

NATIONAL REAL-TIME FLOOD INFORMATION – CURRENT STATUS AND RECENT ADVANCES

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Abstract

The Australian Bureau of Meteorology is the lead national agency for flood forecasting and warning services in Australia, working in partnership with agencies at the State and Local Government levels. These services cover river basins with response times ranging from 6-12 hours through to very large basins with flood travel times of the order of weeks. Flash flood warning services are also provided. Technical development work is advancing across many areas and advances are gradually being included into the on-line system used for flood forecasting operations developed as an integral component of a larger meteorological operations and communications system. These include work on improving the rainfall inputs to the system through the quantitative use of weather radar, precipitation forecasts from numerical weather models and improvements to real-time data systems that facilitate regional scale data monitoring supporting local scale flood warning operations. This system, and the flood information it delivers will be described along with some recent advances to improve effectiveness. Issues influencing the effectiveness of these services will be discussed which include, in particular a need for closer community engagement and improved risk communication.

Key Words: flood information, flood forecasting, total warning system, warning effectiveness

INTRODUCTION

A recent study to determine the economic costs of natural disasters in Australia (BTE, 2001) showed that floods, with an average annual cost of \$314M, had the most significant economic impact of all types of natural disaster. Flood warning is one of the non-structural approaches used to mitigate the damaging impacts of floods and the Bureau of Meteorology takes the lead role in the provision of national flood forecasting and warning services. These services are delivered through Regional Offices in each State and the Northern Territory and are provided in close cooperation with State and Local Government agencies, who assist with the provision of key input data as well as undertaking the emergency management and response activities.

The Bureau of Meteorology's role is to provide relevant agencies and the general public with effective warnings of flooding. These warnings range from specific forecasts of river height and time of occurrence at agreed forecast locations, through more qualitative forecasts which describe flooding in terms of minor, moderate or major flooding and finally to more generalised warnings of flooding in areas where the risk is lower. Flood forecasting systems have been developed for most of the key river basins with systems now developed for 126 river basins and quantitative forecasts being prepared for 316 locations. Generalised warnings are provided for all other areas. A Flood Warning Centre (FWC) in each Bureau Regional Office located in the capital city of each State and the Northern Territory, is responsible for the development, operation and maintenance of the forecasting systems for that region. The concept of a total system approach is the model followed widely in Australia which recognises that, to be fully effective, flood warning services and information systems must be developed on a holistic basis (Figure 1) with a clear view of the ultimate purpose of the system. This total system approach has been actively promoted, especially through the development of national guides to best practice (eg. EMA (1995)) in flood warning and related areas such as flood preparedness and flood response.



Figure 1. Schematic of the Total Flood Warning System Concept

BUREAU OF METEOROLOGY FLOOD FORECASTING SYSTEM

The on-line operational system used for flood forecasting is shown schematically in Figure 2. This system forms part of a larger operational system (the Australian Integrated Forecast System or AIFS) implemented in every Bureau Regional Forecasting Centre (RFC) to support the full range of weather and hydrological services provided by the Bureau. The flood forecasting system has been implemented in every Regional Office across the country and has been designed so that it can be adapted to meet the different forecasting requirements (number of river basins) of each regional FWC. The system is continually being improved as advances are made through research and other development in the different elements of the system. The particular developments undertaken more recently have been:

- Improvements to the real-time data collection system, specifically the system to support local agency warning and response operations;
- Improvements in the area of hydrological modelling, in particular attempts to improve the quality of the hydrometeorological inputs used for modelling, and
- the growth of web-based exchange of data and delivery of services.

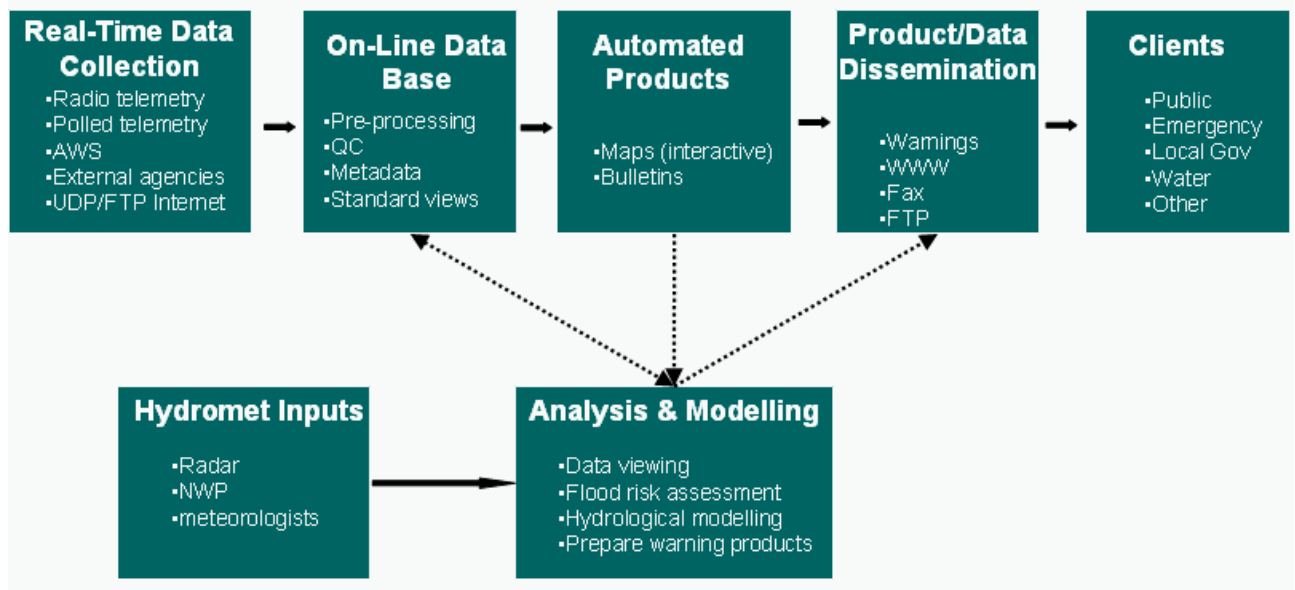


Figure 2. Schematic of Bureau of Meteorology Flood Forecasting System

Real-time data collection

The data used for Bureau flood warning operations comes from the Bureau's basic observing network, as well as a special purpose flood warning network. This latter network includes equipment operated by the Bureau, as well as that operated by State and Local agencies under the cooperative flood warning arrangements that are in place with these agencies. In total, these networks include a wide range of equipment types, data transmission methods and reporting characteristics. The systems used to collect this data in real-time are:

- Event-reporting via VHF radio telemetry and UDP/Internet;
- Polled systems (telephone landline, digital mobile, satellite);
- Computer-to-computer transfer from other agency databases;
- Rainfall data collected through other Bureau collection systems; either automated (eg. Automatic Weather Stations (AWS)) or manual (eg. Remote Observer Terminals).

All of this data is continuously fed into a set of Oracle relational data base tables in AIFS to form the on-line data base to support flood forecasting operations. The types of data held in these tables include rainfall (stored as a mass curve or as a period total), river level, battery voltage (for system maintenance), and water storage contents. Oracle "triggers" are used to continuously create other data types from this input data, including a table of the most recent water levels, regular period (hourly and 24-hourly) rainfalls from the rainfall accumulation data series, and rainfall totals since 0900 local time. General AIFS utilities are used to manage this data, including a communication monitoring facility to check problems with data communication; a manual data entry and editing tool and tools for maintenance of site metadata. In addition a general alerting tool is available to automatically alarm when preset threshold conditions for any observed data type is exceeded.

The ENVIROMON system

A particular feature of Bureau of Meteorology flood forecasting and warning services is the cooperative nature of data collection practices arising from national government policy on the way these services are to be provided. This policy can complicate the application of what are fairly standard data collection technologies, requiring a degree of innovation in some instances. A recent example of this is the software developed for managing the event-reporting radio telemetry system using a new system (known as ENVIROMON) which has been developed to better meet the needs of local cooperating agencies as well as the broader national requirements of the Bureau of Meteorology. This system has been implemented in over 100 local agencies and emergency

management offices throughout the country and provides local scale flood information in real-time to support flood management and response operations.

Flood warning information products

A range of flood warning information products are generated automatically from the on-line data base of rainfall and water level data. These products are then disseminated either by facsimile or, increasingly, using the Internet. They include:

- Bulletins providing tabular views of hourly, 3-hourly and 24-hourly rainfall data for stations grouped by catchment.
- Bulletins of water level data generated every hour for stations grouped by catchment and related to flood classification level, height above known road crossings, etc.
- Simple map views of the data showing rainfall and water level at different time intervals.
- Time-series plots of river data

All of these products are freely available on the Bureau external web site at www.bom.gov.au/hydro/flood. Water level and rainfall bulletins are also available to the public through the Weather-by-Fax system for a small charge.

A major component of the operational flood forecasting system developed on AIFS is the hydrological modelling system (HYMODEL) designed to support the full scope of the flood modelling task in a regional Flood Warning Centre. This system is used to make predictions of future flood levels which are used internally by Bureau flood forecasters to produce warning products but can also be fed direct to emergency management agencies.

Quantitative Radar-Rainfall Applications

The Bureau of Meteorology operate a network of 65 weather radars and have just been funded to install six new Doppler radars as well as to replace obsolete radars at 20 sites in the existing network. Although the radars are used extensively for severe weather and other forecasting services, to date the application of radar data to flood warning has been limited to qualitative applications. Research over recent years however is gradually building the capability to produce quantitative estimates of rainfall from radar and has resulted in the development of a system known as *Rainfields* which is used to serve rainfall data to operational flood warning models where catchments are under the radar. This system will gather data from all appropriate radars into a central location and produce gauge-calibrated rainfall fields at 15 minute intervals along with estimates of the uncertainty of these calibrated rainfalls. The system will run on a central server which will also support the preparation of short-term rainfall forecasts from the Stochastic Ensemble Prediction System (STEPS). STEPS will enable the preparation of probabilistic forecasts of rainfall, potentially out to 12 hours, which will be particularly useful for flash flood warning. This information will soon be available to external users via the Internet.

Use of Numerical Weather Model Inputs

The Bureau of Meteorology operates numerical weather prediction models at both a global and regional scale, generating quantitative precipitation forecasts (QPF) that can be useful to flood forecasting. In addition, products from a number of overseas operational centres are received routinely. More recently the Bureau has investigated a "poor man's" ensemble forecast for rainfall, in which QPF's from several models are combined. This approach is cheap and efficient and gives deterministic forecasts that are more accurate, on average, than any one of the component models. This information is being increasingly used in operational flood forecasting and is now available on the external web through the Water and the Land portal (<http://www.bom.gov.au/watl/index.shtml>) See also Fig 3).

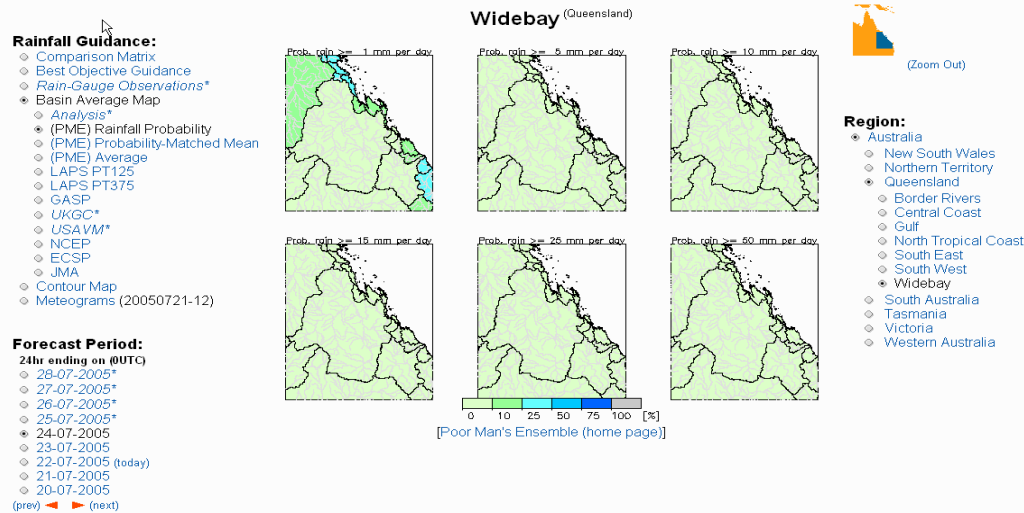


Figure 3. Sample of national rainfall forecasting guidance information for flood forecasting showing probability of rainfalls varying from 1 to 50mm per day for part of Queensland from the "Poor Man's" ensemble system.

Flood Information from Using Remote Sensing

There are many remote areas of Australia than can be significantly impacted by flooding. Communities in these areas, including indigenous communities are disadvantaged by high cost of living and the limited availability of services and facilities and flood monitoring by conventional means can be difficult if not impossible. These factors combine to make these groups quite vulnerable. To meet this particular challenge, the combination of the use of remote sensing imagery with hydrological and geospatial information coupled with local understanding of risk and flooding is being trialled in Northern Australia. The project, with funding support through the Natural Disaster Mitigation Programme, is being undertaken jointly by the Bureau of Meteorology and the Western Australia Department of Land Information (Ezzy and Buchanan, 2006) and aims to:

- identify the availability and suitability of existing and future remote sensing and geospatial technology for flood risk assessment and real or near real-time flood forecasting and warning in northern Australia;
- access, exchange and use early warning knowledge including traditional indigenous knowledge;
- ensure, or at least facilitate the incorporation of local needs (including local language requirements) capacities, cultural perceptions and traditional knowledge in local, regional and national initiatives; and
- develop on-line communication tools and decision support systems providing user access to project data sets and research outputs that support effective operations by disaster managers and the promotion of full and open exchange to, and feedback, from those at risk.

The project has produced the on-line FloodMap map service (<http://floodmap.dli.wa.gov.au>) developed to provide emergency services personnel and the communities at risk with an on-line map application to help in the management of floods. Future work planned includes the continued development of the on-line decision support system, including the use of additional real or near real-time data sets, improving the water mapping algorithm, investigating other remote data sensing sources and further developing the interaction between technical specialists and scientists with local communities within the Fitzroy and Stuart River basins.

ISSUES INFLUENCING EFFECTIVENESS

The performance of warning systems in recent floods has been varied and, while the absence of common assessment and performance review procedures makes conclusions about trends difficult, there does seem to be a common view that official flood warnings are not having their intended impact on community behaviour (see for example Pfister (2002)). To address this concern, a national workshop was convened by EMA to review and discuss the factors which limited current performance and to suggest what future action is needed. The workshop was held for three days (6-8 November 2002) and participants came from the State/Territory Emergency Services, the Bureau of Meteorology, state water and flood management agencies, catchment management authorities, consultants, academic institutions and the Australian Government Solicitor's office. An international dimension was provided by a representative from the National Flood Warning Centre of England and Wales. The workshop identified the following as areas for further action:

- The necessity for community engagement through increased education and awareness;
- The importance of recognising the target audience for flood warnings and the need to utilise this knowledge to improve the way that risk is communicated;
- The need for greater national consistency of practice, including standardising of terminology. This was closely linked with interest in an updated edition of the EMA flood warning guide;
- Investigation of the desirability of a national flood agency/a single national authority;
- The need for policy improvements in the area of flash flood warnings;
- The need for performance assessment that satisfies auditing agencies.

Improved Community Engagement

What is meant here is the need to understand how communities work, their needs when threatened by a flood and how they are likely to communicate information and respond to the threat. Improvement in community education, engagement and awareness was identified as the single most important action that could be taken to improve flood warnings in Australia, although it was recognised that this was difficult to do well.

Understanding communities is difficult but it is important to gain an in-depth picture of the community before attempting to disseminate information. Social mapping is a tool that can assist here. The value of a bottom-up approach to community warning system development involving community engagement has been discussed by Betts (2001). Looking at other sectors, the work of the Country Fire Authority of Victoria with its "Community Fireguard" approach was an example of the benefits of empowering a community with knowledge and an adjustment in roles whereby the authoritarian/expert becomes the community facilitator. The assembly of best practice guidelines (or expansion of the current EMA guidelines) with case studies of effective community engagement that promotes a warning model for communities that includes community ownership is one way ahead. Creating a national grouping of people involved in community flood education to share information, ideas and resources is another.

Individual examples of community engagement in planning and implementing flood warning systems can be found across Australia. Each involves some form of community consultation to develop a shared understanding of the flood risk. McPherson (2002) describes an approach followed in Victoria which involves a variety of community consultation forums and programs to provide an unrestricted and open opportunity for interested community members to participate, normally in a workshop-style forum. Although these may be successful in the short-term, a common problem has been to keep the awareness and involvement "alive" until the time of the next flood. At an agency level, the NSW State Emergency Service are very active at working to improve the effectiveness of their largely volunteer service in warning people about flooding by improvements to the gathering and use of "flood intelligence", reviewing different dissemination technologies and choosing the appropriate technology to match forecast severity, and formulating warning messages outside of flood time (Keys, 2004).

Risk Communication

The best ways to communicate risk at the local level, based on a sound understanding of user needs, was identified as the most pressing research need in the flood warning field. Some technological solutions were supported, based mainly around the Internet and the use of GIS capabilities. While these technologies may be part of the solution, the need to research issues to facilitate a seamless chain for managing and communicating

risks, including the management of uncertainty, was seen to be required. At the policy level, it was also considered important that Local Government be required to advise home owners and businesses of their exposure to flood risk, that flood prone land is openly identified and the legal position regarding obligations on organisations to pass on information on risk to the public be clarified.

Current work on improving the communication of risk is through the use of different presentations of the warning products, particularly through the use of GIS (Crowe et al, 2003). There has also been work to improve interpretation of predictions made for single sites into depths of inundation throughout the floodplain using hydraulic modelling, either directly or indirectly (eg. Babister et al, 2005). Risk communication however involves a social science dimension as well and there is no significant activity underway to complement the present largely technological solutions.

The Bureau has a special interest in improving the effectiveness of warning information in remote areas, including among indigenous communities. To address this, some research has been commissioned to identify the special needs of these areas and recommend appropriate strategies to improve risk communication to indigenous communities (Goudie 2004). Recommendations from this work included the use of simple "stick" figures in warning messages, the use of graphics from model simulations to communicate impacts, incorporating indigenous weather forecasts into mainstream forecasting data and developing "plain English weather warnings" for use in local radio networks. A further project to improve flood risk management in remote outback areas of Australia involves the use of remote sensing by satellite to both track and help predict the movement of floods which extend across many thousands of square kilometres. Representing these events in the form of remotely sensed images within the broader landscape is expected to enable communities to better assess their options on the basis of their extensive local and indigenous knowledge.

Institutions, Policy and National Consistency

A further action strongly supported at the workshop was the idea of improved national consistency and coordination, possibly through some form of national peak body. National consistency was needed to identify and promote the most effective warning terminology to ensure that all of the groups at risk had the benefit of best practice in this area. Furthermore, more nationally consistent terminology would ensure that the increasingly mobile population received consistent warning information. Consistent national approaches also produce efficiencies in being able to mount national level public education and awareness campaigns, rather than separate State or locally based approaches, which is already producing inconsistencies in some areas (for example, colour coding of flood maps). A National Flood Risk Advisory Group has recently been established as a working group under the Australian Emergency Management Committee to develop a more nationally consistent approach to flood risk management.

Flash Flood Warning Policy

The current flood warning policy treats warning for flash flooding (rain-to-flood times of 6 hours or less) in a different manner to other forms of flooding. Because of the limited lead time available, local involvement is more critical and so the current policy encourages the development of locally-based warning systems, facilitated by the Bureau. The Bureau supports these systems through the provision of specialised severe weather warning services and software such as ENVIROMON. There has however been an uneven adoption of this policy and the institutional arrangements for flash flooding are not as formalised as for other forms of flooding.

Performance Assessment

The workshop identified a need for improved approaches to flood warning system performance assessment. This includes post-event analysis to assess the effectiveness of warnings and response actions as well as the establishment of benchmark levels of performance to guide system design. Although different forms of assessment are carried out at present, there is no consistent approach that allows performance to be tracked, apart from the more technical aspects such as forecast accuracy. As pointed out by Handmer (2000), any assessment needs to start with a clear indication of what constitutes success and this needs to be agreed among

all stakeholders. An ongoing program of performance assessment will be useful to ensure continuous improvement and to assist in targeting resources to their most effective ends.

FLOOD IMPACTS ON BUSINESS

The impact of flooding on commercial and/or industrial businesses can be proportionately much greater than residential impacts and the economic value of flood mitigation correspondingly more significant. Wright (2001) undertook a detailed examination of the flood loss exposure of commercial and industrial premises in Keswick Creek in suburban Adelaide to assess the potential damage in the area and the likely impact of different flood mitigation measures, including flood warning. A total of 169 businesses were identified as being at risk, with 21 of these contributing 76% of the total flood loss exposure. A professional in the insurance assessment field was used to estimate the flood loss exposure for a sample of 12 businesses in the floodplain, and the potential value (effectiveness) of different flood exposure minimisation options including prevention (eg. water proofing) and preparedness (eg. flood warning) was estimated. The results are summarised in Table 1 and show that nearly 60% of the total direct flood loss exposure of \$36.8M could be reduced by preventative measures and around 16% (\$5.8M) by improved preparedness measures such as flood warning.

One of the objectives of the survey of businesses was to determine the value of a flood forecasting and warning system for Keswick Creek. While the survey did identify the potential benefits here, it was clear that before these benefits could be achieved it will be necessary to increase the level of flood awareness in the owners and managers of businesses, and for them to be ready to respond appropriately to minimise flood losses. So, accompanying the implementation of a flood warning system, it was recommended that there should be concentration in the initial stages on:

- improving the level of flood risk awareness;
- planning improvements for new development;
- self-protection for existing development;
- preparation of Action Plans by individual businesses;
- improved communication arrangements for flood warnings; and
- a program of training and education about flood risk for all who may be involved in floods and floodplain management.

CONCLUSION

The last ten years have seen significant improvement in many areas of flood warning in Australia. As discussed in the first part of this paper, the technical system has grown with predictions becoming more accurate and timely along with improvements in the presentation and dissemination of warning information, largely through the application of new technologies. Countering this however, has been the observation that the quality of warning outcomes has not improved to the same extent. The remainder of the paper has presented the outcomes of a workshop of stakeholders in the flood warning system aimed at identifying the reasons for this and proposes some ways forward. This involves a number of actions and areas for further research and includes a need for stronger national coordination. This outcome is not unlike those found in other similar reviews (see ISDR, 2002) and it is expected that there will be significant benefit from cooperative approaches to finding solutions through increased international cooperation.

Table 1. Direct Flood Loss Exposure and Potential for Flood Loss Exposure Reduction for a Sample of 9 Businesses in Keswick Creek, SA

Type of Business	Specialist Printer	Furniture Retailer	Nursing Home	Retailer Automotive	Furniture Retailer	Courier Service	Retailer Hobbies	Service provider	Courier	All Businesses
Size	Large	Medium	Medium	Small	Large	Large	Small	Medium	Large	
Building Cost	\$130,000	\$35,000	\$1,000,000	\$50,000	\$425,000	\$350,000	\$20,000	\$500,000	\$10,000	\$2,520,000
Contents	\$7,900,000	\$95,000	\$900,000	\$100,000	\$325,000	\$5,000,000	\$45,000	\$1,370,000	\$350,000	\$16,085,000
Stock	\$1,300,000	\$180,000	n/a	\$50,000	\$4,000,000	nil	\$335,000	\$80,000	\$500,000	\$6,445,000
Total Direct Loss exposure	\$9,330,000	\$310,000	\$1,900,000	\$200,000	\$4,750,000	\$5,350,000	\$400,000	\$1,950,000	\$860,000	\$25,050,000
Direct Loss Exp/Unit Area	\$1,736	\$282	\$525	\$167	\$220	\$3,147	\$1,832	\$363	\$261	\$8,532
Business Interruption	\$3,500,000	\$140,000	\$400,000	\$50,000	\$6,000,000	\$750,000	\$400,000	\$250,000	\$250,000	\$11,740,000
Total Direct Loss Exposure	\$3,500,000	\$140,000	\$400,000	\$50,000	\$6,000,000	\$750,000	\$400,000	\$250,000	\$250,000	\$11,740,000
Overall Loss Exposure	\$12,830,000	\$450,000	\$2,300,000	\$250,000	\$10,750,000	\$6,100,000	\$800,000	\$2,200,000	\$1,110,000	\$36,790,000
Floor Area (sq m)	5375	1100	3616	1200	21600	1700	218	5039	3300	
Damages per unit area	\$2,387	\$409	\$638	\$208	\$498	\$3,588	\$3,663	\$437	\$1,627	\$1,495
Flood Exposure Minimisation/Potential Effectiveness										
Prevention (eg waterproofing, etc) *3	50%	60%	30%	60%	80%	80%	90%	0%	0%	
Potential value*1	\$6,415,000	\$270,000	\$690,000	\$150,000	\$8,600,000	\$4,880,000	\$720,000	\$0	\$0	\$21,725,000
Preparedness (eg. Flood warning)	15%	20%	50%	40%	10%	5%	10%	50%	0%	
Potential value *2	\$1,924,500	\$90,000	\$1,150,000	\$100,000	\$1,075,000	\$305,000	\$80,000	\$1,100,000	\$0	\$5,824,500

Note *1 This is an estimate for each of the businesses sampled, of what can be achieved by flood proofing the premises, including attention to gaps in cladding, door seals, closing of wall penetrations, and sewerage etc.

Note *2 This estimates the additional benefit of flood warning. It is important to note that for some situations, flood warning is necessary to obtain the full benefit of sealing the buildings as outlined above.

Note *3 The percentage (%) indicate the estimated effectiveness of Prevention and Preparedness measures for each type of business considered.

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