

Resilience, vulnerability and adaptive capacity of an inland rural town prone to flooding: a climate change adaptation case study of Charleville, Queensland, Australia

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Abstract Australia is currently experiencing climate change effects in the form of higher temperatures and more frequent extreme events, such as floods. Floods are its costliest form of natural disaster accounting for losses estimated at over \$300 million per annum. This article presents an historical case study of climate adaptation of an Australian town that is subject to frequent flooding. Charleville is a small, inland rural town in Queensland situated on an extensive flood plain, with no significant elevated areas available for relocation. The study aimed to gain an understanding of the vulnerability, resilience and adaptive capacity of this community by studying the 2008 flood event. Structured questionnaires were administered in personal interviews in February 2010 to householders and businesses affected by the 2008 flood, and to institutional personnel servicing the region ($n = 91$). Data were analysed using appropriate quantitative and qualitative techniques. Charleville was found to be staunchly resilient, with high levels of organisation and cooperation, and well-developed and functioning social and institutional networks. The community is committed to remaining in the town despite the prospect of continued future flooding. Its main vulnerabilities included low levels of insurance cover (32% residents, 43% businesses had cover) and limited monitoring data to warn of impending flooding. Detailed flood modelling and additional river height gauging stations are needed to enable more targeted evacuations. Further mitigation works (e.g., investigate desilting Bradley's

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Gully and carry out an engineering assessment) and more affordable insurance products are needed. Regular information on how residents can prepare for floods and the roles different organisations play are suggested. A key finding was that residents believe they have a personal responsibility for preparation and personal mitigation activities, and these activities contribute substantially to Charleville's ability to respond to and cope with flood events. More research into the psychological impacts of floods is recommended. Charleville is a valuable representation of climate change adaptation and how communities facing natural disasters should organise and operate.

Keywords Adaptive capacity · Charleville · Climate change adaptation · Flood · Resilience · Vulnerability

1 Introduction

Disaster risk is an ever-increasing global problem, and hydrometeorological events make up the majority of disaster events (United Nations 2007). In terms of developed countries, Australia is considered one of the most vulnerable to the effects of climate change (Garnaut Review 2008). In Australia, these effects are increasingly evident in the form of higher temperatures, more frequent extremes, such as heat waves, bushfires, more severe, prolonged droughts and floods (McAlpine et al. 2009). During the last 30 years, floods in Australia have accounted for 29% of total natural disaster costs (BTE 2001) and cost the Australian community, on average, in excess of \$300 million per annum (BTRE 2002).

Factors influencing community recovery from disaster events are widely recognised as being complex. These include economic, physical, community, environmental, financial, psychological and emotional factors (COAG 2004; EMA 2004; Ministry of Civil Defence and Emergency Management 2004). Moreover, the nature and quality of communication and relationships between households, businesses and institutions can play a vital role in the vulnerability, resilience and adaptive capacity of these community groups and their ability to recover from disaster events.

Australian Governments use regional and urban planning, land use and development planning, building codes and a range of associated engineering standards for disaster risk mitigation and prevention. State and Territory Governments provide warning systems, planning and education, direction and support to local government bodies working within the disaster area (Williams et al. 2009).

In Queensland, the Government mitigates against the major impacts of natural disasters through instruments and planning regimes such as the South-East Queensland Regional Plan and associated Climate Change Management Plan, the State Planning Policy 1/03: Mitigating the Adverse Impacts of Floods, Bushfires and Landslides (SPP 1/03), Queensland *Sustainable Planning Act 2009*, *Disaster Management Act 2003* and various local government planning schemes and by-laws. The main legislation relevant to flood events and their prevention is the *Sustainable Planning Act 2009* that replaces the *Integrated Planning Act 1997* and places responsibilities on local government and the State Planning Policy 1/03. Considerable variation is found between how different Queensland Councils implement measures to prevent floods (e.g., setting minimum floor levels) (BTRE 2002).

More frequent and severe disaster events such as floods are placing greater strain on the resources and funding of emergency management agencies. Hence, it is imperative to gain a detailed understanding about how areas at risk can adapt and the vulnerabilities, resilience and adaptive capacity of these communities. Social capital is integral to

well-functioning societies. It relates to social networks, cohesion, trust and support systems (Geoscience Australia 2005) and how individuals organise to pursue common goals (Kaufman 1999, p. 1304). Data typically collected to measure it have included data on volunteerism, organisational memberships, contact with friends and family, and feelings of trust and safety in the community (ABS 2004; Geoscience Australia 2005; World Bank 2004). In Australia, in 1997, volunteerism activities alone were valued at contributing between \$24 and \$31 billion to society (ABS 2000). Coordination activities enacted in disaster response and people's willingness to cooperate are also considered aspects of social capital (Krueger et al. 2009; Putnam et al. 1993; Stewart et al. 2009).

1.1 Lessons learnt from previous flood studies

A review of international literature on flood studies revealed important insights as to how communities subject to flooding operate which are worthy of examination in climate adaptation research (refer below). More is currently known about the extremely complex and uncertain nature of the hydrometeorology of floods (Brilly and Polic 2005) and its technical aspects than about people's behaviour (Montz and Grunfest 2002). Researchers have emphasised the importance of studying people's behaviour, information needs, experiences and lessons learnt from past events. They suggest that community resilience needs to be built and self-protective behaviour promoted amongst community members to ensure their readiness and willingness to prepare for flood events. The public also needs to develop a realistic understanding of the threat of floods, be able to interpret flood risk information and understand the evacuation strategy. Flood risk information needs to be persuasive.

Residents in the March 2001 Grafton flood in NSW, Australia, were unprepared, did not have a realistic appreciation of the threat, nor understand the evacuation strategy, and less than 10 per cent of the population left during the 9-h evacuation (Pfister 2002). A study in Nimes, France, of the October 1988 flood that damaged 45,000 homes found only 17% of participants ($n = 187$) were aware they lived in a flood-prone area (Duclos et al. 1991). Migrants and new residents can be unaware of the risk of natural disasters and have difficulty in accessing and interpreting important information. The heterogeneity of populations at risk can add complexity to the designing of relevant and meaningful messages (Pfister 2002). People need to know what action they can take, how much it will cost and its likely effectiveness. Monetary flood damage can be reduced by around 80% in urban areas prone to flood by residents exhibiting self-protective behaviour (Grothmann and Reusswig 2006). A study of flood risk in Glomma, Norway, found less than half the participants would immediately obey an order to evacuate, and a third would wait and see (Krasovskaia et al. 2001). Decision-makers were found to have a poor understanding of the cost and effectiveness of measures to prevent floods.

Communities need strong and cooperative social networks and well-organised institutions. Operational briefs are important to identify areas for improvement and lessons learnt but do not generally capture the public's perspective (Pfister 2002). Lasting psychological consequences associated with disaster events are another public health issue in determining victim support (Verger et al. 2003). Research in the United States has found that in disasters communities rely on assistance from many authorities and organisations (Brudney and Gazley 2009; Gazley et al. 2009; McGuire et al. 2009), and there is a growing realisation that with the exception of smaller emergencies, no one organisation is capable of doing it all (Gazley et al. 2009).

This article presents an historical case study of the 2008 flood in Charleville, an inland rural town in Queensland, Australia, which is subject to frequent flooding. The aim of the

study was to understand how a community such as Charleville, which could become non-viable due to continued flooding, operates and its characteristics of vulnerability, resilience, and adaptive capacity. It involved personal interviews with householders and businesses affected by the flood and with institutions, disaster committees and community service organisations. The effectiveness of flood mitigation measures was also investigated. This study forms part of a national series of climate change adaptation case studies underway in Australia.

2 Method

This qualitative study focused on reconstructing an event rather than social modelling. Its main aim was to identify the characteristics of a society that is regularly flooded in terms of its vulnerability, resilience and adaptive capacity. Two types of data were collected, primary (using personal interviews and structured questionnaires) and secondary (through conduct of an extensive local and international literature review).

2.1 Study area

Charleville was chosen because it is a location where severe floods could, under climate change scenarios, become more frequent in the future. The town is also considered representative of a rural inland town, with a small population and economy, vast hinterland service area, basic infrastructure and slow population and economic growth. It is located on an extensive flood plain with no significant elevated areas for relocation and experiences frequent flooding, which leads to isolation and disruption of services. Charleville is 756 km west of Brisbane in the heart of Queensland's mulga country on the left bank of the Warrego River (Wagner 1991). Its climate varies from -3 to 21°C in winter and in summer from 27 to 46°C , with average rainfall of 450 mm (Lord 1982). It covers an area of 13,924 square km (ABS 2006a, b), lies within the broader region of the South-West Statistical Division and is the main town servicing a large area for the Central West and Warrego regions.

Most of Charleville lies on the flood plain which is constricted to a width of around 3.5 and 5 km upstream (Fig. 1). The Bradley's Creek catchment covers 200 km^2 and flows through Charleville running almost parallel to the Warrego River before it discharges into this river downstream of the town (Sargent 1991). These two water courses are monitored by automatic rainfall and river height monitoring stations: One located approximately 15 km east of Charleville at Raceview monitoring Bradley's Gully established in 2000, and the other located behind the Police Station on the Warrego River, established after the 1990 flood.

Charleville's population has grown from 58 in 1871 (peaking at 5,154 in 1961) (CGQ 2009) steadily declining to 3,278 recorded in the 2006 census (of whom 12.9% were indigenous, more than five times the national average) (ABS 2006a, b). This decline is reportedly linked to the downturn in the pastoral industry, fluctuating sheep-wool and cattle prices, a number of poor seasons and the effect of rising costs (Lord 1982).

2.2 Data collection

Both primary and secondary data were collected and analysed. Methods for collection and analysis are discussed below (see Fig. 2 below).

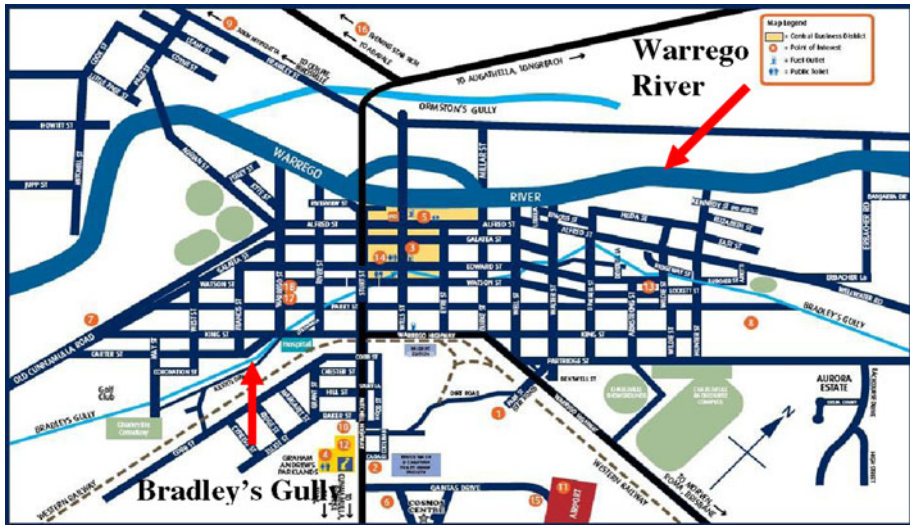


Fig. 1 Charleville town map (Source: Murweh Shire Council)

2.2.1 Primary data

A purposive sampling research design was used to conduct three phases of data collection of primary data, targeted at a different groups of stakeholders: household residents, businesses and institutions (see Fig. 2). Figure 2 depicts Charleville’s Governance Structure in terms of Emergency Management Institutions, and the rectangle labelled ‘Charleville Community’ depicts the community and its subgroups, viz., householders, businesses, and Local, State and Commonwealth Government Organisations and Community Service Agencies (whom we interviewed in our study). Structured questionnaires were administered in personal interviews to householders ($n = 55$), businesses ($n = 13$) and representatives of institutions, disaster committees and community services organisations ($n = 23$) in February 2010 in Charleville. To reduce inconvenience to businesses, questionnaires were dropped off and picked up a day or so later ($n = 13$). Householder and business participants were restricted to those affected by the 2008 flood. The questionnaires used in this study were adapted from one developed in the 1990s by James Cook University, Townsville, which had undergone further development in 2004 by the Bureau of Meteorology for post-flood studies. Questionnaire topics are outlined in Table 1.

Each of the three structured questionnaires contained the same 57 questions, but the institutional questionnaire had an additional 33 questions. These questions related to the roles played by institutions during the flood, issues that arose, details of financial assistance provided, action taken post the 1997 flood, future mitigation and 5 year plans to cope with future floods, and how they might spend additional funding if it was available. They were asked what they believe the community and other institutions need to do to better cope with floods and what needs to happen in the next 5 years to make Charleville a viable community in which to live and work.

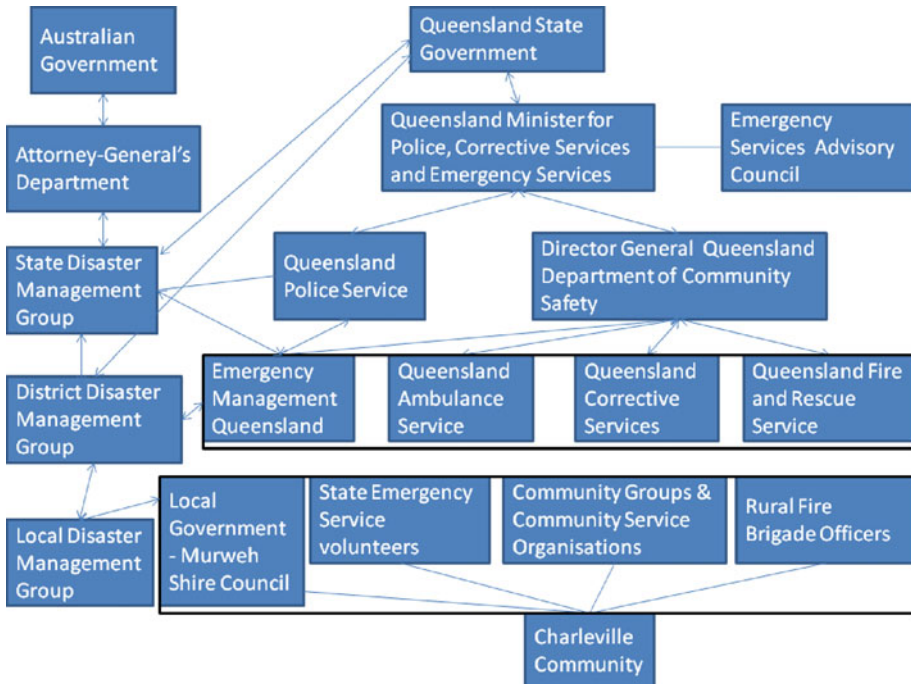


Fig. 2 Charleville Governance Chart of Emergency Management Institutions (Source: Adapted from Department of Community Safety (2009); Department of Community Safety (2011) and State Disaster Management Group (2010))

2.2.2 Secondary data

Reconstruction of the flood event and assessment of its overall impact were conducted from data and viewpoints from primary data (as above) and government agencies, media and local governments (Murweh Shire Council) and using secondary data, interviews and text analysis of news media. Records were consulted of previous and subsequent flood events in order to place the 2008 floods in context. Related international and local literatures were collected and reviewed, including Commonwealth and Queensland government reports, policy documents, manuals, newspaper articles, journal papers, media reports and web pages.

2.3 Data analysis

The collected data were analysed using appropriate quantitative and qualitative techniques. SPSS (Version 18) statistical software was used to create a database and generate basic descriptive statistics and cross-tabulation tables generated with data standardised as percentages and graphs. These simple cross-tabulations of qualitative data are clear statements of the impact, perceptions and attitudes towards the flood event. Qualitative data were analysed by grouping responses by common themes and linking responses to the relevant project objectives, with a focus on associating responses and interpretations with sample

Table 1 Overview of questionnaire topics relevant to the Charleville sample group questionnaires and sample sizes

Questionnaire topics	Householders (n = 55) ^a	Business (n = 13) ^b	Institutions (n = 23) ^c
Experience in the 2008 flood event	✓	✓	✓
Recovery after the flood	✓	✓	✓
Precautions taken before the flood	✓	✓	✓
Previous experience of flooding	✓	✓	✓
Warnings of the January/February 2008 flood	✓	✓	✓
Preparations before the flood	✓	✓	✓
Thoughts about floods (to aid public education campaign planning)	✓	✓	✓
Demographic information	✓	✓	✓
State Planning Policy 1/03 and Integrated Planning Act 1997 ^d	na	✓	✓
Assisting your clients during the 2008 floods	na	na	✓
Institutional preparedness for flood events	na	na	✓
How organisations and community members can better prepare for floods	na	na	✓
Maintaining Charleville as a viable community in which to live and work	na	na	✓

^a 65 householders were contacted and 55 agreed to participate (85% response rate)

^b 15 businesses were contacted and 13 agreed to participate (87% response rate)

^c 30 institutions were contacted and 23 agreed to participate (77% response rate)

^d This Act has now been replaced by the Sustainable Planning Act 2009

^{na} Survey questions relating to these topics were not considered relevant for these sample groups

group and community characteristics in terms of vulnerability, resilience and adaptive capacity, and evaluating the effectiveness of mitigation activities undertaken to prevent flooding.

3 Flood experience, resilience and adaptation

Householder, business and institutional survey results are discussed under each of the following sections: impact of the 2008 flood, vulnerability, flood mitigation measures, resilience and adaptive capacity. In reviewing these results, it is important to note that in Charleville at the time of the 2008 flood the single river gauge height monitoring station at Bradley’s Gully was not working, and this gully was the main source of flood water. Secondly, it is extremely difficult to obtain flood insurance in Charleville for households and businesses located on the floodplain, making them more vulnerable to economic losses.

3.1 Comparison of previous floods

The Warrego River (Figs. 1, 3) has a well-documented history of flooding with records of the larger floods dating back to 1910 (BOM 2009). In Charleville, more than 10 major

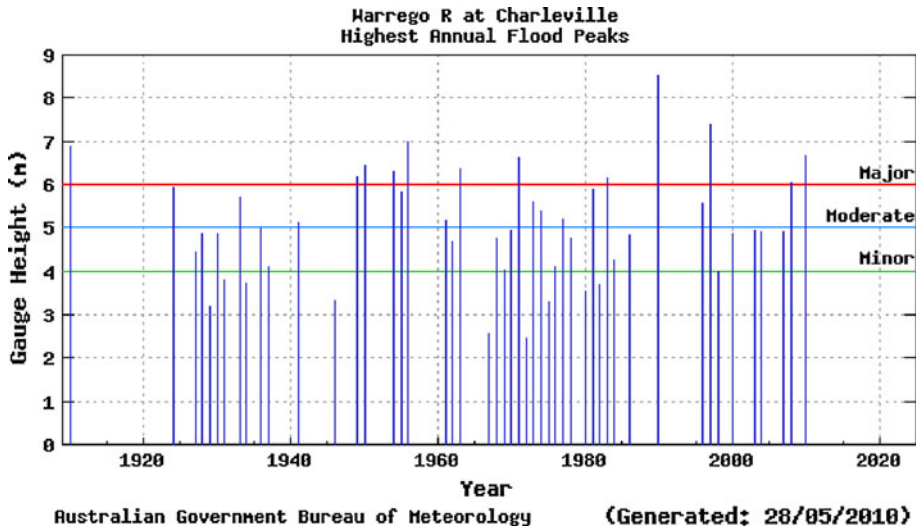


Fig. 3 Significant flood peaks at the Warrego River in Charleville (Source: Bureau of Meteorology 2011)

floods were recorded since this period that caused inundation of large areas, isolating towns and cities, including major disruptions to road and rail links. The significant flood peaks that have occurred at Charleville since records began are illustrated in Fig. 3, and major flooding has occurred in the region including a legendary flood in 1890.

Two major floods in Charleville's recent history occurred in 1990 and 1997 resulting from differing rainfall events. A significant flood also occurred in March 2010 (refer Figs. 3, 4), shortly after the completion of this study, when around a third of the population in Charleville had to be evacuated and flood waters from Bradley's Gully cut through the centre of the town (ABC 2010). Most of the region's highways were cut and infrastructure damage was estimated at \$7–\$9 million (ABC 2010). In 2011, Charleville has once again been affected by the Queensland disaster floods.

The 1990 flood occurred due to prolonged rainfall over a 20-day period, and the 1997 flood from a 6-day rainfall period (BOM 1997). The most intense 24 h periods of rainfall in 1990 at Charleville were much higher than those recorded for 1997 (BOM 1997). Flood river peaks for the Warrego River at Charleville were 8.54 m in the 1990 flood, and 7.39 m in the 1997 flood (BOM 1997). Unlike the 1990 and 1997 floods, the March 2010 flood at Charleville resulted from intense local rains of about 175 mm in 24 h at Charleville and in the nearby Bradley Gully catchment, with much less rain in the main Warrego River catchment above Charleville. Rainfall of 250 mm fell during 1–4 March and 100 mm fell in 8 h from 5 pm on 1st March, and this rainfall was widely distributed in the catchment (Sargent Consulting 2010). This rainfall fell on a catchment that was already wet and resulted in a large amount of runoff (Sargent Consulting 2010). Inundation of the Charleville Township was caused by a record flood in Bradley's Gully, and not by high flood levels in the Warrego River. In the 2010 flood, the peak flood level in the river was only 6.65 metres (BOM 2010; Sargent Consulting) which is almost 2 metres less than the 1990 flood and contained within the main river channel at Charleville.

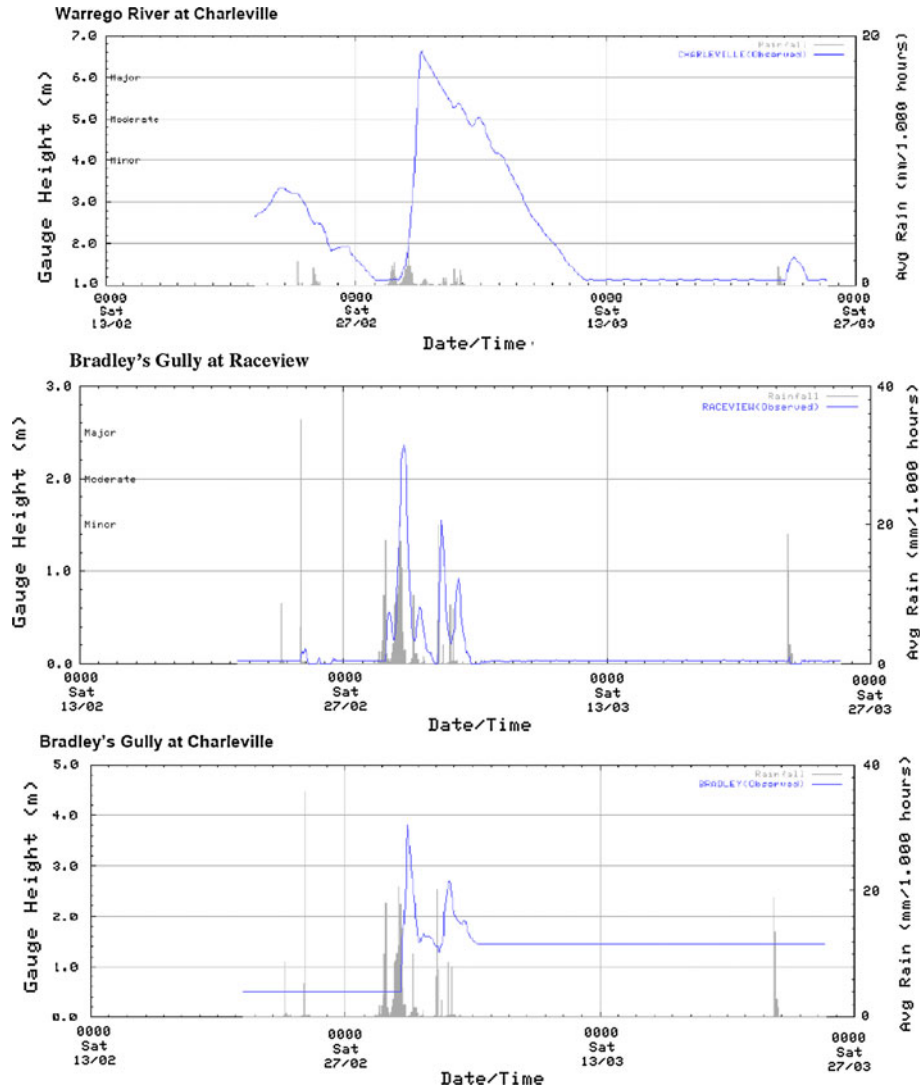


Fig. 4 Flood Hydrographs recorded during March 2010 for the Warrego River and Bradley’s Gully (Raceview and Charleville monitoring stations), Charleville (Source: Bureau of Meteorology (BOM) 2010)

3.1.1 1990 flood

In 1990, Charleville had no form of flood mitigation (BOM 2009). In April 1990, a wide area of Western Queensland experienced a record or near record flooding, and Charleville was the town most affected. All buildings in the business centre and 1,180 of the 1,470 homes were inundated, and most of the town was flooded to depths of 1.2–2 m up to 3 m adjacent to Bradley’s Gully (Sargent 1991). On 21st April, the Warrego River peaked at Charleville at 8.54 m, 1.5 m higher than the previous record height in 1956 of 6.96 m, with peak discharges estimated at around 3,000 m³/s (Sargent 1991). The State Emergency

Services (SES) coordinated the complete evacuation of the town to temporary accommodation at the airport (BOM 1990).

3.1.2 1997 flood

In western Queensland, during 28th January to 3rd February 1997, heavy rainfall fell resulting in major flooding in several catchments (BOM 1997). In Charleville, 780 people were evacuated due to major flooding, and about 60 properties were affected by flood waters which reached above floor level (BOM 1997). Repairs to flood-damaged buildings were estimated at around \$150,000 (BOM 1997). Rail and road traffic underwent severe disruption with large groups of travellers stranded at various areas in the flood-affected region (BOM 1997). Flooding in the Warrego River was so significant because at its peak at Charleville it was the highest recorded since the record flood of April 1990 and was the second highest on the flood record which commenced about 1900 (BOM 1997).

Charleville's flood warning system is for the Warrego River catchment (which covers approx. 65,000 km²) and major towns on this river are Augathella, Charleville, Cunnamulla and Wyandra (BOM 2009). Floods have been recorded at the Warrego River since 1910 (BOM 2009). In the Warrego River catchment, average rainfall exceeding 75 mm in 24 h (over isolated areas) and of 50 mm (over more extensive areas) can cause the stream to rise and possible minor flooding, lesser rainfall in the previous 24–72 h can lead to moderate to major flooding and 100 mm in 24 h will cause isolating flood in the immediate area where the heavy rain is received (BOM 2009).

3.2 Impact of the 2008 Charleville flood

In 2008, floods in Queensland cost the State and local Governments around \$234 million in damages to infrastructure when approximately one million square kilometres of Queensland (or 62% of the area) was underwater (Queensland Government 2009). In Charleville, between 10 and 20 January 2008, heavy rainfall fell along the Queensland coast between Mackay and Townsville, and inland over the Central Interior and Coalfields followed from a tropical low pressure centre which tracked a path across Queensland (BOM 2008a, b; EMA 2009). During 17–20th January 2008, Charleville experienced its biggest Bradley's Gully flood event since 1963. This gully flows through the middle of the town (Fig. 1) and flood waters reached 3.1 m, and funding of \$2.5 million was subsequently approved to reinstate the Murweh Shire road network to its previous condition prior to the flood, under Natural Disaster Relief and Recovery funding (pers. comm. Allan Pemberton, Murweh Shire Council, 2/11/09).

The 1990 and 1997 floods had been the impetus for the construction of Charleville's flood mitigation levee. The Charleville levee was designed to be constructed in two stages—the first stage to provide protection up to the 1997 flood level (approx. 1 in 80 Annual Exceedance Probability (AEP) plus various allowances) and the second stage up to the 1990 level; however, at present only stage one has been constructed which did not include its northern extension to prevent overflows from Bradley's Gully inside the levee, nor the Bradley's Gully diversion (Sargent Consulting 2010). At the time of the 2008 flood in Charleville, work on the levee was not fully completed; however, it did largely prevent flooding of the township from the river.

Flooding, however, did occur in lower-lying properties near Bradley's Gully. In mid-January 2008, power was cut for safety reasons to some areas of Charleville (EMA 2009). The NSW SES arranged a 'pallet barrier' that provided a temporary flood prevention

device to Charleville on 18 January, and a pallet manufacturer donated the 880 pallets needed to build the barrier (EMA 2009). About 40 businesses and residents in the lower-lying areas of Charleville and some hospital patients were evacuated (ABC 2008). Satellite imagery of the 2008 flood is not available, but Fig. 3 presents the record of flood peaks for Charleville recorded since 1900, placing the height of the 2008 flood in the context of long-term records, and a flood hydrograph for the 2008 flood showing flood/height versus date during January 2008 (Fig. 5).

The Charleville population was affected in the early hours of the morning, alerted by a siren. However, some residents due to their location were not able to hear the siren. The suddenness of the event caught people by surprise, and the majority of residents received warnings from Emergency Services and Local Council. The most common areas flooded were outside the home, in the block, garden, garage shed and outbuildings areas and just under half had water enter their homes (reaching up to 1 m inside these homes). Around three quarters of residents were forced to leave home, and most were able to return home within less than a month. Forty per cent of residents incurred personal or business costs as a direct result of the floods which were not covered by insurance. Eligible families in Charleville were assisted through the Natural Disaster Relief and Recovery Arrangements (NDRRA) grants totalling over \$446,000 in Emergency Assistance and Essential Household Contents payments.

All Charleville businesses interviewed suffered flood damage and flood water entered inside their business premises. Most were isolated by flood waters with the depth reaching up to 1 m inside their premises. Three quarters were able to return to the premises in 1–3 days and the balance within a week.

Sixty-eight per cent of householders and 57% of businesses did not have insurance cover, and business responses on the questionnaire indicate that it is virtually impossible to obtain insurance for flood for businesses in Charleville. Many of the business premises are situated on the flood plain area very close to Bradley’s Gully making them very vulnerable to flooding from the gully. Most businesses reported that they incurred expenses as a result of the flood which were not covered by insurance. These costs were estimated at \$375,000. Residents reported uninsured costs incurred of \$100,130. These small uninsured financial losses were likely minimised by the extensive effort expended by residents, businesses,

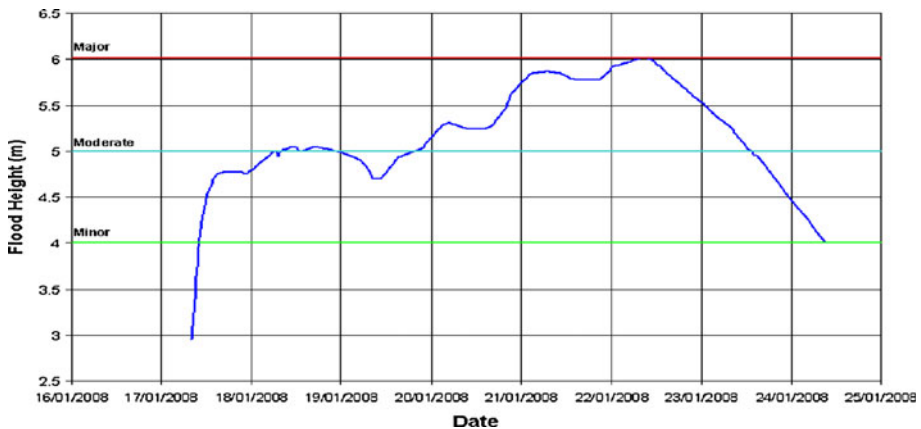


Fig. 5 Charleville hydrograph depicting flood/river heights during the 2008 flood (Source: Bureau of Meteorology)

institutions and the SES in preparation, recovery and response efforts which contributed to a successful emergency response. Charleville's well-functioning social and institutional networks, coordination activities and levels of cooperation make it a sound model of how towns facing future disasters need to organise and operate.

Institutions played a major role in response and recovery. They responded to calls for help, carried out minor rescues, measured water flows, pumped out low-lying buildings that had water, transferred hospital patients by air, provided policing and paramedic services, financial assistance and counselling. One Government department closed its offices for 10 days so that staff could provide volunteer help with sandbagging and other tasks. Low-risk prisoners also assisted and are now well thought of in the community. Institutional personnel hosed and washed out houses and used high-pressure hoses to clean houses and remove mud and other debris, took furniture to the dump, implemented strategies to stop mosquito larvae breeding in stagnant water, inspected hospitality businesses such as butchers for potential health issues, disconnected power, where necessary, and monitored people's assets and safety. Coordination and support activities included attending Local and District Disaster Committee meetings and updates, dealing with community issues, coordination efforts for different services, disaster management coordination, phoning insurance companies on behalf of residents overwhelmed by the event, providing support to the local SES, loans of vehicles and communications equipment, catering for evacuees and registration, helping people get where they needed to go and helped build the temporary levee. To build this temporary levee, engineering expertise was obtained from New Zealand. An emergency accommodation shelter was also established. Swift-water rescue personnel had to be brought in.

Difficulties arose with keeping children out of the water and from children floating downstream; there were a few snakes getting around and there was debris in the river. Sometimes people were reluctant to evacuate. Onlookers caused some problems getting in the way, and some drove through flood waters and created wakes, which were sometimes just enough to force a breach and result in water entering a house. There was a lack of suitable facilities for temporary housing of nursing home patients in the local hospital, staff fatigue occurred due to long periods of overtime, and there were issues of logistics and access. Communicating with rural residents is often via police, radio and distance Education School of the Air (who were reportedly on holidays at the time of the flood). Several institutions felt that some decisions made by staff in locations outside the local area would have been better made by local staff, and it was suggested that local people would be valuable for checking the validity of claims for funding in terms of those reporting they were affected by floods.

It was suggested that handing out food or food vouchers may be better than handing out money straight away, as it can sometimes be spent on alcohol instead of necessary items like food. The amount of paperwork involved in claiming financial subsidies for rural property fencing damage was said to have dissuaded claims. Sandflies were a problem, but water quality was not, and bore water does not usually become contaminated by flood water. The Council continued to sample water during the flood period. One organisation that did not have flood insurance incurred a lot of expense to rent temporary premises, and this reportedly affected their ability to deliver many of their programs and services.

3.3 Vulnerability

Vulnerability relates to *exposure* (how likely a hazardous event is) and *coping ability* (resilience and resistance) (Clark et al. 1998). People cope with hazards differently, and their vulnerability may relate to factors such as age, disability, ethnicity, income, family

structure and social networks, housing and the built environment. Many studies have shown that those aged over 75 years are considered a vulnerable sector of a population (Granger 1995; Blaikie et al. 1994). Sivell et al. (2008) suggest that societies need a plan showing where vulnerable people live. Settlement patterns and building codes can contribute to higher flood risk, as can the building’s construction. Communities with poor management or leadership, lack of disaster preparedness and planning and low levels of confidence about flood warning information are likely to feel vulnerable. New residents may have never experienced a flood, and migrants may face additional pressures and challenges, such as language barriers and the need to build social networks.

3.3.1 Householders

The main vulnerability of this sample group was the low level of flood household insurance cover (only 32% had flood insurance). This insurance is difficult and expensive to obtain, making them more vulnerable to economic losses in flood events. Some residents mistakenly believed their household contents insurance covered them for flood damage, whereas this was frequently not the case. Many homes are located close to Bradley’s Gully, making them vulnerable to flooding. Almost two-thirds of residents believe floods could pose quite a lot, or a great deal, of threat to daily activities (work, leisure, etc.). Close to half believe a damaging flood could occur in the future, and about three quarters believe this could occur during their lifetime. Groups householders believe are responsible for protecting them from floods included individual householders (whom they rated most highly), followed by Local Council and the State Government (Fig. 6). Most residents said they would not leave Charleville if affected by another flood (Fig. 7) nor move to another area of Charleville. Less than 15% of members of resident households had participated in local community groups related to flood or had written letters to authorities. However, almost a quarter had attended meetings about flooding.

3.3.2 Businesses

Close to a third of businesses did not receive any flood warning; however, most are confident about flood warning information. Two-thirds were aware of evacuation routes and centres, and about a third considered they were significantly or very prepared for the 2008 flood. Close to half rated the response of Local Council very or significantly responsive. The time between the first warning and the flood ranged from less than 1 to 24 h. Fifty-seven per cent of businesses did not have flood insurance, and many are located close to Bradley’s Gully, which makes them highly vulnerable to floods. They rely on easy

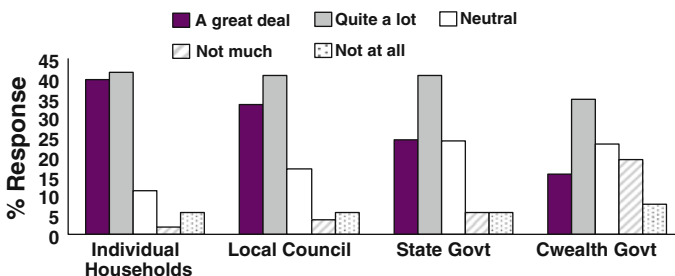


Fig. 6 Groups householders believe are responsible to protect them from floods (n ranges 47–54)

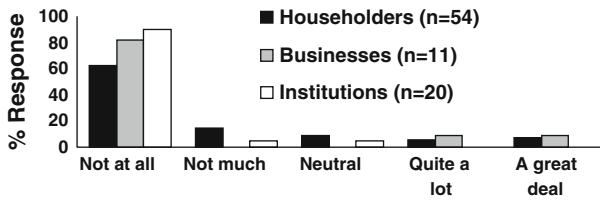


Fig. 7 Per cent of residents, businesses and institutions who would leave Charleville if affected by another flood (*n* ranges from 11 to 54)

access to the town for their custom; hence, moving out of town would not be an attractive economic option. They consider the risk of floods a threat to business activities, and they actively think about, talk about and source information on floods, and consider them a possible threat to personal safety. A small proportion of businesses would consider leaving Charleville if affected by another flood (Fig. 7) or would relocate within the town. Although this proportion may be considered low, if these businesses left Charleville, it would have a quite significant effect on such a small community. Almost 70% strongly believe a damaging flood could occur in the future, and 91% believe it could happen in their lifetime. Most respondents were Managers or Directors/Owners, 70% were women and all were of non-indigenous descent.

3.3.3 Institutions

Representatives of Local, State and Commonwealth Governments, Community Service Agencies and members of Local and District Disaster Committees were interviewed. Most had experienced between 1 and 3 floods and considered the 2008 flood not as severe as that experienced in 1990. Only two institutions were affected by the 2008 flood. One evacuated for 5 days, and the other was situated close to Bradley's Creek and underwent severe inundation and had to relocate to temporary premises for 6 months. This relocation affected their ability to service their clients and deliver programs. Flood waters inside the institutional premises ranged from 130 to 1,500 mm. Few institutions would consider leaving Charleville if affected by another flood event (Fig. 7), and similar proportions would relocate within the town. They considered flood warnings and information accurate and most received warning of the 2008 flood from Emergency Services and Local Council.

About half received the first warning more than 24 h before being affected by the flood waters. They found the most helpful forms of communication for updates were radio alerts, the Bureau of Meteorology website, SES workers and a message sent to their mobile by Murweh Shire Council. Most considered they were prepared for the 2008 flood (70%), and 93% were aware of the evacuation routes and centres. Most believe floods are likely to occur in their lifetime, and there is a need to be prepared for floods. Institutions in Charleville are very committed to remaining in the town and employ between 2 and 150 staff, and two-thirds have operated in Charleville for more than 10 years. Seventy per cent of respondents were men and 15% were of indigenous descent, most were tertiary qualified.

3.4 Flood mitigation measures in Charleville

One of the objectives of this study was to understand the extent to which flood mitigation measures have been applied to reduce vulnerability to flood events, and how these might be improved.

3.4.1 *Householder mitigation measures*

During the 2008 flood vehicles were the most common items moved to higher ground, other items included washing machines, freezers and fridges. A small proportion of residents sampled raised the floor level of their house as a mitigation activity (9%) and just over half moved irreplaceable items above ground level. Almost three quarters regularly carried out maintenance to ensure ditches and drains around their property were clean and free of debris. Fifty-eight per cent of residents had copies of local flood plans of the area or were aware they are in a flood-prone area. Many did not have a household Evacuation Plan, Emergency Plan or Emergency Kit (56, 69, 67%, respectively), and only 32% had flood insurance.

3.4.2 *Businesses mitigation measures*

The most common items moved were vehicles and outdoor equipment, fridges, freezers, chemicals and poisons. Businesses turned off utilities, locked premises and raised furniture. Emptied freezers, put sandbags in the bathroom, and evacuated with the Emergency Kit using the evacuation route. Forty-three per cent of businesses had flood insurance. Some businesses had raised their floor levels as a mitigation activity prior to the flood, and this group tended to be very vigilant in terms of maintaining ditches and drains around their property, keeping them clean and free of debris and in moving irreplaceable items above ground level (92 and 84%, respectively).

3.4.3 *Actions taken by institutions after the 1997 flood*

Most institutions (90%) had taken action to prepare for floods post the 1997 flood. These actions included conducting training, reviewing and preparing emergency supplies, desktop and mock exercises, the establishment of roles, attending meetings e.g., District Disaster Committee Meetings, revisiting their Disaster Management Plan, conducting workshops. Information brochures were also translated into Vietnamese for this migrant group and distributed to Emergency Management Queensland (EMQ) and the Red Cross. Computers and equipment were moved, including a generator to higher ground, airconditioning installed in an operation room, desks were purchased with steel legs and carpet squares to replace carpet (easier to move in a flood). Major mitigation works carried out since the 1997 flood included partial construction of a levee bank, development of flood-free residential real estate areas, desilting and clearing the Warrego River and installing permanent disaster communication lines. Risk management studies and a regional task-force were also deployed for assistance. Few institutions provided an estimate of the cost of these actions, and of the two who did, the total cost was estimated at \$30,000. Three organisations indicated that prior to the 2008 flood they had tested their mitigation strategies, and only one organisation said that they found their mitigation planning and strategy had proved useful in coping with the 2008 flood.

3.4.4 *Institutional mitigation measures*

Prior to the 2008 flood, mitigation activities included moving vehicles and outdoor equipment to higher ground, moving chemicals and poisons, freezers and fridges. Prior to evacuating, others raised furniture, documents and other valuables onto tables and roof spaces, locked premises and took emergency and evacuation kits, turned off power, water

and gas, and emptied freezers and refrigerators leaving doors open. Few had Emergency Plans (14%), Emergency Kits (35%) and Evacuation Plans (25%), suggesting that this could be a potential area for improvement.

3.4.5 Mitigation measures suggested by Institutions post-2008 flood

Institutions suggested that more river height reading stations and other warning devices are needed on Bradley's Creek, the Warrego River and the Nieve River and better data including flood mapping and risk assessment using manual or automatic systems. Bradley's Gully needs to be desilted, and community education programs and training for SES volunteers are needed. An estimate provided for the initial cost of implementing these mitigation activities is \$2 million, with a recurrent cost of \$100,000. It was also suggested that a review of laws with respect to electricity line clearance during emergencies such as during flooding is needed.

The Murweh Shire covers 43,905 km² and includes the towns of Augathella, Charleville, Cooladdi and Morven situated in the Great Artesian Basin. In Charleville, the Murweh Shire Council has a flood overlay as part of the Town Plan. The industrial area in Charleville is outside the flood-prone area, and new commercial premises in the flood area are required to have an upstairs area or an Evacuation Management Plan. The *Murweh Shire Council Planning Scheme* (2005) requires habitable dwellings to be above the 1 in 100 Average Recurrence Interval (ARI) flood level for the site. The Building Code of Australia and the Queensland Development Code (DIP 2008) set out building standards that recommend building at least 300 mm above ARI 100 flood height, and the Council is using the Queensland ARI 100 flood height. The Murweh Shire Council is using the last known flood height (that is 300 mm above the 1997 flood height level) as the Defined Flood Event (DFE). Council has a social, moral and legal responsibility to care for its aged citizens and there would be concerns if the houses of elderly residents had to be raised on stumps, compromising their accessibility and their having to use steps to enter the house. There would be concerns as to how elderly residents would cope with the raised level of the house. A further concern has been the increased confidence amongst some residents in building on a concrete slab, since the construction of the levee. The construction of the levee may have contributed to a false sense of security that has eroded the willingness of people to construct high set houses.

3.5 Resilience

Resilient communities must be able to demonstrate the ability to buffer the event, self-organise before, during and after, and adapt and learn from the event (Trosper 2002). Residents who have lived for a number of years in a community who have a strong sense of belonging and community and feel confident about the capabilities and organisational ability of their institutions are likely to have high levels of resilience and well-developed social networks. Social sources of resilience can include social networks (Eriksen et al. 2005), social security payments, lessons learnt from past events (Finan and Nelson 2001; Nelson and Finan 2008) and consensus building (Brown et al. 2002). Resilience may not necessarily involve physical measures or spending significant funding and can be attained through changes in awareness, procedure and management (Sivell et al. 2008). Resilient societies have individuals and networks that are both resilient (Sivell et al. 2008). Economic resilience is concerned with business resilience e.g., the nature of the business and its practices, flood defences, transport utilities and how many businesses have climate

adaptation strategies and insurance against extreme weather events (Sivell et al. 2008). To date, community resilience has been difficult to accurately measure or quantify (McIntosh et al. 2008).

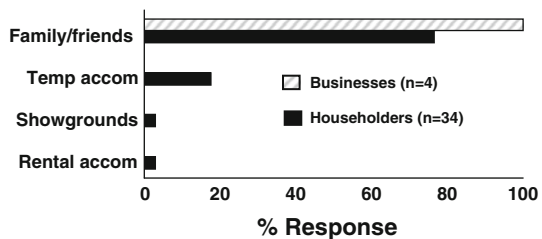
3.5.1 Resilience of Charleville residents and businesses

The study found that more than 60% of residents had lived in Charleville for over 10 years. Residents displayed high levels of resilience as we found strong personal networks (evidenced by 77% of residents evacuating to family or friends during the flood, Fig. 8), high levels of sense of belonging in the community and participation in community activities. Over a third of residents are tertiary qualified and almost half are employed full time. Research has found those working full time who are educated are usually less vulnerable (Anderson-Berry and King 2005). Residents believe they, as well as Local Council, are responsible for preparing for floods. Low rates of formal volunteerism were found, but based on the study results, there is a suggestion of high levels of community spirit, and strong informal volunteering networks. Most businesses had operated in the area for over 10 years and had substantial formal volunteer rates of around 54%. This group’s main non-resilience characteristic related to its low levels of insurance cover, as discussed under vulnerability. Many businesses said they are reluctant to move out of town as they will lose substantial business and need to remain close to town for the convenience of customers.

3.5.2 Recovery

After the 2008 flood, 920 families in the Charleville area were assisted with NDRRA (Natural Disaster Relief and Recovery Arrangements) grants administered totalling over \$446,000 in Emergency Assistance and Essential Household Contents Grant payments (pers. Comm. Jill Peters, Community Recovery Unit, Queensland Department of Communities, Brisbane, 23/12/2009). Concessional loans paid out to primary producers under NDRRA related to 5 applicants, and the total assistance provided was \$0.658 million; 23 small business grants valued at \$0.298 million and 96 primary producer grants valued at \$1.341 million were also paid out (QRAA 2010). The estimate to restore essential public assets for Local Government by the Department of Infrastructure and Planning was \$2,526,835; EMQ counter disaster operations costs for Murweh Shire were \$216,000 and \$482,000 for restoration of essential public assets for State Government; no freight subsidies were paid out to primary producers by the Department of Employment, Economic Development & Innovation (pers. comm. Stephen Hinkler, Queensland Department of Community Safety, 18/1/2010). Estimates of total general insurance claims for the 2008 Charleville flood are not available.

Fig. 8 Where residents and businesses evacuated to during the 2008 Charleville flood



Disease outbreaks following flood events in Australia are not common; however, there is an increased risk of infection if direct contact is made with polluted waters, which can cause conditions such as conjunctivitis, dermatitis, ear, nose and throat infections, wound infections, and risks can increase for diseases such as dengue fever, diarrhoeal diseases, leptospirosis and melioidosis (QH 2008). The South-West Health Service District at the Charleville Base Hospital reported that presentations to the hospital's Emergency Department rose in the March 2008 quarter to 1447, up from 1190 in the December 2007 quarter, and falling to 1091 in the June 2008 quarter; however, the hospital's clinical coder advised they were not able to identify admissions specifically related to the 2008 flood (pers. comm. Sarah Charwood, Queensland Health, 4/1/2010). Most deaths occurring in Australia are as a result of people walking, swimming or attempting to drive through flood waters (QH 2008). No deaths were recorded in Charleville that were directly related to the 2008 flood.

3.6 Adaptive capacity

Adaptation involves change and the practice of individuals, communities and societies as they adjust their locations, life courses and activities to maximise new opportunities (Nelson et al. 2007). Adapting to environmental change can involve adjustment in social, ecological, or economic systems in response to expected or observed changes in the environment, and their impacts and effects, to alleviate adverse impacts (Berkhout et al. 2006; Janssen 2006; Smit and Wandel 2006; Pielke 1998). Examples of adaptive actions include selling assets (Eriksen et al. 2005); livelihood diversification and insurance schemes (Finan and Nelson 2001; Nelson and Finan 2008); developing community-based resources and consensus building for future zoning (Brown et al. 2002); regulatory changes such as enhancements to building codes and zoning, developing plans and committees (Tompkins 2005).

3.6.1 Adaptive capacity of residents

Residents were found to be heeding practical advice provided on floods, such as checking electrical appliances before use and boiling tap water. Boiling tap water is less of an issue in Charleville as their supply is bore water, whose quality tends to be less affected by events such as floods. Increased numbers of Charleville residents intend to move irreplaceable items above ground level in the future and more than three quarters will continue to keep ditches and drains around their properties clear and free of debris. Most residents would not move to another town if their property was affected by another flood (Fig. 7) or relocate within Charleville. Comments were made that some residents had suffered psychologically from past flood events (particularly the 1990 flood). The decision to stay in a community may be more about resilience, whilst a decision to move, rather than indicating a lack of resilience, may be considered an adaptive response. The definition of adaptation used in this study stresses change and includes change in location as an adaptive response. If large numbers of residents or businesses left the town, the impact on Charleville would be considerable.

Residents rated Government and community groups highly in terms of their preparedness for future flood events, suggesting strong levels of capacity amongst these groups (Figs. 9, 10). They rated the preparedness of State Government, utility providers and their Local Hospital highly (78, 59 and 49%, respectively) (Figs. 9, 10). Little

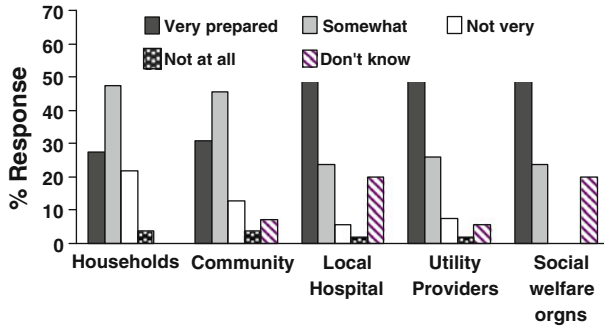


Fig. 9 How prepared householders believe these Charleville groups are for future floods (n = 55)

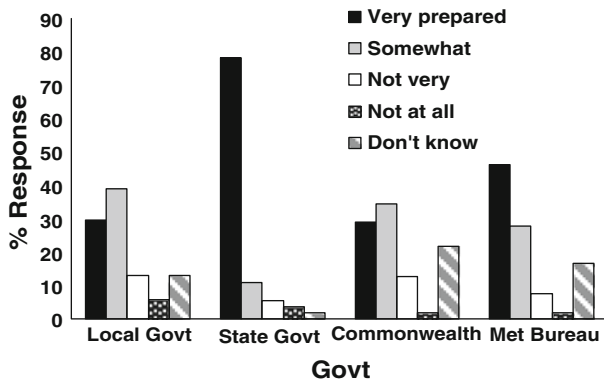


Fig. 10 How prepared householders believe Government institutions are for future floods (n ranges from 54 to 55)

evidence was found of factors that may weaken their adaptive capacity (apart from low levels of flood insurance, mentioned previously).

3.6.2 Adaptive capacity of businesses

Businesses had also heeded practical advice on floods, such as boiling tap water and having electrical appliances checked before use. Most said they intend keeping drains and ditches free and clear of debris and will be moving irreplaceable items above ground level. This group appears to have strong networks with others in terms of cooperation. Most businesses would not move out of Charleville or relocate within the town if there was another flood event. Whilst the number who may consider relocation is low, the impact of 18% of businesses moving due to concerns about future floods could have a large impact on the town. Businesses saw cost as a barrier in terms of preparing for future floods, and they have other things to think about apart from floods. They believed the community and households could be better prepared for future flood events (Fig. 9). Few businesses indicated they intend joining groups to discuss flood risk. Many were unsure how prepared different government and community groups were for future floods.

Table 2 Recommendations by study participants to better cope with future floods events in Charleville

Key characteristic	Recommendations by study participants
Vulnerability	<p><i>Improve flood modelling and warning systems:</i> Improve flood modelling and warning systems, more warning devices upstream in the Warrego River. Strategic placement of additional river height monitoring stations. Develop an improved warning system that can be heard all throughout the town, supplement with door knocking and consider sending SMS messages for flood warnings</p> <p><i>Mitigation works:</i> Engineering assessment of Bradley's Gully in Charleville and impact of upstream catchment practices. Investigate desilting of Bradley's Gully (estimated cost \$500,000); Regular monitoring, clearing and desilting of the river and Bradley's Gully. Install more river height reading stations on Bradley's Gully, Warrego River and Nieve Rivers (estimated cost \$50,000–\$100,000)</p> <p><i>More affordable insurance products:</i> support with evidence of improved mitigation works additional river height monitoring stations</p> <p><i>Animal housing during floods:</i> Set aside areas for use in floods to house domestic and rural stock, so different types of dogs, house cattle, etc., can be separated to reduce animals deaths</p> <p><i>Install evacuation signs:</i> e.g., Erect signs saying e.g., Evacuation area 1 so residents know where they need to go</p> <p><i>Map vulnerable populations and regularly communicate info in the media:</i> Be more targeted in evacuations with plans showing the location of vulnerable populations. Maintain regular information in the media re what needs to be done and what different people's roles are; ensure one person is the key contact for all flood information</p>
Resilience	<p><i>Promote resident responsibility to prepare for floods:</i> Promote the importance of self-protective behaviour</p> <p><i>Additional professionals to help with overtime:</i> Provide relief staff e.g., nurses, police and key professionals to help during flood events to manage overtime and staff fatigue.</p>
Adaptive capacity	<p><i>Developing info resources:</i> Develop info which lists who they call if they need help and detailing what they can do to prepare for, Regular community education program</p> <p><i>Resources for new people to area:</i> Develop flyers on what to do to prepare for floods for new people to the town, including information translated into other languages for migrants</p> <p><i>Continue with translations of information for non-English speakers:</i> continue translating important materials and investigate the possibility having more translators in Charleville</p> <p><i>Swift-water and other flood boat training:</i> Provide swift-water rescue training for SES volunteers and Fire & Rescue personnel. Review all the major training e.g., flood boat training for 3 levels—flood and fast moving water. Ensure the Queensland Ambulance Service (QAS) is in the communication network of organisations that receive information on roads cut to help them plan their service delivery. Road cuts can severely impede the work of the Charleville QAS who do not have helicopters permanently based at Charleville to get to sites.</p> <p><i>Planning and partnerships:</i> Annual mock exercises, training and update recovery plans, Annual, and continuous training, including of new staff. Planning for major events, detailing the chain of command, reviewing what worked well and what didn't. Allocating staff to support local government and help the SES and work with the local people</p> <p><i>Do not discard furniture/whitegoods, managing clothing donations:</i> People not throw out furniture but use this furniture until they obtain new furniture. Also, sometimes whitegoods can be repaired. People need to be dissuaded from sending clothes to the Charleville railway station, as during the 2008 flood around 30 crates of donated clothes arrived there that were not needed and they did not have the people to handle all those clothes. Clothing donations need to be sent through to an organised group.</p> <p><i>Replace financial handouts with food and food vouchers:</i> Discontinue financial handouts and replace with food and food vouchers</p>

The community's adaptive capacity could be vastly improved by solving the Bradley's Gully problem and implementing other mitigation measures and more river height gauging stations to improve monitoring and reduce flood risk. To enable residents and businesses to access more affordable flood insurance, documentation may be needed to persuade the insurance industry of the reduce flood risk due to new mitigation works, better flood modelling and additional river height gauge monitoring tools.

3.7 Recommendations by participants to better cope with future floods

Future actions recommended by study participants are summarised in Table 2 below. Institutions suggested improved catchment flood modelling and planning is needed, better warning systems; further specific mitigation measures, best practice catchment management; localised decision-making; ongoing publishing of information and education; greater departmental cooperation; managing onlookers; more commitment from insurance companies; employing more apprentice plumbers and promoting rail as a service option.

4 Conclusions

This historical case study is one in a series of case studies of extreme events in Australia investigating the adaptive capacity of communities and includes a study of the 2008 flood event in Mackay (Apan et al. 2010). These case studies seek to understand how communities coped with different extreme events and their capacity to cope should more frequent events occur due to climate change.

Our study makes a significant contribution to understanding how a community that is regularly flooded copes, their characteristics of vulnerability and adaptive capacity, resilience and attitude to risk. These characteristics are likely to be present in other small inland rural communities in Australia and developed countries facing extreme events. The Charleville population exhibited a strong sense of personal responsibility to protect themselves and reduce their vulnerability and, in terms of resilience, a determination to remain in the town even if another flood event occurred. Their supportive community ensured that most people were able to evacuate to family or friends rather than to evacuation centres and study participants recommended a number of actions to improve their town's adaptive capacity. The small community of Charleville with just over 3,000 people demonstrated that they are staunchly resilient and possess high levels of social capital in the way their community operates and how they collectively responded to the flood event. They indicated that they are prepared to meet the challenges associated with future flood risk, despite the likelihood of continued risk to their community, businesses and institutions.

Charleville was found to be a useful model of climate change adaptation and how towns facing natural disasters should organise and operate. The findings of this study have implications for the international context.

Firstly, it was found that the strength and quality of connections and relationships within and between social and institutional networks in areas regularly affected by this natural disaster can substantially impact on a community's ability to cope and recover. Communities in high-risk regions need reliable, quality scientific monitoring and modelling data to inform them about the risks and the probabilities associated with these risks. These data can aid preparation of accurate warning information and more targeted evacuations. Residents and organisations need to receive timely information that is accurate and which

they are confident about. Land use planning also needs to be informed by appropriate and regular scientific data and debate.

Secondly, the increasing number of natural disaster events occurring worldwide means that additional financial and resource pressures are being placed on governments to support mitigation and recovery. In some locations, they may need to support multiple disaster events in the same location at short time intervals. Hence, the community needs to be convinced that they have a personal responsibility to prepare for the event and for personal mitigation activities. They need to be advised about the structural and non-structural options available to them, what they cost and how effective they are likely to be. Government agencies with the major responsibility for protecting residents need to ensure mitigation works are at least adequate and that the insurance industry is providing fair and equitable products to areas affected by natural hazards.

Thirdly, strain on professional staff working excessive overtime during these disaster events can lead to fatigue and agencies need to ensure adequate relief staff is made available and budgeted for.

Fourthly, community members who have experienced flood events are better prepared and therefore it is important to provide regular information to new people to the affected area, and have this information translated into other languages for migrants. Such preparation can reduce losses and possibly save lives. People need to know what they can do and who they can contact in an emergency.

Fifthly, vulnerable populations such as aged care residents and animals, including domestic animals, need to be housed in temporary accommodation that is suitable for their needs, with appropriate facilities. Spatial mapping and listings of vulnerable populations are also needed to ensure more targeted evacuations.

Sixthly, the importance of testing warning systems was highlighted in this study as some Charleville community members were unable to hear the warning siren, and hence door-knocks were recommended as an additional strategy. This highlights the importance of regularly testing and evaluation of warning and mitigation systems.

More studies are needed to quantify the social capital of societies affected by natural disasters and their characteristics of vulnerability, resilience and adaptive capacity, as well as to investigate the psychological effects of floods and how these might impact on the decision to stay or to migrate elsewhere, amongst other aspects related to psychological stresses and impacts. This study was carried out in conjunction with an historical case study of the 2008 flood in Mackay, Queensland.

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