zoning and building regulations

The analysis of the questionnaires indicates that many flood prone LGAs in Queensland have regulations that, to some degree, recognise the need to introduce zoning and floor height regulations for river flooding. Similar or linked regulations for surge are uncommon. An exception is the recognition of the threat and related regulations, for new developments, by the former Mulgrave Council which are now in the process of incorporation for the enlarged area of Cairns City Council. Mackay, with a known surge risk, has no related zoning or building regulations.

There are clearly major difficulties for an LGA in introducing regulations for surge but this deficiency is in marked contrast to many other developed countries. The USA is a leader in this field and most States in surge-prone regions have rigorous planning requirements for new developments. Typically these prohibit buildings in the zone exposed to the 1 in 100 year surge unless the floor level is above inundation level and the construction meets stringent engineering standards. In addition, there is a requirement to provide acceptable escape routes in areas liable to surge. In the USA a 'V-zone' is recognised where surge would be accompanied by significant wave height (and therefore an enhanced risk of building failure). For most of the Queensland coast, the physical setting and exposure are such that the majority of the coast would be classified as 'V-zone'. In the USA regulations for surge are similar to those used there for flooding, and stem from the National Flood Insurance Program which is subsidised by the federal government and provides cover for both river flooding and surge - provided that local government adopts planning regulations for new developments.

The occurrence of major surge events for existing urban locations in Queensland is of relatively low frequency but with a magnitude that has potential for huge damages and loss of life. The lack of State or local zoning and building regulations for most of the Queensland coast needs to be urgently addressed.

9.3 Where is the risk?

For over twenty years there have been attempts in Queensland to define the likely magnitude of storm surge, especially for the east coast. In common with overseas studies, there is little information on the vulnerability of the urban areas at risk. The Department of the Environment (notably the Beach Protection Authority) published a series of storm surge studies, based on computer simulation, in the late 1970s, for a range of locations from Cooktown in the north to the Gold Coast in the south. The component reports include estimates of surge heights for the 1 in 100 year event and many also give estimates for the 1 in 500 year surge, these are for still water levels and do not include wave height, wind set-up etc. The Department is currently preparing a review entitled, *Storm tide threat in Queensland.*

There is also a series of storm tide maps, published in the mid-1970s by the Queensland State Survey Office, again for a selection of east coast locations, these include Cairns, Mackay and Townsville. These are designed for use by the emergency services and are basically shaded layered contour maps.

Other useful information is given in Storm tide: warning-response systems (SCDO, 1992). This lists 'all known centres of habitation on the Queensland coast' and gives the height of 'the assumed highest tide' and highest astronomical tide (HAT), together with comments on evacuation zones (up to 1.5 m, 1.5-3.0 m, and 3.0-4.5 m). It also presents brief comments, where known, on the 'inundation of any developed area'. For some locations SCDO (1992) also provides estimates of the surge height for an event with a 1 in 500 year annual recurrence interval. Where appropriate, this is given in Table 9.1. These values for surge height are added to the sea water level current at the time of the event, i.e. allowing forthe state of the tide etc. The aim is to give a broad indication of relative surge risk rather than any kind of precise estimate. No indication is given of the wave height that should be added to the still-water levels.

9.3.1 Mackay, Cairns and Townsville

More recently detailed building-by-building surveys, suitable for use as geographical information systems (GIS) have been undertaken for Mackay and Cairns. Details of the results for Mackay are available in Smith and Greenaway (1994) and Granger and Smith (1995), at both locations details of the hazard are available from recent studies. A summary of the surge data for Mackay is given in Table 9.2.

A comprehensive building data base has been prepared for Cairns by K. Granger (AGSO) and A. Zerger (CRES, supported by an IDNDR Postgraduate Scholarship). Provisional analysis for a near probable maximum surge height of 5.0 m (above HAT) indicates that a total of some 13,000 buildings would be affected with the majority experiencing over floor inundation. Of the total, approximately 10,000 are dwellings and the remainder commercial buildings including major hotels.

To date, there is no data on potential building failures but it can be anticipated that these would be large in number. The estimates are for a still water level, i.e. wave height is not incorporated. Equally important would be the damage to lifelines which would cut power, water and sewerage; road, rail and air traffic links, and thereby totally isolate the Cairns region. Full details of the analysis for Cairns should be available in the next few months.

Much of Townsville is low-lying and liable to surge but to date, to the best of my knowledge, there are no reliable estimates of the numbers of buildings at risk. However, for a low probability surge event these could likely total several thousand.

Table 9.1 **LGAs reporting a surge problem, map availability and SCDO (1992) estimates of height of 1 in 500 year surge**

LGA and sites listed		Map available	SCDO Surge height 1 in 500 year
Bowen	(Queens Beach)	yes	2.6m
Burnett	(Bundaberg Point)	yes	
Caboolture	(various locations)	yes (some locations)*	
Cairns	(City and Northern Beaches)	yes	2.5m
Calliope	(Tannum Sands, Boyne Is.)	yes	
Caloundra	(Kawana Waters)	yes	
Cardwell	(Tully Heads, South Mission Beach)	yes	2.35m
Carpentaria	(Karumba)	no	
Cook	(Ayton, Cooktown)	yes (simplistic)*	1.85m
Douglas	(Port Douglas)	yes	
Gladstone		yes	
Gold Coast		no	1.45m
Hervey Bay		yes	4.2m
Hinchinbrook	(L. Tully)	no	3.1m
Johnstone		yes (in part)*	2.45m
Livingstone		yes	4.7m
Mackay	(City and North Mackay)	yes	4.8m
Noosa		no	
Pine Rivers		yes	
Redcliffe		yes	
Redland	(Bay Island)	no	
Sarina	(various locations)	yes	5.0m
Thuringowa		yes (inaccurate)*	
Tiaro		no	
Townsville	(City)	yes	3.7m

* Comments as given in the questionnaire responses.

\+ 1 in 500 year surge height from SCDO (1992) is the still water level, i.e. no allowance for wave height. wave set-up etc. The estimate is added to the tide height predicted for the time of the surge. Given solely as an indication of relative risk.

Table 9.2 Mackay – number of buildings at risk from inundation and failure in relation to probability of storm tide

	1 in 20 yr 4.0 m	1 in 50 yr 4.70 m	1 in 100 yr 5.20 m	1 in 1000 yr 6.60 m	1 in 10,000 yr 7.90 m	Probable maximum storm tide 8.50 m
<u>Mackay residential</u>						
No. of buildings, overground flooding	154	2879	3576	5268	6263	6531
No. with overfloor flooding	885	1877	2760	4593	5890	6256
No. of building failures	0	885	1748	3740	5299	5714
<u>Mackay commercial</u>						
No. of buildings, overground flooding	118	355	434	1040	1123	1154
No. with overfloor flooding	66	295	419	1001	1122	1150
No. of building failures	1	66	250	558	1067	1094
<u>North Mackay residential</u>						
No. of buildings, overground flooding	26	82	406	912	1104	1147
No. with overfloor flooding	2	42	207	799	1055	1112
No. of building failures	0	2	20	552	925	1055
<u>North Mackay commercial</u>						
No. of buildings, overground flooding	2	27	63	117	127	129
No. with overfloor flooding	0	26	59	117	127	129
No. of building failures	0	0	10	92	125	127

Based on wave height assumptions given in FEMA (1986)

It is likely that Cairns and Mackay pose the greatest threat in terms of number of buildings but comparable studies are urgently needed for other surge-prone settlements before any reliable estimate can be given as to the overall size of the problem in Queensland.

9.3.2 Gulf of Carpentaria

The quality and detail of information on the potential surge risk for the Gulf of Carpentaria is much less than for the more populous east coast. The risk is known but there is little knowledge of the magnitude, frequency and inland extent for the rarer, i.e. the low probability, events. The vulnerability of Karumba, with a resident of population of about 400, is recognised and there are established evacuation plans for the whole settlement, all of which would be inundated by even a moderate surge. Evacuation is to Normanton along 70 km of low-lying road. However, this link could easily be severed by cyclonic rains and there is a need for better designed surge refuges. Acceptable designs however, require knowledge of the height of extreme surge conditions. Further to the west, Burketown presents an equally severe risk and a number of people were drowned there by surge in 1887.

9.4 Responses to the questionnaire

Only three questions directly address the problem of storm tide.

Question 3.1 Asked '*... does a storm tide problem exist?*'

Question 3.2 Requests the date of the last event which caused the flooding of buildings.

Question 3.3 Enquires if a storm tide map exists.

9.4.1 Does a problem exist?

A total of 25 LGAs replied that they had a storm tide problem, in several cases this applied to several locations within their area. A list of the LGAs at risk is given in Table 9.1. This confirms that virtually all coastal LGAs in Queensland acknowledge the risk of surge. The non-respondents of Burdekin and Torres Is. are also known to have a storm tide problem. The magnitude of the risk, in terms of numbers of buildings, varies and reflects the exposure of low lying structures.

For some locations the height of likely surge events is restricted but even for these localities the indirect effects could be considerable. The Gold Coast falls in this category with the likelihood of surge having adverse effects on flood height together with the additional problem that, in some locations, it is possible that extreme surge could break through the coastal dunes and cause direct inundation.

9.4.2 Date of last damaging surge?

Some two thirds of the LGAs reporting a problem provided dates for the last surge event to inundate buildings. These are listed in Table 9.3. In four cases these were from the 1990s although for all of these the damage was relatively small. Mackay and Sarina, with catastrophic losses in 1918, have not experienced a significant surge event in the last 70 years.

9.4.3 Storm tide inundation maps?

Table 9.1 also lists whether or not LGAs have storm tide maps. Nearly three quarters (16 out of 25) report that they do, although it is significant that several of those draw attention to their limitations e.g. 'simplistic', 'only for some locations' etc. Similar reservations are also likely to apply to others that responded that they had storm tide maps, it is suspected that in many cases they are limited to coloured-layered contour maps. Although these are of use for evacuation procedures for the emergency services, they have little scientific foundation and do not express risk in terms of frequency, i.e. they are not comparable to flood maps that show the limits of the 1 in 100 or 1 in 50 flood event.

Table 9.3 Local Governments reporting building damage from storm tides

LGA	Year of storm tide damage
Bowen	1980
Burnett	1942
Cairns	1979
Carpentaria	1976
Cook	1976
Gold Coast	1974
Hervey Bay	1992
Johnstone	1996
Mackay	1918
Maryborough	1976
Noosa	1992
Pine Rivers	1993
Sarina	1918
Thuringowa	1971
Townsville	1971

9.5 Surge in Queensland - a summary

Flooding from storm surge is a potential problem for all low lying coastal areas of northern Australia that experience tropical cyclones. In terms of urban surge risk the problem is especially significant for Queensland, a fact recognised by the majority of coastal LGAs responding to the questionnaire. However, there is a paucity of detailed information on hazard risk that is based on 'state-of-the-art' scientific methodology. Where this has recently become available, for example for Cairns and Mackay, studies have demonstrated the massive potential for damage and for loss of life. It is not possible to state with any certainty the numbers of building in Queensland that are directly at risk from extreme storm surge events but a conservative estimate would indicate a value of the order of 40-50,000.

The impact of a major storm surge on an urbanised community would result in building and infrastructure failure that is akin to that normally associated with an earthquake rather than with riverine flooding.

Only a limited range of questions concerning storm surge were included in the questionnaire. However, it is clear that more resources need to be devoted to this problem in order to assist

LGAs to better define the risk. It is noticeable that much of the recent research on hazard risk and vulnerability to surge has been funded by Commonwealth agencies rather than by the State government.

Unlike river flooding, the problem is concentrated in Queensland and therefore, there is not the same opportunity for the transfer of methodologies and experience between States. Succinctly, inundation of urban areas from storm surge is dominantly a Queensland problem.

In order to lessen further impact, better risk definition will need to be followed by the adoption of land use zoning and building regulations similar in form to those discussed for river flooding in Section 11. The implementation of such measures will not be an easy task and should ideally, be linked to changes and improvements to similar measures for river flooding. Such actions should not be delayed until their significance becomes apparent in the aftermath of the next major surge to impact upon a low lying urban coastal community. There is the need for a review of Queensland's planning and management for surge to match that underway for urban river flooding.

10

The Questionnaire – A Summary

10.1 Response to the questionnaire

This study reports on the state of urban floodplain management in Queensland and is based on a questionnaire sent all to LGAs. Responses were obtained from 103 LGAs and provided information on 133 separate locations. These do not include the flood prone creek catchments in Brisbane or those for the Gold Coast, these are discussed separately in Section 4. The majority of the non-respondents were LGAs that are unlikely to have a urban flood problem, in many cases because of their small and dispersed populations. There were difficulties in designing a questionnaire suitable for LGAs that range in population size from Brisbane City Council to areally extensive, but sparsely populated, local government areas in the west and north of the State. Despite these qualifications, the survey provides, for the first time, comprehensive State-wide data which permits comments to be made on the current state of urban floodplain management and provides a background to suggestions for State policy.

The questionnaire indicates that 92 LGAs have an urban flood problem, if non-respondents are included this becomes 96 out of a State-wide total of 125 LGAs..

10.2 Numbers of buildings at risk

The simplest, and most commonly used, indicator of size of urban flood problems is the number of buildings at risk from the 1 in 100 year flood event. Few LGAs have reliable information on the extent of such a flood and even fewer have information on the number of buildings at risk.

Based on the questionnaire, and including an allowance for non-responses, the number of urban buildings in Queensland at risk from 1 in 100 year flood event is estimated to be about 65,000. For an unknown proportion of these properties, 1 in 100 year flood inundation would not exceed building floor level.

The data are inadequate to classify the properties into separate categories, i.e. residential, commercial etc. There is some evidence that the ratio of residential to other buildings is less than in other Australian states, provisionally it could be assumed that some 25% are non-residential.

Table 3.5 provides a ranked list of the 12 most flood prone LGAs in terms of the number of buildings at risk at risk, these account for some 60 % of the State total.

The area administered by the Gold Coast has the distinction of having one of the largest number flood prone properties (dominantly residential) not only in Queensland but in Australia. The council has completed detailed assessment, including potential damage, for the Nerang catchment and has studies in progress or planned for the other catchments in its area.

It is salutary to note that, until the last year or so, there were no detailed data available for the Gold Coast on the number of properties at risk, that Charleville was not regarded as having a major flood problem until the floods of 1990, the potential magnitude of river flooding for Mackay was not known until 1994 and the size of the flood problem in Queensland was reported to the AWRC national study, in 1990, as comprising only 25,000 properties. It is perhaps, tempting fate to suggest that as a result of the current survey that there will be no more major additions to the list of flood prone communities. However, it is thought unlikely that any major new urban centres will be added to the list given in Table 3.5.

10.3 Extreme floods

It has been stressed throughout this report that the 1 in 100 year flood line should not be regarded as separating flood prone areas from those that are flood free. Only 11 localities had any detail of the size of the probable maximum flood, the worst case event, and of those only 8 had the information available in map form. The number of properties at risk from the probable maximum flood is much larger than for the 1 in 100 year flood and it is not impossible that the number to the limit of the probable maximum flood could be more than three times larger. Many of these additional buildings would only experience over-ground, as opposed to over-floor, flooding but the consequences for some localities is that lightweight structures at lower levels are at risk of structural failure.

10.4 Flood height range

The number of properties at risk from the 1 in 100 year event is only one indicator of flood risk, another is the flood height range which is the difference in flood depth (indicated by heights on flood gauges) between, say, the 1 in 20 and 1 in 100 year floods. There are large variations in the flood height range between localities, examples for some of the major flood prone communities are given in Table 1.1, these range from about 3m to in excess of 20m. Precise data of this kind, i.e. based on detailed hydrological studies, are uncommon in Queensland but a guide can be obtained from the levels of minor, moderate and major floods available from the Bureau of Meteorology.

High flood ranges, associated with even relatively low flood velocities, greatly increase the risk of building failure especially for lightweight structures, eg. detached single storey weatherboard dwellings. The significance of extreme floods, above the 1 in 100 year event to the level of the probable maximum flood, is especially marked for communities with a high flood range.

Table 1.1 can be used as a guide to localities where flood height range is of major concern. The situation for Ipswich, confirmed by the failure of over 30 dwellings in the 1974 flood, is the most severe example in Queensland in the last thirty years.

10.5 Flood warning systems

Much of the State, especially Brisbane and the south-east, is well provided with locally-based flood warnings, most based on ALERT installations. Quantitative flood forecasts from the Bureau of Meteorology are available for many other communities with a known urban flood risk and the situation is one of continued upgrading and extension although smaller and remote communities do not have the benefit of such services. However, the lack of basic data on what localities are flood prone has been a problem for the Bureau, all too often communities with a major urban risk have only become apparent after a major flood has occurred.

Information provided by the Bureau, and reproduced here as Appendix 5, shows that the length of the flood warning time (with the current provision of field instrumentation and techniques) is, for the majority of flood prone locations, less than 12 hours.

Such short warning times form a further indicator of flood risk. A warning time of less than 12 hours gives much less time to evacuate, reduce losses and to reduce stress and anxiety than a warning time of several days.

As is almost universally the case, improvements to flood forecasts demonstrate the need for better community response in order to more fully capture the benefits of enhanced warnings. The questionnaire responses confirm that there is scope to more fully integrate flood warnings into LGA emergency plans and flood policy. The need is now, to incorporate improved forecasts and warning times into a comprehensive flood warning system which includes better community awareness and response.

10.6 Priority listing of flood prone urban communities

The preceding sections have stressed that urban flood risk is an amalgam of the current numbers of properties at risk, the flood height range and the length of warning time that can be provided to reduce tangible and intangible losses. Hence, the three factors that together define vulnerability are:

- size of the existing problem
- flood height range
- flood warning time.

It is not possible to rank these factors in a truly quantitative manner but qualitative guidance can be given based on an A, B, C system. This is presented in Table 10.1, where A represents a high rank for a specific factor, B is moderate and C is relatively less important. Thus, three As indicate a high priority on grounds of overall vulnerability and three Cs a much lower ranking.

The three factors provide a ranking of flood risk but do not of themselves indicate the state of information and response. For example, Brisbane has excellent hydrological background information (although currently under improvement for the main Brisbane River), local flood warning systems but relatively poor information on the buildings at risk. This handicaps measures to increase community awareness and response although it would not be a difficult matter to combine building data with existing geographical information systems. Until the last year or so, the Gold Coast (including the former Albert Shire) had only scant information on the number of properties at risk. Within a short time studies, now complete for the Nerang catchment but underway elsewhere, have completely transformed the information base. Rockhampton and Murweh (e.g. Charleville) are among the few LGAs that have close to best practice information on all aspects of vulnerability, including potential flood losses.

The ultimate test is not restricted to the availability of a full information on vulnerability but its use to formulate acceptable locally based urban floodplain management. Such management requires full data on vulnerability but such availability does not guarantee its use to establish acceptable local policy.

Table 10.1 is limited to communities that are known to have a relatively large number of buildings already at risk from flooding. There are many more small communities which would likely have a high ranking of vulnerability in terms of flood height range and flood warning time. The need here, as with those listed in Table 10.1, is for background studies in order that future developments do not increase future flood risk.

Table 10.1 A ranking of the vulnerability of major flood prone communities in Queensland

LGA and location	Number of buildings	Flood height range	Effective warning time
Gold Coast	A	C	A
Mackay	A	B	A
Brisbane			
Brisbane River	A	B	B
Creeks	A	B	B
Dalby	A	A	A
Ipswich	A	A	A
Hinchinbrook (Ingham)	A	B	A
Logan	A		
Logan River		B	B
Creeks		B	A
Murweh			
Charleville	B	B	B
Augathella	C	B	A
Rockhampton	B	C	C
Burdekin	B	B	B
Cairns (inc. Mulgrave)	B	C	A
Caboolture	B	?B	A
Blackall	C	B	A
Gympie	?C	A	B
Johnstone (Innisfail)	B	C	A
Balonne	C	C	A
Gulf Rivers (Normanton)	C	A	C

It needs to be stressed that some of the major flood prone communities were close to green field sites at the time of the extensive floods in 1974. It is not possible from the present information base to give any firm data on the increase in the size of the problem over the last twenty years or so but there is no doubt that it has been significant. The Gold Coast is a prime example of this but undoubtedly the expansion of developments, many of which are dominantly residential, into flood prone sites has been a State-wide phenomenon.

10.7 Background studies in hydrology and mitigation

The survey results show that hydrological studies are available for only some 40% of flood prone urban localities; note that 'localities' are sub-sets of local government areas. However, what is meant by 'hydrological studies' and the purposes to which they are put are quite different questions. It would appear that only 28 localities have used this information as a basis on which to define a designated flood that is at the level of 1 the 100 year flood (or better). A disturbingly large number of the major flood prone communities do not have a designated flood to an accepted level.

Hydrological studies are necessary to define hazard risk and the next step along the path to effective floodplain management is to investigate the potential flood damage to existing developments. This has only been undertaken by for 11 localities, see Table 5.2 for detail. Again many high priority flood vulnerable locations do not fall into this group.

Only 35 responses to the questionnaire reported that there is a 'flood policy' in place. The number of councils that have a policy for urban flooding is unacceptably small and often, where such a policy exists, the information on which it is based is inadequate.

10.8 The use of mitigation measures

Mitigation measures are divided into structural and non-structural, the detailed responses are described in Section 5.8. Only 29 localities reported that they used structural measures. Levees are used at 13 of these although few are extensive systems designed to protect larger urban flood prone communities to the level of the 1 in 100 year event. The use of other structural measures is limited to a small number of localities. For example, dams utilised for flood control are few and in all cases are restricted to locations downstream of dams developed primarily as water resource storage's; although for Brisbane, and to a lesser extent Townsville and the Nerang catchment, they have significantly reduced future flood losses especially for minor and moderate flood events. Their smaller equivalent, flood retention basins, are rarely used to reduce the adverse effects of mainstream flooding although they are more widely used to mitigate the effects of flooding associated with stormwater drainage..

It is especially noteworthy that flood proofing, especially the raising of weatherboard dwellings, located in flood prone locations, is rarely reported and there are no reports of the flood proofing of other types of building. Channel improvements are another example of a structural measure used on a local basis although these have been used more extensively and to good effect in some of the smaller developed Brisbane Creek catchments. Voluntary acquisition of dwellings in especially hazardous locations is rarely used.

The relatively low rate of adoption of structural measures for existing flood prone developments is not necessarily an indication of poor floodplain management. Indeed, the construction of major levee systems and other structural works can have adverse implications for community awareness and behaviour and create problems for emergency management. It is probable, however, that the relative paucity of such mitigation measures in Queensland more likely reflects problems with low level State funding to assist LGAs to construct, what are often, expensive works.

Nonstructural measures, usually involving the use of land use controls and building regulations within the area delimited by the designated flood, are reported as used at some 66 locations. Some 36 of these combine land use and building controls measures although many of these lack essential hydrological information.

The use of fill, to elevate habitable floor levels above the level of the designated flood, is widely used throughout Queensland, to a much greater extent than elsewhere in Australia. For such techniques to be effective it is essential that the impact of cumulative fill decisions on flood levels is fully known. It is suspected that often this is not the case and that the widespread use of fill for new developments is not consistent with sound urban floodplain management. It is certainly necessary to carefully control the afflux effects especially when a catchment extends across a number of LGAs.

Despite the use locally of a range of mitigation measures there is scope for the experience of LGAs who have used such individual measures to share their experiences with others who have not. This applies especially to structural mitigation. It would invaluable if examples of the successful (and even the unsuccessful) use of such measures could be used as illustrative examples in a State manual designed for use by LGAs throughout Queensland. Relative to urban floodplain management in New South Wales, the adoption rate of structural and nonstructural mitigation measures is low.

10.9 Summary

The details of the individual responses to the questionnaire are given in Appendix 1, and an analysis of the overall pattern for the State in the preceding sections. The responses to the questionnaire have enabled a much fuller account to be presented of the urban flood problem than was previously possible. Caution is urged in placing undue weight on individual responses but the overall pattern provides a valuable background against which to assess the problem of urban floodplain management in Queensland and a basis upon which to recommend future improvements.

There is no doubt that increased contact between elected representatives and professional staff of councils, with and without adequate floodplain management policies, would lead to the sharing of information and experience. Such meetings of councils with urban flood problems have been held annually in New South Wales for over thirty years and, it is suggested, would be invaluable in Queensland

11

Towards Better Urban Floodplain Management

11.1 Effective floodplain management – the steps

The steps necessary to provide the information integral to effective urban floodplain management have been stressed throughout this report. In summary they are:

i. hydrological studies

ii. analysis of what is at risk- combined with hydrology to give vulnerability.

iii. decision on the appropriate designated flood

iv. flood management plans for:

v. new developments

vi. residual flood risk

vii. existing flood prone developments

viii. adoption of measures into local planning regulations.

11.1.1 Steps (i) & (ii) - hydrological and risk assessment studies

'Flood studies' incorporate the first two steps in the process. The hydrological studies define the flood hazard risk, they should use the best available modelling techniques and use all available information on historic floods. The studies should include data on all floods to the level of the probable maximum flood and information on over-floodplain velocities especially for the more extreme events.

Once the hazard is so defined, a survey should be undertaken of all buildings (and ideally infrastructure) that is at risk, this should include all buildings, residential, commercial/industrial etc. Information to be gathered should include ground and floor heights, type of construction and, for the commercial/industrial, size, use and estimates of liability to flood loss. Stage-damage curves should be constructed or obtained for each of the major building classes recognised in the field survey. Guidance to the detail is given, for example, in the ANUFLOOD manuals.

The output can be combined with geographical information systems (GIS). This forms an excellent method for storage and, for many LGAs, can be linked into GIS for other information available for the area. GIS methodology also allows for rapid appraisal of the effects of floods of differing magnitude and frequency.

The flood hydrology and what is at risk (buildings etc), are then combined to give estimates of all forms of flood damage for a range of flood events. Such analysis forms the basis for the adoption of the designated flood level. Background to damage estimation is given in Section 8.

11.1.2 Step (iii) – the designated flood

Decisions on the choice of the designated flood are the key to successful urban floodplain management, this is because the designated flood determines where future developments will be located. Worldwide the tendency has been, regardless of local circumstances, to select the 1 in 100 year flood as the designated flood. There is no scientific or economic basis for a universal selection of this kind. Throughout this report it has been stressed that the flood risk is dependant on local circumstances of which flood height range is especially significant.

Decisions of the designated flood should, be made at the local level and consider all aspects of the flood background; hydrological, socio-economic and safety factors. For some flood prone locations the 1 in 100 year flood would form a sensible choice for the designated flood, for others it would not. In some instances, i.e. where there is a high flood range, a level approaching the 1 in 50 year is likely to be a better choice. For others, say with a lower flood range and low velocity flood flows, it could be closer to the 1 in 200 year event.

Because of the overwhelming importance of local factors and the costs and benefits of the choice of the designated flood, the local community should play a major role in the discussion. However, the decision should be made within floodplain guidelines decided by the State government. There is a case to be made that final approval for local plans should be at State level, if only to ensure that the decision has been made on the basis of best practice analysis from the flood studies.

If LGAs are reluctant or slow to comply with State guidelines, there is the option of superimposing an interim designated flood. Reluctantly, it is suggested that this could be the 1 in 100 year event although even in that case the imposition of a more severe standard for locations with a high risk should be considered.

The role given to the State government is, in part, because it is responsible for relatively large proportions of flood relief payments and for the safety of its citizens. To attain these aims, which will be considered in more detail below, the State government also has responsibility for assistance with funding the studies and mitigation measures.

11.1.3 Step (iv) – flood management plans

New developments

Once the selection of the designated flood has been made, the next step is to consider the regulations that apply to new developments. These will be based on land use zoning and building controls within the area delimited by the designated flood. They may vary from no new construction whatsoever, to controls on habitable flood levels with the possibility of different controls for different uses, eg. restricted residential but allowable commercial and industrial development. Again much will depend on the local flood hydrology. At this stage the possibility of building failure due to extreme floods may require the definition of sub-zones for land use and building controls. For example, especially vulnerable uses (hospitals, emergency service facilities, homes for the elderly etc) may require additional limitations on siting. It is also import to consider the location of flood free evacuation routes and available flood warning times. Locations that could become 'islands' at times of flooding need special attention.

Residual flood risk

A major problem for the formulation of flood policy for urban areas is that there are usually existing flood prone developments, often extensive, located below the level of the designated flood. Such development frequently forms the major barrier to policy formulation. The problems are several. First, whether or not to provide mitigation measures and secondly, to agree policy for future re-development of existing buildings. Stakeholders representing existing flood prone developments will normally press for structural solutions to reduce their flood risk. Such measures are often expensive and beyond the ability of the LGA to fund and rarely produce a complete solution, i.e. most structural measures retain a residual flood risk. For some locations the upgrading of flood warning systems provides a partial response. The problem is that those at risk are reluctant to pay for the reduction of their risk, those with no risk feel equally strongly that they should not be required to contribute to the costs.

Clearly, there is no easy solution to this problem. It can be said however, that local community debate aided by clear and accessible information on the costs and benefits should be encouraged prior to a decision.

Residual risk

This is of major concern to the emergency services and is an aspect of flood management that is often ignored or poorly handled. First, it is essential that the community is aware that any designated flood (apart from the probable maximum flood!) leaves a residual risk of flooding. Second, that any structural mitigation measure carries with it the risk of exceedance of the design criteria (often the designated flood) or of structural failure. It should be recognised that any structural solution needs to be accompanied by a corresponding emergency plan and that the costs of the emergency measures should be included in the overall costs and benefits.

If the flood study data are incorporated into a GIS, this offers an excellent way of demonstrating the extent and costs of the residual flood problem. A key to the reduction of the effects of residual risk is the availability, or installation, of a flood warning system which should incorporate a well formulated program for community awareness and response.

A simple and inexpensive method to improve awareness and response is the installation a series of flood markers throughout the flood prone areas. These should show the level of the flood of record and also repeat the heights given on the town's flood gauge. This is critical to give meaning to flood forecasts for the residents of the flood prone area. However, in Queensland and elsewhere such simple methods are rarely implemented because of concern of the possible adverse effect on property values. Such flood markers should be obligatory in local and State policy.

11.1.4 Step (v) – implementing a local flood policy

The final step is to implement the local flood policy and to incorporate the designated flood, land use zoning and building controls into the local planning scheme. It would appear from the questionnaire, and in Smith et al (1996), that State planning legislation to allow for effective local planning is confused. If this is the case, and discussions with many Queensland officials confirm that it is, it is necessary to clarify, and perhaps change, the situation. Without such clarification, the implementation of best practice management at LGA level will be jeopardised.

11.2 Background to hazard policy

It can be argued that relationships between national, state and local governments for hazards differ in style to those of other inter-governmental interactions. The higher tiers of government tend to place a greater emphasis on matters of safety and are concerned to establish best practice procedures for hazard management at local level. To this end they are willing, to a degree, to provide assistance to achieve these aims. Such assistance is usually tied to the lowest tier, local government, adopting planning measures to reduce the risk. In addition to assistance for mitigation and funding emergency procedures, higher tiers of government assist with relief aid in the aftermath of a disaster.

The perception from local government is somewhat different. Frequently local government, which is directly responsible to the local community, perceive attempts to impose planning controls from above as unwarranted interference that is counter to local development. The community, all too often, regard the occurrence of a damaging disaster to be that of a very low risk which can be ignored. When the rare event occurs there are commonly two responses:

- requests for assistance to recover from the event;
- the search for a scapegoat, for example the council '... gave us permission to built here without telling us it was hazard prone'.

This outline of the problems of hazard management and governance is not unique to flooding, to Queensland or to Australia but is common among developed nations regardless of hazard. It is for example, a major on-going problem for planning and building regulations for earthquake risk in the USA. A detailed recent account of the problem, using flood hazard as an example, is available in *Environmental Management and Governance-Inter-governmental Approaches to Hazards and Sustainability*, (May *et al.*, 1996). This presents international comparisons between New Zealand, New South Wales and the USA.

11.2.1 Policy responses

The study by May *et al.* (1996) describes the public policy options available to governments for hazard management as a representing a spectrum from coercive to cooperative approaches.

Coercive policies, as used in for example Florida, are at one extreme and marked by the State government setting rigid rules and timetables to which local governments must comply. Local flood plans, follow a pattern determined by the State, and are required to be submitted by a set date. Non-compliance results in severe fines and reductions in State contributions to a range of services. It needs to be added that there is State assistance for the production of such plans and the possibility of assistance with funds for any subsequent approved mitigation measure.

At the other extreme, a co-operative approach, the State provides flood planning guidelines but leaves local government to decide on local policy within a broad framework. Again funding from the State is required for success.

11.2.2 Lessons from New South Wales

New South Wales was used in May *et al.* (1996) as a detailed case study and a lengthy questionnaire was completed by some 100 LGAs to provide background data. Prior to the mid-1980s New South Wales government had, for some ten years, followed a flood policy that had many elements of a coercive approach. LGAs were required to use the 1 in 100 year event as the designated flood, if they did not they were legally liable for any flood damages suffered by those to whom they gave planning approval. This policy was accompanied by the production, by State agencies, of some 70 high quality flood maps for many of the flood prone urban communities. In 1984 community concern over provisional flood maps on display for public comment for Fairfield (an inner Sydney council) at the time of a State election resulted in a major shift in policy. This event acted as a focus for widespread dissatisfaction with the coercive policy by councils statewide. In 1985 the draft of the New

South Wales flood manual was released (NSW PWD, 1986) and a new 'merits based' policy introduced.

The 'merits based' policy can be regarded as representing a cooperative approach, it has remained in force ever since. LGAs were encouraged to establish community floodplain committees to oversee the steps outlined in the preceding section of this report. Overall, the policy has met with favour from LGAs and a large number of flood prone communities have now progressed to the stage where their decisions are formalised into local planning schemes. Interestingly, virtually every LGA selected the 1 in 100 year as the designated flood, a decision that they violently opposed under a coercive policy. This is in spite of advice from State agencies to consider alternative definitions.

A unique feature of the New South Wales approach is that if LGAs follow the guidelines given in the flood manual that the council and its staff are exempted, in legislation, from future action over duty of care for flooding decisions. This was welcomed by LGAs and undoubtedly played a major role in the favourable response of LGAs to the post-1985 cooperative policy.

It is again necessary to state very clearly that the New South Wales government has been prepared, over many years, to make available financial and technical assistance to flood prone LGAs. In the early 1990s the State contribution was of the order of $10 m annually, matched by a similar sum from the Commonwealth, LGAs in general contributed 20% of the costs. This applied to funding for flood studies and to the cost of structural measures, all of the latter were required to show a favourable cost benefit ratio based on rigorous analysis of the damage costs which were available from the flood studies. Assistance from the State government has also included analysis of flood hydrology and other technical advice on a range of flood related issues. To these ends permanent, well-staffed, well-qualified and resourced units devoted to flood management have been maintained at State level for well over twenty years.

Overall, the cooperative flood policy followed in New South Wales can be counted as a success. Precise data are not available but the rate of increase of developments in flood prone areas is very small and the potential for damage to existing flood prone developments has been reduced. The only problem with a fully cooperative approach is that LGAs, if they so wish, need not participate. Such a decision however, means that funding for mitigation measures is not available and they still face possible liability under duty of care.

11.2.3 Commonwealth assistance

For many years the Commonwealth provided assistance on a 40:40:20 basis (Commonwealth, State, local) funding basis for approved schemes for flood studies and mitigation. This was originally part of the Federal Water Resources Assistance Program (FWRAP) and, later, the flood component was administered by the National Landcare Program. Queensland did not participate, in any major way, in this process as the State lacked information on which to promote claims for assistance.

The Commonwealth, in partnership with the States, separately contributes to flood relief under the long established Natural Disaster Relief Arrangements (NDRA). The assistance is mainly to LGAs to repair infrastructure losses (mainly related to the transport network) and for assistance with personal hardship and distress. Relief of this kind was not linked to programs to improve floodplain management and to reduce flood losses. In mid-1996 the Commonwealth indicated that in future the provision of NDRA relief payments (except for personal hardship) would require evidence of policies and management to reduce future loses.

It is important to note that, over recent years, the contributions of the Commonwealth to the NDRA, relative to those of the States, have been progressively reduced. Thus, it is surprising that State Treasuries have not also pressed for planning to reduce future losses and thereby, State flood relief payments. Without the wider adoption of urban floodplain management in Queensland such payments will continue to escalate and as mitigation measures are usually founded in favourable cost benefit ratios it would be in the State's interest to take such steps to lessen future outlays on flood relief.

11.3 The Queensland Government and LGA floodplain management

In the Australian context the adoption of fully coercive policies, as described from the USA, are not considered as a viable strategy. A cooperative model, similar to that employed in New South Wales for over ten years, offers an alternative. However, for this to be successful it would be necessary for the State government to contribute both in terms of direct funding and with technical advice. Unfortunately changes in Commonwealth funding for assistance with studies and mitigation have declined and it can be expected that this trend will continue.

The expenditures in New South Wales have been large, however much of the outlay was for structural measures to protect existing flood prone developments. This was important to the stick and carrot approach which required the adoption of, and compliance to, land use controls consistent with the choice of a suitable designated flood and thereby, for indemnity from duty of care. The carrot was often in the form of structural mitigation for existing flood prone developments. It could be that the Queensland government could achieve these aims but lessen the expenditure by restricting the use of structural measures.

The need in Queensland is for a cooperative, locally based approach but combined with technical advice, the input of funding (especially for assistance with flood studies), and a limited degree of coercion from State government.

11.3.1 Technical assistance

A major contribution would be for State agencies to produce and publish a Queensland-based manual to acceptable flood management practice. This could include information that is not presented in detail in the New South Wales equivalent. For example, appendices that deal with building methods and flood materials compatible with developments in flood prone locations. Another example, would be guidance to flood proofing, especially that concerned with house raising and for commercial premises. Flood proofing has the advantage that it can be undertaken by individual building owners and a subsidy contribution towards such mitigation may be considered appropriate. Assistance with the analysis of hydrological and rainfall records and rainfall/runoff modelling methods would also be helpful to many LGAs. Queensland has a good exemplar with the Queensland urban drainage manual (QDPI, 1992). Such a manual and appendices could usefully incorporate examples of mitigation measures already used by some LGAs within the State.

The recommendation is to produce a Queensland-based manual for use by local government to give guidance on all aspects of best practice floodplain management. Such a manual should also give guidance to the planning legislation in order that local floodplain management could be fully integrated into the State's overall planning policy.

11.3.2 Funding

The allocation of funding is clearly a decision for the State government but without improved funding the costs to governments, at all levels, and to individual citizens of permitting developments in flood prone locations will continue to escalate. The linking of flood relief to the adoption of acceptable floodplain management, as prompted by the Commonwealth, should be reinforced at State level.

It is unrealistic, whatever policy stance is adopted, to expect that the total costs of flood studies and mitigation, essential to attain best practice floodplain management, can be borne by LGAs alone.

11.3.3 Duty of care

It is not the aim of this study to persecute LGAs for not pursing acceptable floodplain management, but there remains the legal responsibilities under duty of care. It is thought that such concern has played a major part on prompting a number of LGAs in Queensland to adopt good quality urban floodplain management. The problem is why this does not apply to others?

It is likely that a clear statement on the legal liability for decisions to allow building in flood prone areas would lead to improved floodplain management. Indemnity for such liability for LGAs following acceptable procedures, is a strategy that has much to commend it.

There is little doubt that a local policy that gives as a defence for no action, 'we had no information on liability to flooding' is not acceptable either morally or legally.

11.4 Summary

Urban floodplain management in Queensland is below the standard that could be expected for the State with the largest urban flood problem in Australia. Improvements will require financial and resource outlays by both State and local governments although the benefits of these to the avoidance of losses from poorly sited future developments would outweigh the costs in the medium to long term. State assistance will certainly be necessary for those LGAs with small populations and rate base. The wider use of differential rating by LGAs, although unpopular, could lead to those who benefit from mitigation contributing to the costs.

It is to be hoped that improvements to floodplain management, and to related planning for storm surge, are not delayed so that action is only taken after the occurrence of a major disaster with extensive damage and loss of life. It is the responsibility of governments at all levels to ensure that this does not happen.

References

AEMI (1995) *Flood warning in Australia: an Australian guide.* Mt Macedon: Australian Institute of Emergency Management.

AWRC (1992) *Floodplain management in Australia.* Australian Water Resources Council, Water Management Series 21(2). Main Report. Canberra: Australian Government Publishing Service.

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

BM (1992) *Logan and Albert Rivers flood warning system.* Brisbane: Bureau of Meteorology.

Camp, Scott and Furphy Pty Ltd (1992) *Rockhampton flood management study.* Consultant's report to Water Resources Commission, Queensland.

Carroll, D.G. (1991) *Flood warning and monitoring in the Brisbane City area using event-based radio telemetry systems.* M.Eng.Sci. Thesis, Queensland University of Technology.

Carroll, D.G. (1993) PROPHET – The Brisbane City Council creek flood monitoring and forecasting system. *Proceedings of the 7th National Local Government Engineering Conference, Adelaide 30 August-3 September 1993.* Canberra: Institute of Engineers Australia.

Chamberlain *et al* (1981) *Queensland flood report Australia Day 1974.* Canberra: Australian Government Publishing Service.

CRCE Water Studies (1986) *A revised system of floodplain management for Brisbane.* Prepared for the Brisbane City Council.

Devin, L.B. and Purcell, D.L. (1983) *Flooding in Australia. Water 2000 Consultant's report No.11.* Australian Department of Resources and Energy. Canberra: Australian Government Publishing Service.

FEMA (1986) *Coastal construction manual (FEMA - 55).* Washington D.C.: Federal Emergency Management Agency.

Granger, K.J. and Smith, D.I. (1995) Storm tide impact and consequence modelling: some preliminary observations. In: McAteer, M. and Jakeman, A. (eds.) *International Conference on Modelling and Simulation.* Perth: University of Western Australia. Vol.2: 535-541.

Hopley, D. and Harvey, N. (1979) Regional variations in storm surge characteristics around the Australian coast. In: Heathcoate, R.L. and Thom, B.G. (eds.) *Natural Hazards in Australia.* Canberra: Australian Academy of Science. 107-112.

May, P.J., Burby, R.J., Eriksen, N.J., Handmer, J.W., Dixon, J.E., Michaels, S. and smith, D.I. (1996) *Environmental management and governance: inter-governmental approaches to hazards and susceptibility.* London: Routledge.

NSW (1986) *Floodplain development manual.* PWD Report No. 86010. Sydney: Public Works Department.

Parker, D.J., Green, C.H. and Thompson, P.M. (1986) *Urban flood protection benefits: a project appraisal guide.* Aldershot: Gower.

Penning-Rowsell, E.C. and Chatterton, J.B. (1977) *The benefits of flood alleviation: a manual of assessment techniques*. Saxon House: Farnborough.

Penning-Rowsell, E.C. and Smith, D.I. (1987) Self-help flood hazard mitigation: the economics of house-raising in Lismore, New South Wales, Australia. *Journal of Economic and Social Geography* 78(3): 176-189.

QDPI (1992) *Queensland urban flood drainage manual volume 1 – text*. Prepared for Water Resources Commission Department of Primary Industries, The Local Government Engineers' Association of Queensland and Brisbane City Council by Neville Jones and Associates Pty Ltd and Australian Water Engineering.

SCDO (1992) *Storm tide: warning-response system*. Brisbane: State-Counter Disaster Organisation and Bureau of Meteorology.

SMEC (1975) *Brisbane River flood investigation – final report*. Report by Snowy Mountains Engineering Authority for Cities Commission. Canberra: Australian Government Publishing Service.

Smith, D.I. (1996) *National and State residential flood damages for Australia*. Unpublished report for the Insurance Council of Australia.

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: an assessment of tangible and intangible damages*. Canberra: Centre for Resource and Environmental Studies, Australian National University.

Appendix 1

Responses to the Questionnaire

A spreadsheet comprising the replies to all questions for all localities was prepared. A copy of this, together with the original returned questionnaire forms, is held by the Department of Natural Resources in Brisbane.

Appendix 1 is a modified version of the full spreadsheet. Information on contact names etc. has been omitted and manuscript comments have also been removed.

For some questions the number of replies may not tally exactly with those given in the text, this often reflects the extra information given in manuscript form.

All questionnaire returns are listed in this appendix, i.e., including those that did not have an urban flood problem as defined in the study. The latter are listed separately at the end of the alphabetical LGA listing of those judged to meet the definition.

APPENDIX 1

Local Government	Town/Community	Drainage	Coastal	2-1	2-2	2-3	2-4	2-5	2-6	2-7	3-1	3-2	3-3
Aramac Shire	Aramac	Inland	no	Aramac Ck	320		100	10	5	2	no	April 1990	
Aurukun Shire	Urukun	Gulf	yes	Archer River	1 000	+2%	100	4	0	0	no		
Balonne Shire	Bollon	Inland	no	Wallam Creek	158	0	15	7			no		
Balonne Shire	Dirrabandi	Inland	no	Condamine/Balonne	460	0	168	15	5		no		
Balonne Shire	Hebel	Inland	no	Condamine/Balonne		0	56	23	1		no		
Balonne Shire	St George	Inland	no	Condamine/Balonne	2 509	+10%	848	187	20		no		
Balonne Shire	Thallon	Inland	no	Moonie River	159	0	41	17			no		
Banana Shire	Baralaba	Inland	no	Fitzroy (Dawson R.)	269	+0.3%	200	yes	yes	yes	no		
Banana Shire	Biloela	Inland	no	Fitzroy (Callide Cr.)	5 500	+0.32%	1800	yes	yes	yes	no		
Banana Shire	Moura	Inland	no	Fitzroy (Dawson R.)	2 800	+0.3%	900	yes	yes	yes	no		
Banana Shire	Theodore	Inland	no	Fitzroy (Dawson R.)	500	+0.3%	307	yes		yes	no		
Barcaldine Shire	Barcaldine	Inland	no	Alice River	1 500		650	50	5	5	no		
Barcoo Shire	Jundah	Inland	no	Thomson River	100	0	38	8	2	2	no		
Barcoo Shire	Stonehenge	Inland	no	Thomson River	35	0	10	1	1	1	no		
Barcoo Shire	Windorah	Inland	no	Cooper Creek	85	0	34	6	-	-	no		
Beaudesert Shire	Northern area of shire	Pacific	no	Logan River	11 417	+8.4%	5620	25	35	1	no		
Biggenden Shire	Biggenden	Pacific	no	Burnett	800	+0.5%	400	40	10	10	no		
Blackall Shire	Blackall	Inland	no	Barcoo River	1 600	0	524	46		10	no		
Boonah Shire	Boonah	Pacific	no	Teviot Brook	2 300	+0.5%	840	70	3	40	no	1991	no
Booringa Shire	Mitchell	Inland	no	Murray/Darling	1 200	0	450	46	8	0	no		
Bowen Shire	Bowen/ Queens Beach	Pacific	yes	Don River	8000	+1-2%	2500	200	60	654	yes	1980	yes
Brisbane City	Main Brisbane River	Pacific	yes	Brisbane River	750 000	+1%	42,500			2 500	yes	May 1996	no
Bulloo Shire	Thargomindah	Inland	no	Bulloo River	230	0	80	5	4	10	yes		no
Bundaberg City	Bundaberg	Pacific	no	Burnett	45 000	+2%	15,000				no		
Burnett Shire	Burnett Heads/ Bundaberg Port	Pacific	yes	Burnett	1 500	+3%	500	15	10	50	yes	1942	yes
Caboolture Shire	Beachmere	Pacific	yes	Pumicestone Passage	2 800	+6%	1200	4	0	10	yes		yes
Caboolture Shire	Bellara	Pacific	yes	Pumicestone Passage		+5%	1 560	25	-	96	yes	nil	
Caboolture Shire	Burpengary	Pacific	no	Burpengary Creek	6 000	+5%	2000	40	10	-	no		
Caboolture Shire	Caboolture	Pacific	no	Lagoon Creek, Cabooture River	8 050	+5%	5 000	15	110	113	no		
Caboolture Shire	Deception Bay	Pacific	yes	Deception Bay	13 200	+6%	4 800	27	18	158	yes		yes
Caboolture Shire	Donnybrook	Pacific	yes	Pumicestone Passage	350	+6%	240	7	-	30	yes		no
Caboolture Shire	Toorbul	Pacific	yes	Pumicestone Passage	580	+4%	350	3		39	yes		yes
Caboolture Shire	Woodford	Pacific	no	Stanley River	1 750	+5%	450	35	3	nil	no		

APPENDIX 1

Local Government	Town/Community	4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8
Aramac Shire	Aramac	April 1990		2 days	7				c
Aurukun Shire	Urukun								c
Balonne Shire	Bollon	1950							c
Balonne Shire	Dirrabandi	1990		3 weeks	0	0	0		c
Balonne Shire	Hebel	1990			0	0	0	0	c
Balonne Shire	St George	1990		2 days	5	0	0	0	c
Balonne Shire	Thallon	1976		1 week					c
Banana Shire	Baralaba	1956							b
Banana Shire	Biloela	1942							b
Banana Shire	Moura								
Banana Shire	Theodore	1956							
Barcaldine Shire	Barcaldine	1990		7 days	4	20	-	-	c
Barcoo Shire	Jundah	01/06/1955			1	1	-	-	c
Barcoo Shire	Stonehenge	31/01/1974			0	0	0	0	b
Barcoo Shire	Windorah	02/02/1974							c
Beaudesert Shire	Northern area of shire	27/28 Jan 1974	4 000	4 days	38	4	-	-	c
Biggenden Shire	Biggenden	1956		24 hours	8	0	0	0	c
Blackall Shire	Blackall	20 April, 1990	1 650	4 days	30	13	2	-	c
Boonah Shire	Boonah	1991		12 hrs	5	2	-	-	b
Booringa Shire	Mitchell	1990		12 hours	8	3	0	0	b
Bowen Shire	Bowen/ Queens Beach	1946	7 700	6 hrs		0		-	c
Brisbane City	Main Brisbane River	Jan 1974	9 000 m3/s	4 days	9 746	1 084	1 627	428	b
Bulloo Shire	Thargomindah	Jan-Feb 1974	-	37 days	25	2	1	10	c
Bundaberg City	Bundaberg	1942							b
Burnett Shire	Burnett Heads/ Bundaberg Port	1890							b
Caboolture Shire	Beachmere	19-1-75	-	2 hrs			-	-	c
Caboolture Shire	Bellara	19-1-75	-	2 hours	0	-	-	-	b
Caboolture Shire	Burpengary	12-2-72	500	12 hrs	40	0	0	0	b
Caboolture Shire	Caboolture	12-2-72	1 279	12 hours	2	0	0	20	b
Caboolture Shire	Deception Bay	19-1-75	-	2 hrs	2	-	-	-	b
Caboolture Shire	Donnybrook	12-2-72	-	2 hours	0	0	0	0	a
Caboolture Shire	Toorbul	19-1-75	-	2 hrs	20	2	-	-	c
Caboolture Shire	Woodford	12-2-72		2 days	0	0	0	0	b

Local Government	Town/Community	4-9	4-10	4-11	4-12	4-13	4-14	4-15	5-1	5-2
Aramac Shire	Aramac	d	a	a	b	a		2 days	yes	
Aurukun Shire	Urukun	d	a	a	a	a			no	no one cared to document
Balonne Shire	Bollon	d	a		a	a				
Balonne Shire	Dirrabandi	c	a	a	a	a		4 weeks	yes	
Balonne Shire	Hebel	d	c	a		a		4 weeks	yes	
Balonne Shire	St George	d	a	a	a	a		3 weeks	yes	
Balonne Shire	Thallon	c	c	a		a		2 weeks		
Banana Shire	Baralaba		a						yes	
Banana Shire	Biloela								no	expected water resources commission to keep data
Banana Shire	Moura								yes	
Banana Shire	Theodore		a						yes	
Barcaldine Shire	Barcaldine	c	a	a	b	a		2 days	yes	
Barcoo Shire	Jundah	d	b	b	b	a		72	no	
Barcoo Shire	Stonehenge	d	a	b	a	a			no	
Barcoo Shire	Windorah	d	a	b	a	b			no	
Beaudesert Shire	Northern area of shire	d	c	a	a	b		1-2 days	yes	
Biggenden Shire	Biggenden	c	c	b	-	a		12 hours	no	uncommon event
Blackall Shire	Blackall	c	b	a	b	b	Ambulance centre & fire station innundated	72	yes	
Boonah Shire	Boonah	d	c	a	b	a		6hrs	no	
Booringa Shire	Mitchell	b	a	a	b	b		4 hours	no	no-one bothered to record it
Bowen Shire	Bowen/ Queens Beach	c	b	b	a	b		12 hrs	yes	
Brisbane City	Main Brisbane River	a	a	b	b	b		48 hours	yes	
Bulloo Shire	Thargomindah	d	a	a	b	b			yes	
Bundaberg City	Bundaberg	b	a		b				yes	
Burnett Shire	Burnett Heads/ Bundaberg Port	d	c	a					yes	
Caboolture Shire	Beachmere	d	c	a	a	a		18 hours	yes	
Caboolture Shire	Bellara	d	c	a	a	a			yes	
Caboolture Shire	Burpengary	a	c	a	a	a		6 hours	yes	
Caboolture Shire	Caboolture	a	a	a	a	a		12 hours	yes	
Caboolture Shire	Deception Bay	d	c	a		a			yes	
Caboolture Shire	Donnybrook	d	c	a		a			yes	
Caboolture Shire	Toorbul	d	c	a		a			yes	
Caboolture Shire	Woodford	d	c	a	a	a		12 hours	yes	

Local Government	Town/Community	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
Aramac Shire	Aramac		yes		0 m	2.0 m		19-4-97	no	a
Aurukun Shire	Urukun		no						no	a
Balonne Shire	Bollon		yes						no	
Balonne Shire	Dirrabandi	DNR	yes							
Balonne Shire	Hebel		no							
Balonne Shire	St George	reference	yes		-	-	-	-	no	a
Balonne Shire	Thallon		yes							
Banana Shire	Baralaba	town planning	yes						no	interviews
Banana Shire	Biloela		no						no	interviews
Banana Shire	Moura		yes							
Banana Shire	Theodore	town planning	yes						yes	b,d
Barcaldine Shire	Barcaldine	disaster plan	no						yes	b
Barcoo Shire	Jundah		yes	46 years	0 m	3.0 m	8.46 m	1/6/1955	no	a
Barcoo Shire	Stonehenge		yes	26 years	0.0 m	2.0 m	6.88 m	31/1/1974	no	
Barcoo Shire	Windorah		no						no	a
Beaudesert Shire	Northern area of shire	subdivision & building applications, strategic plan	yes						no	b,c
Biggenden Shire	Biggenden		no						no	a
Blackall Shire	Blackall	Flood prediction and monitoring, flood mitigation	yes				7.30 m	20/4/90	yes	b
Boonah Shire	Boonah		yes						no	a
Booringa Shire	Mitchell		yes		0 m	8.28 m	8.28 m	1990	no	a
Bowen Shire	Bowen/ Queens Beach	planning, flood warnings and predictions	yes	40	0 m	5.5 m	-	-	yes	b
Brisbane City	Main Brisbane River	calibration of flood models, setting min. development levels.	yes	156 years	-0.9 m	5 m (lower other locations)	5.44 m	Feb.1893	yes	b,c
Bulloo Shire	Thargomindah		yes	30 years	2 m	3.94 m	6.78 m	9-1-1974	yes	b
Bundaberg City	Bundaberg		yes						yes	c
Burnett Shire	Burnett Heads/ Bundaberg Port	predicting flood profiles							no	
Caboolture Shire	Beachmere	flood studies	no						yes	c
Caboolture Shire	Bellara	inundation maps	no						no	
Caboolture Shire	Burpengary	flood studies	no						yes	c
Caboolture Shire	Caboolture	flood studies and mapping	no						yes	c
Caboolture Shire	Deception Bay	not used	no						no	
Caboolture Shire	Donnybrook	not used	no						no	
Caboolture Shire	Toorbul	not used	no						no	
Caboolture Shire	Woodford	inundation maps	no						yes	b

Flood Properties

APPENDIX 1

Local Government	Town/Community	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8	6-9	6-10	6-11	6-12	6-13
Aramac Shire	Aramac	no		no	no									
Aurukun Shire	Urukun	no												
Balonne Shire	Bollon	no												
Balonne Shire	Dirrabandi													
Balonne Shire	Hebel	DNR												
Balonne Shire	St George	yes (DNR)		yes		none								
Balonne Shire	Thallon	DNR												
Banana Shire	Baralaba	no												
Banana Shire	Biloela	no		no	no									
Banana Shire	Moura	no												
Banana Shire	Theodore	no												
Barcaldine Shire	Barcaldine	no												
Barcoo Shire	Jundah	no												
Barcoo Shire	Stonehenge	no												
Barcoo Shire	Windorah	no												
Beaudesert Shire	Northern area of shire	yes	1974 flooding	no	no	1 in 50, 100, highest known	no		38	4	-	-	no	no
Biggenden Shire	Biggenden	no												
Blackall Shire	Blackall	yes	max. flood event	no	yes								no	yes
Boonah Shire	Boonah	no												
Booringa Shire	Mitchell	no												
Bowen Shire	Bowen/ Queens Beach	yes	1 in 50 and 100	yes	yes	1 in 50	yes	b	940	15	6	100	no	yes
Brisbane City	Main Brisbane River	yes	1 in 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 10 000, 100 000, and PMF	yes	no	1 in 100	no	b,c	4 420	648	773	186	yes	yes
Bulloo Shire	Thargomindah													
Bundaberg City	Bundaberg	no		yes	no	none							no	no
Burnett Shire	Burnett Heads/ Bundaberg Port	no												
Caboolture Shire	Beachmere	yes	1 in 10, 50, 100	no	no	1 in 100	yes	c	95	0	0	0	no	yes
Caboolture Shire	Bellara	yes: tidal prediction	1 in 100	no	no	1 in 100	no		25	-	-	-	no	yes
Caboolture Shire	Burpengary	yes	1 in 10, 50, 100	no	no	1 in 100	yes	c	130	5	0	10	no	no
Caboolture Shire	Caboolture	yes	1 in 10, 50, 100	no	no	1 in 100	yes	c	10	1	2	30	no	yes
Caboolture Shire	Deception Bay	yes: tidal prediction	1 in 100: tide event	no	no	1 in 100	yes	c	30	-	-	-	no	yes
Caboolture Shire	Donnybrook	yes	1 in 100	no	no	1 in 100	yes	c	15	-	-	-	no	yes
Caboolture Shire	Toorbul	yes: tidal prediction	1 in 100	no	no	1 in 100	yes	c	80	2	-	-	no	yes
Caboolture Shire	Woodford	yes	1 in 100	no	no	1 in 100	yes	b	20	0	0	0	no	yes

Local Government	Town/Community	7-1	7-2	7-3	7-4	7-5	7-6	7-7	8-1
Aramac Shire	Aramac	no							none
Aurukun Shire	Urukun	no							none
Balonne Shire	Bollon	no	0						none
Balonne Shire	Dirrabandi	no							a
Balonne Shire	Hebel	no							none
Balonne Shire	St George	no							none
Balonne Shire	Thallon	no							none
Banana Shire	Baralaba	no							
Banana Shire	Biloela	no							
Banana Shire	Moura								
Banana Shire	Theodore	no							
Barcaldine Shire	Barcaldine	yes	a	yes		0.2 m	on application to council	a, council policy	improved drainage in town
Barcoo Shire	Jundah								
Barcoo Shire	Stonehenge	no							
Barcoo Shire	Windorah	no							
Beaudesert Shire	Northern area of shire	yes	a,b	yes		0 - 1.0 m	c	a,b	
Biggenden Shire	Biggenden	no							
Blackall Shire	Blackall								vegetation clearing
Boonah Shire	Boonah	yes	a	yes		500 mm	a	a	none
Booringa Shire	Mitchell	yes	planned data	yes			a		diversion drains
Bowen Shire	Bowen/ Queens Beach	yes	a,b	yes			c	a,b	d
Brisbane City	Main Brisbane River	yes	a, b	yes		res: 525 mm. com./ind: 0 or more	b,c	a,b	a,b,c
Bulloo Shire	Thargomindah	yes		yes			a	a	
Bundaberg City	Bundaberg	no							a
Burnett Shire	Burnett Heads/ Bundaberg Port	no							
Caboolture Shire	Beachmere	yes	b	no		0.1 m	c	a,b	none
Caboolture Shire	Bellara	yes	b	no		0.1	c	a,b	none
Caboolture Shire	Burpengary	yes	b	no		0.01 m	b,c	a,b	none
Caboolture Shire	Caboolture	yes	b	no		0.1 m	c	a,b	none
Caboolture Shire	Deception Bay	yes	b	no		res: 0.3 m. other: 0.1m	c	a,b	none
Caboolture Shire	Donnybrook	yes	b	no		res: 0.3 m, com: 0.0 m	c	a,b	none
Caboolture Shire	Toorbul	yes	b	no		res: 0.3 m	c	a,b	none
Caboolture Shire	Woodford	yes	b	no		0.1 m	c	a,b	none

APPENDIX 1

Local Government	Town/Community	8-2	8-3	8-4	9-1	9-2	9-3	9-4	9-5	9-6	9-7
Aramac Shire	Aramac				yes	yes	yes	no	no	2-3-97	3.1 m
Aurukun Shire	Urukun	a	none	none	yes	yes	no	no	no		
Balonne Shire	Bollon				yes	yes	no		yes	1990	
Balonne Shire	Dirrabandi	c			yes	yes	no		yes		
Balonne Shire	Hebel				yes	yes	no		yes		
Balonne Shire	St George				yes	yes	no	no	yes	1990	-
Balonne Shire	Thallon	none			yes	yes	no		yes	1976	
Banana Shire	Baralaba	a			yes	yes	yes	yes	yes		
Banana Shire	Biloela	a	c		yes	yes	no	no	yes		
Banana Shire	Moura										
Banana Shire	Theodore	a,b,c			yes	yes	yes	yes	yes		
Barcaldine Shire	Barcaldine	b	none	b		yes	no	no	yes	1990	
Barcoo Shire	Jundah				yes	yes	no	no	yes	20/2/97	4.8 m
Barcoo Shire	Stonehenge				yes	yes	no	no	yes	20/02/97	
Barcoo Shire	Windorah				no	no	yes	no	no		
Beaudesert Shire	Northern area of shire	a,b,c			yes	yes	no	no	no	7-10 Feb 1991	
Biggenden Shire	Biggenden	a			no	yes	no	no	yes	1956	-
Blackall Shire	Blackall	a,b,c	b	b,c	yes	yes	yes	no	yes	1997	6.2 m
Boonah Shire	Boonah	a,b,c	c		yes	yes	no	no	no	1991	
Booringa Shire	Mitchell	c		b	yes	yes	yes	no	yes	1990	8.28 m
Bowen Shire	Bowen/ Queens Beach	a,b,c	b,c	b,c	yes	yes	no	no	no	1991	
Brisbane City	Main Brisbane River	a,b,c	b,c	a,b,c	yes	yes	no	yes	no	May 1996	2.75 m
Bulloo Shire	Thargomindah	c			yes	yes	no	no	yes	12-2-97	5.17 m
Bundaberg City	Bundaberg	a,b			yes	yes	no	no		1974	
Burnett Shire	Burnett Heads/ Bundaberg Port	a,b			yes	yes	no	no	no	1942	
Caboolture Shire	Beachmere	none	c	none	yes	yes	no	no	no		1.60 m
Caboolture Shire	Bellara	none	c	none	yes	yes	no	no	no		
Caboolture Shire	Burpengary	none	c	none	yes	yes	no	no	yes	1991	
Caboolture Shire	Caboolture	none	c	none	yes	yes	no	no	no	1991	-
Caboolture Shire	Deception Bay	none	c	none	yes	yes	no	no	no		1.60 m
Caboolture Shire	Donnybrook	none	c	none	yes	yes	no	no	no		
Caboolture Shire	Toorbul	none	c	none	yes	yes	no	no	no		1.60 m
Caboolture Shire	Woodford	none	c	none	yes	yes	no	no	no		

Local Government	Town/Community	9-8	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4	11-6
Aramac Shire	Aramac		a		no		yes	no	no	yes	yes
Aurukun Shire	Urukun		a	a	no		no				
Balonne Shire	Bollon		c	b	yes	b	yes	yes	yes	yes	no
Balonne Shire	Dirrabandi		c	b	yes	b	yes	no	yes	yes	no
Balonne Shire	Hebel		c	b	yes	b	yes	yes	yes	yes	no
Balonne Shire	St George	-	c	b	yes	b	yes	no	yes	yes	no
Balonne Shire	Thallon	1 in 10-15	c	b	yes	b	yes	yes	yes	yes	no
Banana Shire	Baralaba		c	b	no						
Banana Shire	Biloela		a		no		yes				
Banana Shire	Moura										
Banana Shire	Theodore		c	b	no						
Barcaldine Shire	Barcaldine		c	c	no		yes	yes	yes	yes	yes
Barcoo Shire	Jundah		b	b	no		yes	no	no	yes	yes
Barcoo Shire	Stonehenge		b	b	no		yes	no	yes	yes	yes
Barcoo Shire	Windorah		b	a	no		yes	no	no	yes	yes
Beaudesert Shire	Northern area of shire		b,c	c	no		yes	yes	yes	yes	yes
Biggenden Shire	Biggenden	-	a	a	no		yes				
Blackall Shire	Blackall		b,c	b,c	yes	a,b,c	yes	no	yes	yes	no
Boonah Shire	Boonah		c	a	yes	d	yes	yes	no	yes	no
Booringa Shire	Mitchell	1 in 100	b	c	yes	a,b,d, fire siren	yes	yes	no	no	no
Bowen Shire	Bowen/ Queens Beach	1 in 50	b	c	yes	b,d, telephone	yes	yes	yes	yes	yes
Brisbane City	Main Brisbane River	1 in 10	c	c	yes	b, telephone	yes	yes	no	yes	yes
Bulloo Shire	Thargomindah		b,c	b,c	yes	word of mouth	yes	yes	yes	yes	no
Bundaberg City	Bundaberg		c	c	no		yes	yes			
Burnett Shire	Burnett Heads/ Bundaberg Port	1 in 50	c	a	no		no				
Caboolture Shire	Beachmere	1 in 10	a	a	no		yes	no	no	no	yes
Caboolture Shire	Bellara		a	a	no		yes	no	yes	yes	yes
Caboolture Shire	Burpengary	<1 in 20	a	c, rainfall data	yes	b, telephone	yes	no	yes	yes	yes
Caboolture Shire	Caboolture	1 in 20	a	c, rainfall data (flood studies)	no		yes	no	yes	yes	yes
Caboolture Shire	Deception Bay	1 in 10	a	a	no		yes	no	no	no	yes
Caboolture Shire	Donnybrook		a	a	no		yes	no	no	yes	yes
Caboolture Shire	Toorbul	1 in 10	a	a	no		yes	no	no	no	yes
Caboolture Shire	Woodford		a	c, rainfall data (flood studies)	no		yes	no	yes	yes	yes

APPENDIX 1

Local Government	Town/Community	Drainage	Coastal	2-1	2-2	2-3	2-4	2-5	2-6	2-7	3-1	3-2	3-3
Cairns City	Cairns city	Pacific	yes	Cairns city area	70 000	+4%	20 000				yes		yes
Cairns City	Mulgrave	Pacific	yes	Barron	5 800	+3.5%	1610	12	20	80	yes	1979	yes
Calliope Shire	Tannum Sands, Boyne Island	Pacific	yes	Boyne River	7 500	+3%	2500	200	100	500	yes		yes
Caloundra City	Kawana Waters	Pacific	yes	Mooloolah							yes		yes
Cambooya Shire	Cambooya	Inland	no	Hodgson Ck, Condamine Ctchmt, Murray-Darling Basin	790	+2.5%	272	6	1		no		
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach	Pacific	yes								yes		yes
Carpentaria Shire	Kurumba	Gulf	yes	Norman /Flinders	500						yes	1976 major	no
Carpentaria Shire	Normanton	Gulf	no	Norman /Flinders	1 500						no		
Chinchilla Shire	Chinchilla	Inland	no	Condamine	3 500	+0.2%	1000	100	20	30	no		
Cook Shire	Ayton	Pacific	yes	Bloomfield	65	+2%	30	4	1	10	yes	March 1996	no
Cook Shire	Coen	Pacific	no	Coen	350	+7%	70	8	3	20	no		
Cook Shire	Cooktown (including Marton)	Pacific	yes	Endeavour	1 700	+5%	700	40	10	60	yes		yes
Cooloola Shire	Gympie	Pacific	yes	Mary	20 000	+1.5%					no		
Croydon Shire	Croydon	Gulf	no	Gilbert	300	+1%	60	5	-	15	no		
Dalby Town		Inland	no	Myall Creek	10 199	+1.08%	3 249	243	200	80	no		
Diamantina Shire	Birdsville	Inland	no	Diamantina	100	+5%	30	4	2	8	no		
Douglas Shire		Pacific	yes		9 867						yes		yes
Eacham Shire		Pacific	no	North Johnstone	1 200	+2.4%	450	33	20	30	no		
Emerald Shire	Emerald	Inland	no	Nogoa	10 500		2900	160	150	100	no	1950	no
Esk Shire		Pacific	no	Brisbane and Lockyer	7 000	+3%	2500	100	80	20	no		
Gatton Shire	Grantham	Pacific	no	Sandy Creek	200	< 2%	100	15			no		
Gayndah Shire	Gayndah	Pacific	no	Burnett	1 800	+0.5%	602	60	17	2	no		
Gladstone City	Gladstone	Pacific	yes	Auckland Creek	27 000	+2%	8, 500				yes		yes
Gold Coast City	Nerang	Pacific	yes	Nerang		+6.0%					yes	1974?	no
Goondiwindi Town	Goondiwindi	Inland	no	McIntyre	4 600	+1.5%	1200	200	100	3	no		
Herberton Shire	Herberton	Inland	no	Herbert	1 000	+2%	300	2	5	12	no		
Hervey Bay City	Pacific Haven	Pacific	yes	Burrum/Cherwell	150	+8%	80 est.	0	0	6-10	yes	20/21 Feb. 1992	no
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	Pacific	yes	Hervey Bay Foreshore	10-15 000	+8%	600	30-40	-	3-4 parks	yes	Cyclone Fran, 1992	yes
Hinchinbrook Shire	Ingham/Lower Herbert area	Pacific	yes	Herbert River	12 000	0	5 000	300	50	200	yes		no
Inglewood Shire	Inglewood town	Inland	no	Macintyre	1 000	-1%	348	40	6	2	no		

Local Government	Town/Community	4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8
Cairns City	Cairns city	Jan '79		1 day					c
Cairns City	Mulgrave	March 177	4 600 m3/s	3 days	125	0	4	40	c
Calliope Shire	Tannum Sands, Boyne Island	1947	8 200 m3			0	0	0	b
Caloundra City	Kawana Waters	3-2-1893	1 134						
Cambooya Shire	Cambooya	1988			0	0	0	0	c
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach	1967		1 week					b
Carpentaria Shire	Kurumba								
Carpentaria Shire	Normanton	1974		few days	20+	limited	-	limited	c
Chinchilla Shire	Chinchilla	1942			20	20	0	0	c
Cook Shire	Ayton	March 1996		2 days	15	1			c
Cook Shire	Coen	1989			10	2			c
Cook Shire	Cooktown (including Marton)	1982			15	4	6	-	c
Cooloola Shire	Gympie	1893							c
Croydon Shire	Croydon	1974/75			0	0	0	0	c
Dalby Town		7-2-1981	1 850	48 hours	700	90	50	10	c
Diamantina Shire	Birdsville	1974			0	0	0	0	c
Douglas Shire		1979		3 days	6	3	1	0	b
Eacham Shire		1967			12	0	2	20	c
Emerald Shire	Emerald	27 Nov 1950	4 430 m/s		20	3	2		c
Esk Shire		Jan 1974	2200m3/s (May 1996)	7 days	10	0	0	0	b
Gatton Shire	Grantham	Jan 1974		3 days	35	10			c
Gayndah Shire	Gayndah	Feb 1942		2 weeks					b
Gladstone City	Gladstone	.							a
Gold Coast City	Nerang	1974	1 730 cumecs	24 hrs		many buildings			b
Goondiwindi Town	Goondiwindi	26-1-1996		0	0	0	0	0	c
Herberton Shire	Herberton	1967		2 days	12	-	1	-	c
Hervey Bay City	Pacific Haven	1992		6 - 12 hrs	31	-	-	-	c
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	Believed to be Cyclone Daisy		12 - 14 hours					b
Hinchinbrook Shire	Ingham/Lower Herbert area	March 1967	12 000	1 week	2000	100	25	50	c
Inglewood Shire	Inglewood town	1956		2-3 days	300	35	4	2	c

Local Government	Town/Community	4-9	4-10	4-11	4-12	4-13	4-14	4-15	5-1	5-2
Cairns City	Cairns city	c	b	b	b			2 hrs	yes	
Cairns City	Mulgrave	c	b	b		b	Capactiy of emergency services was limited	30 hours	yes	
Calliope Shire	Tannum Sands, Boyne Island	d	c					24 hours	yes	
Caloundra City	Kawana Waters								yes	
Cambooya Shire	Cambooya	c	c	a					no	
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach	c	b	b	b	b			no	Information supplied by DNR
Carpentaria Shire	Kurumba									
Carpentaria Shire	Normanton	c	b	b			hospital isolated by floods	days	limited	
Chinchilla Shire	Chinchilla	c	b	a	a	a	roads cut		yes	
Cook Shire	Ayton	d	c	a	b	b		12 hours	no	
Cook Shire	Coen	d	b	b	b	a		24 hours	no	
Cook Shire	Cooktown (including Marton)	d	b	b	b	b		10 hours	no	
Cooloola Shire	Gympie	a	b	a	b	a		varies	yes	
Croydon Shire	Croydon	c	a	a			Surrounding properties flood bound. Town cut off by road and rail.		no	
Dalby Town		c	b	a	a	a		7 hours	yes	
Diamantina Shire	Birdsville	d	a	a	a	a			no	no recording
Douglas Shire		a	c	b	a	b		12 hrs	no	
Eacham Shire		d	c	b						
Emerald Shire	Emerald	b	b	a	a	a		200 hrs	yes	
Esk Shire		d	c	a	a	a		24 hrs	yes	
Gatton Shire	Grantham	a	c	b	c	a		12 hours	yes	
Gayndah Shire	Gayndah	b	c						yes	
Gladstone City	Gladstone	a	a	a	a	a			no	
Gold Coast City	Nerang	a	a	a	b	b	Ambulance, Fire and Aged care affected,	24-48 hrs	yes	
Goondiwindi Town	Goondiwindi	c	a	a	a	a		48 hours	not held by council	DNR/Met Bureau responsibility
Herberton Shire	Herberton	c	c	b		b		2 hrs	no	didn't have an engineer on staff
Hervey Bay City	Pacific Haven	d	c		b			6 hours	limited	
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	d	c		b			12 hours	limited	
Hinchinbrook Shire	Ingham/Lower Herbert area	c	b	a	b	b	Fire buildings affected. Roads flooded	1.5 days	yes	
Inglewood Shire	Inglewood town	c	b	b	b	b		48 hours	no	lack of resources

Local Government	Town/Community	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
Cairns City	Cairns city	referenced by owners, developers and consultants	no						yes	b
Cairns City	Mulgrave	calibrating flood modelling	yes	30 years	1.8 m	varies	3.6 m	Mar. 1977	yes	b,c
Calliope Shire	Tannum Sands, Boyne Island		no						no	b
Caloundra City	Kawana Waters	public information, calibration etc.	no						no	b
Cambooya Shire	Cambooya		no						no	
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach		no						yes	b,c
Carpentaria Shire	Kurumba									
Carpentaria Shire	Normanton		yes						yes	b
Chinchilla Shire	Chinchilla	Advice to interested persons	yes						yes	b
Cook Shire	Ayton		no						no	a
Cook Shire	Coen		no						no	
Cook Shire	Cooktown (including Marton)		no						no	a
Cooloola Shire	Gympie	planning	yes	125 years	probably zero	varies	25.4 m	1893	yes	b,c,d
Croydon Shire	Croydon		no						no	a
Dalby Town		information to public	yes	16 years		1.0 m	4.5 m	7-2-1981	yes	b
Diamantina Shire	Birdsville		no						no	a
Douglas Shire										
Eacham Shire			no						no	
Emerald Shire	Emerald	flood study and prediction of current events	yes	40+ years	161.95 m	169 m+	177.65 (15.69 m)	27/11/50	no	b
Esk Shire		flood information -Development. Control - rate searches	yes				16.43 m	1974	yes	b,c
Gatton Shire	Grantham	setting minimum floor levels for new buildings	no						no	a
Gayndah Shire	Gayndah		no						yes	b
Gladstone City	Gladstone		no							b
Gold Coast City	Nerang	basis for modelling	yes	60+ years	tidal	3.5 - 4.5 m	6.0 m	1974	yes	b,c,d
Goondiwindi Town	Goondiwindi		yes			levee does not overtop	10.61 m	26-1-1996	yes	d
Herberton Shire	Herberton		no						no	a
Hervey Bay City	Pacific Haven	public awareness, development of flood warning system	no						yes	b
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	public education	no						no	b
Hinchinbrook Shire	Ingham/Lower Herbert area	building floor levels (new), flood prediction	yes	30 years	0 m	6 m+	12.7 m	Mar. 1967	yes	b
Inglewood Shire	Inglewood town		yes	75+ years	12 m	9-10 m	12 m	1956	no	a

APPENDIX 1

Local Government	Town/Community	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8	6-9	6-10	6-11	6-12	6-13
Cairns City	Cairns city	yes	from 1 in 5 to 1 in 100	no	no	1 in 100	no						no	no
Cairns City	Mulgrave	yes	1 in 5, 10, 50, 100, 25	yes	no	1 in 100	yes	c,d	660	8	20	40	no	yes
Calliope Shire	Tannum Sands, Boyne Island	yes	1 in 50 and 100	yes	no	1 in 100	yes	b,c	98	0	0	0	no	yes
Caloundra City	Kawana Waters	yes	1 in 20 and 100	no	no	1 in 100	yes	b,c	0	0	0	0	no	no
Cambooya Shire	Cambooya	no		no	no		no							
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach	no												
Carpentaria Shire	Kurumba													
Carpentaria Shire	Normanton	no		no	no	none	no						no	no
Chinchilla Shire	Chinchilla	no											no	no
Cook Shire	Ayton	no												
Cook Shire	Coen	no												
Cook Shire	Cooktown (including Marton)	no												
Cooloola Shire	Gympie	no												
Croydon Shire	Croydon	no												
Dalby Town		yes	1 in 250	yes		none	no	a					yes	no
Diamantina Shire	Birdsville	no												
Douglas Shire														
Eacham Shire		no												
Emerald Shire	Emerald	yes	1 in 50, 100	yes	no	1 in 50,100	yes	b	200	10	25	50	no	no
Esk Shire		no		no	no	1 in 100	no	b,c					no	no
Gatton Shire	Grantham	no												
Gayndah Shire	Gayndah	no												
Gladstone City	Gladstone	yes	1 in 50, 100	yees	yes	1 in 50	yes	b		1	1		no	no
Gold Coast City	Nerang	yes	1 in 2, 5, 10, 20, 50, 100, to 1 in 200 yr	no	no	1 in 100, max. recorded	yes	c	13 400	400	-	200	yes	no
Goondiwindi Town	Goondiwindi	no												
Herberton Shire	Herberton	no												
Hervey Bay City	Pacific Haven	no												
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	no		no	no	1 in 100	no	b						
Hinchinbrook Shire	Ingham/Lower Herbert area	yes	1 in 3	no	no	1 in 50	yes	b	2 000	100	25	50	yes	yes
Inglewood Shire	Inglewood town	no												

Local Government	Town/Community	7-1	7-2	7-3	7-4	7-5	7-6	7-7	8-1
Cairns City	Cairns city	yes	a,b			0.15 m			c
Cairns City	Mulgrave	yes	b	yes		res:150 mm, com./ind: 0 m	b	b,c	flood channel improvements
Calliope Shire	Tannum Sands, Boyne Island	no	b	yes			a,b	a,b	none
Caloundra City	Kawana Waters	yes	b, physical model	yes		0.50 m	a	b	
Cambooya Shire	Cambooya	no							
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach	no							
Carpentaria Shire	Kurumba								
Carpentaria Shire	Normanton	no						b	none
Chinchilla Shire	Chinchilla	no							
Cook Shire	Ayton	no							
Cook Shire	Coen	no							
Cook Shire	Cooktown (including Marton)	no							
Cooloola Shire	Gympie	yes	a,b	no	acceptable for commercial to flood	0.3 m	a	b	
Croydon Shire	Croydon	no							
Dalby Town		no							d
Diamantina Shire	Birdsville	no							
Douglas Shire									
Eacham Shire		no							
Emerald Shire	Emerald	no	b	yes		300 mm	c	b	a
Esk Shire		yes	a,b	yes		300 mm	c	b	
Gatton Shire	Grantham	yes	a	yes		0.3 m	c	a,b	none
Gayndah Shire	Gayndah	no							
Gladstone City	Gladstone	no		yes			c	a	none
Gold Coast City	Nerang	no	b	yes			b	b, council	b (HINZE- multipurpose)
Goondiwindi Town	Goondiwindi	no							a
Herberton Shire	Herberton	no							none
Hervey Bay City	Pacific Haven	yes	a				a	a	none
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	yes	a	no		3.5 m	a,b,c	a,b	c
Hinchinbrook Shire	Ingham/Lower Herbert area	yes	b	yes		300 mm	c	b	a,d, flood-gated creeks, overflow channels
Inglewood Shire	Inglewood town	no							none

APPENDIX 1

Local Government	Town/Community	8-2	8-3	8-4	9-1	9-2	9-3	9-4	9-5	9-6	9-7
Cairns City	Cairns city		various sources	varies incl. developer contributions	yes	yes	no	yes	yes	Jan 1979	
Cairns City	Mulgrave	a,b,c, requisitions on properties up to 1 in 100	c, Cairns Port Authority	c	yes	yes	no	yes	yes	Jan 1979	3.6 m
Calliope Shire	Tannum Sands, Boyne Island	a,b	c	none	no	yes	no	no	no	1973	
Caloundra City	Kawana Waters	b	b, Kawana Estate P/L		no	no	no	no			
Cambooya Shire	Cambooya										
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach				yes	yes	no	no	yes		
Carpentaria Shire	Kurumba										
Carpentaria Shire	Normanton				yes	yes	no	no	no	1974	
Chinchilla Shire	Chinchilla				yes	yes	no	no	yes	1983	RL. 991
Cook Shire	Ayton				yes	yes	no	yes	yes	March 1996	
Cook Shire	Coen				yes	yes	no	no	yes		
Cook Shire	Cooktown (including Marton)				yes	yes	no	no	yes		
Cooloola Shire	Gympie				yes	yes	no	no	yes	1992	16.1 m
Croydon Shire	Croydon										
Dalby Town		b,c	a,b,c	a,b,c	yes	yes	yes	no	yes	23-6-1983	3.8 m
Diamantina Shire	Birdsville	a			yes	yes	no	no	yes		
Douglas Shire											
Eacham Shire		a			yes	yes	yes	no	yes		
Emerald Shire	Emerald	a,b	c	c	yes	yes	yes	no	no	4/4/56	176.79 (14.84 m)
Esk Shire		a,b	b,c		yes	yes	no	no	yes	May 1996	16.43 m
Gatton Shire	Grantham	a,b			yes	yes	yes	no	yes	May 1996	
Gayndah Shire	Gayndah	a,b					no	no	no	1942	
Gladstone City	Gladstone	a									
Gold Coast City	Nerang	a,b,c	c		yes	yes	no	no	no	1974	2.89 m
Goondiwindi Town	Goondiwindi	b	c	c, subsidies	yes	yes	no	no	yes		
Herberton Shire	Herberton	none	none	none	no	no	no	no	yes	1986	-
Hervey Bay City	Pacific Haven	c	a,b,c		yes	yes	no	yes	yes	1992	-
Hervey Bay City	Urangan, Toogoom & Burrum Heads. Eli Waters Pialba	a,b	a,b,c		yes	yes	no	yes	yes	17 March 1992	-
Hinchinbrook Shire	Ingham/Lower Herbert area	a,b,c	b,c	a,b,c	yes	yes	no	yes	yes	1991	11.3 m
Inglewood Shire	Inglewood town	a,b,c	none	none	yes	yes	no	yes	yes	1976	11 m

Local Government	Town/Community	9-8	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4	11-6
Cairns City	Cairns city		b	b	no		yes	no	no		
Cairns City	Mulgrave	1 in 30	c	b	no		yes	yes	no		yes
Calliope Shire	Tannum Sands, Boyne Island	1 in 20 w/o dam, 1 in 100 year with dam	b	a	no		yes	no	no		no
Caloundra City	Kawana Waters		b	b	no		yes	no	yes	yes	no
Cambooya Shire	Cambooya				no		yes	no	no		no
Cardwell Shire	Tully Heads, Cardwell, South Mission Beach		b	b	no		yes	yes	yes	yes	no
Carpentaria Shire	Kurumba										
Carpentaria Shire	Normanton		a	a		a,b	yes	no			
Chinchilla Shire	Chinchilla	1 in 20	c	b	yes	b,c, recorded message	no				
Cook Shire	Ayton		a	a	yes	a	yes	yes	yes	yes	no
Cook Shire	Coen		a	a	no		yes	no	no	no	no
Cook Shire	Cooktown (including Marton)		a	c	yes	a,b	yes	yes	no	no	no
Cooloola Shire	Gympie	< 1 in 50	c	b	no		yes	yes	yes	yes	yes
Croydon Shire	Croydon		c	c	yes	a,b, telephone	yes		yes	yes	no
Dalby Town			c	b	yes	b,c,d	yes	yes	yes	yes	yes
Diamantina Shire	Birdsville		a	b	no	a	yes	no	yes	yes	no
Douglas Shire											
Eacham Shire			b		no		yes	yes	no		no
Emerald Shire	Emerald	1 in 40	a	a	yes	b,c	yes	yes	yes	yes	yes
Esk Shire		1 in 7	b	c	no		yes	yes	yes	yes	yes
Gatton Shire	Grantham		b	activating counter disaster organisations	no		yes	yes	no	yes	no
Gayndah Shire	Gayndah		c	a,b	no		no				
Gladstone City	Gladstone		a				no				
Gold Coast City	Nerang	1 in 80	b,c		yes	phone-in					
Goondiwindi Town	Goondiwindi		c	b	yes	notice at town gauge	yes	no	no		no
Herberton Shire	Herberton		a	a	no		yes	no	no	no	no
Hervey Bay City	Pacific Haven	-	b,c	c	yes	a	yes	yes	no		yes
Hervey Bay City	Urangan, Toogoom & Burrum Heads, Eli Waters Pialba	-	b,c	c	yes	a,b	yes	yes	no		yes
Hinchinbrook Shire	Ingham/Lower Herbert area	1 in 20	b,c	c	yes	b, phone-in	yes	yes	yes	yes	yes
Inglewood Shire	Inglewood town	1 in 20	b,c	c	yes	a,b,telephone	yes	yes	yes	yes	no

APPENDIX 1

Local Government	Town/Community	Drainage	Coastal	2-1	2-2	2-3	2-4	2-5	2-6	2-7	3-1	3-2	3-3
Ipswich City	Ipswich city	Pacific	no	Brisbane/Bremer	135 000	+2%	45 000				no		
Isisford Shire	Isisford	Inland	no	Barcoo	140	0	80	3	0	0	no		
Jericho Shire	Alpha	Inland	no	Alpha Creek	340	0	160	27	4	8	no		
Jericho Shire	Jericho	Inland	no	Jordan Creek	160	0	55	5	1	1	no		
Johnstone Shire		Pacific	yes	Johnstone	9-18 000	+1%	2 500	150	5	0	yes	1996	yes
Jondaryan Shire	Jondaryan township	Inland	no	Lagoon Creek	150	<1%	~60	4	1	-	no		no
Jondaryan Shire	Oakey	Inland	no	Oakey Creek	4 200	+1-2%	1100	100	50	30	no		
Kilcoy Shire	Kilcoy	Pacific	no	Kilcoy/Sheepstation Creeks	1 650	+1.8%	700	50	20	20	no		
Kingaroy Shire	Kingaroy	Pacific	no	Stuart River	8 000	+3.0%					no		
Laidley Shire		Pacific	no	Laidley Creek	13 500	+7%	3595	150	25	100	no		
Livingstone Shire	Nerimbera	Pacific	yes	Fitzroy	400	+2%	180	4	2	10	no		
Logan City		Pacific	no	Logan	160 000	+3.5%	52, 435	1 125	1 010	732	no	-	no
Mackay City	Mackay	Pacific	yes	Pioneer River	55 000	+2%	25 648	1 479	938	250	yes	1918	yes
Maroochy Shire	Whole of Shire	Pacific	yes	Maroochy, Mary and Mooloolah Rivers	108 000	+5.5%	27, 000				no		
Maryborough City		Pacific	yes	Mary River	26 000	+1.2%	9 467	706		350	yes	Feb 1976	yes
McKinlay Shire		Gulf	no	Nth-Flinders River, Sth-Diamantina	1 300	0	280	30	3	10	no		
Mirani Shire	Finch Hatton	Pacific	no	Cattle Creek		0	120	10	5	5	no		
Mount Isa City	Mount Isa	Inland	no	Leichhardt	24 000	0	7369	250		570	no		
Mt Morgan Shire	Mount Morgan	Inland	no	Dee River	4 000	+1%	1 262	54	15	2	no		
Mundubbera Shire	Mundubbera	Pacific	no	Burnett, Bayne + Auburn River Systems	1 250	+0.9%	550	55	20	70	no		
Murweh Shire	Augathella	Inland	no	Warrego	400	-5%					no		
Murweh Shire	Charleville	Inland	no	Warrego	3 500	+0.2%	1750	80	20	40	no		
Nanango Shire		Pacific	no	Sandy Creek	2 800	+5%	1000	50	20	3	no		
Noosa Shire		Pacific	yes	Noosa	30 000	+10%	10, 000	1 000	200	1 000	yes	Feb 1992	no
Paroo Shire	Cunnamulla	Inland	no	Warrego	1 500	0	600	50	1	20	no		
Pine Rivers Shire		Pacific	yes	Pine River	110 000	+4%	35, 000	935		100	yes	1993	yes
Quilpie Shire	Quilpie	Inland	no	Bulloo	650	0	300	45	20		no		
Redcliffe City	Redcliffe	Pacific	yes	Saltwater Creek/Coastal	50 052	+0.6%	17 085	456	483	365	yes	1974	yes
Redland Shire	Bay Island	Pacific	yes	Moreton Bay	2 810	+8%	800				yes		no
Redland Shire	Part Brewer Street Capalaba	Pacific	yes	Tingalpa Creek	15 homes		15	-	-	-	no		no
Richmond Shire	Richmond	Gulf	no	Flinders	900	0	665	15	8	2	no		
Rockhampton City	Rockhampton	Pacific	no	Fitzroy	65 000	+1-1.5%	27 000				no		

Local Government	Town/Community	4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8
Ipswich City	Ipswich city	1974	4 105 m3/s	3 to 4 days	1635	200		99	c
Isisford Shire	Isisford	April 1990		2 weeks	0	0	0	0	c
Jericho Shire	Alpha	April 1990		2 days	123	15	0	6	c
Jericho Shire	Jericho	April 1990		3 days	55	5	1	1	c
Johnstone Shire		1913							c
Jondaryan Shire	Jondaryan township	May 1996		-	-	-	-	-	b
Jondaryan Shire	Oakey	1983		few hours	12	-	-	-	b
Kilcoy Shire	Kilcoy	1897		4 days					c
Kingaroy Shire	Kingaroy	March 1982		3.5 hours	4	8	3	-	c
Laidley Shire		1974		5 days	200	80	10		c
Livingstone Shire	Nerimbera	1918							c
Logan City		1974	4 650	3 days	2 034	51	83	189	b
Mackay City	Mackay	1958	9 439	24 hours	6 800				b
Maroochy Shire	Whole of Shire	1992		12 hours	200	0	0	0	b
Maryborough City		1893	25 000	5 day	330	50	20	-	c
McKinlay Shire			-	-	-	-	-	-	c
Mirani Shire	Finch Hatton	1958	-	-	25	5	2	0	c
Mount Isa City	Mount Isa	1974	-	7 days		20			c
Mt Morgan Shire	Mount Morgan	1929	12 000	2 weeks	5	0	0	0	c
Mundubbera Shire	Mundubbera	9-13 Feb 1942	River height 108 ft	3 days	30	3	1	0	c
Murweh Shire	Augathella	20 April 1990	3 400 m3/s						
Murweh Shire	Charleville	20 April 1990	5 700 m3/s	3 days	1 250	all	0	20	c
Nanango Shire		1974		2 hours	5	0	1 school		b
Noosa Shire		Feb 1992			53			2 council + 2 private parks	b
Paroo Shire	Cunnamulla	1990 April		2 weeks	2	0	0	0	c
Pine Rivers Shire		Jan 1974		1 day					b
Quilpie Shire	Quilpie	4/1963			0	0	0	0	c
Redcliffe City	Redcliffe	1974		6-12 hours	50	20	20	50	b
Redland Shire	Bay Island				2 000				
Redland Shire	Part Brewer Street Capalaba				0	-	-	-	
Richmond Shire	Richmond	1974		21 days	0	0	0	0	c
Rockhampton City	Rockhampton	1918	23 500	14 days	411	161			c

APPENDIX 1

Local Government	Town/Community	4-9	4-10	4-11	4-12	4-13	4-14	4-15	5-1	5-2
Ipswich City	Ipswich city	c	b	b	b	b		24-48 hours	yes	
Isisford Shire	Isisford	d	a	a	a	a		3-4 days	yes	
Jericho Shire	Alpha	c	b	b		b		24 hrs	yes	
Jericho Shire	Jericho	c	c	b		b		24 hrs	yes	
Johnstone Shire		c	b	b	b	b	totally immobilise community	4 hrs	some	
Jondaryan Shire	Jondaryan township	a	c	a		a			some	lack of resources
Jondaryan Shire	Oakey	a	a	a	b	b		7 hours	little	lack of resources
Kilcoy Shire	Kilcoy	d	c						no	
Kingaroy Shire	Kingaroy	c	b	a	b	a	access - major difficulty	1 day	minimal	
Laidley Shire		c	c	b	b	b	ambulance, hospital, fire dept - all isolated	1 day	some	
Livingstone Shire	Nerimbera	c	b						no	heights in adjacent shire are recorded
Logan City		b	c	b	b	b		6-8 hrs to 2 days	yes	
Mackay City	Mackay	a	a	a	b	b	Access roads may be cut	6-12 hours	yes	
Maroochy Shire	Whole of Shire	a	a	a	b	a		> 6 hours	yes	
Maryborough City		b	a	a	b	a		3 days	yes	
McKinlay Shire		c	a	a	a	a		-	no	urban areas unaffected
Mirani Shire	Finch Hatton	d	c	b	b	b	-	few hours	yes	-
Mount Isa City	Mount Isa	c	a	a	a	b			limited	
Mt Morgan Shire	Mount Morgan	c	c	a	a	b		12 hours	yes	
Mundubbera Shire	Mundubbera	c	b	b	b	b		24 hours	yes	
Murweh Shire	Augathella									
Murweh Shire	Charleville	c	a	b	b	b	all essential services affected	24 hours-3 days	yes	
Nanango Shire		d	c	a	b	a		2 days	no	cost of damage didn't warrant survey
Noosa Shire		a	b	a	b	a		12 hours	yes	
Paroo Shire	Cunnamulla	c	a	a	a	a		5 days	yes	
Pine Rivers Shire		a	c	a	a	a	minor limitations on services as a result of local flooding	6-12 hours	yes	
Quilpie Shire	Quilpie	c	a	a	a	a			no	
Redcliffe City	Redcliffe	d	b	a	b	a		3-5 hours	yes	
Redland Shire	Bay Island								no	
Redland Shire	Part Brewer Street Capalaba								no	
Richmond Shire	Richmond	c	b	a	a	b		36 hours	no	
Rockhampton City	Rockhampton	c	b	a	a	a		up to 14 days	yes	

Local Government	Town/Community	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
Ipswich City	Ipswich city	Reference material. Flood warning, prediction	yes	100 years	6 m to 2.2 m (tidal influence)	7 m	24.7 m	1893	yes	b,c,d
Isisford Shire	Isisford	predict flood levels downstream	yes	35 years	2 m	4 m	10 m	April 1990	yes	b
Jericho Shire	Alpha	town planning and warning information	yes	6 years	0 m	8 m	10.26 m	20-4-1990	yes	b
Jericho Shire	Jericho	town planning and warning information	yes	6 years			1.1 m	April 1990	yes	b
Johnstone Shire			yes	7 years					no	b,c
Jondaryan Shire	Jondaryan township	general information	no						some	b
Jondaryan Shire	Oakey	general information	no						some	b
Kilcoy Shire	Kilcoy		no						no	a
Kingaroy Shire	Kingaroy	flood investigations	no						no	a
Laidley Shire		building control, town plan development	yes						yes	b,c
Livingstone Shire	Nerimbera		no				9.72 m		no	a
Logan City		Flood plain management for rezoning, subdivision and building control including emergency management	yes	40 years	1.5 m (tidal)	3.5 m (varies)	13.7 m	1974	yes	b,c,d
Mackay City	Mackay		yes	25+ years	tidal	4.3 m	6.05 m	1958	yes	b
Maroochy Shire	Whole of Shire	model calibration and issuing of fill and floor levels	yes	40 years			-	-	no	c
Maryborough City		public information on property flooding	yes	100 years	3.0 m	4.40 m	12.27 m	1893	yes	b,d
McKinlay Shire			no						no	a
Mirani Shire	Finch Hatton	Local Town Planning, Flood estimation, River Management	yes	recent	-	-	93.7m S.D. (1958 flood)	-	yes	b,d,c
Mount Isa City	Mount Isa		no						no	b
Mt Morgan Shire	Mount Morgan	dam design	no						no	
Mundubbera Shire	Mundubbera	reference	yes	10 years	-2 m	14 m			no	a
Murweh Shire	Augathella					6 m	7.28 m	April 1990	yes	b
Murweh Shire	Charleville	flood warning, etc.	yes	87 years, 7years: telemetric system	0.0 m	6.5 m	8.54 m	20-4-1990	yes	b,c
Nanango Shire			no						no	a
Noosa Shire		1992 flood used as benchmark	yes	8.5 years			1.81 m	23/2/92	yes	b,d
Paroo Shire	Cunnamulla	flood prevention measures	yes	many years		8.5 m	10.25 m	April 1990	yes	d,e
Pine Rivers Shire		Flood advice to owners. Verification of hydrological model analysis	no						yes	b,c
Quilpie Shire	Quilpie		no						no	a
Redcliffe City	Redcliffe	Verify computer programs to define floods. Set minimum floor levels	no						yes	b
Redland Shire	Bay Island								no	
Redland Shire	Part Brewer Street Capalaba		no						no	
Richmond Shire	Richmond		no						no	a
Rockhampton City	Rockhampton	flood prediction and warnings to households	yes	138 years	-1.5m to +1.6m (tidal)	6.2 m	9.7 m	Feb 1918	yes	b

APPENDIX 1

Local Government	Town/Community	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8	6-9	6-10	6-11	6-12	6-13
Ipswich City	Ipswich city	no		yes	yes	1 in 20	yes	c					yes	no
Isisford Shire	Isisford	no												
Jericho Shire	Alpha	yes	1 in 50			1 in 50	yes	b	120	15	0	0	no	no
Jericho Shire	Jericho	no	1 in 50	no	no	1 in 50	yes	b	55	5	1	1	yes	yes
Johnstone Shire		yes	1 in 50	no	no	1 in 50	yes	b,c					no	no
Jondaryan Shire	Jondaryan township	no												
Jondaryan Shire	Oakey	no												
Kilcoy Shire	Kilcoy	no												
Kingaroy Shire	Kingaroy	no		no	no	1 in 50	no	c			-	-	no	no
Laidley Shire		no	1 in 20 and 100	no	no	1 in 50, 100	no		150	50	10	0	no	no
Livingstone Shire	Nerimbera	no												
Logan City		yes	1 in 2, 10, 20, 50,100, other: 1974 and > 1 in 100 & 500	no	no	1974 flood, 1 in 50, 100	yes	b,c,d	2 034	51	83	189	no	yes
Mackay City	Mackay	yes	1 in 10, 50, 100, 60 and 200	no	no	1 in 42, 50	no	a					yes	no
Maroochy Shire	Whole of Shire	yes	1 in 20, 50, 100	no	no	1 in 100	no		< 50	minimmal	minimmal	minimmal	no	yes
Maryborough City		no												
McKinlay Shire		no												
Mirani Shire	Finch Hatton	no		no	no	1958 flood	yes	b	25	5	2	-	no	yes
Mount Isa City	Mount Isa	yes	1 in 5, 50, 15	no	no	1 in 15	yes	c	50	20			no	no
Mt Morgan Shire	Mount Morgan	no		no	no	none	no	a					no	no
Mundubbera Shire	Mundubbera	no												
Murweh Shire	Augathella	yes		no	no								yes	yes
Murweh Shire	Charleville	yes	1 in 100, 150	no	no		yes	b					yes	yes
Nanango Shire		no												
Noosa Shire		yes	1 in 20, 50, 100	yes	yes	1 in 100	yes	b	60	20	0	0	yes	yes
Paroo Shire	Cunnamulla	yes	1 in 100	no	yes	1 in 100	no	a	2				no	no
Pine Rivers Shire		yes	1 in 2, 50, 100	yes	yes	1 in 50, 100	yes	b,c					no	no
Quilpie Shire	Quilpie	no												
Redcliffe City	Redcliffe	yes	1 in 2, 5, 10, 50, 100	no	no	1 in 100	yes	b	20	0	10	0	no	yes
Redland Shire	Bay Island	yes	1 in 100, tidal storm surge	yes	yes	1 in 100	yes	d	20					
Redland Shire	Part Brewer Street Capalaba	yes	1 in 100			1 in 100	yes	b	15	1	-	-	no	no
Richmond Shire	Richmond	no				none	no		0	0	0	0		
Rockhampton City	Rockhampton	yes	1 in 2, 5, 10, 20, 50,100	yes	yes	1 in 100	yes	b					yes	yes

Local Government	Town/Community	7-1	7-2	7-3	7-4	7-5	7-6	7-7	8-1
Ipswich City	Ipswich city	yes	derived 1 in 20	yes		0.3 m	combination in various circumstances	a,b,d	
Isisford Shire	Isisford	yes	a	yes				a,b	
Jericho Shire	Alpha	no		yes		0			
Jericho Shire	Jericho	no		yes					a
Johnstone Shire		no		no				b, building application	a
Jondaryan Shire	Jondaryan township								none
Jondaryan Shire	Oakey	no							none
Kilcoy Shire	Kilcoy	no							b
Kingaroy Shire	Kingaroy	no							stream modification and clean up
Laidley Shire		no	a	no	as per QUDM	300 mm	c	b	
Livingstone Shire	Nerimbera	no							
Logan City		yes	b	yes		150 mm	b,c	a,b	c,d
Mackay City	Mackay	yes	physical model	yes			b	b,d	a,c
Maroochy Shire	Whole of Shire	yes	a,b	yes			b	a,b, Brisbane Flood Mitigation Act	a,c
Maryborough City		yes	a	yes		0.3 m			d
McKinlay Shire		no							none
Mirani Shire	Finch Hatton	yes	a,b	yes		300 mm	1958 flood	b,d	
Mount Isa City	Mount Isa	yes	b	yes			c	b	
Mt Morgan Shire	Mount Morgan	no							
Mundubbera Shire	Mundubbera	yes	a	yes					
Murweh Shire	Augathella								none
Murweh Shire	Charleville	yes	a, local knowledge	yes			a		d
Nanango Shire		no							
Noosa Shire		yes	b	yes		0.6 m	b	b	redevelop above flood level
Paroo Shire	Cunnamulla	yes	a,b	yes			c	a,b,c	a
Pine Rivers Shire		yes	a,b	yes		0.6 m to 1.0 m	b,c	a,b,c	c, drainage schemes
Quilpie Shire	Quilpie	no							
Redcliffe City	Redcliffe	yes	b	yes			no filling below Q100 flood	b	c
Redland Shire	Bay Island	no					b	b	
Redland Shire	Part Brewer Street Capalaba	no							
Richmond Shire	Richmond	no							
Rockhampton City	Rockhampton	yes	a,b	yes			b	b	none

APPENDIX 1

Local Government	Town/Community	8-2	8-3	8-4	9-1	9-2	9-3	9-4	9-5	9-6	9-7
Ipswich City	Ipswich city	a,b,c	a,b,c		yes	yes	yes	yes	yes	May 1996	17.3 m
Isisford Shire	Isisford	b				yes	yes	no	yes	1990	-
Jericho Shire	Alpha		c	c	yes	yes	yes	yes	yes	April 1990	10.2 m
Jericho Shire	Jericho	c	c	c	yes	yes	yes	yes	yes	Feb 1997	0.3 m
Johnstone Shire		a,c	a,b,c	b,c	yes	yes	no	no	yes	1996	-
Jondaryan Shire	Jondaryan township	none			yes	yes	no	no	no	-	
Jondaryan Shire	Oakey	none			no	yes	no	no	no	1983	-
Kilcoy Shire	Kilcoy	a	b,c	b,c	yes	yes	no	no	no	1992	
Kingaroy Shire	Kingaroy	none	c	c	yes		no	no	no	Jan1996	-
Laidley Shire		a,b,c	Water Infrastructure Task Force	c	yes	yes	yes	no	yes	May 1996	
Livingstone Shire	Nerimbera	a,b			yes	yes	no	no	no	Jan 1991	9.35 m
Logan City		a,b,c, property aquisition (DCP)	a,b,c	c	yes	yes	no	yes	yes	May 1996, Feb 1991	9.06 m
Mackay City	Mackay	c	c	a,b,c, Pioneer River improvement Trust	yes	yes	no	yes	yes	Jan 1991	
Maroochy Shire	Whole of Shire	a,b,c	c	a,b,c	yes	yes	yes	no	yes	1992	-
Maryborough City		c			yes	yes	yes	no	no	1992	9.48 m
McKinlay Shire		none	none	none		yes					
Mirani Shire	Finch Hatton	a,b,c	a,b,c	a,b,c	yes	yes	no	yes	yes	1958	-
Mount Isa City	Mount Isa		c		yes	yes	no	no	no	1991	
Mt Morgan Shire	Mount Morgan				no	no	no	no	yes		
Mundubbera Shire	Mundubbera				yes	yes	yes	no	yes	1974	
Murweh Shire	Augathella				yes	yes	no	no	-	4-2-1997	6.45 m
Murweh Shire	Charleville	c			yes	yes	yes	no	yes	3-4 Feb 1997	7.44 m
Nanango Shire		a,b			yes	yes	no	no	yes	1974	
Noosa Shire		a	c		yes	yes	no	no	yes	Feb 1992	1.81 m
Paroo Shire	Cunnamulla	b	a,b,c	a,b,c	yes	yes	no	no	yes	1990	10.25 m
Pine Rivers Shire		a,b	c	b,c	yes	yes	no	no	yes	1993	
Quilpie Shire	Quilpie	c			yes	yes	no	no	yes		
Redcliffe City	Redcliffe	b	c	c	yes	yes	no	no	no	1974	
Redland Shire	Bay Island	b	b,c	c	yes	yes	no	no	no		
Redland Shire	Part Brewer Street Capalaba	b	c		no	no	no	no	no		
Richmond Shire	Richmond				yes	yes	no	no	yes		
Rockhampton City	Rockhampton	a,b,c	a,b,c		yes	yes	no	yes	yes	Dec-Jan 1990/91	9.3 m

APPENDIX 1

Local Government	Town/Community	9-8	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4	11-6
Ipswich City	Ipswich city	1 in 20	c	c	yes	b, SES, police, citizens watch	yes	yes	yes	no	yes
Isisford Shire	Isisford	-	c	b	yes	b	yes	yes	no	yes	yes
Jericho Shire	Alpha	1 in 200	c	b	yes	a	yes	yes	yes	yes	yes
Jericho Shire	Jericho		c	b,c	yes	a	yes	yes	yes	yes	yes
Johnstone Shire			b,c	c	yes	a,b	yes	yes	yes	yes	no
Jondaryan Shire	Jondaryan township		a		no		no				
Jondaryan Shire	Oakey	-	a		no		no	no	no		no
Kilcoy Shire	Kilcoy	1 in 10	b	b	no		yes	no	no		no
Kingaroy Shire	Kingaroy	1 in 10	a		no		yes	yes	no		no
Laidley Shire		1 in 20	c	c	no		yes	yes	yes	yes	no
Livingstone Shire	Nerimbera		c	b	no	b,c	yes	yes	yes	yes	no
Logan City		1 in 5 (1996), 1 in 20 (1991)	c	b,c	yes	a, telephone, warden system (local area emergency group)	yes	yes	yes	yes	yes
Mackay City	Mackay		c	b	yes	b,c	yes	no	no	yes	yes
Maroochy Shire	Whole of Shire	1 in 70	b	c	yes	b,c, telephone	yes	yes	no	-	yes
Maryborough City		1 in 20	c	c	no		yes	yes	yes	yes	no
McKinlay Shire											
Mirani Shire	Finch Hatton	-	'alert' system	b,c	yes	b,c	yes	yes	no	-	-
Mount Isa City	Mount Isa	1 in 5	a	a	no		no				
Mt Morgan Shire	Mount Morgan		a	a	no		yes	yes	no	yes	no
Mundubbera Shire	Mundubbera		a	b	no		yes	no	no	no	
Murweh Shire	Augathella		c	c	yes	a					
Murweh Shire	Charleville	1 in 85	b,c	b,c	yes	a,b,d	yes	yes	yes	yes	yes
Nanango Shire			a	a	no		no				
Noosa Shire		1 in 70	b	c	yes	a,b	yes	yes	yes	yes	yes
Paroo Shire	Cunnamulla	1 in 100	c	b,c	no		yes	no	yes	yes	no
Pine Rivers Shire			b	b	no		yes	yes	no		yes
Quilpie Shire	Quilpie		c	b,c	no		no				
Redcliffe City	Redcliffe	1 in 45	a	a	no		yes	no	no		no
Redland Shire	Bay Island		a								
Redland Shire	Part Brewer Street Capalaba		a	a			no				
Richmond Shire	Richmond		b	b	no		yes	no	yes	yes	no
Rockhampton City	Rockhampton	1 in 60	c	c	yes	b,c	yes	yes	yes	yes	yes

Local Government	Town/Community	Drainage	Coastal	2-1	2-2	2-3	2-4	2-5	2-6	2-7	3-1	3-2	3-3
Roma Town	Roma	Inland	no	Balonne	6 738	0	2384	295	119	3	no	7/03/1997	yes
Rosalie Shire	Cooyar	Inland	no	Brisbane River, Cooyar Ck	70	0	30	10			no		no
Rosalie Shire	Quinalon	Inland	no	Myall Ck, Murray-Darling Basin	50	< 2%	20	8	1		no	1989	no
Sarina Shire	Armstrong Beach	Pacific	yes		200	+3%	80	1	0	25	yes	Cyclone - 1918	yes
Sarina Shire	Campuri/Sarina Beach	Pacific	yes		425	+0.5%	150	5	0	30	yes	Cyclone 1918	yes
Sarina Shire	Grasstree Beach	Pacific	yes		330	+1%	130	3	2	0	yes	Cyclone - 1918	yes
Sarina Shire	Louisa Creek	Pacific	yes		250	+0.1%	100	-	-	-	yes	Cyclone 1918	yes
Sarina Shire	Salonica Beach/Half Tide	Pacific	yes		370	+1%	150	4	5	40	yes	Cyclone 1918	yes
Tambo Shire	Tambo	Inland	no		400		109	18	-	6	no		
Tara Shire	Tara	Inland	no	Undulla Ck Moonie R.	4 030	+1%	2200	60	20	40	no		
Taroom Shire	Taroom	Inland	no	Fitzroy	700	-0.2%	250	24	6	4	no		
Thuringowa City		Pacific	yes	Ross River/Bohle River	40 000	+5-8%	15 000	500	100		yes	December 1971 cyclone "Althea"	yes
Tiaro Shire		Pacific	no		4 500	+9%	1700	50	10	200	yes	potential only	no
Toowoomba City	Toowooomba City	Inland	no	Gowrie, Westbrook & Spring Cks -- Condamine River	90 560	+1.53%	33 000				no		
Townsville City	Townsville	Pacific	yes		88 855	+1%	21,000	3 300			yes	1971	yes
Waggamba Shire		Inland	no	Border Rivers	438	0	182	30	1	0	no	1984	no
Wambo Shire	Jandowae	Inland	no	Condamine	875	+0-2%					no	1981	no
Waroo Shire	Surat	Inland	no	Balonne	500	-5%	250	20	6	1	no		
Warwick Shire	Warwick	Inland	no	Condamine River	12 000	+1.7 %	4 000	250	150	115	no		
Winton Shire	Winton	Inland	no	Western River	1 000	Negative	250	40	22	50	no	1993	no
Atherton Shire		Pacific	no										
Belyando Shire	No communitites at risk	Inland	no										
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	Pacific	yes	nil			2400	60	20	200	yes	nil	no
Bungil Shire	Injune	Pacific	no	Injune Creek - not flood prone	1 100	0	153	53	8	6	no		
Clifton Shire		Inland	no										
Cloncurry Shire		Gulf	no										
Diamantina Shire	Bedourie	Inland	no	Georgina	100	+5%	30	3	2	10	no		
Duaringa Shire		Pacific	no	Dawson/Mackenzie	11 000	+1%	2000	100		100	no		no
Isis Shire		Pacific	no										
Kilkivan Shire		Pacific	no										
Kolan Shire		Pacific	no										
Millmerran Shire		Inland	no										

Local Government	Town/Community	4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8
Roma Town	Roma	7/3/1997.		48 hours	40	2	2	2	b(97), c(63)
Rosalie Shire	Cooyar	1989		12 hours	12	6			c
Rosalie Shire	Quinalon	Feb 1983		24 hours					c
Sarina Shire	Armstrong Beach	1918 (storm surge)					Today: 1.5m tidal surge would affect > 50% population		c
Sarina Shire	Campuri/Sarina Beach	1918 (storm surge)					1.5m tidal surge would affect 60 persons		c
Sarina Shire	Grasstree Beach	1918 (storm surge)					3m tidal surge would affect 30% or about 100 persons		c
Sarina Shire	Louisa Creek	1918 (storm surge)					100 persons would be affected by 1.5m storm surge		c
Sarina Shire	Salonica Beach/Half Tide	1918 (storm surge)					30 persons would be affected by 3m storm surge		c
Tambo Shire	Tambo	1983		1 week	3				c
Tara Shire	Tara	1983		2 weeks	15	0	0	0	b
Taroom Shire	Taroom	1890			25	12		4	b
Thuringowa City		1940's		1-2 days		yes	yes	yes	c
Tiaro Shire		1894		3 weeks					b
Toowoomba City	Toowooomba City	1890's		< 1 day					b
Townsville City	Townsville	varies		0.25 - 3 hrs					c
Waggamba Shire		1956		5 days	100% - 110 buildings	7	1 (sawmill)	-	c
Wambo Shire	Jandowae	1946	229m3/s	2 days	6	3	-	-	c
Waroo Shire	Surat	Jan/Feb 1996		10 days	1	0	1	0	c
Warwick Shire	Warwick	11-2-76	1 400	2-3 days	90	1	2	0	c
Winton Shire	Winton	1954		1 week	40	20	2	15	c
Atherton Shire									
Belyando Shire	No communitites at risk								
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	Dec 1990, Jan 1991		3 - 4 weeks	0	0	0	0	c
Bungil Shire	Injune				0	0	0	0	b
Clifton Shire									
Cloncurry Shire									
Diamantina Shire	Bedourie	1974			0	0	0	10	c
Duaringa Shire									
Isis Shire									
Kilkivan Shire									
Kolan Shire									
Millmerran Shire									

Local Government	Town/Community	4-9	4-10	4-11	4-12	4-13	4-14	4-15	5-1	5-2
Roma Town	Roma	b(97), d(63)	a(97), c(63)	a	b(63 & 97)	b(97), a(63)			yes	
Rosalie Shire	Cooyar	d	c			b		6	yes	
Rosalie Shire	Quinalon	d	c					12 hours	yes	
Sarina Shire	Armstrong Beach	d	c			b				
Sarina Shire	Campuri/Sarina Beach	d	c	a		b				
Sarina Shire	Grasstree Beach	d	c	a		b				
Sarina Shire	Louisa Creek	d	c	a		b				
Sarina Shire	Salonica Beach/Half Tide	d	c			b				
Tambo Shire	Tambo	d	b	a		b			no	no records
Tara Shire	Tara	c	b	a	a	a		1 day	no	
Taroom Shire	Taroom	d	a	a	b	b		3/4 day	no	lack of resources
Thuringowa City		c	c					12 hours	no	too early in history
Tiaro Shire		c	c	a		b		6	no	partial data available - some aerial photographs
Toowoomba City	Toowooomba City	b	a	a	a	a		15-30min	limited	storm durations are usually too short
Townsville City	Townsville	c	b		b	b		0.5-4 hours	yes	
Waggamba Shire		c	c	b	a	b		1-2 days	no	apathy - some unconfirmed data available
Wambo Shire	Jandowae	c	b	a	a	a		18 hours	no	-
Waroo Shire	Surat	d	a	a	a	a		72 hours	yes	records now being kept by Council and police
Warwick Shire	Warwick	a	b	a	b				yes	-
Winton Shire	Winton	c	b	a	b			24 hours	no	
Atherton Shire										
Belyando Shire	No communitites at risk									
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	c	a	a	a	a		2-4 hours	no	no flooding problems exist
Bungil Shire	Injune		a	a	a	a			no	no flooding in town
Clifton Shire										
Cloncurry Shire										
Diamantina Shire	Bedourie	d	a	a	a	b			no	no official recording
Duaringa Shire										
Isis Shire										
Kilkivan Shire										
Kolan Shire										
Millmerran Shire										

Local Government	Town/Community	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
Roma Town	Roma	town planning regulations, contours map	yes	15 years	2 m to 3 m	6.10 m	7.32 m	7/3/1997	yes	b,c,d
Rosalie Shire	Cooyar	building approvals	no						yes	b
Rosalie Shire	Quinalon	building approvals	no						yes	b
Sarina Shire	Armstrong Beach								storm surge	b
Sarina Shire	Campuri/Sarina Beach								storm surge	b
Sarina Shire	Grasstree Beach								storm surge	b
Sarina Shire	Louisa Creek								storm surge	b
Sarina Shire	Salonica Beach/Half Tide								storm surge	b
Tambo Shire	Tambo		yes	3 years	0 m	4.5 m	5.2 m	2/2/97	no	a
Tara Shire	Tara		yes		1m	6m	0.9 m	May 1983	no	a
Taroom Shire	Taroom		yes	135 years			14.78 m	March 1890	no	a
Thuringowa City			yes	10 years				24/3/1990	no	a
Tiaro Shire		house siting	no						no	b,d
Toowoomba City	Toowooomba City	calibration of Flood Study	yes						no	a
Townsville City	Townsville	Public information. Identifying flood prone areas. Strategic planning, mitigation works. Access roads cut.	no						- yes	b,c,d
Waggamba Shire		building heights	no	-	-	-	-	-	limited	a
Wambo Shire	Jandowae	-	yes	3 years	-	-	-	-	no	a
Waroo Shire	Surat		yes			10 m	13.8 m	Jan/Feb 1996	no	a
Warwick Shire	Warwick	property searches, etc.	yes	120 years	0.15 m	3.0 m (lowest point)	9.10 m	11-2-76	yes	b
Winton Shire	Winton		no						no	a
Atherton Shire										
Belyando Shire	No communitites at risk									
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.		no						no	a
Bungil Shire	Injune		no						no	a
Clifton Shire										
Cloncurry Shire										
Diamantina Shire	Bedourie		no						no	a
Duaringa Shire										
Isis Shire										
Kilkivan Shire										
Kolan Shire										
Millmerran Shire										

APPENDIX 1

Local Government	Town/Community	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8	6-9	6-10	6-11	6-12	6-13
Roma Town	Roma	no	1 in 50	no	yes	1 in 50	yes		-	-	-	-	yes	
Rosalie Shire	Cooyar	no												
Rosalie Shire	Quinalon	no												
Sarina Shire	Armstrong Beach	no												
Sarina Shire	Campuri/Sarina Beach	no												
Sarina Shire	Grasstree Beach	no												
Sarina Shire	Louisa Creek	no												
Sarina Shire	Salonica Beach/Half Tide	no												
Tambo Shire	Tambo	no												
Tara Shire	Tara	no												
Taroom Shire	Taroom	no		no	no	1 in 100	no	a	25	12		4	no	no
Thuringowa City		yes	1 in 20, 50	no	no	1 in 50	yes	b,c	20	0	0		no	yes
Tiaro Shire		no												
Toowoomba City	Toowooomba City	yes	1 in 2, 20, 100	no	no	1 in 100	no	b		>10			no	yes
Townsville City	Townsville	yes	design studies on AR & R information	no	no	1 in 2, 10, 20, 50							yes	
Waggamba Shire		yes	1 in 50	no	no	1 in 50	no		110 (100%)	7 (100%)	1 (100%)	-	no	no
Wambo Shire	Jandowae	no		no	no	none	no	a	-	-	-	-	no	no
Waroo Shire	Surat	no		no	no		no	a	2		1		no	no
Warwick Shire	Warwick	yes	1 in 10, 20, 50, 100, 200, 500, and PMF	yes	yes	1 in 100	yes	b	90	1	32	0	no	no
Winton Shire	Winton	no		no	no									
Atherton Shire														
Belyando Shire	No communitites at risk													
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	no												
Bungil Shire	Injune	no		no	no	none	no	a	0	0	0	0	no	no
Clifton Shire														
Cloncurry Shire														
Diamantina Shire	Bedourie	no		no	no	none	no	a					no	no
Duaringa Shire														
Isis Shire														
Kilkivan Shire														
Kolan Shire														
Millmerran Shire														

Local Government	Town/Community	7-1	7-2	7-3	7-4	7-5	7-6	7-7	8-1
Roma Town	Roma	yes	a	yes		-	c	b	none
Rosalie Shire	Cooyar	yes	b	no		300 mm	a	a,b, local law	a,d
Rosalie Shire	Quinalon	yes	b	yes		300 mm		a,b, local law	d
Sarina Shire	Armstrong Beach	no							none
Sarina Shire	Campuri/Sarina Beach	no							none
Sarina Shire	Grasstree Beach	no							none
Sarina Shire	Louisa Creek	no							none
Sarina Shire	Salonica Beach/Half Tide	no							none
Tambo Shire	Tambo	no							
Tara Shire	Tara	no							
Taroom Shire	Taroom	no		yes			a		
Thuringowa City		yes	b	yes		450 mm	b	b	a
Tiaro Shire		yes	b	yes			a	a, Building Act	
Toowoomba City	Toowooomba City	no							
Townsville City	Townsville	yes	a	no			c	a,b, council policy	a,b,c, improvement to channels
Waggamba Shire		no							a
Wambo Shire	Jandowae	no				-	levee bank by-laws etc.	a,d	d
Waroo Shire	Surat	no							none
Warwick Shire	Warwick	yes	a	yes		0	Local laws and policies	a,b,c,d	none
Winton Shire	Winton	no							none
Atherton Shire									
Belyando Shire	No communitites at risk								
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	no							none
Bungil Shire	Injune	no							
Clifton Shire									
Cloncurry Shire									
Diamantina Shire	Bedourie	no							
Duaringa Shire									
Isis Shire									
Kilkivan Shire									
Kolan Shire									
Millmerran Shire									

Local Government	Town/Community	8-2	8-3	8-4	9-1	9-2	9-3	9-4	9-5	9-6	9-7
Roma Town	Roma	a,b	c	-	yes	yes	yes	no	yes	7/3/1997	7.32 m
Rosalie Shire	Cooyar	a,b		c	yes	yes	yes	no	yes	1989	
Rosalie Shire	Quinalon	a,b		c	yes	yes	yes	no	yes	1989	
Sarina Shire	Armstrong Beach	a,b,c	c			yes	no	yes	yes		
Sarina Shire	Campuri/Sarina Beach	a,b,c	c			yes	no	yes	yes		
Sarina Shire	Grasstree Beach	a,b,c	c			yes	no	yes	yes		
Sarina Shire	Louisa Creek	a,b,c	c			yes	no	yes	yes		
Sarina Shire	Salonica Beach/Half Tide	a,b,c	c			yes	no	yes	yes		
Tambo Shire	Tambo	c			yes	yes	yes	no	yes	1983	6.2 m
Tara Shire	Tara		c	b,c	yes	yes	no	no	yes	Jan/May 1996	0.9 m
Taroom Shire	Taroom				yes	yes	yes	yes	yes	11/1/1996	7.15 m
Thuringowa City		a,b	c, developer's contribution	developers contribution	yes	yes	no	no	yes	19 Feb 1991	
Tiaro Shire					yes	no	no	no	no	1992	
Toowoomba City	Toowooomba City	a			yes	yes	no	no	no	Feb 1995	
Townsville City	Townsville	a,b, advice	c	c, works undertaken by subdividers	yes	yes	no	yes		1990	-
Waggamba Shire		a	a,b,c	c	yes	yes	no	no	yes	1984	-
Wambo Shire	Jandowae	b,c		River Trust Channel Improvement	yes	yes	no	no	yes	1983	-
Waroo Shire	Surat	c			yes	yes	yes	yes	yes	Jan/Feb 1996	13.8 m
Warwick Shire	Warwick	a,b,c	a,b,c		yes	yes	no	no	no	5-5-96	7.0 m
Winton Shire	Winton	none	none	none	yes	yes	yes	no	yes	1993	-
Atherton Shire											
Belyando Shire	No communitites at risk										
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.	none	none	none	yes	yes	no	no	yes		
Bungil Shire	Injune							no	yes		
Clifton Shire											
Cloncurry Shire											
Diamantina Shire	Bedourie	b			yes	yes	no	no	yes		
Duaringa Shire											
Isis Shire											
Kilkivan Shire											
Kolan Shire											
Millmerran Shire											

Local Government	Town/Community	9-8	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4	11-6
Roma Town	Roma	1 in 34	b,c	c	yes	a,b	yes	yes	yes	yes	yes
Rosalie Shire	Cooyar	1 in 100	a	a	no		yes	no	yes	yes	no
Rosalie Shire	Quinalon	1 in 20	a	a	no		yes	no	yes	yes	no
Sarina Shire	Armstrong Beach		c	c	yes	b,c, SES	yes	yes	no		yes
Sarina Shire	Campuri/Sarina Beach		c	c	yes	b,c, SES	yes	yes	no		yes
Sarina Shire	Grasstree Beach		c	c	yes	b,c, SES	yes	yes	no		yes
Sarina Shire	Louisa Creek		c	c	yes	b,c, SES	yes	yes	no		yes
Sarina Shire	Salonica Beach/Half Tide		c	c	yes	b,c, SES	yes	yes	no		yes
Tambo Shire	Tambo	1 in 10	b,c	c, road closures	yes	SES	yes	no	yes	yes	yes
Tara Shire	Tara	1 in 5	b	b, SES	no		yes	yes	no		yes
Taroom Shire	Taroom		b,c	c	no	b	yes	yes	no		no
Thuringowa City		1 in 8	a	a	no		yes	no	no	yes	yes
Tiaro Shire		1 in 4	a	a	no		yes	yes	no	no	yes
Toowoomba City	Toowooomba City	1 in 2-5	a	a	no		no				
Townsville City	Townsville	1 in 40	a	counter disaster procedures	yes	b,c, police, post	yes	yes	no		yes
Waggamba Shire			c	b	yes	recorded message	yes	yes	no	yes	no
Wambo Shire	Jandowae		a	a	no		yes	no	no	no	no
Waroo Shire	Surat		c	b,c	yes	b,c	yes	yes	yes	yes	yes
Warwick Shire	Warwick	1 in 10	b,c	b,c	yes	a	yes	no	no	no	no
Winton Shire	Winton	1 in 5	a		no	-	yes	no	no		no
Atherton Shire											
Belyando Shire	No communitites at risk										
Broadsound Shire	no towns or buildings in the Broadsound Shire are subject to flooding.		b	b	no		yes	yes	no	no	yes
Bungil Shire	Injune		a		no		yes				
Clifton Shire											
Cloncurry Shire											
Diamantina Shire	Bedourie			b	no	a	yes	no	yes	yes	no
Duaringa Shire											
Isis Shire											
Kilkivan Shire											
Kolan Shire											
Millmerran Shire											

Local Government	Town/Community	Drainage	Coastal	2-1	2-2	2-3	2-4	2-5	2-6	2-7	3-1	3-2	3-3
Monto Shire	Monto	Pacific	no	Three Moon Creek / Montal Creek: Burnett River	1 600	+2%	600	80	20	20	no		
Murgon Shire	Murgon (see comment)	Pacific	no	Barambah Creek	3 000	+1%	820	100	20	5	no		no
Peak Downs Shire	Capella and Tieri	Pacific	no										
Perry Shire	Mount Perry	Pacific	no	Burnett	350		175	6	2	2	no		
Whitsunday Shire	Towns of Whitsunday and Prosperpine	Pacific	yes	no questionnaire answers									
Wondai Shire		Pacific	no	no questionnaire answers									

Local Government	Town/Community	4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8
Monto Shire	Monto	1942, 1996		1 week	0	0	0	0	c
Murgon Shire	Murgon (see comment)				-	-	-	-	b
Peak Downs Shire	Capella and Tieri								
Perry Shire	Mount Perry	1946			0				c
Whitsunday Shire	Towns of Whitsunday and Prosperpine								
Wondai Shire									

APPENDIX 1

Local Government	Town/Community	4-9	4-10	4-11	4-12	4-13	4-14	4-15	5-1	5-2
Monto Shire	Monto	c	a	a	a	a		5-10 hours	no	lack of resources
Murgon Shire	Murgon (see comment)	c	a	a	a	a			no	DNR maintain records of Barambah Creek
Peak Downs Shire	Capella and Tieri									
Perry Shire	Mount Perry	d	c			b	ambulance affected		no	
Whitsunday Shire	Towns of Whitsunday and Prosperpine									
Wondai Shire										

Local Government	Town/Community	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
Monto Shire	Monto		no						no	a
Murgon Shire	Murgon (see comment)		no						no	a
Peak Downs Shire	Capella and Tieri									
Perry Shire	Mount Perry		no						no	a
Whitsunday Shire	Towns of Whitsunday and Prosperpine									
Wondai Shire										

APPENDIX 1

Local Government	Town/Community	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8	6-9	6-10	6-11	6-12	6-13
Monto Shire	Monto	no												
Murgon Shire	Murgon (see comment)	no												
Peak Downs Shire	Capella and Tieri													
Perry Shire	Mount Perry						no	a	1	0	0	0	no	no
Whitsunday Shire	Towns of Whitsunday and Prosperpine													
Wondai Shire														

Local Government	Town/Community	7-1	7-2	7-3	7-4	7-5	7-6	7-7	8-1
Monto Shire	Monto	no							none
Murgon Shire	Murgon (see comment)	no							
Peak Downs Shire	Capella and Tieri								
Perry Shire	Mount Perry	no							
Whitsunday Shire	Towns of Whitsunday and Prosperpine								
Wondai Shire									

APPENDIX 1

Local Government	Town/Community	8-2	8-3	8-4	9-1	9-2	9-3	9-4	9-5	9-6	9-7
Monto Shire	Monto	none	none	none	no	yes	no	no	yes	1996	
Murgon Shire	Murgon (see comment)		none	none	no	no	no	no	no	-	
Peak Downs Shire	Capella and Tieri										
Perry Shire	Mount Perry						no	no	yes		
Whitsunday Shire	Towns of Whitsunday and Prosperpine										
Wondai Shire											

Local Government	Town/Community	9-8	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4	11-6
Monto Shire	Monto		c	a	no		yes	yes	no	no	no
Murgon Shire	Murgon (see comment)		c	signs at creek crossings	no		no				
Peak Downs Shire	Capella and Tieri										
Perry Shire	Mount Perry		a	a	no		yes	yes	no		no
Whitsunday Shire	Towns of Whitsunday and Prosperpine										
Wondai Shire											

Appendix 2

The Questionnaire as Circulated to all LGAs

Where appropriate, aggregate responses have been added to the questionnaire. These are restricted to replies which indicated that an urban flood problem, as defined in the study, existed.

Some LGAs submitted responses for more than one flood prone locality. **The aggregate replies are for locality and not for LGA.** Details of LGAs responding and for the individual localities are given in Appendix 1.

Urban Flood Risk in Queensland

The Department of Natural Resources has commissioned a study of Urban Flood Risk in Queensland as part of an overall project addressing floodplain management in Queensland. The objectives of this study are to:

- define the size, vulnerability & spatial distribution of flood prone communities in Queensland; and
- provide a basis for prioritising more detailed investigations into the extent of flood problems and establishing ways of mitigating the problems.

This questionnaire has been designed to provide the basic data for this study.

As mainstream flooding is the primary focus of this investigation, consideration of flooding from urban drainage surcharge should be excluded. However, flooding resulting from storm tide should be included as flooding and storm tide are often coincident. Where possible flooding from storm tide should be identified.

It is requested that a separate questionnaire be completed for **each** town/community within your Local Government boundary where the number of buildings at risk of flooding during the largest recorded event or during the estimated 1 in 100yr event is greater than 10. If the number of buildings within a town/community at risk to flooding is less that 10, no response is required.

In the case of major towns, it maybe appropriate to complete separate questionnaires for areas with discrete separate flow systems.

It is acknowledged that not all Local Governments will be able to complete every item in this questionnaire. However, it is requested the each Local Government provide the best information available for each flood affected town/community.

Definitions of some terms used in this questionnaire are attached at the end of the questionnaire.

Local Government	
Town/Community	

1 *Contact Person*

1.1 Contact Person	
1.2 Position	
1.3 Telephone Number	

2 *Town/Community Data*

2.1 River Basin	
2.2 Total Population in Town/Community	
2.3 Percentage Growth Rate	

Total Number of buildings within the Community (Please estimate from the best data available)	
2.4 Residential	
2.5 Commercial	
2.6 Industrial	
2.7 Caravans & Mobile Homes	

3 *Storm Tide*

3.1 Does a storm tide problem exist?	❑ yes	❑ no

If "no" is the answer to the above question, please go to Question 4.

3.2 Date of the last event which caused flooding of buildings		
3.4 Does a storm tide inundation map exist?	❑ yes	❑ no

4 *Largest Known Flood Data*

Details of Largest Known_Event	
4.1 Date of largest known flood event	
4.2 Estimated Max Discharge (cumecs)	
4.3 Duration of Flood Inundation	

Total Number of buildings flooded by Largest Recorded Event (Please estimate from the best data available)	
4.4 Residential	
4.5 Commercial	
4.6 Industrial	
4.7 Caravans & Mobile Homes	

Effect of Largest Known Flood on Lifelines	
4.8 Major Roads	❑ no access roads affected ❑ some access roads cut ❑ all access road cut
4.9 Rail	❑ no rail links affected ❑ some rail links cut ❑ all rail links cut ❑ not applicable
4.10 Airport	❑ airport unaffected ❑ airport closed or services interrupted ❑ not applicable
4.11 Water Supply	❑ water supply unaffected ❑ water supply interrupted by flooding
4.12 Sewerage Facilities	❑ sewerage facilities unaffected ❑ sewerage facilities flooded
4.13 Electricity Supply	❑ electricity supply unaffected ❑ electricity supply interrupted by flooding
4.14 Other (eg fire,ambulance or hospital)	

Estimates of Flood Warning Time for Largest Known Flood	
4.15 Time between commencement of rainfall and initial flooding of urban area (hr)	

5 *Mappingof Past Flood Events*

Data Collection		
5. 1 Is historical flood data available?	❑ yes	❑ no
5. 2 If no historical flood data has been recorded, please give reasons.		
5. 3 If historical data is available, what is the data used for?		

Town Flood Gauge		
5.4 Does a town flood gauge exist?	❑ yes	❑ no

If "no" is the answer to the above question, please go to Question 5.10.

5.5 Length of Gauge Record (years)	
5.6 Gauge Height corresponding to zero flow conditions (m)	
5.7 Gauge Height at which water flows over the river banks (m)	

5.8 Max Recorded Gauge Height (m)	
5.9 Date corresponding to Max Recorded Gauge Height	

Flood Mapping	
5.10 Are the flood limits for the largest known flood available in map form?	❑ yes ❑ no
5.11 Historical Flood Mapping Method	❑ none ❑ paper plans ❑ GIS ❑ Aerial Photographs ❑ Satellite Imagery

6 *Flood Studies*

6.1 Has a hydrologic/hydraulic flood study been carried out for this community?	❑ yes ❑ no

If "no" is the answer to the above question, please go to Question 7.

6.2 Floods Studied	❑ 1 in 2 yr event ❑ 1 in 5 yr event ❑ 1 in 10 yr event ❑ 1 in 20 yr event ❑ 1 in 50 yr event ❑ 1 in 100 yr event ❑ other (please specify) ....

Probable Max Flood Event		
6.3 Has the Probable Max Flood Discharge been estimated?	❑ yes	❑ no
6.4 Has the Probable Max Flood Event been mapped?	❑ yes	❑ no

Designated Flood Event	
6.5 Adopted Designated Flood Event	❑ no designated event ❑ 1 in 20 yr event ❑ 1 in 50 yr event ❑ 1 in 100 yr event ❑ other (please specify) ....

Designated Flood Mapping		
6.6 Have the designated flood limits been mapped?	❑ yes	❑ no

6.7 Designated Flood Mapping Method	❑ none ❑ paper plans ❑ GIS ❑ Aerial Photographs ❑ Satellite Imagery

Total Number of buildings flooded by the Adopted Designated Event (Please estimate from the best data available)	
6.8 Residential	
6.9 Commercial	
6.10 Industrial	
6.11 Caravans & Mobile Homes	

Further Studies		
6.12 Has a Damage Study been carried out?	❑ yes	❑ no
6.13 Have Floodplain Management options been developed?	❑ yes	❑ no

7 *Flooding Policy*

7.1 Has a flooding policy been developed for this community?	❑ yes	❑ no

If "no" is the answer to the above question, please go to Question 8.

7.2 Hydraulic basis for flooding policy	❑ historical data ❑ adopted designated flood event ❑ other (please specify) …………………………………
7.3 Is the Designated Flood for residential buildings the same as the Designated Flood for commercial buildings?	❑ yes ❑ no
7.4 If the answer to question 7.3 is 'no', please explain policy decision	

7.5 Difference between allowable floor levels and designated flood levels (m)	
7.6 Allowable filling requirements	❑ adhoc individual approvals ❑ filling policy determined on the basis of hydraulic studies ❑ individual approvals based on developer demonstrating impacts ❑ other (please specify) …………………………………

7.7 Legislative mechanisms used	❑ Local Government Act ❑ Local Government (Planning & Environmnet) Act ❑ Water Resources Act ❑ River Improvement Trust Act ❑ other (please specify) ……………………………………

8 *Flood Mitigation Measures*

Flood Mitigation Measures used to reduce effect of flooding on community	
8.1 Structural	❑ Levees ❑ Flood Control Dams ❑ Retention Basins ❑ Flood Proofing of Buildings ❑ other (please specify) ……………………………………
8.2 Non-structural	❑ Building Controls ❑ Land Use Controls ❑ Flood Warning system ❑ other (please specify) ……………………………………

8.3 Funding for Flood Studies	❑ Commonwealth Government ❑ State Government ❑ Local Government ❑ other (please specify) ....
8.4 Funding for Structural Works	❑ Commonwealth Government ❑ State Government ❑ Local Government ❑ other (please specify) ....

9 *Current Level of Flooding Awareness*

9.1 Is the community aware it is located on a floodplain?	❑ yes	❑ no
9.2 Is the community aware it can be flooded?	❑ yes	❑ no
9.3 Are past flood levels indicated locally (eg flood markers)?	❑ yes	❑ no
9.4 Are public education/awareness programs or activities conducted?	❑ yes	❑ no
9.5 Is the community aware of counter disaster arrangements?	❑ yes	❑ no

Last Flood causing Flooding of Buildings	
9.6 Date of the last flood	
9.7 Max Height at the Town Gauge, if available (m)	
9.8 Estimated Average Recurrence Interval, if available	

10 *Flood Warning System*

10.1 Flood Warning supplied by the Bureau of Meteorology	❑ None ❑ Qualitative information (ie min/moderate/major flooding) ❑ Predicted heights at given locations ❑ other (please specify) ....
10.2 What use is made of the information supplied by the Bureau of Meteorology?	❑ None ❑ information relayed to the community unaltered ❑ information is interpreted and translated into predictions in particular areas ❑ other (please specify) ....

10.3 Does your Local Government maintain a local Flood Warning System for this Town/Community	❑ yes ❑ no
10.4 If the answer to Question 10.3 is 'yes', how is the flood information relayed to the affected community? (tick more than one box, if appropriate)	❑ door-knocking ❑ radio ❑ television ❑ loudspeakers ❑ other (please specify) ....

11 *Counter Disaster (Flood) Plan*

11.1 Does an Counter Disaster (Flood) Plan for this community exist?	❑ yes ❑ no

If "no" is the answer to the above question, you need not answer any further questions.

11.2 Is the Counter Disaster (Flood) Plan linked to any flood warning procedures?	❑ yes ❑ no
11.3 Was the Counter Disaster (Flood) Plan activated during the last major flood event?	❑ yes ❑ no
11.4 Was the Counter Disaster (Flood) Plan effective when last activated?	❑ yes ❑ no
11.5 Was the Counter Disaster (Flood) Plan reviewed after the last major flood event?	❑ yes ❑ no

11.6 Does the Counter Disaster (Flood) Plan use or contain information from flood studies?	❑ yes	❑ no

Definitions

Town/Community to be included in this study	Town/Community where the number of buildings at risk of flooding during the largest recorded event or during the estimated 1 in 100yr event is greater than 10
Flood	overbank mainstream flooding
Storm Tide	total water level caused by storm surge adding to the height of the astronomical tide
Residential	residences plus, where possible, number of dwelling units in blocks of flats
Commercial	retail outlets, service stations etc
Industrial	any large enterprise eg milk factory, port installation, extensive rail yards etc
Lifelines	roads rail links airport water supply sewerage facilities electricity supply
Flood warning time	time between the commencement of rain and the initial urban flooding
Designated flood event	flood event selected for planning purposes
Probable Maximum Flood	the largest flood that could conceiably occur at a particular location
Damage Study	study of damage costs associated with particular statistical flood events
Floodplain Management Plan	plan which details strategies for minimising flood damage on the floodplain based on economic, social and environmental factors
Flood Proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages
Average	the long-term average number of years between the occurrence of a

Recurrence Interval
flood as big or larger than a given eflood event

Counter Disaster Plan
plan prepared by Local Government, in accordance with Part 4 of the State Counter Disaster Organisation Act

Appendix 3

The Significance of Probable Maximum Flood Case Studies from New South Wales

Areas for which detailed residential (and other) damage estimates have been prepared are for the Hawkesbury-Nepean river system to the west of Sydney (Penrith to Windsor), Queanbeyan and Canberra and with less detail for several flood prone catchments in Sydney. With the exception of Sydney, these studies were undertaken in order to provide estimates of damage from dam failure but to undertake this work it was necessary to consider the worst possible case for river flooding, i.e. to the level of the PMF. The results presented below refer entirely to river flooding not to damage from potential dam failure. Much of the detail is reported in consultant reports to Sydney Water although a summary is given in Smith (1991). The third study was for the Georges River, Prospect Creek and the Upper Parramatta catchments in Sydney, this was reported in Smith et al. (1990). In this case the numbers of buildings were estimated from air photos in contrast to the dam failure studies which used databases from detailed field surveys of all buildings at risk.

Table A3.1 Numbers of residential buildings with overfloor flooding and failure from extreme floods for a selection of sites in New South Wales

	Total Urban	Rural*
(a) Hawkesbury-Nepean region		
1 in 100 year	1762 (67)	415 (237)
1867 floor	5411 (733)	555 (380)
1 in 1,000 year	10,602 (5090)	915 (563)
PMF	11,594 (7162)	915 (625)
(b) Queanbeyan (data collected 1987)		
1 in 10 year	3 (0)	
1 in 100 year	448 (N/A)	
1 in 2,000 year	1360 (992)	
PMF	1953 (1422)	
(c) Prospect Creek and Georges River (Data collected 1986. No information on building failure)		
1 in 20 year	1422 (N/A)	
1 in 100 year	2807 (N/A)	
PMF	5381 (N/A)	
(d) Canberra		
1 in 100 year	0	
1 in 2,000 year	76(1)	
PMF	750 (135)	

• Based on reconnaissance survey only.

Numbers in brackets indicate building failure, data collected early 1989.

The increases in the numbers of properties at risk from extreme floods in the study area is given in Table A3.1. the numbers at the level of the PMF are 4 to 6.5 times greater than for the 1 in 100 year event. In general terms the increases are related to the increases in stage between the 1 in 100 year and PMF. The best information on these stage increases is presented in Table A3.2. For instance, the increase of over 4.35m at Queanbeyan changes the number of residential buildings at risk from 448 to 1953. Table 3.7b lists a selection of sites in Queensland for which the flood range, in this case from the 1 in 20 to 1 in 100 year flood events, is known to be large.

Table A3.2 Increases in flood height from the 1 in 100 year flood to the PMF for a selection of sites in New South Wales

Hawkesbury-Nepean (at Windsor)	10.0+m
Queanbeyan	4.35 m
Prospect Creek and Georges River	4.0 m

Appendix 4

Flood Studies for the Brisbane Creeks

Brisbane
Flood mitigation schemes in Brisbane – an overview. BCC. 1989.

Bulimba Creek
Bulimba Creek flood study. BCC. 1992.

Cabbage Tree Creek
Flood mitigation study. Kinhill, Cameron, McNamara. 1991.

Cubbera Creek
Cubbera Creek flood study. BCC. 1996.

Enoggera Creek/Breakfast Creek
Reidel and Byrne. 1986.
Macdonald Wagner. 1988.

Gold Creek
Dam safety review. SMEC. 1993.

Kedron Brook
Kedron Brook flood study. Connell Wagner. 1995.

Moggill Creek (including Gold and Gap creeks).
Moggill Creek flood study. Sinclair, Knight, Merz. 1994.

Norman Creek
Norman Creek flood mitigation report. BCC. 1987.
Norman Creek flood study. Connell Wagner. 1995.

Oxley Creek
Oxley Creek and Stable Swamp Creek. BCC. 1981.
Oxley Creek system – flood mitigation report. BCC. 1984.

Sandy Creek
Sandy Creek flood study report. BCC. 1997.

Wolston Creek
Wolston Creek flood study. BCC. 1996.

Appendix 5

Effective Flood Warning Times for Flood Prone Queensland Locations

These data were provided by the Brisbane Office of the Bureau of Meteorology, in April 1997, as a specific contribution to the report into urban flooding in Queensland.

Effective warning time is classified into three categories:

A is less than 12 hours

B is 12-24 hours

C is greater than 24 hours

Effective warning time is an estimate of the river height prediction lead time currently available and is limited by climatological factor and/or flood monitoring networks and prediction tools.

The appendix also contains other information from the Bureau's data base, for example estimates of the number of flood prone properties, presence of flood gauges, key flood heights, the nature of the flood warning system etc. In some cases these are not identical to those given elsewhere in this report. The Bureau's data base is the most comprehensive available account of flood-related information for Queensland but it is stressed that some of the information is not necessarily precise. The Bureau would be pleased to receive additions or modifications to the information given.