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TOWNSVILLE CITY NATURAL DISASTER RISK MANAGEMENT STUDY STAGE 1: DRAFT FINAL REPORT

Townsville from Mt Stuart

January 2009
IID 7017-AD

DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Queensland Government
Department of Emergency Services
Emergency Management Queensland

THE NEW TOWNSVILLE CITY

1 CITY COMMUNITY COUNCIL DIRECTION

IID

The Institute for International Development

IID7017-AD
27 January 2009

Manager Engineering Services
Mr Brian Milanovic
City of Townsville
103 Walker Street
Townsville QLD 4810

Dear Mr Milanovic

RE: CONTRACT T3320 - TOWNSVILLE ALL HAZARD RISK ASSESSMENT

We take pleasure in providing 1 bound copy and 1 electronic PDF version of our Townsville City Natural Disaster Risk Management Study Stage 1: Draft Final Report. This version has been amended in accordance with discussions with the SAG. We have also included a Report Summary for use in consultation.

Please do not hesitate to contact Mr Ken Granger or the undersigned should you require further clarification or have any queries.

For and on behalf of
INSTITUTE FOR INTERNATIONAL DEVELOPMENT

AW Batten

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IID7017-AC	Draft Final Report	May 2008	Draft Final for presentation to Client
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IID7017-B	Report Summary	Jan 2009	Summary for use in consultation

DISTRIBUTION LIST

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ABBREVIATIONS

ABS	Australian Bureau of Statistics
AC	asbestos cement
AEP	annual exceedance probability
AGSO	Australian Geological Survey Organisation (now Geoscience Australia)
AGD 84	Australian Geodetic Datum 1984 edition
AIRS	Australian Incident Reporting System
ALARP	as low as reasonably practicable
ANCOLD	Australian National Committee on Large Dams
ARI	average recurrence interval
ASL	above sea level
AWE	Australian Water Engineering Pty Ltd
BCA	Building Code of Australia
BoM	Bureau of Meteorology
BTE	Bureau of Transport Economics
CBD	central business district
CCD	census collector’s district
CDMA	code division multiple access (mobile phone system)
CIPMA	Critical Infrastructure Protection Modelling and Analysis Program
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTS	Cyclone Testing Station (James Cook University)
DCDB	digital cadastral data base
DES	Department of Emergency Services
DEM	digital elevation model
DFE	defined flood event
DLGP	Department of Local Government and Planning
DNRM	Department of Natural Resources and Mines
DoTARS	Department of Transport and Regional Services
DPI	Department of Primary Industry
EMA	Emergency Management Australia
LDCC	emergency operation centre
EPA	Environmental Protection Agency
EPR	earth potential rise
FABC	Fire and Biodiversity Consortium
GA	Geoscience Australia
GCCC	Gold Coast City Council
GIS	geographic information system
GPS	global positioning system
GSM	global system for mobile communication (mobile phone system)
ha	hectare
hPa	hectopascal
ICA	Insurance Council of Australia
ID	identification (number)
IPCC	Intergovernmental Panel on Climate Change

JCU	James Cook University
km	kilometre
km/h	kilometres per hour
LDMG	local disaster management group
LGAA	Local Government Association of Australia
LGAQ	Local Government Association of Queensland
m	metres
m/sec	metres per second
ML	megalitre
M_L	local (Richter) magnitude
MM	Modified Mercalli (earthquake intensity)
MPI	maximum potential intensity
mm	millimetres
mm/h	millimetres per hour
nd	no date
NDMP	Natural Disaster Mitigation Program
NDRRA	Natural Disaster Relief and Recovery Arrangements
OESR	Office of Economic and Statistical Research
P&C	Parents and Citizens Association
PMF	probable maximum flood
PPRR	prevention, preparedness, response and recovery
PSPA	Public Safety Preservation Act
QAS	Queensland Ambulance Service
QCWA	Queensland Country Women's Association
QFRS	Queensland Fire and Rescue Service
QPWS	Queensland Parks and Wildlife Service
SA	Standards Australia
SCADA	supervisory control and data acquisition
SCARM	Standing Committee on Agriculture and Resource Management
SCDO	State Counter Disaster Organisation
SEA	Systems Engineering Australia P/L
SEMC	(NSW) State Emergency Management Committee
SES	State Emergency Service
SEWS	Standard Emergency Warning Signal
SNZ	Standards New Zealand
SPP 1/03	State Planning Policy 1/03
sq km	square kilometre
TC	tropical cyclone
TCC	Townsville City Council
t/ha	tonnes per hectare
TOR	terms of reference
UHF	ultra high frequency
WICEN	Wireless Institute Civil Emergency Network
WMO	World Meteorological Organisation

PREFACE

This report has been prepared for Townsville City Council by the Institute for International Development Ltd (IID), disaster risk management consultants. The report details the outcomes of the multi-hazard Disaster Risk Management Study undertaken under the Commonwealth Government's Natural Disaster Mitigation Program. The study follows the methods for disaster risk assessment contained in the Australian & New Zealand standard AS/NZS 4360-2004 *Risk management* (SA & SNZ, 2004) and process described in Zamecka and Buchanan (1999).

The emergency risk management process is outlined in the following figure:

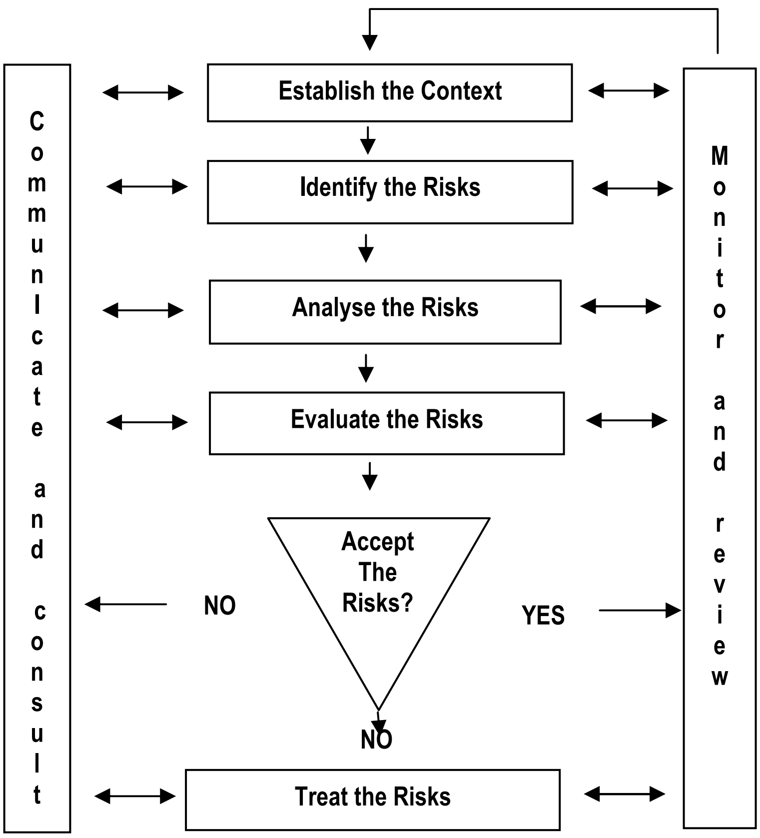


Figure i: Risk management overview (based on SA & SNZ, 2004, Fig 3.1)

The report is presented in a narrative form supported by tables and figures, rather than in the proforma style suggested by Zamecka and Buchanan. The study follows the risk management standard in the following way:

> **Establish the context**: Chapter 1 describes the study area and provides a basic description of its key attributes; identifies the legislative framework within which the emergency risk management process is conducted; describes the risk management approach taken and establishes the study setting; identifies previous studies undertaken; discusses the role of probability and establishes the evaluation criteria (DES Form A5).
>
> **Identify the risks**: Chapter 2 describes the hazards that have had, or have the potential to, impact on the study area. This takes the place of Form A6. Chapter 3 describes in detail the elements of the community that would be exposed to each of the hazards and their likely vulnerability to such an exposure. This takes the place of Forms A7 and A8.
>
> **Analyse the risks and evaluate the risks**: Chapter 4 draws together the risk analysis including an assessment of each hazard across a range of recurrence/severity probabilities and their likely consequences. The spatial distribution of the risks is explored to identify elements of the study area's communities that may have a level of risk that is greater than the community average. This chapter is the equivalent of Forms A9 and A10
>
> **Treat the risks**: This stage is dealt with in Chapter 5. A range of both generic and hazard-specific treatment options are proposed. This takes the place of Forms A11, A12 and A13

The study was led by Mr Ken Granger, IID's principal disaster risk scientist, supported by Dr David King (JCU) and Dr Marion Leiba (IID). Editorial support report production was provided by Dr Leiba. Project management was provided by Mr Tony Batten (IID business manager).

Considerable assistance and support was provided by Mr Brian Milanovic and Mr Joe Cullen (Townsville City Council) and members of the study advisory group (SAG).

The assistance and support of all those involved is greatly appreciated.

Ken Granger
Principal Disaster Risk Scientist
Institute for International Development Ltd

1 THE CONTEXT

This chapter outlines the factors that impact on the analysis of natural hazard disaster risks in Townsville City and their management.

1.1 THE STUDY AREA

Townsville City was amalgamated with neighbouring Thuringowa City in March 2008, however, this study is confined, by its Terms of Reference (TOR), to the area previously administered by Townsville City Council (TCC). It extends over a land area of approximately 1870 square kilometres.

Townsville City was surrounded by Thuringowa City (to the west), Burdekin Shire (to the east) and Dalrymple Shire (in the south). The study area is shown in Figure 1.1.

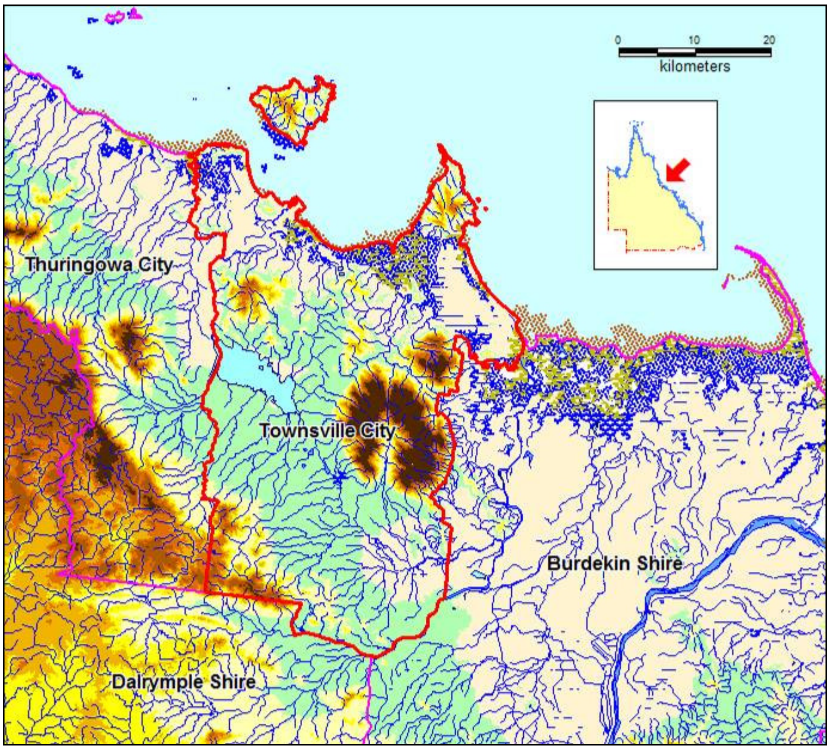


Figure 1.1: Townsville City study area

1.1.1 Terrain

The topography of the study area is characterised by low-lying, relatively flat plains interspersed by localised ranges of low steep-sided hills. There are four main topographic regions:

- The low-lying coastal plain with extensive areas of mud flats, clay pans and wetlands – elevations from sea level to a few tens of metres;
- The low-lying floodplains of the Ross River, Major Creek and the upper Houghton River- elevations up to 100 m;
- The foothills of the Hervey Range – elevations to 650 m within the study area;

- The individual steep-sided hills including Mt Elliot (1234 m), Saddle Mountain (882 m), Mt Stuart (533 m), Castle Hill (286 m), Mt Cleveland (558 m) and Magnetic Island (506 m).

Figure 1.2 provides a generalised view of the study area's topography.

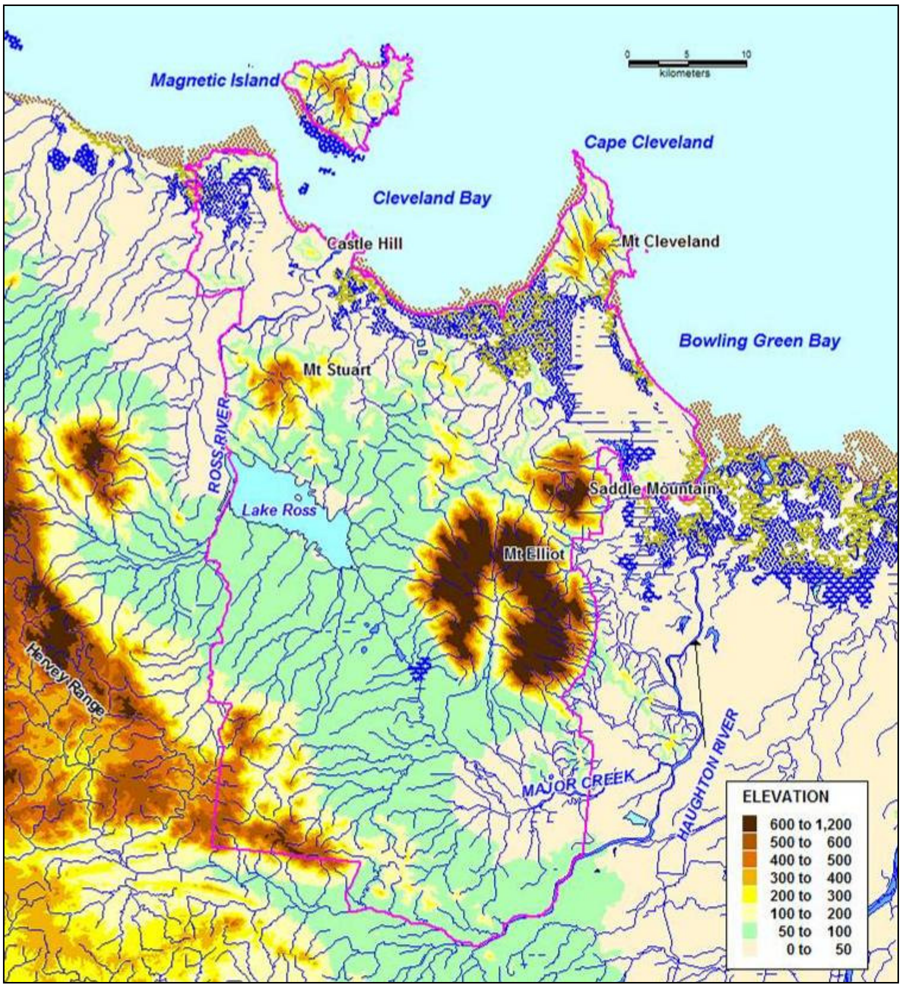


Figure 1.2: Study area generalised topography (Geoscience Australia data)

The study area is drained by the Ross River which flows to Cleveland Bay, and the Haughton River, together with its largest tributary (Major Creek), which flows to Bowling Green Bay. The Ross River is dammed to form Lake Ross, which has a catchment of 750 sq km and a storage capacity of 219,000 ML.

Magnetic Island sits about 4.4 km off the nearest point on the mainland and 7.8 km from Townsville Harbour. It has a distinctly different topography from the mainland, being dominated by steep, boulder-covered hills and localised areas of gently sloping land along the coastal strip and in the broader gullies. The island is approximately 11 km long and 8.5 km across its widest point.

The immediate offshore topography and tidal regime is also highly significant to an understanding of several of the hazards that affect the area. Cleveland Bay is generally shallow, with a maximum depth of 15 m. The west channel, which separates Magnetic Island from the mainland, has a maximum depth of

4 m. Access by ocean-going vessels to the Port of Townsville, at the mouth of Ross Creek, is via a dredged channel that runs to the east of Magnetic Island. It currently has a minimum depth of 8.1 m (Queensland Transport, 2007a).

Key tidal statistics for the Townsville Port are given in Table 1.1.

Table 1.1: Townsville Port semidiurnal tidal planes 2007 (Queensland Transport, 2007b)

Tidal Plane	**Port Standard (metres)**
Highest astronomical tide	2.05
Mean high water springs	1.11
Mean high water neaps	0.26
Mean sea level	0.0
Australian Height Datum	-0.11
Mean low water neaps	-0.37
Mean low water springs	-1.20
Lowest astronomical tide	-1.96

1.1.2 Geology

The terrain of the study area is dictated by its underlying geology. In broad terms, the area is made up of alluvial material (alluvium, colluvium, sand etc) of Quaternary age (to 1.6 million years) on the coastal plain and in the river flood plains. The high country of the Hervey Range is a complex mixture of Devonian or Carboniferous-era (410 to 298 million years) sedimentary rocks and Permian-era (298 to 251 million years) intruded granites. The separate hill blocks such as Mt Elliot and Magnetic Island are Permian-era intruded granites. The generalised geology is shown in Figure 1.3.

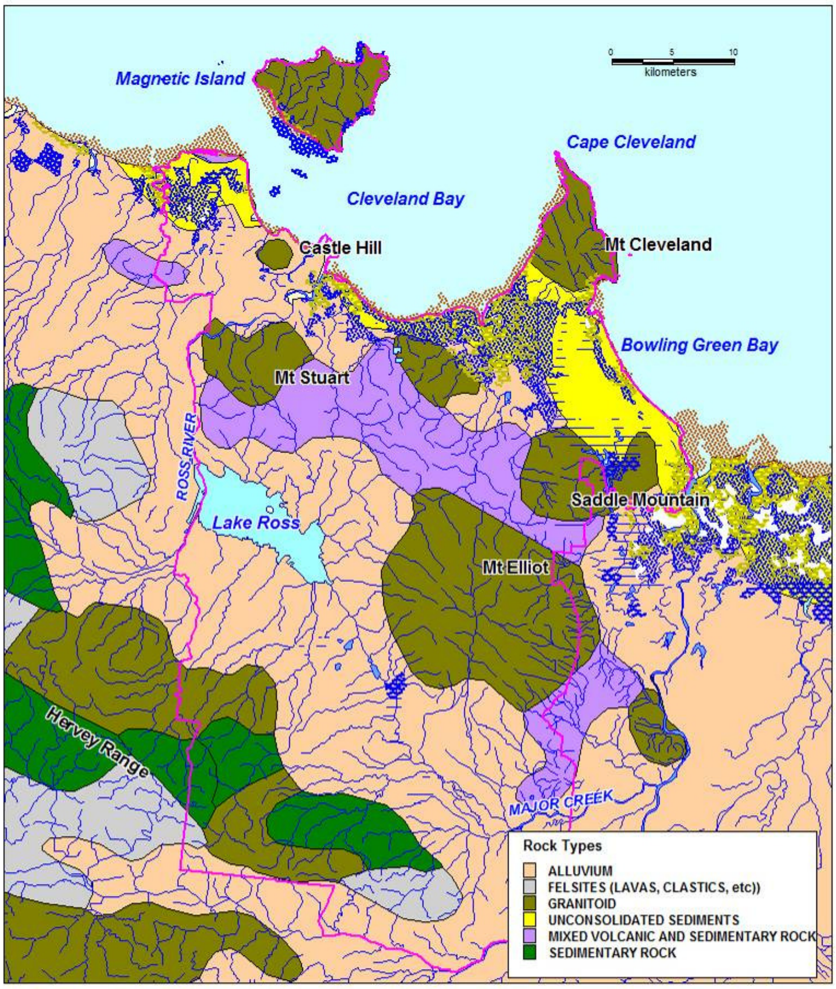


Figure 1.3: Study area generalised geology (based on DNRMW Australia data)

1.1.3 Vegetation

Large areas of the native vegetation of the study area have been removed or greatly modified by agriculture and urban development. The native vegetation that remains ranges from littoral forms such as mangrove forests or samphire, to lowland woodlands and grasslands, to forests on the higher and wetter country such as Mt Elliot. A more detailed description of vegetation is included in the Chapter 2 discussion of the bushfire hazard.

1.1.4 Climate

The study area has a climate that is classed, under the Koeppen climate classification system, as ‘tropical with a moderately dry winter’. The drier than ‘normal’ winter rainfall is explained in part by the local topography and the orientation of the coastline – the east-west orientation of the coastline does not provide uplift for the prevailing winter south-easterly trade winds.

The Bureau of Meteorology (BoM) website provides climate summaries for three stations within the study area – the former Townsville Hospital site on the Strand (data from 1913 to 1941); the current

Townsville Airport (data from 1940 to 2007) and the Cape Cleveland Lighthouse (data from 1927 to 1987). Key statistics for each site are contained in the following three tables.

Table 1.2: Townsville Hospital selected climate statistics 1913 to 1941 (source BoM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Mean max (ºC)	30.9	30.8	30.5	29.6	27.9	25.4	24.3	25.4	27.1	28.5	29.6	30.8	28.4
Mean min (ºC)	24.7	24.3	23.3	21.6	19.0	17.0	15.5	16.3	18.7	21.3	23.4	24.4	20.8
Mean rain (mm)	300.6	264.9	148.9	66.5	24.4	38.4	18.3	10.0	11.1	28.9	58.6	123.4	1102.1
Highest rain (mm)	1008	825.5	349.7	461.0	145.3	127.6	144.0	66.3	102.6	304.6	368.7	457.9	
Lowest rain (mm)	30.7	10.7	0	0	0	1.1	0	0	0	0	0.3	1.3	
Highest daily rain	221.0	290.6	129.3	236.7	121.7	109.7	89.7	38.9	65.8	229.6	151.6	167.4	290.6

Table 1.3: Townsville Airport selected climate statistics 1940-2007 (source BoM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Mean max (ºC)	31.4	31.1	30.7	29.6	27.6	25.6	25.1	26.0	27.7	29.4	30.8	31.4	28.9
Highest max (ºC)	44.3	42.7	37.6	35.8	32.2	32.2	31.6	33.3	36.5	37.1	41.0	42.1	44.3
Mean min (ºC)	24.2	24.0	22.9	20.6	17.6	14.6	13.6	14.7	17.3	20.7	22.9	24.0	19.8
Lowest min (ºC)	18.7	17.9	16.7	10.9	6.2	4.4	3.5	1.1	7.7	8.2	14.1	17.9	1.1
Mean rain (mm)	265.3	292.6	183.4	68.0	33.9	21.1	12.9	16.3	10.1	25.1	58.0	124.7	1110.0
Highest rain (mm)	1141	904.2	682.8	546.2	180.8	111.4	173.7	258.2	81.4	252.8	345.2	458.0	2399.8
Lowest rain (mm)	8.8	4.2	7.2	0.3	0	0	0	0	0	0	0.2	0	464.2
Highest daily rain	548.8	317.6	366.5	271.6	96.0	93.0	51.1	134.2	50.3	89.4	132.8	160.4	548.8
Max wind gust (k/h)	97	115	143	130	78	85	76	68	71	84	80	197	197

Table 1.4: Cape Cleveland selected climate statistics 1927-1987 (source BoM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Mean max (ºC)	30.7	30.1	29.4	27.9	25.6	23.5	22.8	24.1	26.1	28.5	30.0	31.0	27.5
Mean min (ºC)	24.8	24.5	24.0	22.5	20.4	18.2	17.4	18.3	20.1	22.2	23.8	24.6	21.7
Mean rain (mm)	283.7	295.7	227.0	69.2	44.5	28.8	17.3	14.5	10.9	25.7	51.2	100.0	1165.2

The extremes of rainfall and wind speed are associated with the impact of active or decayed tropical cyclones. The greatest 24 hour rainfall of 548.8 mm, for example, occurred on 11 January 1998 (ex TC *Sid*), whilst the greatest wind gust speed of 197 km/h was experienced on 24 December 1971 (TC *Althea*).

1.1.5 Population and Settlement

At the national census held in September 2006 the study area had a total population of 95,464, the great majority of it concentrated in the Townsville urban area.

The Department of Local Government and Planning (DLGP) in 2004 produced a series of projections of resident population using high, medium and low growth assumptions. The medium range projections forecast the resident population of Townsville to reach 118,653 by June 2026 at an annual growth rate of 0.7% from the 2001 population of 92,074. These projections are given in Table 1.5.

Table 1.5: Study area range of estimated resident population growth to 2026 (DLGP, 2004)

	2006 census	2006 forecast	2011	2016	2021	2026
Low		98,763	103,048	105,979	107,747	108,537
Medium	95,464	99,564	105,230	110,241	114,741	118,653
High		100,544	107,538	114,673	121,897	129,001

It is worth noting that the actual population enumerated at the 2006 census was 3.4% lower than the low projection for the 2006 population made in DLGP (2004), 4.1% lower than the medium projection and 5.1% lower than the high projection. This suggests that the forward projections given in the table may be unrealistically high. Some of this underestimate, however, may be explained by the fact that the census counted people where they were in Australia on census night (i.e. a *du jure* census) – it did not count Defence Force personnel and other residents who were overseas or in 'fly-in/fly-out' mine sites on census night.

The study area has an average population density of 51 persons per square kilometre. Densities across the 196 census collectors districts (CCD) used in the 2006 census, however, range from 3680 people per sq km in a Heatley CCD, to zero persons per sq km in the five CCD that have no population. Of the populated CCD the lowest density is in Stuart where one CCD has a density of 0.07 people per sq km. The distribution of population density across the study area is shown in Figure 1.4 and for the urban area in Figure 1.5.

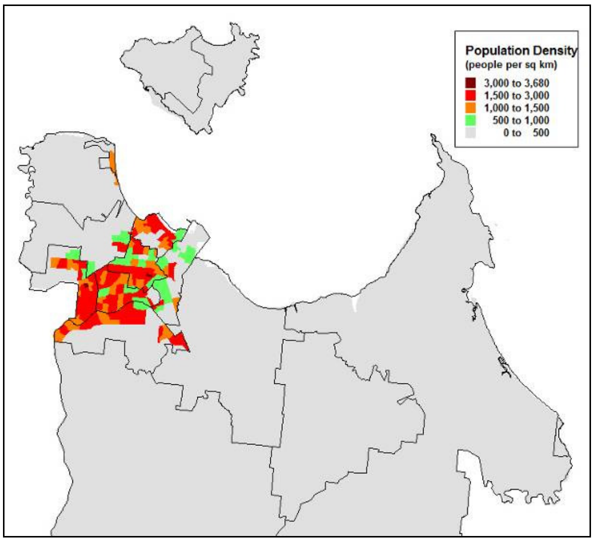


Figure 1.4: City-wide population density

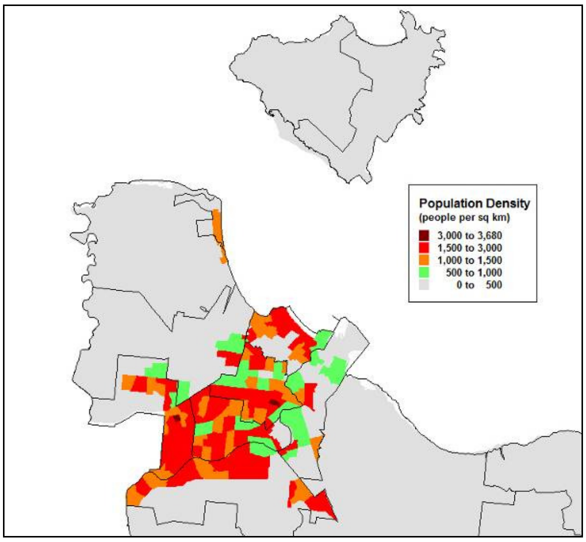


Figure 1.5: Urban area population density

The study area is divided into 58 suburbs or localities, the boundaries of which do not all coincide very well with the census boundaries. To simplify the analysis the 58 suburbs have been grouped into 12 risk assessment zones and two 'outlier' suburbs. The boundaries of these zones are shown in Figure 1.6 and the suburbs contained in each zone are detailed in Table 1.6. The zones have been constructed to group like land uses and similar periods of development.

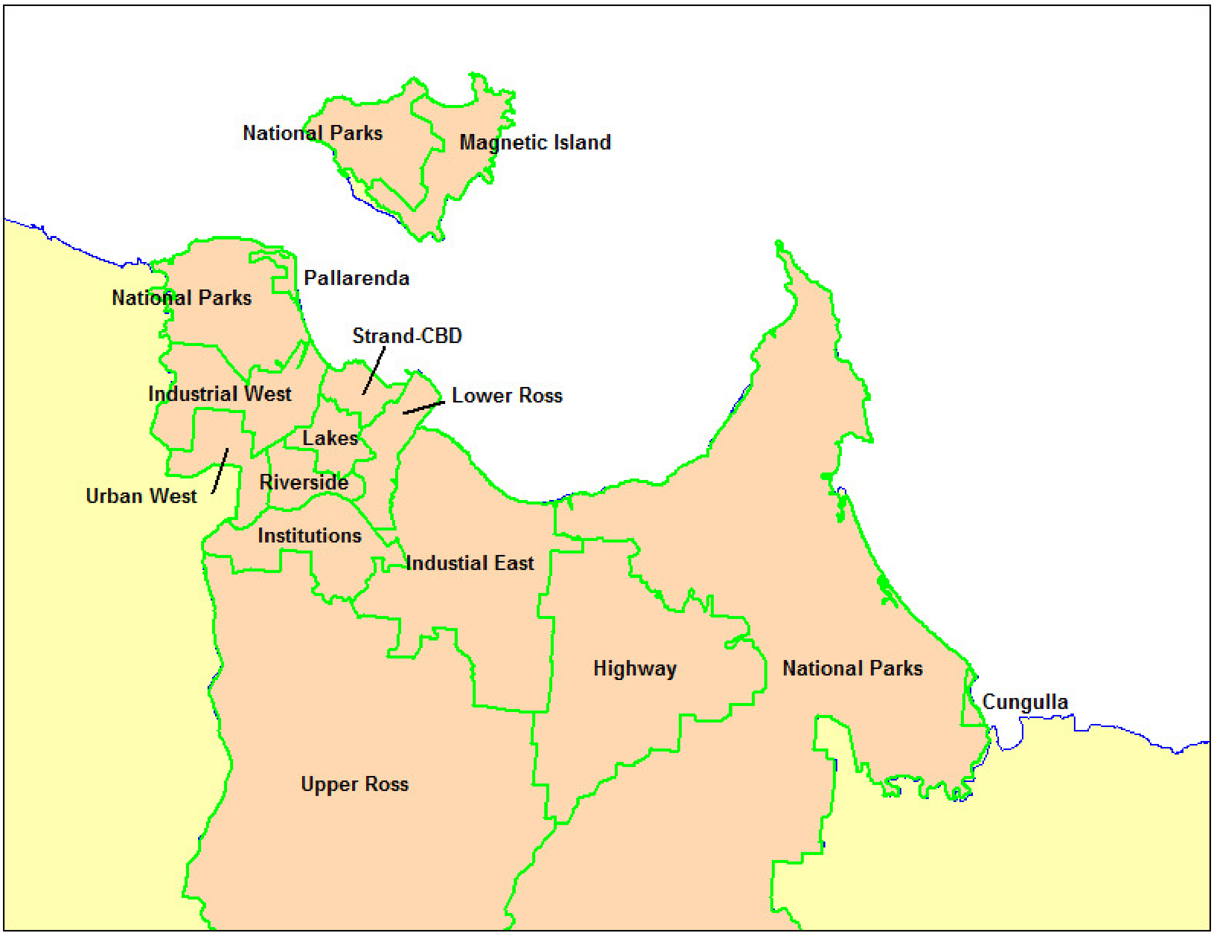


Figure 1.6: Study area risk zone boundaries

Table 1.6: Study area risk zone composition

ZONE	SUBURBS	AREA (sq km)	POPULATION
Cungulla	Cungulla	1.705	247
Highway	Alligator, Creek Nome	102.958	1599
Industrial East	Cluden, Julago, Roseneath, Stuart	95.437	2398
Industrial West	Bohle, Garbutt, Mount St John, Rowes Bay	32.122	3749
Institutions	Annandale, Douglas, Murray, Wulguru	30.542	19,503
Lakes	Currajong, Hermit Park, Hyde Park, Mysterton, Pimlico, West End	10.320	14,235
Lower Ross	Idalia, Oonooba, Railway Estate, South Townsville	15.646	7789
Magnetic Island	Arcadia, Florence Bay, Horseshoe Bay, Nelly Bay, Picnic Bay	24.422	2077
National Parks	Cape Cleveland, Mount Elliot, Shelly Beach, Town Common, West Point	555.641	1036
Pallarenda	Pallarenda	2.563	1025
Riverside	Aitkenvale, Gulliver, Mundingburra, Rosslea, Vincent	10.678	15,468
Strand-CBD	Castle Hill, North Ward	8.318	9379
Upper Ross	Barringha, Brookhill, Calcium, Majors Creek, Mount Stuart, Oak Valley, Reid River, Ross River, Toonpan, Woodstock	958.680	1661
Urban West	Cranbrook, Heatley, Mount Louisa	15.776	15,275

1.1.6 Land use

In terms of area, the study area is dominated by agricultural land uses. Grazing of cattle for beef is important, whilst horticultural crops (mainly field crops such as turf, potatoes, capsicum and melons) and orcharding (especially mangos) account for a significant proportion of the value of the area's agricultural production. According to OESR (2007) in 1998-9 (the last year for which data are available) livestock and livestock products produced in the City were valued at $2.6 million whilst crops were valued at $6.4 million.

The second largest area of use is public open space including national parks, catchment protection areas and Defence Force facilities.

The key aspects of urban land uses, especially residential, commercial and industrial, are described in detail in Chapter 3.

1.2 THE HISTORICAL CONTEXT

The Townsville area has been occupied by Aboriginal people for approximately 40,000 years. At least five tribal or linguistic groups are said to have either occupied or regularly moved through the area. Their patterns of occupation and use were complex, however, according to TCC (nd):

> *The old Townsville municipal area* (i.e. the urban area) *may not have supported a permanent tribe or language group because of its geography, being a low lying area with river tributaries. Rather it was a place through which Aboriginal tribes moved.*

The first Europeans to sight the area were with Cook on the *Endeavour* in 1770. Cook charted the coastline and named Magnetic(al) Island, Cleveland Bay and Cape Cleveland, but did not make a landing. Alan Cunningham, botanist with Philip Parker King's 1819 survey, was probably the first European to land on the shores of Cleveland Bay. The first European 'resident' of the area was James Morrill, a shipwrecked sailor who lived and travelled with the local Bindal tribe from 1846 to 1863.

The first European occupation of the area was at Woodstock on the headwaters of the Ross River. This pastoral property was owned by Sydney entrepreneur Robert Towns and was settled overland from the Burdekin. 'Woodstock' manager, John Melton Black, sent a party to search for a possible port and in April 1864 that party camped at the mouth of Ross Creek. They reported it to be a suitable site for a port and settlement. By 1865 Cleveland Bay had been declared a Port of Entry and in the following year the settlement was named Townsville in honour of its patron Robert Towns.

The fledgling settlement was almost wiped out by a cyclone in 1867. However, the discovery of gold in the hinterland at Cape River that year, Ravenswood in 1868 and subsequently at Charters Towers in 1871 ensured the future of the town and its port. Townsville was proclaimed a city in 1902.

Development of the large deposits of copper, lead and zinc at Mt Isa in the late 1920s further reinforced the importance of Townsville as a port to service the pastoral and mining industries, whilst its strategic importance became clear with its development as a major forward base during WW II and again in the 1960s during 'confrontation' with Indonesia.

The University College of Townsville was opened in 1961 and in 1970 legislation was passed to proclaim it as James Cook University (JCU). The university became the nucleus of an expanding scientific research community based on Townsville including the CSIRO Davies Laboratories, the Australian Institute of Marine Science (AIMS) and the Great Barrier Reef Marine Park Authority (GBRMPA).

Throughout its development Townsville has periodically suffered the impact of natural disasters including the 1867 cyclone, TC *Leonta* (1903), the loss of the SS *Yongala* with 100 lives in 1911, TC *Althea* (1971) and ex-TC *Sid* (1998), amongst others.

1.3 LAND MANAGEMENT

The study area contains a wide range of both discrete and overlapping land management jurisdictions. The nature of these jurisdictions has an important bearing on the management of a number of hazards, especially bushfire and landslide. The various forms of control and their respective areas are shown in Table 1.7. The figures in Table 1.7 do not include road reserves, most of which are under the control of Council. They could amount to around 70 sq km.

Table 1.7: Study area land control authorities

TENURE	PARCELS	AREA (sq km)	% AREA
Commonwealth land	51	106.48	5.93
Commonwealth housing	249	0.61	0.03
State land	493	181.79	10.13
State housing	1153	1.03	0.06
National Parks	19	449.42	25.04
Council land	790	167.13	9.31
Council housing	4	0.19	0.01
Port Authority	33	2.53	0.14
Private land	35,335	884.92	49.31
TOTAL	**38,147**	**1794.58**	

1.3.1 Public Land

The State Government controls the largest area of public land with a total of 634.77 sq km or 35.4% of the total area. The total includes a range of uses such as National Parks, State infrastructure (including the Port Authority) and State housing agencies. The Townsville City Council controls the next largest area of public land (167.32 sq km) which is made up of Council reserves, parks and infrastructure. The Commonwealth holds a total of 107.09 sq km, the bulk of it in the Lavarack Barracks (including the Mount Stuart exercise area) and Garbutt air base.

1.3.2 Private Land

A total of 49.31% of the area and 92.6% of the land parcels in the study area are controlled by private entities. They range from broad-hectare agricultural holdings; to individual residential properties; to non-government institutions such as schools and hospitals.

1.3.3 Native title and culturally sensitive sites

There are currently three active native title claims over land in study area – two areas on Magnetic Island (Wulgurukaba People claims one and two) and a large part of the mainland (Gurambilbarra People claim). Should any part of those claims be successful, the transfer to Native Title will not change the responsibility of the owners to manage the land in a way that conforms to legislation such as the Local Government Act. The existence of certain sites of cultural sensitivity, such as burial and ceremonial sites, may, however, inhibit the willingness of site custodians to agree to access by emergency workers under some circumstances.

1.4 OTHER SPECIAL INTERESTS

There are, in addition to the land management interests identified above, a range of other groups that may have a role in influencing the management of multi-hazard risk in the study area. These include:

- Landcare groups;
- Coastcare groups;
- environmental groups;
- the tourist industry;
- the development industry.

1.5 LEGISLATION AND STANDARDS

A range of Queensland legislation and national standards have an influence on disaster risk management within the study area. The key pieces of legislation, standards and guidelines are:

1.5.1 Emergency Services and Risk Management

(Commonwealth) Meteorology Act 1955
Disaster Management Act 2003
Public Safety Preservation Act 1986
Fire and Rescue Service Act 1990
AS/NZS4360-2004 Risk management
Natural Disaster Relief and Recovery Arrangements (NDRRA) Determination 2007
NDRRA Community Recovery Package Guidelines 2007
Townsville/Thuringowa Local Disaster Management Plan 2005

1.5.2 Land and Water Management

Land Act 1994
Aboriginal Land Act 1991
Native Title (Queensland) Act 1993
Aboriginal Cultural Heritage Act 2003
Mineral Resources Act 1989
Forestry Act 1959
Nature Conservation Act 1992
Nature Conservation (Forest Reserves) Regulations 2000
Environmental Protection Act 1994

(Commonwealth) Environmental Protection and Biodiversity Conservation Act 2000
Vegetation Management Act 1999
Land Protection (Pest and Stock Route Management) Act 2002
Water Act 2000

1.5.3 Development and Construction

Integrated Planning Act 1997
- *State Planning Policy 1/03* Mitigating the effects of flood, bushfire and landslide

Coastal Protection and Management Act 1995
- *State coastal management plan*
  - *Mitigating the adverse impacts of storm tide inundation* (Guideline)

Local Government Act 1993
Building Act 1975
- *Building Regulation* 1991
- *Standard Building Regulation* 2006

AS3959-1999 Building in bushfire prone areas
AS 1170.2-2002 SAA Loading Code Part 2: Wind loads
AS 4055-2006 Wind loading for housing
AS 1170.4-2007 Structural design actions – Earthquake actions in Australia
AS3826-1998 Strengthening existing buildings for earthquake
SAA HB132.1 Structural upgrading of older houses part 1: non-cyclone areas
SAA HB132.2 Structural upgrading of older houses part 2: cyclone areas

1.5.4 Local Planning Instruments

(Former) *Townsville City Plan 2005*

The main objects of the *Disaster Management Act* 2003 are as follows (Part 1 paragraph 3):

(a) to help communities-
- *(i) mitigate the potential adverse effects of an event; and*
- *(ii) prepare for managing the effects of an event; and*
- *(iii) effectively respond to, and recover from, a disaster or an emergency situation;*

One of the more significant features of the Act, which came into force on 1 April 2004, is its clear statement of the responsibilities of local governments in regard to the Act. This is contained in Part 5 paragraph 80 (1)a, which states that each local government is ‘to ensure it has a disaster response capability’. This is defined as:

> ***“disaster response capability”,*** *for a local government, means the ability to provide equipment and a suitable number of persons, using the resources available to local government, to effectively deal with, or help another entity to deal with, an emergency situation or a disaster in the local government area.*

1.6 THE HAZARDS

1.6.1 The Hazards Considered

The Terms of Reference (TOR) limit consideration in this study to those sudden onset natural hazards that are covered under the Natural Disaster Relief and Recovery Arrangements (NDRRA) program. *NDRRA Determination 2007* (DoTARS, 2007) defines natural disaster as follows:

> *In this Determination* **natural disaster** *means a serious disruption to a community or region caused by the impact of a naturally occurring rapid onset event that threatens or causes death, injury or damage to property or the environment and which requires significant and coordinated multi-agency and community response. Such serious disruption can be caused by any one, or a combination, of the following natural hazards: bushfire; earthquake; flood; storm; cyclone; storm surge; landslide; tsunami; meteorite strike; or tornado.*

In line with the TOR and *NDRRA Determination 2007* this study will be confined to consideration of the risks posed by the following natural hazards:

- Tropical cyclones and severe storms (and their attendant phenomena of destructive winds, storm tide and torrential rain);
- Floods (including inundation potentially caused by failure of the Ross River Dam);
- Bushfires;
- Landslides; and,
- Earthquakes (and the potential for tsunami impact).

The likely affects of climate change on the frequency and severity of those hazards that have a climatic association will also be considered.

1.6.2 Previous Studies and Mitigation Action

The Townsville area has been the subject of numerous studies into a range of natural hazards, particularly tropical cyclones and their associated storm tide, destructive wind and flood hazards. Indeed, systematic research into the risks posed by tropical cyclones in Queensland probably began as a result of the impact of TC *Althea* on Townsville and Magnetic Island in 1971.

The most recent hazard studies undertaken for TCC provide the foundation for this multi-hazard risk study. They are:

- Bushfire hazard mapping: analysis of bushfire susceptibility based on vegetation type and slope (Trinity Software, 1999);
- Development of a cyclone wind damage model for use in Cairns, Townsville and Mackay – Part 4 of the project ‘Queensland climate change and community vulnerability to tropical cyclones: Cyclone hazards assessment’ (CTS and CTS, 2003);
- Townsville landslide hazard zonation study (Coffey Geoscience, 2001) and Townsville steep slope risk assessment (Coffey Geoscience and Landmarc, 2004);
- Ross River hydraulics study: downstream flood assessment (Maunsell McIntyre, 2001);
- Ross River Dam upgrade risk analysis and consequence analysis (GHD, 2005a and b);

- Townsville flood hazard assessment (Maunsell, 2005a and b);
- Earthquake risk assessment of Townsville City (CERA, 2006);
- Townsville-Thuringowa storm tide study (GHD and SEA, 2007).

TCC responded to the findings of these studies by undertaking several major risk reduction projects including the $15 million flood mitigation capital works program based on the flood study recommendations; $1.5 million stabilisation works to reduce landslide risks in the Castle Hill area following the steep slope study; the installation of a rainfall station on Castle Hill to provide alerts of potentially hazardous landslide conditions; and implementation of a sophisticated storm tide warning system based on the storm tide study. NQ Water (now part of the New Townsville City Council) has also completed the $115 million upgrading of the Ross River Dam to bring it up to international dam safety standards.

The development of the 2.2 km-long Strand sea wall (finished in 1999) to withstand a 100-year average recurrence interval (ARI) storm tide predates the recent storm tide study.

Also significant to this project are the studies undertaken under the so-called *Cities Project* by the Australian Geological Survey Organisation (AGSO – now Geoscience Australia), particularly those of Cairns (Granger and others, 1999) and Mackay (Middelmann and Granger, 2000). These studies established a benchmark for multi-hazard risk assessments in Australia.

1.7 RISK MANAGEMENT METHODOLOGY

The risk management Standard AS/NZS 4360-2004 (SA/SNZ, 2004) defines ‘risk’ as:

> *the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.*

Department of Emergency Services provide a similar definition of risk, namely:

> *A concept used to describe the likelihood of harmful consequences arising from the interaction of hazards, community and the environment.* (Zamecka and Buchanan, 1999)

The ‘likelihood’ component is derived largely from consideration of the hazard phenomena involved and the assessed probability of events of differing magnitude or severity occurring. It can also include measures of the ‘likelihood’ that those elements exposed to the hazard will be harmed, i.e. their degree of vulnerability. ‘Consequences’ are usually measured in terms of lives lost, people injured, the amount of damage to property and disruption to economic activity. Risk can thus be assessed in terms of the interaction between three key elements – the hazard, the community elements exposed to that hazard and their vulnerability. The relationship between these three elements is shown in Figure 1.7.

In the figure, the triangle portrays each of the variables as being equal and risk being represented by the area of the triangle. The amount of total risk may be diminished by reducing the size of any one or more of the three contributing components. In the smaller (hachured) triangle the total risk has been reduced by mitigating the exposure and vulnerability components[1]. The reduction of any of the factors to zero (e.g. by eliminating flood plain development) would consequently eliminate the risk. Conversely, an increase in any one of the elements (e.g. an increase in poorly designed development in high hazard areas) will increase the risk.

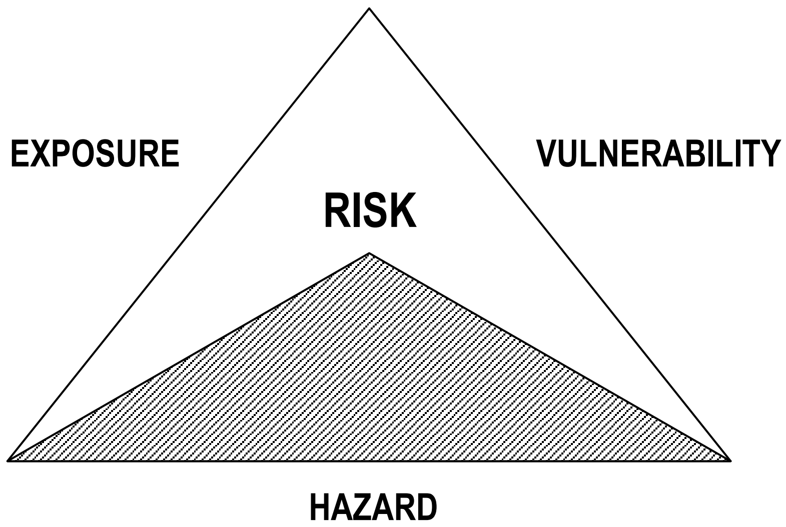


Figure 1.7: The risk-hazard-exposure-vulnerability relationship (based on Crichton, 1999)

In this study, the risk assessment and risk treatment options are developed in terms of these three components.

A more detailed description of the IID risk assessment methodology and definitions of the terms used are included in Appendix A.

1.8 EVALUATION CRITERIA

The degree to which risk is accepted or tolerated, by both individuals and the community, is very much dependant on the frequency, magnitude and controllability of the hazards involved. It is also influenced by the length of time that has elapsed since the last significant hazard impact – the more recent that event, the lower the threshold of acceptance or tolerance. For regulators such as TCC, this poses a significant (if not impossible) challenge – that is to determine the ultimate comfort levels of an informed public and to satisfy their concerns over the inevitable trade-offs affecting their safety.

There is no definition of what constitutes an ‘acceptable’ level of community risk. There are, however, thresholds of exposure or structural resilience established in the Townsville City planning scheme, State Government policies (e.g. State Planning Policy 1/03 *Mitigating the adverse effects of flood, bushfire and landslide* – known as SPP 1/03) and the construction standards established under the Building Code of Australia (BCA) that establish *de facto* thresholds. For hazards including destructive winds, inundation and earthquake these documents establish an event probability (known as the *average*

[1] It should be noted that bushfire is the only hazard that can be influenced directly by human intervention.

recurrence interval or ARI) above which it has been deemed impractical or uneconomical to reduce the risks further. For bushfire and landslide the restrictions are based on boundaries within which development may take place. Those thresholds, at they apply in the study area, are summarised in the following table.

Table 1.8: Notional 'design' level of hazard severity employed in Townsville

HAZARD	THRESHOLD	COMMENTS
Destructive wind	500 year ARI	Established in the wind loading standard of the BCA since about 1981.
Flood	50 year ARI	This has been the threshold for development in the planning scheme for many years, but it has been increased to the 100 year ARI level in the past few years.
Storm tide	100 year ARI	Established under the State Coastal Management Plan and implemented since 2005.
Landslide	Planning boundary only	Established under SPP 1/03 and implemented since 2004.
Bushfire	Planning boundary only	Established under SPP 1/03 and implemented since 2004.
Earthquake	500 year ARI	Established in the earthquake loading standard under the BCA since about 1985.

It is important to note that these thresholds **apply only to development that has taken place since they were introduced** – they have no retrospective force. This means that development that took place before these thresholds came into force will not necessarily meet the currently desired standard of safety.

To provide a consistency of analysis across all six hazards, this study has adopted an event likelihood in the 50 to 100 year average recurrence interval (ARI) range (i.e. an event that might occur only once in a lifetime) against which to assess the current level of natural hazards risk posed and to provide a benchmark against which to the develop risk reduction strategies. Those strategies can thus be measured against the following criteria, in priority order, <u>for events up to and including the 100 year ARI level</u>:

1. reduce, and preferably eliminate, the risk of death or injury to emergency workers engaged in responding to any hazard impact;
2. reduce, and preferably eliminate, the risk of death or injury to the general population;
3. reduce, to an acceptable level, the risk of destruction or damage to public infrastructure and facilities;
4. reduce, to an acceptable level, the risk of destruction or damage to private property;
5. manage the impact of natural hazard impacts on cultural heritage and the natural environment to the extent that loss of heritage is minimised and the biodiversity of flora and fauna is maintained;
6. minimise the long-term impact on the local economy.

2 THE HAZARDS

This chapter describes and analyses the hazards that have a history of serious impact within the study area.

2.1 NATURAL HAZARD TYPOLOGY

The Office of the United Nations Disaster Relief Coordinator (UNDRO) in 1979 developed a series of definitions relating to risk. Their definition of natural hazard was cited by Fournier d'Albe (1986) as follows:

> ***Natural hazard*** *means the probability of occurrence, within a specified period of time in a given area, of a potentially damaging natural phenomenon.*

Most 'damaging natural phenomena' are very complex and can be associated with a range of harm-producing elements. A tropical cyclone, for example, may be seen as the main hazard, but it is its attendant 'damaging natural phenomena' of storm tide, coastal erosion, destructive winds, widespread rainfall, riverine flooding and numerous widespread landslides that actually produce the damage.

Similarly, some hazards are regional in nature (i.e. they are mega-hazards that have a widespread impact) whilst others are smaller in scale and impact on a relatively small area. The relationships between the scale of a hazard and their associated damaging phenomena are illustrated in Figure 2.1.

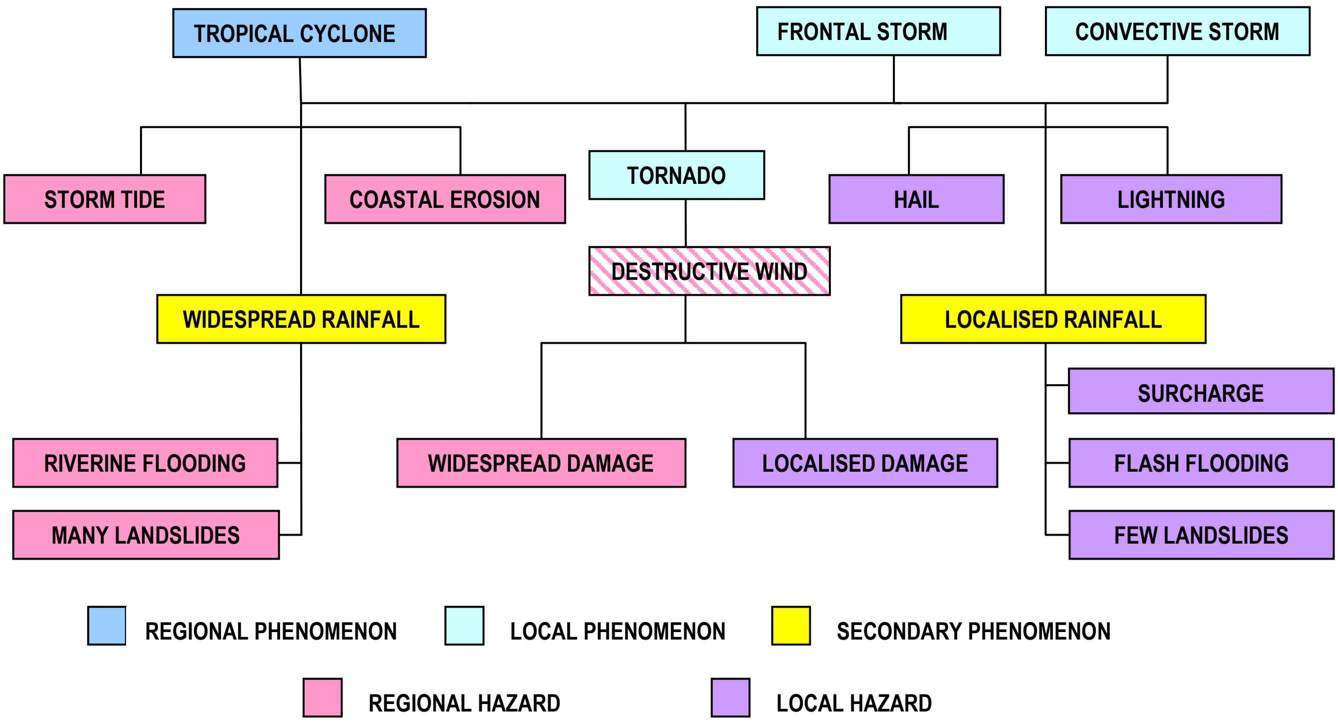


Figure 2.1: A typology of severe weather hazards

In a similar vein, hazards such as flood and storm tide inundation, landslides and (to some extent) bushfires are confined in their extent by factors such as terrain. Hazards such as earthquake, severe wind, and heatwave, by comparison, have no such spatial constraints. Others, such as hail and lightning, tend to have a localised impact, but they can have an impact anywhere.

These are key factors to be considered in developing disaster risk management strategies.

2.2 TROPICAL CYCLONES AND SEVERE THUNDERSTORMS

2.2.1 The Phenomena

The phenomena of tropical cyclones and severe thunderstorms each bring with them potentially destructive winds and intense rainfall. Thunderstorms also bring the potential for damaging hail and lightning strike. Both of these forms of severe weather have had damaging impacts within the study area. In this section, only the severe wind, hail and lightning threat will be addressed. The flooding and landslides produced by intense rainfall, as well as storm tide are addressed separately below.

Tropical cyclones are defined by the World Meteorological Organisation (WMO, 1997) as:

> *A non-frontal cyclone of synoptic scale developing over tropical waters and having a definite organized wind circulation with average wind of 34 knots (63 km/h) or more surrounding the centre.*

These are very large-scale and intense tropical low-pressure weather systems that form over warm tropical seas, generally during the warmer months between November and April. Typically, they degenerate rapidly into rain depressions once they cross the coast.

Their destructive capacity is defined by the strength of the winds generated. In Australia there are two measures used – sustained wind (averaged over a ten minute period) and gust (wind speed averaged over three seconds). The Bureau of Meteorology (BoM) web site (www.bom.gov.au/weather/cyclone) contains the following observation relating to cyclone wind speeds:

> *Typically gusts over open land will be about 40% greater than the mean wind and gusts over the ocean will be 25 - 30% greater than the mean wind. It is often the stronger gusts that cause the most significant damage to buildings.*
>
> *While a cyclone advice may refer to a certain maximum sustained wind or gust, there will be localised points where the winds will exceed this value, particularly in gullies, about ridges and between buildings where winds can be funnelled by the landscape.*

Threshold wind speed velocities are used to define the five-point cyclone intensity scale. This scale, and the wind thresholds employed in Australia, is given in Table 2.1.

Table 2.1: Australia tropical cyclone category system

CATEGORY	SUSTAINED WIND	GUST	POTENTIAL DAMAGE
1	65-90 km/h	90-125 km/h	Negligible house damage.
2	91-118 km/h	125-164 km/h	Minor house damage
3	119-166 km/h	165-224 km/h	Some roof and structural damage
4	167-212 km/h	225-279 km/h	Significant roof loss and structural damage
5	<213 km/h	<280 km/h	Extremely dangerous with widespread destruction

Cyclones of Category 3 and above are termed 'severe cyclones'.

Thunderstorms, by comparison, are produced by relatively small-scale convective processes that can occur when the atmosphere is moist and unstable. Many thunderstorms are typically short-lived (up to an hour) and limited in size (up to 10 km in diameter) but can traverse large distances during that time. They are capable of inflicting significant damage. Individual storm impacts can vary significantly both in space and time.

In Australia, a severe thunderstorm is defined as a storm that produces one or more of the following phenomena (BoM, 1995):

- *a tornado;*
- *wind gusts of 90 km/h or more at 10 m above the ground;*
- *hail with diameter of 20 mm or more at the ground;*
- *an hourly rainfall intensity in excess of the 10 year ARI* (average recurrence interval) *for a region (about 70 mm/h or greater, dependent on the location and previous rainfall).*

Interestingly, lightning is not used as a discriminator of thunderstorm intensity. Almost all convective storms will exhibit some lightning and hence some thunder but there is no established link between lightning display and overall storm intensity.

Storm impacts: Between 1967 and 1999 tropical cyclones accounted for a national average annual loss of $266.2 million, of which Queensland incurred an average $89.8 million annually. Because of their much more widespread occurrence nationally, the losses produced by severe thunderstorms were greater than those from cyclones. Indeed, they were the cause of the second largest losses (after flood) caused by all natural hazards in Australia. It has been estimated that nationally, severe thunderstorms caused on average $284.4 million damage each year, of which Queensland contributed an average $37.3 million (BTE, 2001).

2.2.2 Cyclone Impact Recurrence

Analysis of the official BoM cyclone databases for the seasons from 1959/60 to 2003/04 by GHD and SEA (2007, p24) show that, on average, 1.78 cyclones come within 500 km of Townsville in each season. The time history is shown in Figure 2.2.

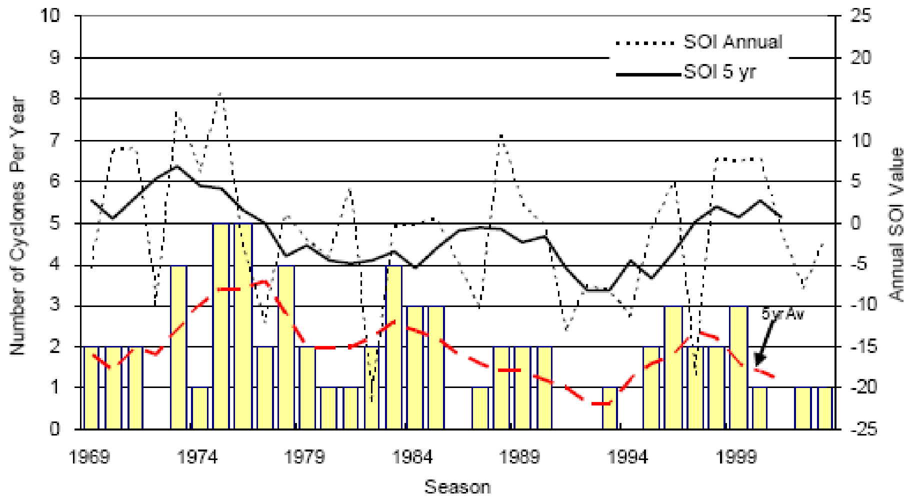


Figure 2.2: Time history of cyclone occurrence within 500 km of Townsville (GHD & SEA, 2007, Fig 4-2)

This shows a fluctuation in frequency about a five-year average value of between 1 and 3 storms per year. This fluctuation is explained by GHD and SEA (2007, p24-5) as follows:

> *Some years indicate zero storms within the 500 km radius while the maximum number during this time has been 5 storms in one season, which has occurred on two occasions: 1975/76 and 1977/78.*
>
> *The variability in cyclone occurrences over a 3 to 5 year span is now known to be strongly associated with the so-called El Niño - Southern Oscillation (ENSO) phenomenon (Basher and Zheng, 2000). ENSO refers to a quasi-biennial oscillation of the sea surface temperatures (SST) in the eastern tropical Pacific Ocean. During a so called El Niño period, the SST is warmer than normal in the east and rainfall and tropical cyclone activity in northern Australia tends to decrease. In the reverse situation, called La Niña, the SST in the eastern Pacific is cooler than normal and rainfall and tropical cyclone activity increases along the east coast of Australia.*
>
> *The Southern Oscillation Index (SOI) is a measure of the strength of the ENSO episodes, derived from surface pressure data at Darwin and Tahiti. The SOI is also plotted on Figure* [2.1]*, where it can be seen that a generally persistently negative SOI (El Niño) has been associated with a decrease in cyclone occurrences over the past 20 years in the Townsville region. Since 1959 though, the number of El Niño - La Niña cycles is approximately equal, although the strengths have varied (Pielke and Landsea 1999). This suggests that the long-term average frequency of occurrence of 1.78 storms per season for the statistical region is reasonably reliable. However, it should be noted that ENSO fluctuations specifically alter the true likelihood of storm tide risk in any particular year of exposure. Some researchers (e.g. Power et al. 1999) suggested that the trends of the past 10 to 15 years may have started reversing and that the western Pacific could be entering a period of prolonged La Niña activity in the new millennia, but recent years have seen only mild La Niña or near neutral conditions persisting.*

IID's analysis of the longer BoM cyclone record from 1906 to 2006 (which is certainly incomplete for earlier and more distant storms) shows that of the 155 events recorded as having approached to within 400 km of Townsville, 33 came to within 100 km (Figure 2.3). Around 55% of all storms were classed as severe cyclones (i.e. Category 3 or higher) with one event (TC *Aivu*) now classed as a Category 5 storm.

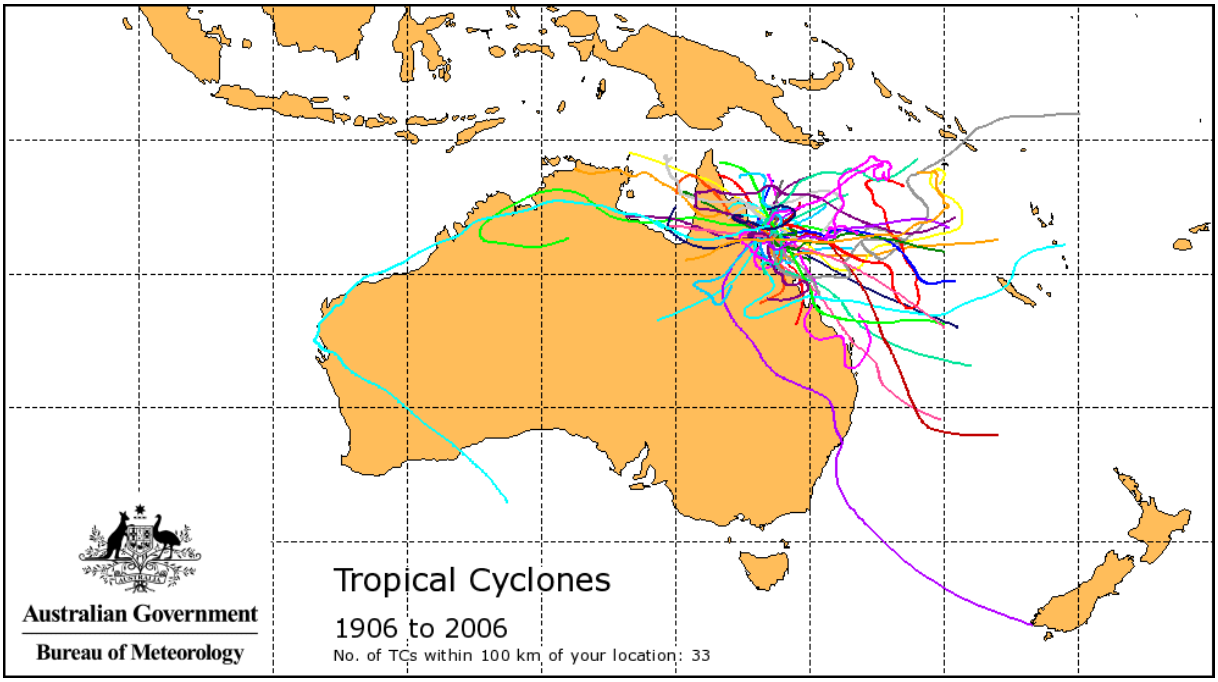


Figure 2.3: Cyclone tracks passing within 100 km of Townsville 1906-2006 (BoM web site)

GHD and SEA (2007, pp26-28) estimated the average recurrence interval (ARI) of cyclones of different categories up to and including the maximum potential intensity (MPI). They describe the process as follows:

> *The most significant parameter affecting regional* [destructive wind and] *storm tide is the intensity of the tropical cyclone winds. This is typically indirectly represented by the central pressure of the cyclone but also depends in part on other scale parameters. The estimated minimum central pressure for each of the 80 storms is then statistically analysed using Extreme Value Theory (Benjamin and Cornell, 1970) to obtain the likelihood of particularly intense storms occurring anywhere within the 500 km radius region. The statistical analyses are undertaken firstly for each separate track class and then combined into a single regional prediction, summarised graphically in Figure* [2.4]... *It can be shown that the most intense cyclones are contributed mainly by the onshore class, which typically represent fully mature storms in favourable steering currents. On this basis, the 100 year return period cyclone intensity in this region is predicted to be approximately 921 hPa.*

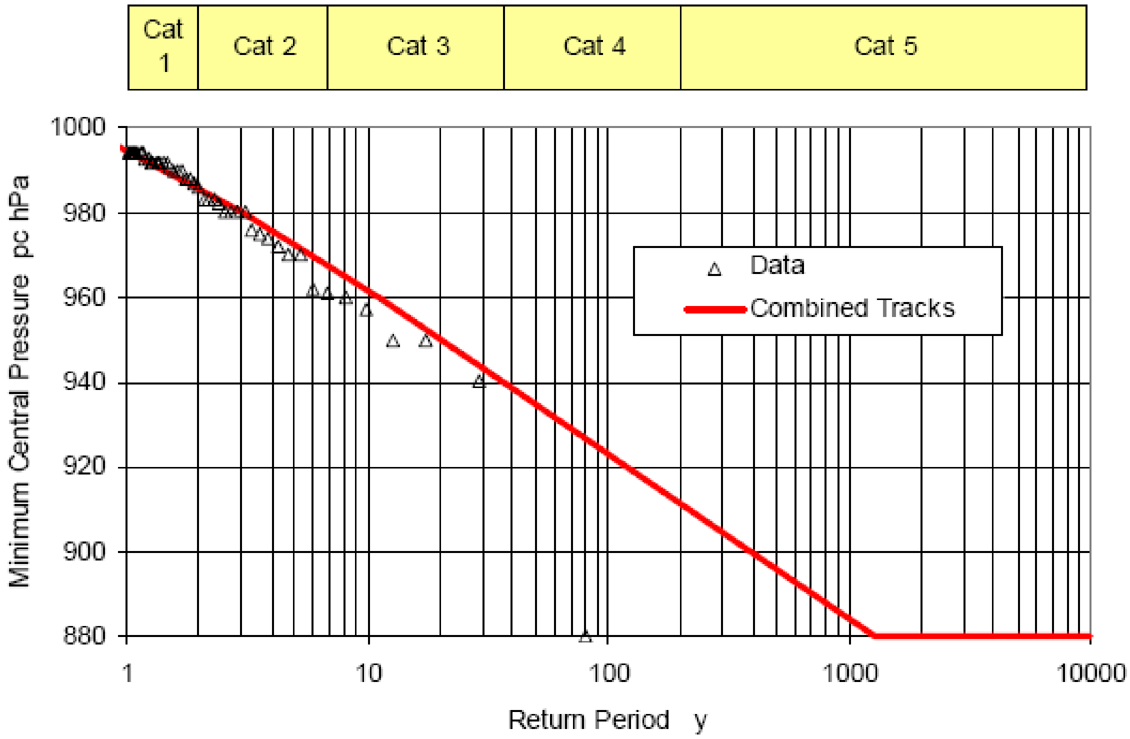


Figure 2.4: Extreme value analysis of cyclone intensity within 500 km of Townsville (GHD & SEA, 2007, Fig 4-5)

> *Coupled with this theoretical (normally unbounded) analysis there needs to be a consideration of the maximum potential intensity (MPI) that might be sustained in any region. This is a function of a number of physical parameters but principally the sea surface temperature and the upper atmosphere profile (Holland 1997b). For the Townsville region the MPI is assessed as 880 hPa (Holland 1997a) – equivalent to the revised* Aivu[2]*. Based on the present analysis, this MPI has a return period of approximately 1000 years anywhere within 500 km of Townsville.*

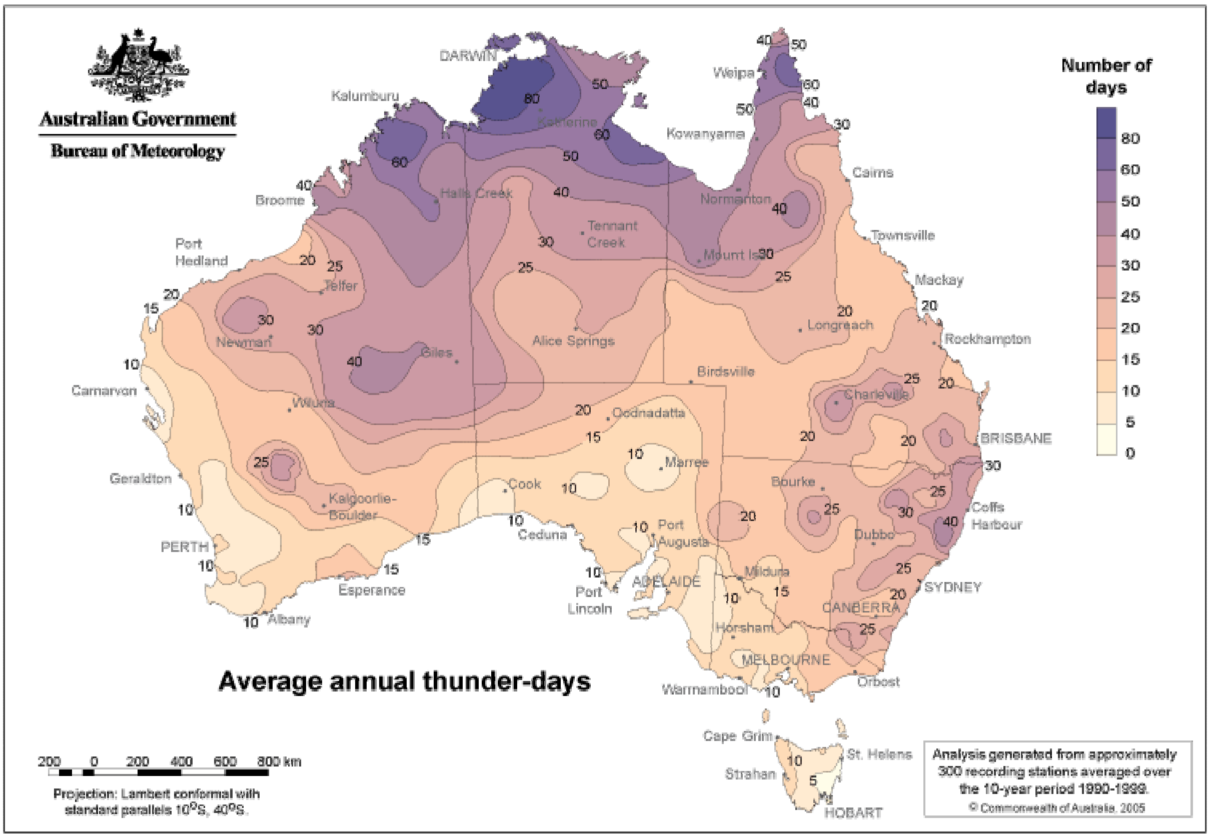
Appendix A provides a short description of the more significant cyclone impacts on Townsville.

2.2.3 Severe Thunderstorm Recurrence

Based on national-level data the Townsville area experiences, on average, between 15 and 20 thunderstorm days every year. This is somewhat less than the experience of Brisbane (between 30 and 40 thunderstorm days) or Cairns (between 20 and 30 days). The national distribution of average thunderstorm days is shown in Figure 2.5.

IID has not been able to identify any specific analysis of the thunderstorm regime of the Townsville region.

[2] See Appendix A of GHD and SEA (2007) for a detailed analysis of TC Aivu that indicates that at one point in its approach to the Queensland coast it may have achieved a central pressure close to 880 hPa – the estimated MPI for east coast cyclones.



Figures 2.5: Australian average annual thunderstorm days (BoM web site).

2.2.4 Harm Producing Elements

Destructive Wind: Most of the damage done by tropical cyclones and severe thunderstorms is caused by their strong winds. The most severe winds, however, are associated with the tornadoes that may be spawned by both tropical cyclones and super-cell thunderstorms. Peak wind speeds in these storms are estimated to approach 450 km/h in the largest tornadoes, although actual measurements are sparse. Their spatial extent, however, is small, ranging from just a few tens of metres up to a few hundred metres. Track lengths typically vary from as little as 1 km but can extend for over 100 km, if conditions are 'favourable'.

Wind damage tends to increase disproportionately to the wind speed. According to Meyer (1997), winds of 70 m/sec (250 km/h) cause, on average, 70 times the damage of winds of 35 m/sec (125 km/h). Damage tends to start where sustained wind speeds begin to exceed 20 m/sec (about 75 km/h)[3]. In addition to the high wind speeds, the turbulence of the winds caused by terrain features and large buildings is also a decisive factor. These issues have been analysed in detail for Townsville in JCU CTS (2003) and are covered in greater detail in Chapter 3. See Appendix B for a conversion table for the various wind speed measure scales.

---

[3] Several scales are used to communicate wind speed – metres per second (usually by engineers), kilometres per hour (the general public) and knots (mariners and aviators). The terminology of the Beaufort Scale is also used to describe different levels of wind speed. Appendix C provides a conversion table for the key threshold values in each scale.

Thankfully, the strength of destructive winds from thunderstorms is inversely related to the area they impact. For example, very severe downdrafts (or microbursts) can attain speeds of more than 200 km/h and affect areas up to 1 km wide, while severe tornadoes might have winds in excess of 400 km/h but are typically restricted to widths of less than 100 m (Fujita, 1981).

Severe winds can destroy buildings, topple trees, flatten standing crops, bring down power lines and block roads with fallen vegetation. People are most at risk of injury or death from wind driven projectiles such as roofing iron and tree branches. **No part of the study area is immune from severe wind damage.**

Hail: BoM records suggest that approximately 30% of all severe thunderstorms produce damaging hail, with actual sizes varying depending on the strength of the recirculating updrafts in the storm system. Hail is thought to grow by the accumulation of super-cooled water droplets as the hail nucleus is supported by the strong updrafts. Eventually, the mass of ice particles cannot be maintained and the hailstones typically fall in intermittent 'shafts', which form damage swaths at ground level due to the forward movement of the storm. These swaths vary in size, but are commonly a few kilometres in width and up to 10 kilometres in length. The formation of hail (and lightning) is not completely understood.

Hail can destroy tree plantations and standing crops as well as crops such as pawpaw and bananas. It can kill livestock, do extensive damage to buildings and vehicles in the open, damage power supply and telecommunications infrastructure and block roads. Under the more extreme conditions hail can kill or seriously injure people. **No area in the study area is immune from hail impact** though the incidence of <u>damaging</u> hail storms in the Townsville area is rare**.** Records from the BoM Townsville Airport weather station show that hail has been observed during 21 of the past 68 years. The records also show that hail has been observed in every month of the year. The data does not, however, indicate whether the hail was of a size that might cause damage.

Lightning: Almost all storms produce some lightning and associated thunder. An average thunderstorm produces a few lightning flashes each minute and generates several hundred megawatts of electrical power during its lifetime.

Specific lightning protection is required for commercial and industrial buildings and structures to provide isolation for electrical, telecommunications and computer equipment and personnel who operate such systems. As well as the immediate impact of the peak current from a lightning strike, earth potential rise (EPR) is a common cause of extensive damage to underground cables and is the most common form of injury through the use of telephones during an electrical storm (Quelch and Byrne, 1992). Telephone subscribers are warned against the possibility of lightning-induced electrical or acoustic shock if the handset is used during thunderstorms. Lightning strike can also start wildfires.

Fatalities from lightning strike are not particularly rare - during the period 1803–1991 some 650 people were killed by lightning strike in Australia (i.e. an average of 3.4 per year). These fatalities are especially seasonal and gender/age-based. Over 85% of all outdoor lightning strike victims nationally have been males between the ages of 15 and 19 struck between midday and 6pm in the summer months of November to February. Historically, most outdoor fatalities involved those working on the land, however, urbanization and the rise in outdoor recreation, especially water related sports, golf and cricket, is changing this statistic (Coates and others, 1993). **No point within the study area is immune from lightning strike.**

2.2.5 Warnings

The approach of tropical cyclones is well tracked by satellite and radar systems for several days before they are within destructive range of Townsville. Computer models of cyclone behaviour are also greatly improved. The combined application of these technologies ensures that forecasts of cyclone track and intensity are increasingly more accurate and the warnings provided are both timely and appropriate.

Modern weather radar systems are also proving to be invaluable for detecting and tracking severe thunderstorms. This information is used by the BoM to provide as long a warning time as possible. There are instances, however, when storms form very rapidly and practical warnings are not possible. Townsville City is well covered by the dedicated weather watch radar installed on Mt Stuart.

2.2.6 The Wind Risk Study

The study undertaken to develop a cyclone wind damage model for Cairns, Townsville and Mackay (CTS and SEA, 2003) as part of the wider *Queensland climate change and community vulnerability to tropical cyclones* project provides the basis for the wind risk analysis provided here. The wind damage modelling process is described as follows (CTS and JCU, 2003 p 4):

> *The deterministic wind field model SEACATd was amalgamated with the CTS housing wind resistance models to provide a user-friendly software interface to estimate the number of houses suffering wind induced damage from a cyclone of given parameters (track, intensity, radius etc). In the wind model framework, topographic factors such as ground height, surrounding terrain and neighbouring structures were represented in accordance with the boundary layer coefficients as detailed in the Australian Wind Loading Standard AS1170.2-1989.*

The SEACATd proprietary wind risk catastrophe model is based on the original work of Holland (1980) and enhanced by Harper and Holland (1999). The Holland model has been widely used in wind risk studies in Australia and the USA. The primary parameters considered in the Holland model include:

> *the central pressure, ambient pressure, radius to maximum winds, forward speed, track and wind profile peakedness.*(CTS and SEA, 2003 p 29)

The Holland model delivers wind speeds that are deemed representative of over-ocean conditions far from the influence of land. To assess the threats to structures on land, however, it is necessary to take into account the degree to which wind speeds vary over land as a function of the local topography and surface roughness. The SEACATd model incorporates the terrain and topographic classification system established in the wind loading standard AS1170.2-1989 (under the Building Code of Australia – BCA). Three wind speed multiplier factors are included:

- height and terrain category-dependent multiplier (based on the height of the house and the AS1170 surface roughness categories)
- topographic multiplier, dependent on ground slope

- shielding multiplier, dependent on proximity of houses

A digital elevation model (DEM) with a horizontal resolution of 30 m was used to develop the terrain (slope) input and LANDSAT imagery was used to provide the roughness classification. Figure 3.4 of CTS and SEA (2003) provides the graphic output of the terrain modelling.

The SEACATd model provides a very robust basis on which to undertake wind risk modelling.

2.2.7 Conclusions

Townsville City has a long history of destructive impacts of tropical cyclones and severe thunderstorms. The destructive winds associated with these hazards probably represent the most significant and widespread threat to the Townsville community.

2.3 FLOODS

2.3.1 The Phenomena

Flood is defined in SCARM (2000) as:

> *Relatively high water levels caused by excessive rainfall, storm surge, dam break or a tsunami that overtop the natural or artificial banks of a stream, creek, river estuary, lake or dam.*

State Planning Policy 1/03 (DLGP/DES, 2003a, p11) provides a similar definition that emphasises the effects, rather than the causes, as follows:

> *A temporary inundation of land by expanses of water that overtop the natural or artificial banks of a watercourse i.e. a stream, creek, river, estuary, lake or dam.*

To put it simply, floods are *water where and when it is not wanted*.
Floods of all kinds account for the largest amount of loss caused by natural hazards in Australia. Between 1967 and 1999 the annual average loss caused by floods across Australia is estimated to be $314.0 million of which Queensland contributes $111.7 million (BTE, 2001).

Riverine (i.e. main stream) flooding is the most commonly analysed form of flood hazard, but in the study area it is the flash flooding in smaller streams and sub-catchments and stormwater surcharge that have been demonstrated in recent years to be the principal problems. Flash flooding is defined in SCARM (2000) as:

> *Sudden and unexpected flooding caused by local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within six hours of the rain which causes flooding.*

Riverine and flash flooding is typically associated with the natural drainage systems, but stormwater surcharge is more correctly associated with the engineered drainage network of urban areas. It is defined (as 'stormwater flooding') in SCARM (2000) as:

> *Inundation by local runoff caused by heavier than usual rainfall. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow.*

The final form of flooding of concern in the study area is dambreak flooding, defined in SCARM (2000) as:

> *Flooding caused by the breaking of a dam embankment. Note that dambreak flooding may inundate areas* ***outside the floodplains****...*
>
> (emphasis in the original)

2.3.2 River Catchments

The study area contains about half of the catchment of the Ross River and a much smaller proportion of the Haughton River catchment. Both rivers have their sources in the Hervey Range and on Mt Elliot. The two catchments and their water courses are shown in Figure 2.6.

The Ross River basin also contains the smaller Bohle River, however, only a small portion of its lower course lies within the study area, the bulk being within the former Thuringowa City.

Flooding in the Ross River has been modified (but not controlled) by construction of the Ross River Dam in the 1970s. Maunsell (2005a) make the following important observation regarding the overall flood hazard environment in the study area:

> ***An important finding of the review of previous studies was that the local catchment (downstream of the Ross River Dam) can potentially produce a significantly greater runoff peak than the larger dam catchment once routed through the Dam.***
>
> (emphasis in original)

Ross River Dam Failure Hazard: Townsville is probably the only major urban centre in Australia that has had a large earth-filled dam constructed upstream of it. The risk of a catastrophic failure of the dam has been recognised for many years and various studies have been undertaken to assess the safety (or otherwise) of that structure.

As a result, the dam has recently undergone a major upgrade, in part to reduce its storage capacity and in part to bring it into compliance with the safety standards of the Australian National Committee on Large Dams (ANCOLD). Part of that upgrade includes lowering the level of the spillway and the installation of dam gates to control the downstream flow. A risk analysis of flooding caused by a failure of the Ross River Dam has been undertaken by GHD (2005a and b) and its outcomes are considered in this study.

There are three weirs below the dam (Black, Gleeson's and Aplin's), the oldest of which (Aplin's) dates from the 1920s.

There is no flood control infrastructure on the Haughton River tributaries within the study area.

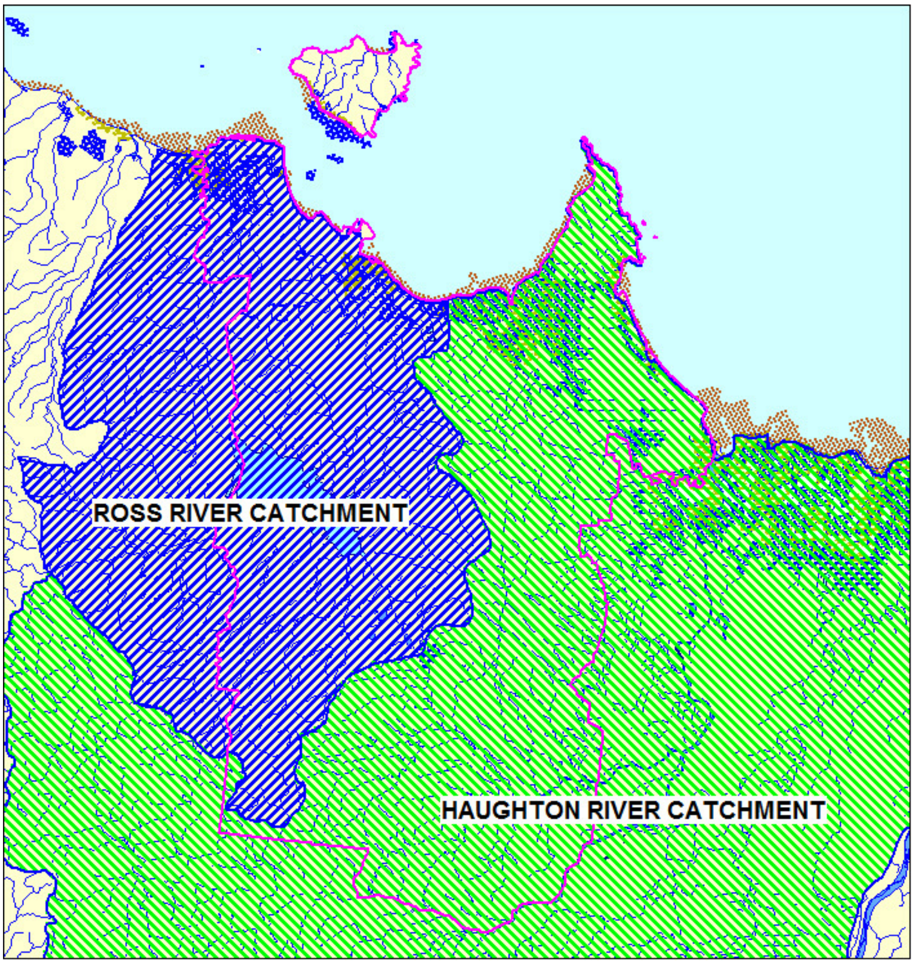


Figure 2.6: Drainage catchments in Townsville City

2.3.3 Minor Catchments

Within the City, the flash flood hazards posed by eight natural sub-catchments on the Townsville flood plain and four on Magnetic Island have been investigated by Maunsell (2005a and b). Details of the Townsville flood plain sub-catchments are provided in Table 2.2. The Magnetic Island sub-catchments are less complex.

The Maunsell (2005a) study also included an investigation of the storm tide hazard in the coastal communities of Pallarenda and Cungulla.

The engineered stormwater infrastructure also forms part of these minor catchments in the urban areas. There are around 760 km of stormwater infrastructure in the study area, the major components of which are open drains (214.6 km) and stormwater pipes (391.7 km).

Table 2.2: Summary of sub-catchments for the Townsville flood plain (Maunsell 2005a, Table 17)

Catchment	Catchment Area (ha)	No of Sub-Catchments
Ross River	6,686	121
Stuart Creek	6,506	25
Gordon Creek	2,078	55
Ross Creek	1,983	94
Rowes Bay Canal	729	22
North Ward*	371	21
Louisa Creek	1,392	62
Northern Slopes of Mount Louisa*	1,262	37
Total	**21,007**	**437**

* Numerous drainage paths

2.3.4 Flood History

There is 'precious little flood data for the Ross River' (Peter Baddiley, BoM flood hydrologist, personal communication, 2007) and the data that is available is from post-1990 events. Prior to the damming of the Ross River, main stream flooding was a major problem for the study area. Since completion of the dam, however, that hazard has been greatly reduced. This reduction may, in part, also be explained by the decline in the number of cyclones and tropical storms crossing the Ross River catchment since the 1970s.

Appendix C contains extracts relating to the Townsville area from the BoM Queensland flood history web page www.bom.gov.au/hydro/flood/qld/fld_history/index.shtml. This material is based on contemporary press and official reports. There are only five entries that refer directly to flooding in the Ross River, however, all of the others are likely to have had some flood impact in that catchment.

The recent history of flash flooding and stormwater surcharge, by contrast, has been quite dramatic. Maunsell (2005a) uses detailed data from three events – March 1990, January 1998 and February 2002 – to calibrate their hydrologic and hydraulic models. Details of earlier events, however, were not available to that study. Of the events used, the 1998 flooding, produced by very intense rainfall from ex-TC *Sid*, was by far the most serious. The rainfall intensities experienced in that episode have been assessed as having an ARI of around 500 years.

2.3.5 Flood Studies

Maunsell (2005a) reports on the flood hazard modelling undertaken within the Townsville urban area and on Magnetic Island. This hazard modelling was based on industry standard modelling tools including the RAFTS hydrologic runoff/routing model, the 1-D hydraulic model Mike 11 (used for Magnetic Island and the Townsville floodplain) and 2-D hydraulic model Mike 21 (used only for the Townsville floodplain). A 20 m horizontal resolution DEM provided the ground surface for this modelling. It should be noted that not all of the potential flood inundation hazards across the study area were modelled, but the area that was modelled includes the great majority of the developed properties.

The modelling was undertaken to establish the likely inundation extents for 2, 5, 10, 20, 50 and 100 year ARI events and for the probable maximum flood (PMF) level. Of these scenarios the 50 year, 100 year and PMF outputs will be used in this risk assessment. A summary of the results of the Mike 11 modelling of Magnetic Island is provided in Table 2.3, for the Townsville floodplain Mike 11 modelling in Table 2.4 and the Mike 21 modelling for the Townsville floodplain in Table 2.5.

Figure 2.7 shows the inundation extent for the 50 and 100-year ARI events on Magnetic Island and Figure 2.8 shows the extent of inundation for the same scenarios in the Townsville floodplain. These figures are based on data developed by Maunsell.

The maps are interesting in that they show how little difference there is in the horizontal extent of inundation between the 50 year and 100 year events. The extent of PMF flooding however is considerable greater than the 100 year ARI extent. The PMF flood depth modelling is shown in Figure 2.9.

No comparable data were available to estimate the inundation of a PMF event on Magnetic Island, however, given the more deeply incised nature of the streams on the island and the relatively small coastal extent of their flood plains the areal extent is unlikely to be much greater than that illustrated for the 100 year ARI event.

The Maunsell study does not provide analysis of flood water velocity. It is likely that the streams on Magnetic Island will have very high velocity flood waters while those on the mainland (because of their much wider flood plain) are likely to have much lower flood velocities.

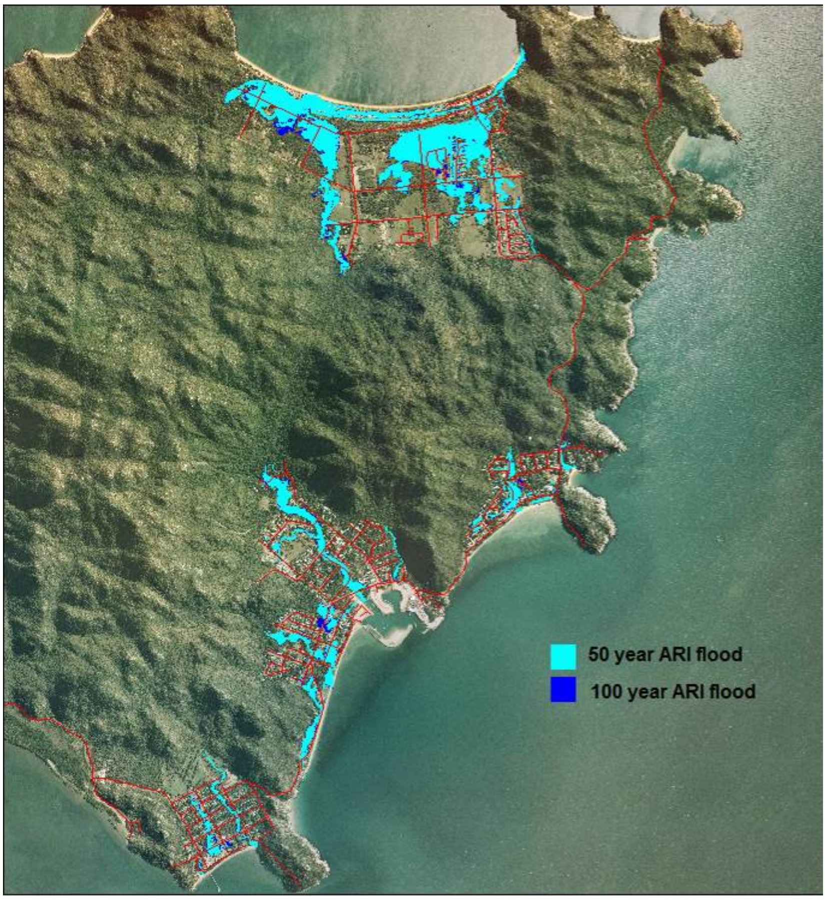


Figure 2.7: Magnetic Island 50 and 100 year ARI flood inundation

Table 2.3: Flood inundation characteristics (Mike 11) – Magnetic Island (Maunsell, 2005a Table 25)

Catchment	ARI	Description of flooding
Picnic Bay	2-5	▪ Flows exceed the unnamed drainage path that runs parallel to and between Granite Street and Yule Street. ▪ Flooding along Picnic Street occurs due to the insufficient capacity of road culverts at Picnic Street.
	10-20	▪ Birt Street and Picnic Street road crossings are overtopped due to a 10 Year ARI event at Butlers Creek.
	50-100	▪ Flood waters overtop the road and inundate low-lying areas upstream and downstream, extending east to Granite Street.
	PMF	▪ Widespread flooding occurs along the two drainage paths with significant inundation of Picnic Street.
Nelly Bay	2-5	▪ Localised flooding occurs along Gustav Creek. ▪ Some properties adjacent to drainage path between Lilac Street and Yates Street are inundated.
	10-20	▪ Properties built in low-lying areas downstream of Sooning Street are subject to flooding. ▪ Elena Street and Barton Street road crossings are overtopped in the 20 and 10 Year ARI events respectively.
	50-100	▪ Properties along Compass Crescent are subject to flooding with water backing up behind Sooning Street.
	PMF	▪ Widespread flooding with inundation of properties along Murray Street from overflows from Gustav Creek. ▪ Properties downstream of Sooning Street are inundated. ▪ Access along Nelly Bay Road restricted for majority of its length.
Arcadia	2-5	▪ Localised flooding occurs along Petersen Creek, particularly at road crossings and low-lying areas.
	10-20	▪ Build up of floodwater upstream of Marine Parade.
	50-100	▪ Localised flooding around Arcadia Resort.
	PMF	▪ Significant number of properties inundated, and access along Marine Parade restricted.
Horseshoe Bay	2-5	▪ Horseshoe Bay Road overtopped at the swamp crossing. ▪ Flows surcharge the existing drainage along Apjohn Street and cause localised flooding of the urbanised area downstream. ▪ Properties located within the low-lying areas upstream of the road culverts on Gifford Street are subjected to frequent flooding due to the insufficient capacity of the culverts.
	10-20	▪ Further inundation of properties upstream of Gifford Street and adjacent to Corica Crescent.
	50-100	▪ Flooding of properties adjacent to Dent Street.
	PMF	▪ Widespread flooding of all urbanised areas with shops along Henry Lawson Street and properties adjacent to the drainage path in this area inundated. ▪ Significant flooding of residential development upstream of Gifford Street.

Table 2.4: Flood inundation characteristics (Mike 11) – Townsville floodplain (Maunsell, 2005a Table 25)

Catchment	ARI	Description of flooding
City	2-5	▪ Localised flooding at Barryman Street and Kitchener Street, and build up of floodwaters upstream of Bayswater Road. ▪ Flooding along overland flow path in Mundingburra, particularly at Arthur Fadden Park and the Love Lane / Brairfield Street intersection. ▪ Inundation at Cuthbert Crescent (Vincent), and various sites within North Ward, particularly the intersections of Howitt Street and Cook Street, Landsborough Street and Warburton Street, Mitchell Street and Oxley Street and the length of Mitchell Street between Kennedy Street and Burke Street. ▪ Bayswater Terrace on Mindham Park Drain overtopped (5 Year ARI).
	10-20	▪ Widespread local flooding of overland flow paths through Cranbrook, Heatley, Vincent and Currajong. ▪ Inundation of industrial properties along Peewee Creek, with inundation at the Duckworth Street / Bayswater Road intersection. ▪ Airstrip free from flooding.
Fairfield	2-5	▪ Abbott Street near service station and Bruce Highway at Jurekey Street intersection overtopped (2 Year ARI). ▪ Floodwaters surround service station opposite the racecourse, with significant inundation of racecourse car park. ▪ Properties east of Lavarack Barracks and south of University Drive (Newton Street) subject to localised flooding. ▪ Inundation of development at end of Minehane Street. ▪ Mervyn Crossman Drive overtopped at turnoff to Townsville Hockey.
	10-20	▪ Access along Bruce Highway at Stuart Creek restricted in the 20 Year ARI flood event, as is Stuart Drive just north of University Drive. ▪ Inundation of Mervyn Crossman Drive / Murray Lions Crescent intersection near William Ross School (access to the school restricted).
South Townsville	2-5	▪ No flood inundation evident outside tidal zones
	10-20	▪ Floodwaters contained within drainage systems, although extend to Boundary Street, Ninth Street and Seventh Street.
Mount Louisa	2-5	▪ Louisa Creek of sufficient capacity until constriction at Ingham Road. ▪ Flooding north of Ingham Road in areas around Mt St John STP and Town Common. ▪ Localised flooding upstream of Woolcock Street at Calvary Drain.
	10-20	▪ Widespread flooding of residential properties upstream of Woolcock Street along Calvary drain east to Louisa Creek, in addition to properties along Bayswater Road. ▪ Inundation of some properties along Buchanan Street.
Annandale	2-5	▪ Annandale area generally flood free (some inundation of Palmetum area).
	10-20	▪ Access to the hospital flood free for events greater than 20 Year ARI.

Table 2.5: Flood inundation characteristics (Mike 21) – Townsville floodplain (Maunsell 2005a Table 26)

Catchment	ARI	Description of flooding
City	50-100	▪ Continuous flooding along Albert Street and Alfred Street (Stockland Plaza) with overland flows reaching Mindham Park drainage system. ▪ Widespread surface flooding through Gulliver and Pimlico. ▪ Surcharge of flows from Mindham Park to Ross Creek. ▪ Lake drainage network surcharged with flows overtopping Kings Road and connecting to Mindham drainage system.
	PMF	▪ Extensive overland flow throughout the majority of suburban areas. ▪ No overflows from Ross River left bank until Bowen Road (inundation of areas upstream of Bowen Road due to local flooding). ▪ Lakes drainage system surcharges north to Rowes Bay Canal, effectively encircling Castle Hill. ▪ Continuous inundation along Mitchell Street to Heatleys Parade. ▪ Eastern taxiway at airport inundated but main runway above floodwaters. ▪ Lower slopes of Castle Hill flood free as are some areas within Pimlico and Mysterton, as well as areas around Charles Street in Heatley.
Fairfield	50-100	▪ Property upstream of Bruce Highway between Stuart Creek and the racecourse inundated. ▪ Major access routes cut at numerous locations. ▪ Murray Sporting Complex inundated. ▪ Inundation of Cluden residential area off Racecourse Road.
	PMF	▪ Continuous inundation between racecourse and Ross River, including all access roads leading into town. ▪ Island of high ground around old drag strip off Abbot Street. ▪ Full length of Bruce Highway to University Drive, including major intersection at Stuart Drive inundated.
South Townsville	50-100	▪ Significant inundation of land and property between Boundary Street and Abbot Street, although Civic Theatre flood free.
	PMF	▪ Ross River completely connected to Ross Creek. ▪ Port area north of Allen Street generally flood free.
Mount Louisa	50-100	▪ Most areas within RAAF base flood free. ▪ Significant inundation of property adjacent to Louisa Creek.
	PMF	▪ Widespread inundation along Louisa Creek caused in part by overflows from the Bohle River system. ▪ Lower slopes of Mount Louisa flood free. ▪ Significant inundation south of Dalrymple Road.
Annandale	50-100	▪ Inundation along Fardon Street, however floodwaters generally contained within drainage systems. ▪ Access to hospital has flooding immunity greater than 100 Year ARI event.
	PMF	▪ Extensive flooding along all major drainage paths, with connectivity of flows from University Drive to Macarthur Park drain, Annandale Drain and Marabou Drive Drain.
Sandfly Creek	50-100	▪ Inundation of Cleveland Bay Purification Plant.
	PMF	▪ Whole of Sandfly Creek sub area underwater to depths greater than 2m.

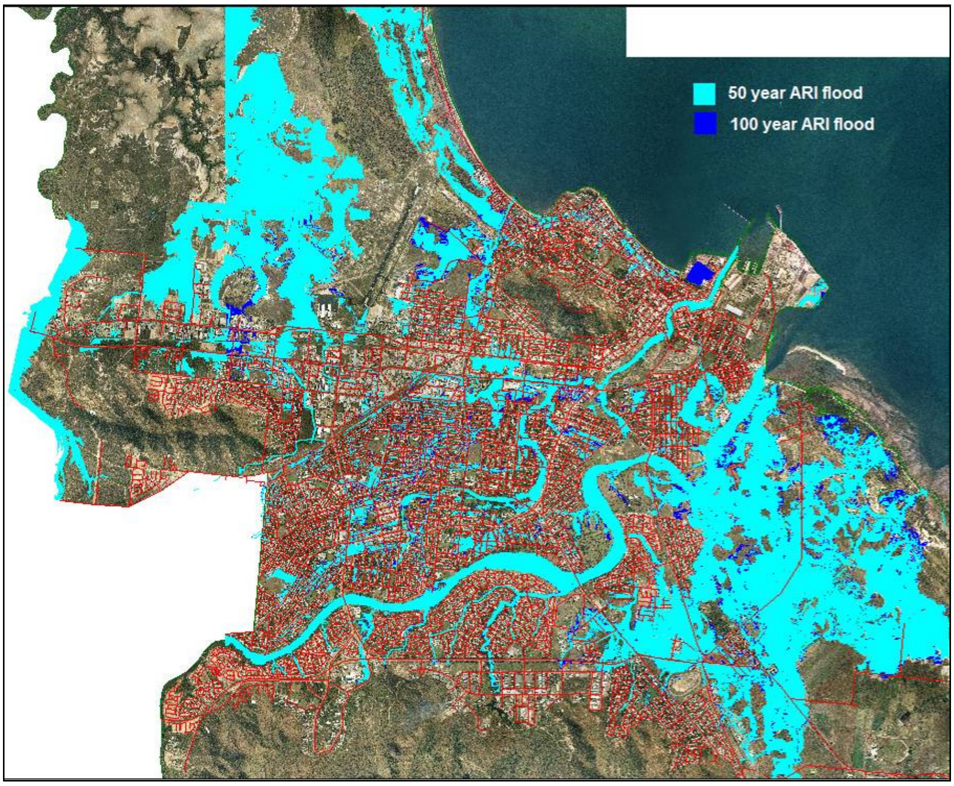


Figure 2.8: Townsville floodplain 50 and 100 year ARI flood inundation

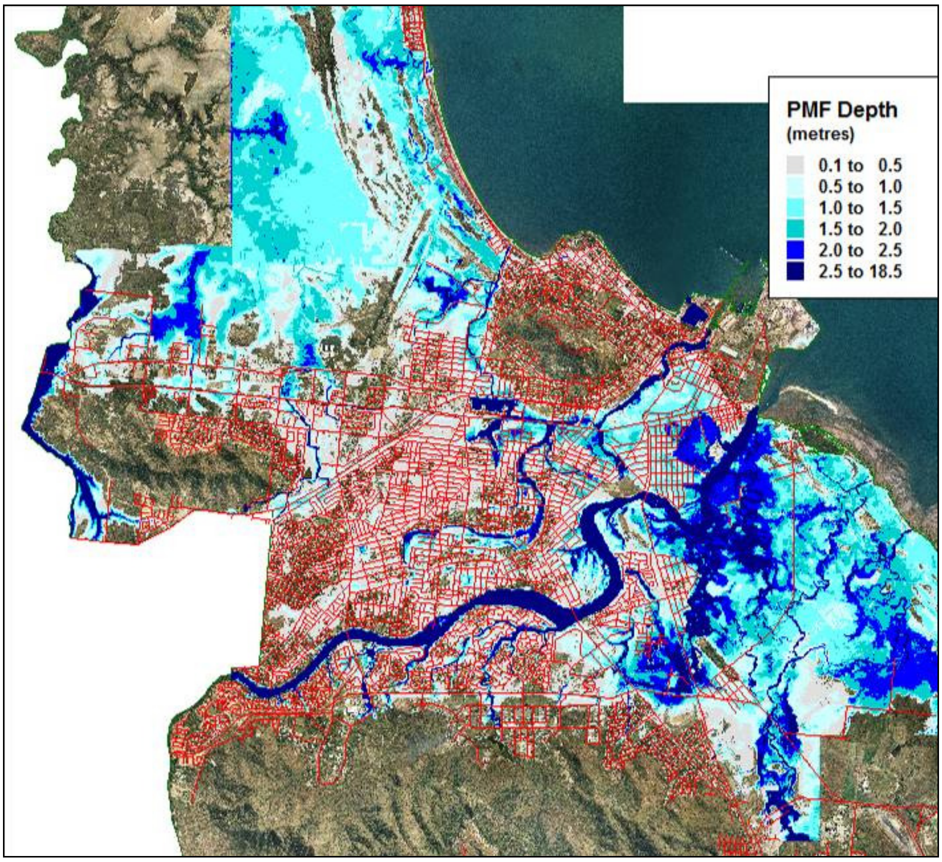


Figure 2.9: Townsville floodplain potential PMF flood extent

Dam Failure Inundation: The flood extent that could be expected in the event of a failure in the Ross River Dam has been modelled by a number of agencies before the recent upgrade work on that facility had been undertaken. Modelling undertaken for NQ Water (Maunsell McIntyre, 2001) has used scenarios based on a breach at two different points – one at the dam spillway and the other on the embankment dam. The Maunsell McIntyre (2001) inundation extent modelling undertaken does not extend across the whole urban area – it cuts out at Woolcock Street.

The source of the other modelling is unknown to this study, but the extent mapping covers the whole urban area. It is based on two scenarios of flow rates over the dam spillway. Those rates are 4200 m^3s and 23,500 m^3s. The extent mapping for the latter flow rate is slightly greater to that shown in Figure 2.9 as the extent of PMF inundation. This is not unexpected given that a dambreak flood onset is significantly more rapid than that of a conventional flood with the result that phenomenon such as hydraulic lift will push waters into locations above the floodplain.

2.3.6 Warnings

The BoM, in conjunction with local councils, provides warnings of potential flooding in identified catchments based on data from a network of automatic weather stations (AWS) and river stream gauges. These are linked to flood behaviour models and form an Alert System. There are Alert systems installed on the Ross and Haughton Rivers. There are at least 22 flood warning stations within Ross River basin operated by various agencies. These are shown on Figure 2.10. Within the Haughton basin only two flood warning stations lie within the study area.

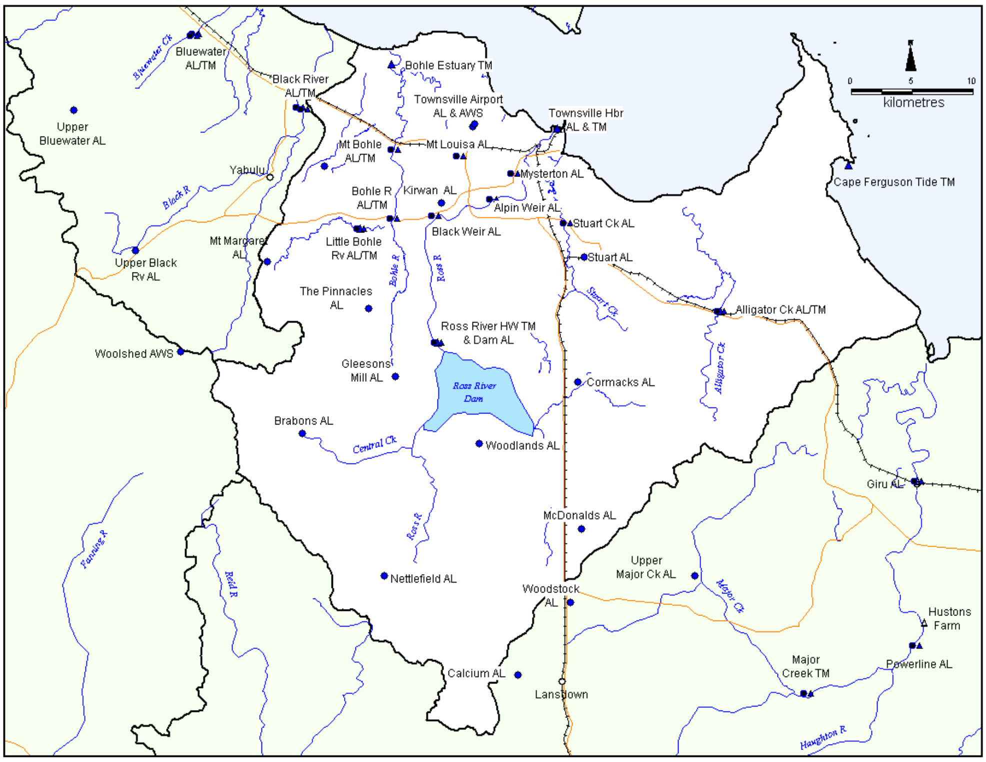


Figure 2.10: Ross River basin flood warning network (BoM)

2.3.7 Conclusions

The Townsville urban area has a significant flood risk, especially from flash flood and stormwater surcharge in the smaller urban catchments. Main stream flooding from the Ross River is less frequent and has been significantly modified by construction (and subsequent upgrade) of the Ross River Dam.

2.4 STORM TIDE

2.4.1 The Phenomenon

All tropical cyclones on or near the coast are capable of producing a storm surge, which can increase coastal water levels for periods of several hours and simultaneously affect over 100 km of coastline. When the storm surge is combined with the daily tidal variation, the absolute combined water level reached is called the storm tide. An individual storm surge is measured relative to the mean sea level (MSL) at the time, while storm tide is given as an absolute level such as its height above the Australian Height Datum (AHD). Only the storm tide level can thus be referenced to a specific ground contour value.

Figure 2.11 summarises the various components that work together to produce an extreme storm tide. Firstly, the storm surge is generated by the combined action of the severe surface winds circulating around the storm centre generating ocean currents, and the decreased atmospheric pressure causing a local rise in sea level (the so-called inverted barometer effect). The strong currents impinging against the coast are normally responsible for the greater proportion of the surge. As shown in Figure 2.11, the surge adds to the expected tide level at the time the storm makes landfall.

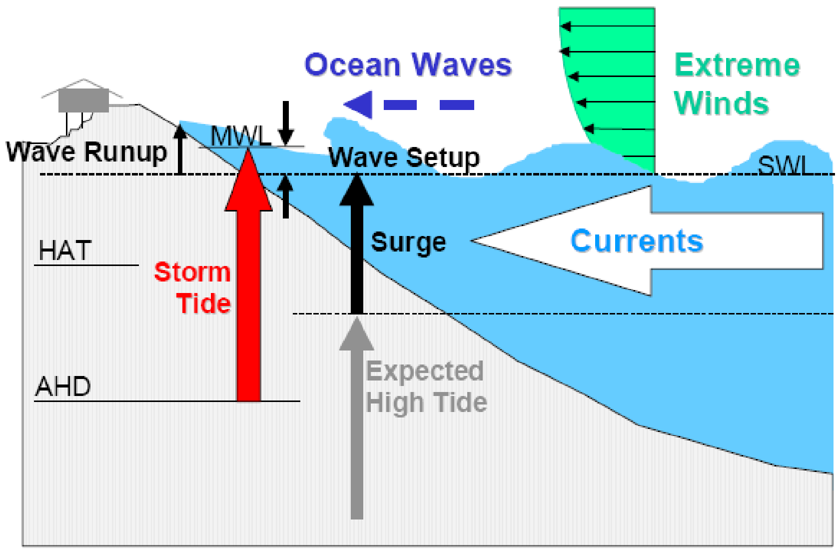


Figure 2.11: Components of a storm tide (from GHD and SEA, 2007)

Also accompanying the surge are the extreme wind-generated ocean waves - a combination of 'swell' and local 'sea' driven before the strong winds. These waves shoal as they approach the shore and, as part of the process of wave breaking, a portion of their energy can be transferred to a localised increase in the still-water level. This effect is termed wave setup and, although generally much smaller than the surge, can add 0.5 m or more to the surge level at exposed locations. Additionally, waves will run up sloping beaches to finally expend their forward energy and, when combined with elevated sea levels, this allows them to attack fore-dunes or near-shore structures to cause considerable erosion and/or destruction of property.

The potential magnitude of storm surge is affected by many factors; principally the intensity of the tropical cyclone, its size and its forward speed. As the cyclone approaches the coast, the local shape of the coastline and the slope of the undersea bathymetry are particularly significant contributors to the resulting surge height. When the resulting storm tide exceeds the normal range of the daily tide the local beach topography will dictate whether significant coastal inundation will occur. Results from a study of cyclone impacts in Vanuatu (Shorten et al, 2003; Appendix 3b) showed that - depending on bathymetric, wind and storm conditions – the contribution to inundation from very large waves can overwhelm the component of storm surge alone. It is likely that this aspect can also explain the differences between the reported depth of storm tide inundation from TC *Mahina* in Bathurst Bay in 1899 (up to 15 m above sea level) and the physical evidence of storm-generated deposits (not more than 5 m above sea level) reported by Nott and Hayne (2000).

2.4.2 Storm Tide History

Of the cyclones listed in Appendix A only three (of 23) explicitly mention storm tide impacts. They were:

- 1896 TC *Sigma*
- 1940 unnamed cyclone
- 1971 TC *Althea*

It is likely that several other cyclones also produced elevated sea levels in the Townsville area, however, they would not appear to have been sufficiently significant to have been worthy of note.

Of those identified, the TC *Althea* storm tide event is the best documented. *Althea* had a central pressure of 950 hPa and produced a storm surge of 2.9 m. A storm of such intensity has an ARI of 20 years anywhere within 500 km of Townsville, however, the probability of reproducing a similar track, size and speed is much lower. The surge reached the coast very close to low tide so the height of the storm tide was almost 1.5 m lower than it would have been had it crossed the coast at the top of the tide around 6 hours later. The trace of the various elements of the TC *Althea* storm tide is shown in Figure 2.12 (from GHD and SEA, 2007 attributed to Stark, 1972).

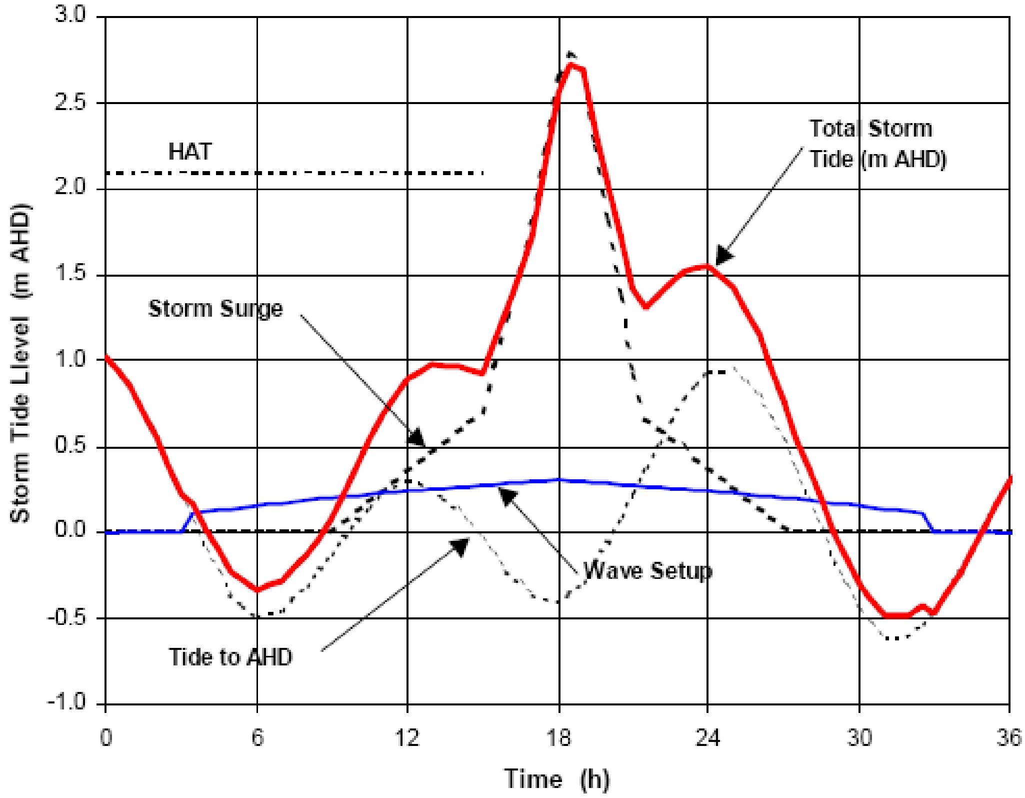


Figure 2.12: TC *Althea* storm surge, tide and storm tide relationship (GHD and SEA, 2007 Figure E.1)

2.4.3 Storm Tide Studies

Two storm tide hazard assessments have been undertaken of the Townsville area in recent years. That by Maunsell (2005a) covered the Townsville floodplain, Pallarenda and Cungulla and employed Mike 11 and Mike 21 to model the on-shore inundation. The event scenarios employed were to repeat the TC *Althea* event and to place the *Althea* surge arrival at the top of a Mean High Water Spring tide (i.e. *Althea* plus 4.0 m). The storm tide model used in that study is obviously unsophisticated, though the on-shore inundation modelling using industry standard hydraulic models and a high resolution DEM is quite sophisticated.

By comparison, the more recent GHD and SEA (2007) study covered the area from Crystal Creek (in the former Thuringowa City) to Cleveland Palms (in the study area) as well as Magnetic Island and Cungulla. This study develops a very sophisticated storm tide model employing a catalogue of 90,000 synthetic cyclones (equivalent to a 50,000 year event record) and high resolution bathymetric data. Its estimates of storm tide elevations at the beach for events with an ARI ranging from 50 to 10,000 years can be considered to be 'state-of-the-art'.

The on-shore inundation modelling employed, however, simply employed projecting the storm tide elevation value to its equivalent contour inland (with a small adjustment for reduced wave set up influence beyond a nominal 150 m of the shore line). The approach is described as follows:

> *Following from the methodology adopted for the study, the effects of the above factors are accounted for throughout the implementation of SATSIM* (Surge and Tide Simulation Model)

and mapped by extending inland the resulting SATSIM water level at the coastline until a matching terrain height is encountered. In addition to these effects, the landward increase in inundation depth caused by overland flow under the effect of cyclonic winds acting on the free water surface beyond the HAT line has also been included.

This approach is virtually identical to the approach employed by Granger in the AGSO *Cities Project* studies of Cairns, Mackay, Gladstone and South-East Queensland (Granger and others, 1999; Middlemann and Granger, 2000; Granger and Michael-Leiba, 2001 and Granger and Hayne, 2001). It is, however, somewhat less dynamic than modelling employing 2-D hydraulic techniques combined with a high resolution DEM.

Given the more suitable storm tide modelling techniques the outcomes reported in the GHD and SEA (2007) study will be used in this risk analysis.

Table 2.5 provides the estimates of storm tide elevation (including wave set up) above highest astronomical tide (HAT) for key reference points along the Townsville and Magnetic Island coastlines and Figures 2.13, 2.14 and 2.15 show the inundation extent for 100, 500 and 10,000 year ARI storm tide events on Magnetic Island, Townsville and Cungulla respectively.

Table 2.6: Study area estimated storm tide depths for selected ARI (from GHD and SEA, 2007 Table 6-2)

SITE	50 year ARI	100 year ARI	500 year ARI	1000 year ARI	10000 year ARI
Bohle River	0.1	0.2	0.7	1.0	2.7
Shelly Beach	0.8	1.0	1.8	2.3	4.4
Cape Pallarenda	0.4	0.5	1.2	1.6	3.5
Pallarenda	0.5	0.7	1.5	1.9	3.1
Rowes Bay	0.6	0.9	1.7	2.2	3.8
Kissing Point	0.5	0.8	1.6	2.1	3.4
North Ward	0.6	0.9	1.7	2.3	3.3
Breakwater Casino	0.5	0.7	1.4	1.9	3.0
Townsville Harbour	0.5	0.7	1.4	1.4	3.3
South Townsville	0.5	0.8	1.6	1.9	3.5
Ross River	0.8	0.9	1.1	1.6	3.6
Florence Bay	0.7	1.0	1.7	2.1	3.5
Arthur Bay	0.3	0.5	1.0	1.3	3.0
Arcadia (Alma Bay)	0.4	0.5	1.1	1.5	2.9
Nelly Bay	0.4	0.6	1.3	1.6	3.0
Picnic Bay	0.4	0.6	1.3	1.7	3.7
Bolger Bay	0.6	0.8	0.9	1.0	1.8
West Point	0.3	0.5	1.0	1.3	2.8
Huntingfield Bay	0.3	0.4	0.9	1.2	2.7
Wilson Bay	0.3	0.4	1.0	1.3	2.7
Horseshoe Bay	0.3	0.5	0.9	1.3	2.6
Radical Bay	0.4	0.6	1.1	1.4	2.5
Cungulla	0.5	0.7	1.5	1.6	2.9

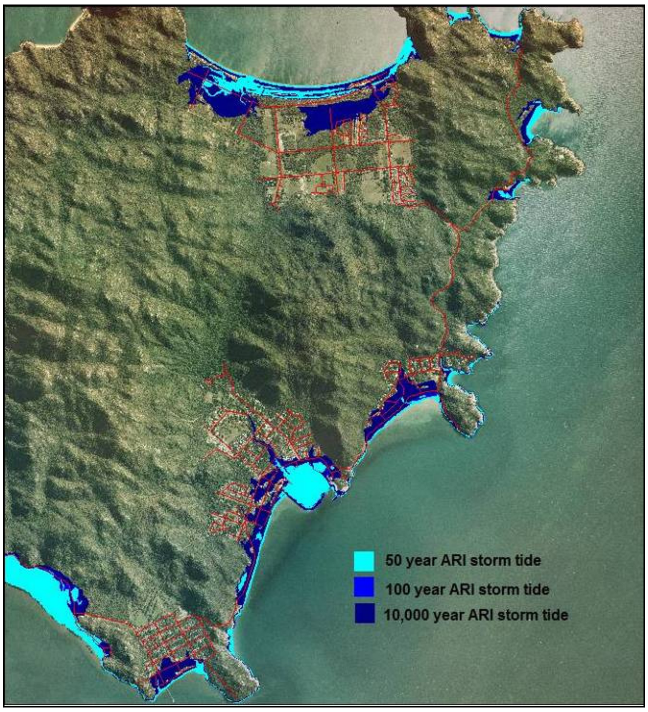


Figure 2.13: Magnetic Island storm tide inundation

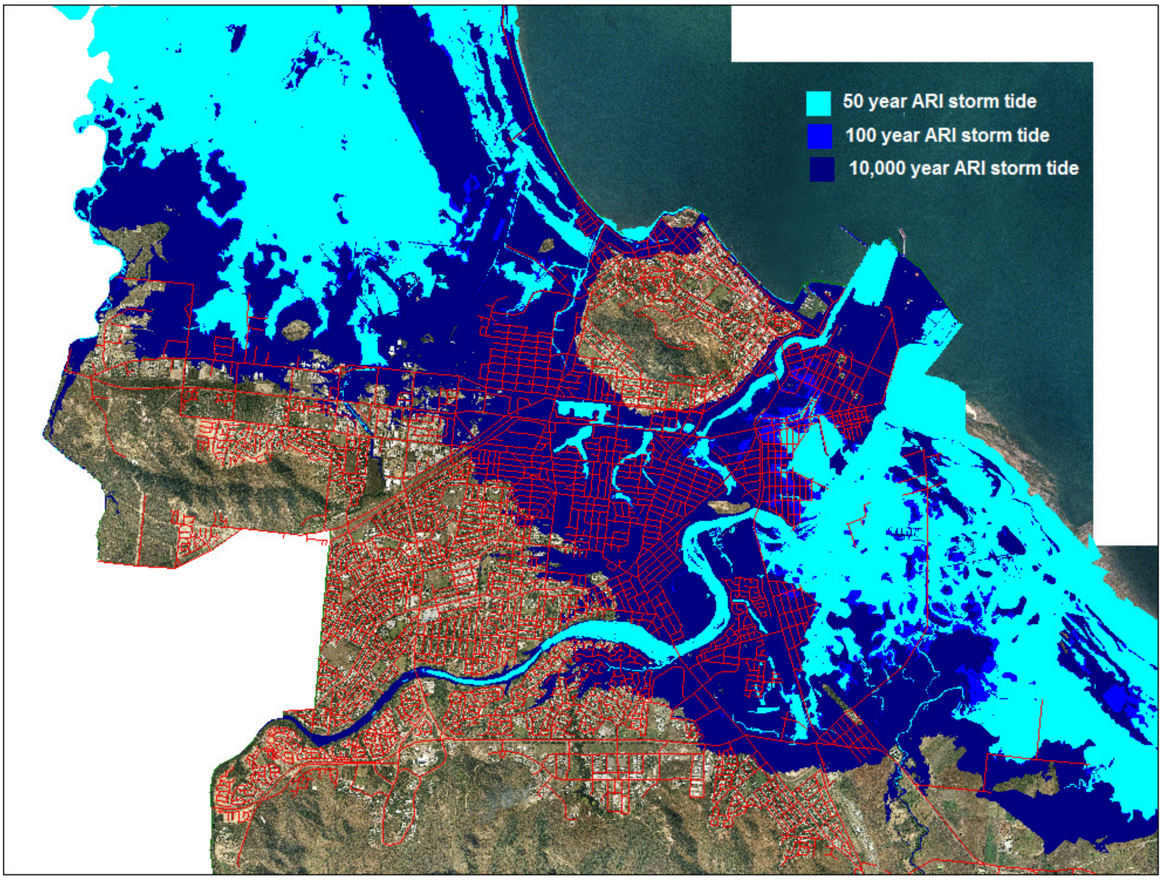


Figure 2.14: Townsville urban storm tide inundation

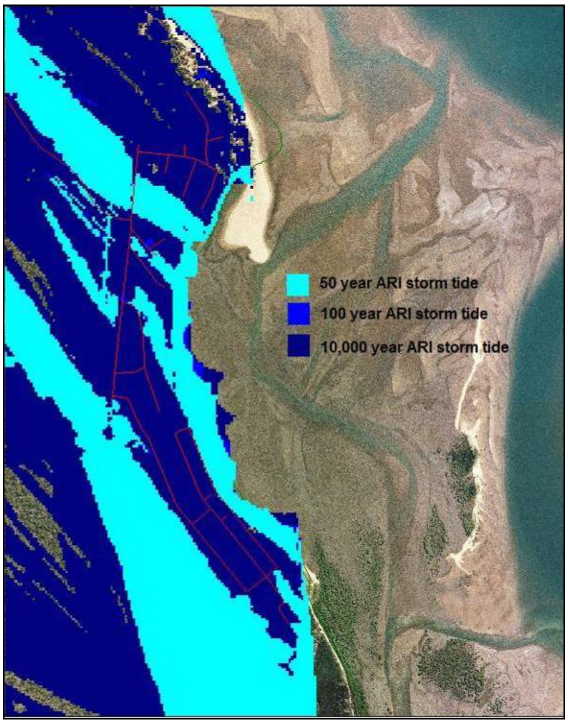


Figure 2.15: Cungulla storm tide inundation

2.4.4 Warnings

The BoM, in conjunction with the EPA, produces warnings of storm tide generated by tropical cyclones as part of their overall cyclone warning process. Data provided to disaster managers are quite specific as to the forecast time of impact and the relative height of the storm tide relative to the AHD. Public warnings, however, simply refer to 'sea levels above the highest tide of the day'.

2.4.5 Conclusions

Townsville faces a potentially significant storm tide threat, though it would require a relatively rare event to cause major problems.

2.5 LANDSLIDES

2.5.1 The Phenomenon

Landslides are defined in SPP 1/03 (DLGP/DES, 2003a) as:

> *a movement of material downslope in a mass as a result of shear failure at the boundaries of the mass.*

Hayne and Gordon (2001) provide a broader description, namely:

A landslide is the movement of a mass of rock, debris or earth down slope. Whilst the causes of slope movement can be quite complex, all slides have two things in common, they are the result of failure of part of the soil and rock materials that make up the slope and they are driven by gravity. Landsides can vary in size from a single boulder in a rock fall to tens of millions of cubic metres of material in a debris avalanche. While not as well recognized as many other hazards such as cyclones, storm surge, floods and earthquakes, in Australia landslides cause more economic loss as well as injury and loss of life than is generally recognized.

In Australia, 85 landslides are known to have caused injury or death in the period from 1842 to 2007, with at least 107 people killed and 142 injured (Marion Leiba, personal communication 2008). Many were, either directly or indirectly, the result of human activity, while others were naturally occurring events. Eighty landslides throughout Australia are known to have caused damage, during the period 1842 to 2007, to a total of over 200 buildings, many of which were destroyed. Landslides also cause considerable economic loss, particularly to infrastructure such as roads and railways, but the data are not available with which to place a dollar value on it.

2.5.2 Landslide Processes

The landslide process is complex and involves a range of factors including the underlying geology and soils, slope, geomorphology, drainage and vegetation status (cleared or uncleared). Developing landslide hazard management strategies based simply on slopes of 15% (8.5°) or more, as suggested as a default method by the SPP 1/03 Guidelines (DLGP/DES, 2003b), is most undesirable, as Willmott (1983) observed:

To the layman, landslides are visualised as occurring on steep slopes, generally where there is a thick accumulation of soil or debris. However, there are numerous examples of steep, but quite stable hillsides, such as the older Brisbane suburbs of Paddington, Red Hill and Taringa, and equally numerous examples of major landslides occurring on slopes lower than 7° (or 12%). ***Clearly, any landslide risk assessment cannot be based on slope angle alone****.*

(emphasis added)

Certainly the most common trigger for landslides is an episode of intense rainfall. The rainfall threshold values for slope failure in various parts of the world are in the range 8-20 mm over one hour, or 50-120 mm over a day depending on geology and slope conditions. In the study area, rainfall intensities of such magnitude have an average recurrence interval (ARI) of less than one year.

Rainfall is clearly the most common trigger for landslides and the more widespread the rainfall - as with a tropical cyclone or east coast low - the more widespread will be the occurrence of landslides. Conversely, the more localised the rainfall, the more localised will be the landslide occurrence. As a broad rule-of-thumb, the following rainfall intensities are likely to produce landslides:

- 500 mm cumulative rainfall over four weeks, and/or
- 200 mm rainfall in 24 hours, and/or
- 50 mm rainfall in one hour

though lower intensities have been known to cause slope failure.

Developed slopes, such as road cuttings and benched house sites, tend to be more susceptible to landslide than natural slopes because of:

- artificially steepening the slope with batters;
- potentially weakening the site with fill;
- loading the upper part of the slope;
- removing support from the base of the slope;
- clearing vegetation during development; and,
- watering developed land.

Such risks can, however, generally be mitigated by carrying out the development with appropriate geotechnical advice.

2.5.3 Landslide History

The presence of well developed debris fans at the base of hills such as Mt Stuart and Castle Hill are clear evidence of a long and ongoing history of landslides in the study area. Two recent events illustrate the type of risks posed by landslide.

In January 1998 ex-TC *Sid* produced the most intense rainfall on record for Townsville. That rainfall caused two significant debris flows in the Nelly Bay area of Magnetic Island. The smaller one fortunately ended before reaching a house. The larger debris flow caused significant damage to the Magnetic Island International Resort, including the destruction of a small car that was crushed by the debris flow against a resort building (see Figure 2.16). A very large boulder transported by the debris flow was left perched in the gully above the resort and had to be broken up by engineers to remove the further threat.

In April 2000 TC *Tessi* produced record rainfalls for April in Townsville with over 420 mm being recorded in a 24 hour period. That rainfall produced significant landslides and coalescing debris flows off the north-eastern slopes of Castle Hill. Those landslides did little direct damage however the debris flows entered the swimming pools and basements of houses and left a very large boulder perched up-slope from some of the City's most expensive residential properties. Engineering activity was again required to stabilise that boulder (see Figure 2.17). A debris flow was also triggered from the northern slopes of Castle Hill and its runout entered houses at the foot of the slope.

2.5.4 Landslide Studies

Two landslide studies have been undertaken that focus on the potential of landslides causing harm in the study area. The earliest (Coffee Geoscience, 2001) was undertaken to review the landslide hazard across the study area in response to the 1998 and 2000 events described above. Coffee Geoscience (2001) employed manual methods to develop slope zone mapping from hard-copy contour maps combined with hard-copy geological mapping. The analysis was informed by the interpretation of past landslide activity from recent aerial photos and field surveys in specific areas. The area covered was confined to already developed, or soon-to-be developed, areas rather than the whole study area.

Figure 2.16: Magnetic Island 1998 (AGSO photo)

Figure 2.17: Castle Hill 2000 (Townsville Bulletin photo)

The landslide hazard potential was classified using a modification of the scheme proposed by the Australian Geomechanics Society in the second edition of their *Landslide risk management concepts and guidelines* (AGS, 2000). The zonation of the study area used is shown in Table 2.7. The zonation and mapping are accompanied by the following note:

> *It should be noted that the zonation given (*in the table*) relate solely to undeveloped natural ground. They take no account of any development that has occurred or which may take place in the future. The Zones do take account of the potential distance of travel of landslides or debris flows should they occur.*

Coffey Geoscience (2001) makes the following observation regarding landslide frequency:

> *The expected frequency of landslide or debris flow events is conjectural. It was suggested that the rainfall event which resulted in the Magnetic Island debris flow had a one in five hundred year intensity. The landslide and debris flow on Castle Hill is considered to correspond to a one in one hundred year rainfall event.*

Figures 2.18 and 2.19 show the zonation mapping for Magnetic Island and the Townsville urban area respectively.

Table 2.7: Definitions of landslide hazard zones (Coffey Geoscience, 2001 Table 1)

ZONE	HAZARD CATEGORY	DEFINITION	CHARACTERISTICS	ADDITIONAL FACTORS
1	Very unlikely landslide hazard.	A landslide is very unlikely.	Slope angles generally 15º or less.	
2	Unlikely landslide hazard.	A landslide is unlikely, without development.	Slope angles generally less than 25º but greater than 15º, residual and colluvial soils.	Unlikely landslide hazard areas include isolated slopes of 25º to 30º that are less than approximately 10 m high.
3	Potential landslide hazard.	There is some likelihood of a landslide without development.	Slopes generally greater than 25º, colluvial and residual soils, evidence of previous slope instability.	Potential landslide hazard areas include ridges and spurs on hilltops with more moderate slopes, areas with slope angles of 15º or less within 20m downhill of slopes of 25ºor more.
4	Potential for debris flow.	There is some likelihood of a debris flow, with or without development.	Slope angles generally 25º or greater at initiation point, colluvial soils, boulders may be present.	Requires a well-formed gully, potential source of material and sufficient catchment to produce significant water flow in gully. Potential run-out distance discussed in text.

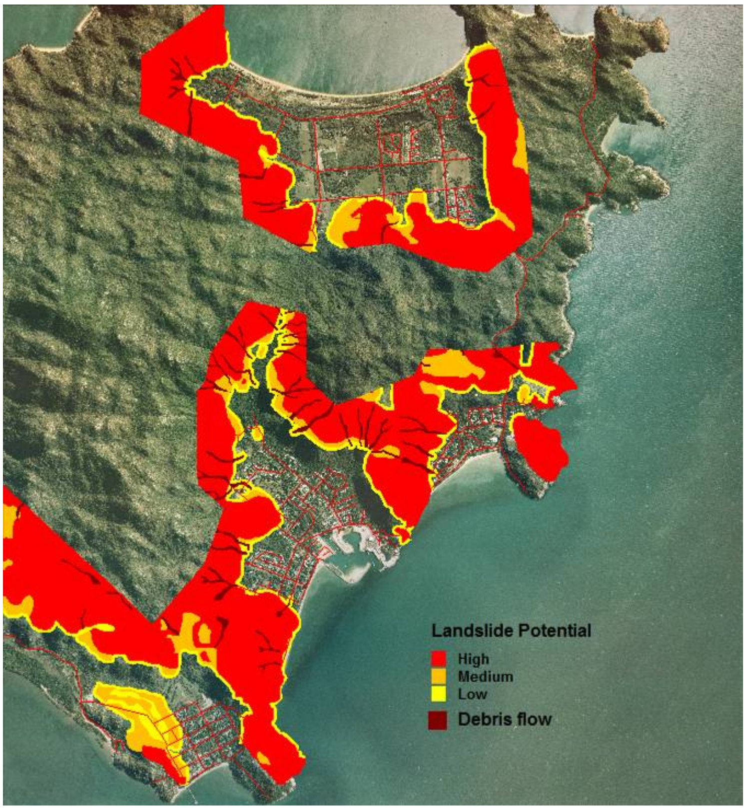


Figure 2.18: Magnetic Island landslide and debris flow hazard potential

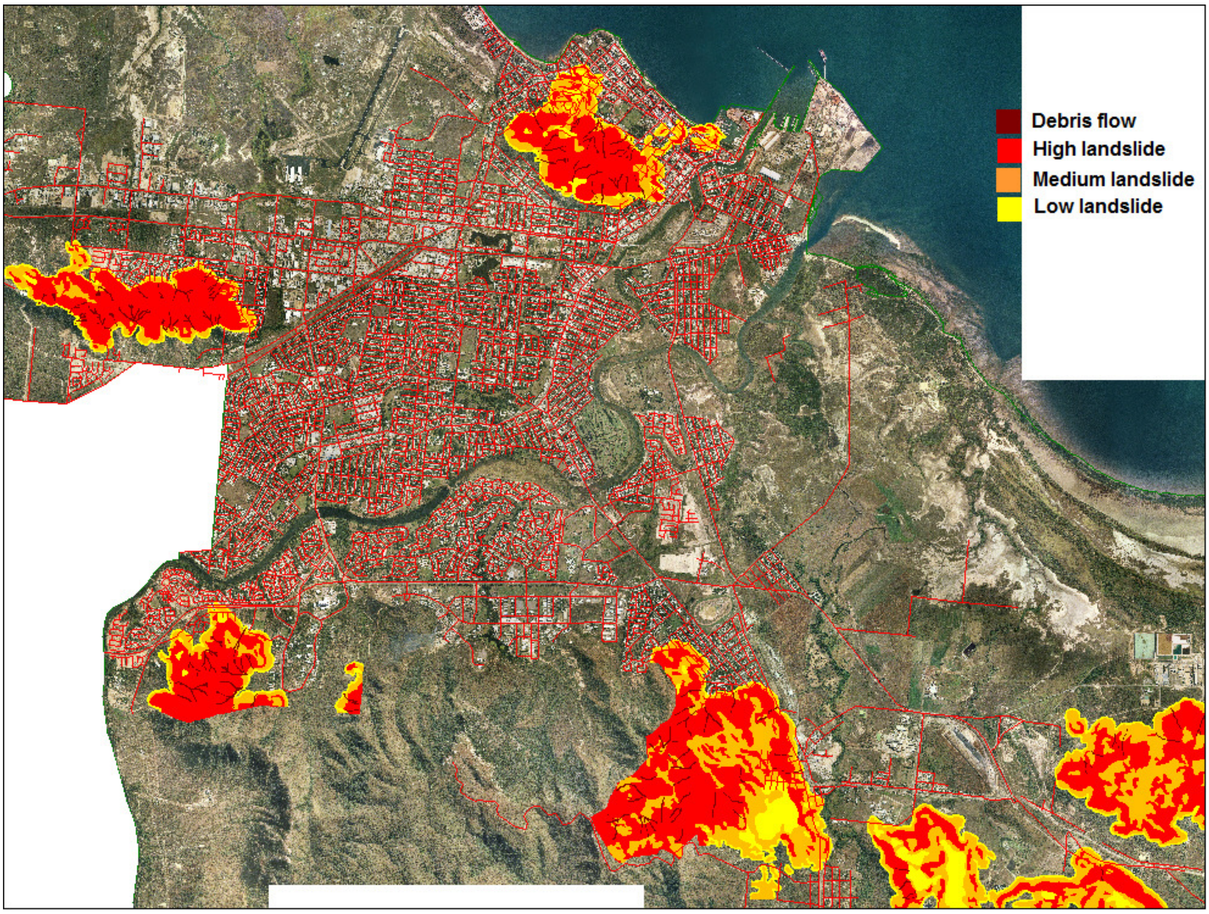


Figure 2.19: Townsville urban area landslide and debris flow hazard potential

The research reported in Coffey Geoscience (2001) was undertaken before publication of SPP 1/03 and its guidelines (DLGP/DES, 2003b). It is, none-the-less, consistent with the hazard analysis approaches advocated in that policy.

It should be noted that SPP 1/03 states that where no other source of landslide hazard mapping is available to a local government they should adopt an approach that for land use planning purposes all land with a slope of 15% (8.5 degrees) or greater should be regarded as having a landslide hazard potential. That threshold is substantially more conservative than the 15 degree slope threshold established by Coffee Geoscience using industry best practice methods which took into account the soils and geology of the study area and the local history of landslide events.

Appendix D provides a conversion table for slope angles, percent and ratios.

A steep slope risk study (Coffey Geoscience and Landmarc, 2004) was undertaken to explore the risks posed to the properties surrounding Castle Hill from landslides, debris flows, perched boulders and rock falls as well as several man-made slopes including cuttings and fill along Castle Hill Road. This study employed very sophisticated photogrammetric techniques using oblique aerial photos (taken from helicopters) and terrestrial photos to accurately measure individual boulders and large rock flakes that could, under specific circumstances, pose a threat to people and property in the Castle Hill area. That remote technique was further informed by detailed field investigation.

Six ‘boulder catchments’ were identified as posing a high risk and eight as posing a medium risk. Their distribution is shown in Figure 2.20.

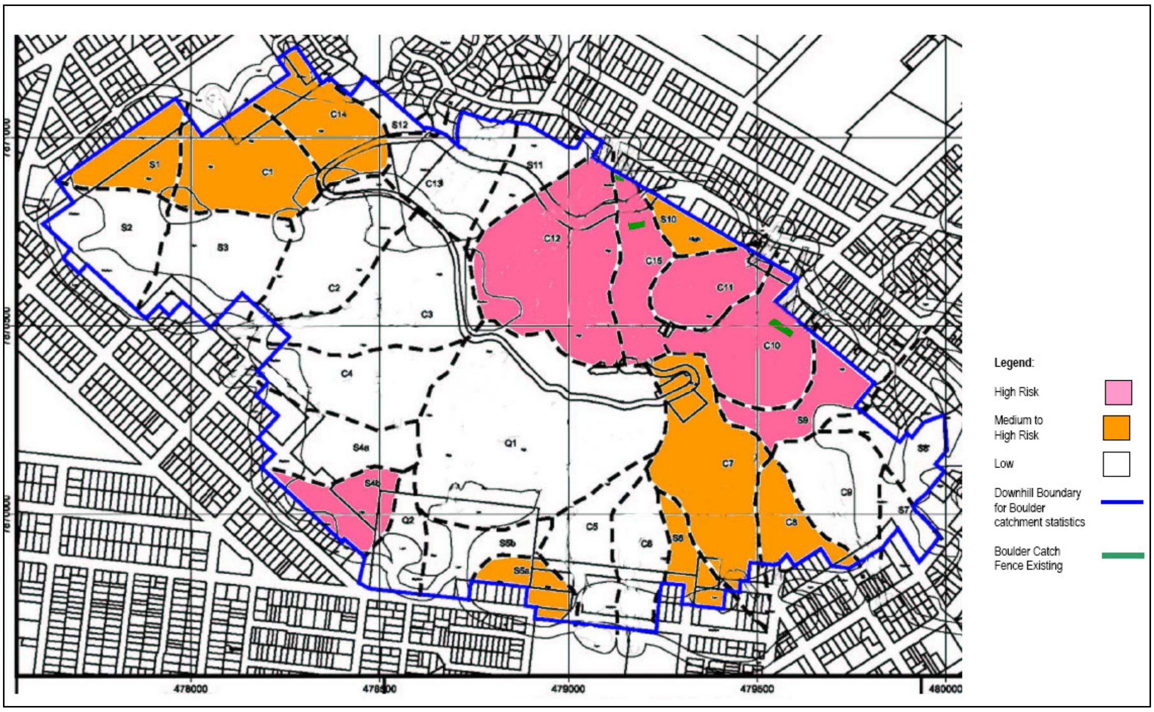


Figure 2.20: Castle Hill boulder fall risk catchments (Coffey Geoscience and Landmarc, 2004, Figure 3.10)

Apart from the well known potential triggers for landslide from Castle Hill, such as intense rainfall, there is a small probability of landslides being caused by very close earthquakes of moderate magnitude. It is possible that a very close earthquake of M_L 4.0 or greater could cause some of the less stable boulders or large flakes to fall (Marion leiba, personal communication, 2008). This potential trigger needs to be researched much further.

2.5.5 Warnings

There are no systems or procedures designed to provide warnings of landslide in Australia. Since 2001, however, the BoM Queensland Regional Office has included statements relating to the possibility of landslide in their severe weather warnings when they anticipate intense rainfall. Such warnings are non-specific.

2.5.6 Conclusions

The study area overall has a small landslide hazard. In a few well identified zones of steeper slopes, the runout areas beneath them and slip-prone soils, however, the hazard is very significant. The Castle Hill steep slope issue requires constant review and monitoring given the potential risk to life and property from boulder falls.

2.6 BUSHFIRES

2.6.1 The Phenomenon

Bushfires are defined in SPP 1/03 (DLGP/DES, 2003a, p10) as:

> *an uncontrolled fire burning in forest, scrub or grassland vegetation, also referred to as wildfire.*

According to a review of the costs of natural disasters in Australia from 1967 to 1999 (BTE, 2001), bushfires cost the Australian community an average of $77.2 million annually. The Queensland annual average loss was only $0.4 million.

Ignition Sources: Over past millennia the most common sources of bushfire ignition have been lightning strike or the 'firestick farming' practices followed by the Aboriginal people of the area. Lightning strikes may be experienced at any time of the year though they are most commonly associated with the severe thunderstorms that typically occur between September and April each year. The month of peak severe thunderstorm activity is December, though September-November is the period during which both lightning and fire weather (a combination of dry winds and low humidity) are most likely to coincide in so-called 'dry storms'.

Statistically, no point in the study region is immune from the impact of lightning strike, though anecdotal evidence suggests that sites on ridge crests are more likely to be hit than sites in valleys.

Unfortunately, in more recent years, this natural source of ignition has been overtaken by non-natural sources including:

- power line failure (e.g. caused by power lines coming in contact with vegetation or being brought down by high winds or falling vegetation);
- human carelessness (e.g. a poorly supervised burn-off), stupidity (e.g. a discarded cigarette butt, or fires lit by bored and unsupervised children); or,
- criminality (e.g. by outright arson, or by car thieves disposing of stolen cars by setting them alight in bushland).

These sources are, in contrast to lightning, spatially concentrated along power supply easements; roads, tracks and other transport corridors; and, within a few hundred metres of the urban-bush interface. Anecdotal evidence suggests that there is also a temporal dimension to ignitions – there is an increase in incidents at times such as:

- periods publicised in the media as having a 'high fire danger'; and,
- school and public holidays.

Harm-Generating Components: Bushfires cause damage, injury or loss through the action of one or more of their four harm-generating components.

Flames: Exposure to flames is typically only a threat where vegetation or other fuel is allowed to accumulate under, against, or on the exposed building. Similarly with infrastructure elements, fuel must be present close to the pole, bridge timbers and so on, for it to be affected directly by flames.

Embers: Buildings are at risk from wind-blown sparks and embers that can be carried significant distances from the fire front. In the fires around Sydney in early December 2002 there were reports of embers being carried more than four kilometres from the fire front, whilst during the fatal Canberra fires of January 2003, spotting distances of 15 km were reported. Embers can also be propelled at great speed by the strong winds generated by the fire and be of a size large enough to smash unprotected windows.
Sparks and embers can enter buildings through gaps such as open or broken windows, or unlined eaves, thus introducing a source of ignition to the interior of the building. Sparks can start small fires in curtains, carpets and other interior furnishings. These develop rapidly and if not combated, can destroy the building from the inside. Similarly, sparks can lodge in combustible material close to, on the roof of, or even under the building, thus causing exterior fires that can quickly envelop the structure.

Radiant heat: Temperatures close to the fire front can be extreme and are capable of progressively causing heat stress, severe injury and fatalities. Radiant heat can cause the more volatile fuels such as synthetic fabrics, rubber and paper, to ignite at considerable distances from the fire front. It can cause glass to shatter; gas bottles to vent; plastics and fibre-glass to melt; metal to lose its strength; and painted surfaces to blister. Radiant heat is also a significant threat to heat-sensitive power supply and other electronic equipment such as computers and telephone equipment.

Strong winds: Wind speeds in excess of 42 metres per second (m/s) (150 km/h) can be experienced in bushfires. Such winds can cause direct damage, such as un-roofing buildings; they can cause impact damage by propelling debris, including burning debris, at a considerable velocity; and can cause trees and power poles to be toppled, especially if they have already been weakened by the fire.

Proximity to the hazard: It is clear that in measuring the risks posed by bushfire it must be recognized that structures that are some distance from the fire front will be at risk in addition to those that are directly exposed. Ember attack, radiant heat and strong winds, in particular, extend the risk well beyond the fire front. Studies of buildings destroyed in Australian bushfires (for example Ahern and Chlardil, 1999 and Chen and McAnerney, 2004) and their distance from the bushland interface have demonstrated that property can be destroyed as far as several hundred metres down-wind from the fire front. This has been taken into account in the development of SPP 1/03 which defines natural hazard management areas (bushfire) as extending 100 m beyond the edge of the high hazard areas and 50 m beyond the boundaries of the medium hazard areas.

Smoke: Fire smoke can produce direct physical effects on people, especially those with respiratory illnesses such as asthma or emphysema, as well as psychological effects. It contains high levels of harmful chemicals such as carbon monoxide and dioxin. Stress and anxiety levels in many people can be raised simply by the smell of fire smoke in the air.

Smoke can also reduce visibility to the extent that roads, and even airports, may need to be closed temporarily to prevent accidents. Dense smoke is also capable of acting as an electrical conductor, with the result that high voltage power lines can arc to the ground through the smoke. This can present a significant hazard to people on the ground and act as a further source of ignition remote from the fire front. Dense smoke can also reduce the effectiveness of line-of-sight telecommunications, especially UHF and VHF radio.

2.6.2 Bushfire History

The fact that most of the native vegetation types encountered in the study region are 'fire tolerant'[4] or 'fire climax'[5] forms provides a clear indication that fire has played a major part in the evolution of the area's landscape over many millennia.
The recorded history of bushfires in the study area is rather scant though it is clear that fires, sometimes serious, have occurred perhaps as frequently as every five years on average. An analysis of the climate data for Townsville by IID shows that single-day episodes of potential fire weather (i.e. temperatures of 30^{o}C or more; humidity of 25% or less and winds of 25 km/h or greater) occur on average about once every two years. Longer events (two consecutive days or more) occur about once in 25 years.

Bushfires can occur in any month of the year, however, the majority of fire weather events occur in the study area between August and December, with October, November and December being the peak months.

The most recent records of fires include the 24 October 2002 grass and scrub fire around Cungulla that threatened six houses and a cattle property. Another scrub and grass fire around Bohle on the same day also caused fire fighters problems. This episode occurred during the first-ever State-wide total fire ban.

The most recent fires appear to have occurred in October 2008 when properties in Townsville southern suburbs were threatened.

2.6.3 Bushfire Hazard Study

The bushfire hazard potential of the study area was analysed by Trinity Software (1999) following a methodology that pre-dated that subsequently established in 2003 in SPP 1/03. Whilst it did base its hazard ratings on a combination of slope and vegetation type, the scaling system used tends to reduce the variability of hazard across the City and also tends to produce a more conservative analysis than had the SPP 1/03 State-wide methodology been used.

The five-point slope scale used is identical to that used in SPP 1/03. The DEM used to produce the slope mapping had a horizontal resolution of 25 m – the same as that used by IID in seven bushfire risk strategy studies it has undertaken in South East Queensland since 2003. The score for each slope class is given in Table 2.8.

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[4] Can survive occasional cool fires.

[5] Require occasional fires (including hot fires) to maintain their biodiversity.

Table 2.8: Slope categories and fire hazard rating (source DLGP/DES, 2003b, p59)

SLOPE	RATING
0 – 3%	1
3 – 10%	2
10 – 20%	3
20 – 30%	4
>30%	5

The vegetation scale, by contrast, is significantly different. SPP 1/03 uses a ten-point scale for vegetation 'flammability', whereas the Trinity Software study used a five-point scale. It is the intent of SPP 1/03 to have a consistent vegetation scale across the State, rather than employ scales that are based only on local vegetation variability. For example, the study area does not have any vegetation with a fire potential that comes close to the tall wet sclerophyll forests of the South East (rated 10 under the SPP 1/03 scheme). At the other end of the scale are grasslands and pasture (score of 2) and mangrove communities with a score of zero.

Trinity Software used a composite of three different vegetation map sources, the total coverage of which left some gaps in the urban areas and in the south-west of the study area. That mapping was done largely in 1996 – now more than a decade out of date. SPP 1/03 recommends the State-wide vegetation mapping produced by the Queensland Herbarium for bushfire hazard studies. Their current mapping is based on 2002 satellite imagery and field survey work. It covers the whole study area with a consistent classification scheme. QFRS has allocated bushfire potential scores to each category of the Herbarium classification to ensure State-wide consistency.

SPP 1/03 also incorporates a scale for slope aspect which the Trinity Software study chose not to include. From its analysis of Townsville fire weather data over the past 54 years IID suggests that aspect scores are warranted because that factor takes into account the degree of exposure to the drying winds during episodes of fire weather. The IID-suggested modification to the SPP 1/03 aspect scale are shown in Table 2.9[6].

Table 2.9: Aspect and fire hazard rating for the Townsville Region

ASPECT	SPP 1/03 VALUES	SUGGESTED TOWNSVILLE RATING
North to North-East (0–45)	1.0	2.5
North-East to East (46-90)	1.0	2
East to South-East (91-135)	0	1
South-East to South (136-180)	0	3
South to South-West (181-225)	2.0	3.5
South-West to West (226-270)	2.0	1
North-West to West (271-315)	3.0	0
North to North-West (316-360)	3.5	0
All slopes <5%	0	0.5

[6] It would appear that the SPP 1/03 scale has been taken from Victorian literature rather than an analysis of Queensland data.

The final difference between the methodology employed by Trinity Software in 1999 and that established by SPP 1/03 is that the scores for each factor are added together to produce a hazard score rather than multiplied together as was done by Trinity Software. The sum score determines the relative hazard severity. The score sum ranges suggested in DLGP/DES (2003b) Appendix 3, Table 4 are given in Table 2.10.

Table 2.10: Fire hazard potential scores sum (source DLGP/DES, 2003b, p59)

SCORE SUM	SEVERITY RATING
13 or greater	High
6 to 12.5	Medium
1 to 5.5	Low

Probably the most widespread combination of slope and vegetation across the study area is grassland or pasture (score =2) on low undulating terrain (score = 2) with an insignificant aspect (score = 0.5). The score sum would be 4.5 which would classify that combination as low hazard.

SPP 1/03 also requires, for land use planning purposes, buffering of the hazard zones to take into account the threat posed by radiant heat and ember attack beyond the edge of the vegetation boundary. Areas classified as having a high hazard should be buffered 100 m and medium hazard zones buffered 50 m. No buffering was done by Trinity Software.

Whilst the Trinity Software analysis is likely to prove to be a little conservative if compared with mapping produced using the SPP 1/03 methodology, it is the only worked-through study available so it will be employed in this study to assess bushfire risk. The bushfire hazard potential mapping based on the Trinity Software analysis is shown Figure 2.21. Given the conservative nature of that mapping no buffering was considered necessary.

QFRS Rural Fire Service has also produced a ‘fire risk analysis’ (actually ‘hazard potential’) mapping based on the SPP 1/03 methodology. Their mapping is State-wide and is based on a grid cell of 250 m. Using a DEM with a grid of that size tends to mask the variability of slope so that the slope component of the analysis is lower than it would be if a higher resolution grid size was employed (Trinity Software used a 25 m grid). The QFRS mapping therefore tends to understate the hazard. The QFRS bushfire hazard mapping is shown as Figure 2.22.

2.6.4 Warnings

The BoM issues fire weather warnings that typically lead to the QFRS imposing restrictions or bans on the lighting of fires in the open. During active fires, public warnings, including the use of the Standard Emergency Warning Signal (SEWS), will be broadcast over the ABC.

There are several fire threat condition displays in areas covered by rural brigades. Additional displays, located at strategic positions, would be helpful in increasing awareness of dangerous fire conditions.

2.6.5 Conclusions

The study area has a significant potential bushfire hazard, especially on Magnetic Island and on the steeper forested country. Much of the threat is to public land such as National Parks, however, agricultural land and some residential properties are potentially exposed in areas with medium or low levels of potential hazard. There are, however, no communities that have an especially high level of risk.

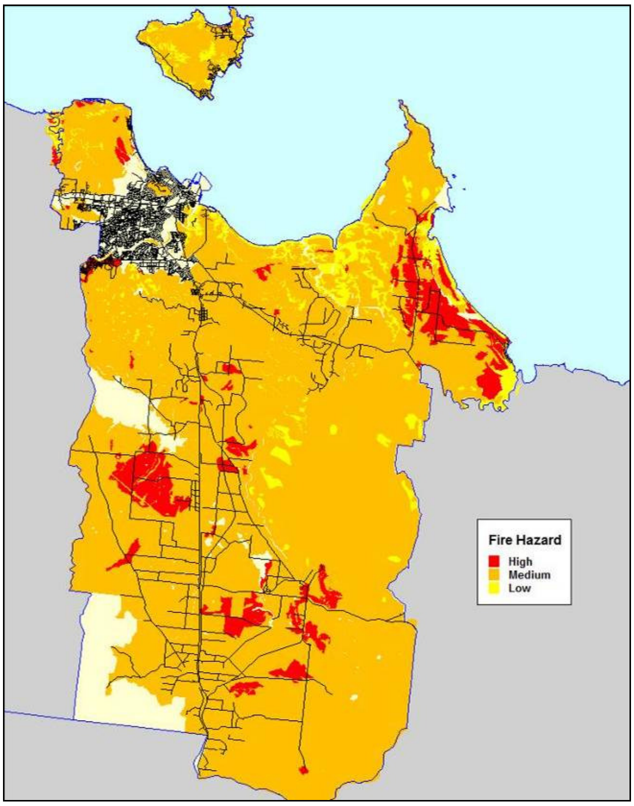

Figure 2.21: Townsville City bushfire potential hazard (Trinity Software, 1999 data)

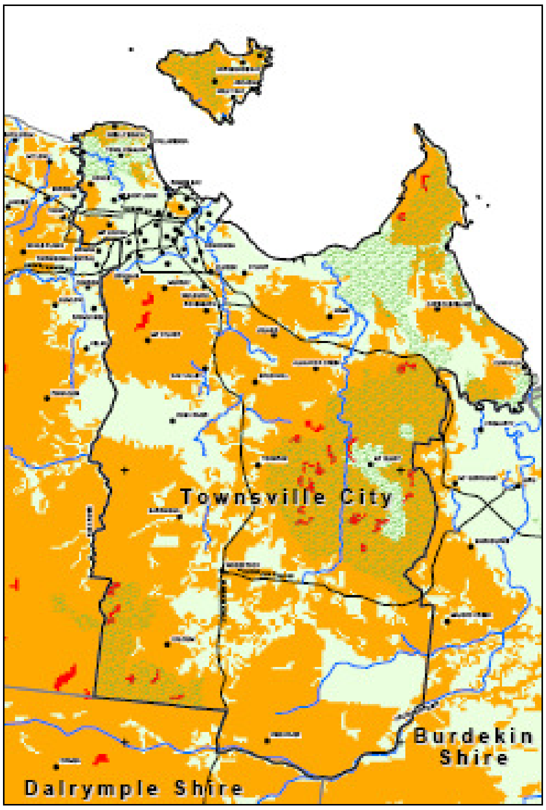

Figure 2.22: Townsville City bushfire mapping (QFRS Rural Fire Service)

2.7 EARTHQUAKES

2.7.1 The Phenomenon

Earthquakes occur when stresses in the Earth exceed the crust's strength to resist, thus causing the sudden rupture of rocks and displacement along a fault. The fault may already have existed or may be newly created by the earthquake rupture. Nearly all damaging earthquake effects are caused by the energy from the fault rupture which is transmitted as seismic waves.

The size of earthquakes is often expressed in terms of Richter (or local) magnitude, denoted by M_L. The energy released by earthquakes varies enormously and so the Richter scale is logarithmic. An increase in magnitude of one unit is equivalent to an increase in energy released of about 33 times. For example, an earthquake with Richter magnitude M_L 6 releases about 33 times the energy of an earthquake with magnitude M_L 5, and about 1000 times the energy of an earthquake with magnitude M_L 4.

Descriptions of the severity of an earthquake at any place may be given using intensity scales such as the Modified Mercalli intensity scale. The Modified Mercalli (MM) scale describes the strength of shaking by categorising the <u>effects</u> of an earthquake through damage to buildings, the disruption of ground conditions, and the reactions of people and animals. A full description of the Modified Mercalli intensity scale is provided in Appendix E.

Although damaging earthquakes are relatively rare in Australia, the high impact of individual events on the community has made them a costly natural hazard. Earthquakes account for around $144.5 million of the $1.14 billion annual average loss caused by natural hazards in Australia (BTE, 2001). This amount was greatly influenced, however, by the 1989 Newcastle earthquake, which produced an insurance loss of around $1 billion and a total loss of around $4 billion.

2.7.2 Earthquake History

Earthquakes are regional hazards. Their effect is not influenced or constrained by topography in the way that floods, for example, are contained in a floodplain. It is therefore necessary to look at a wide region when considering the earthquake risk to the study area. Within a radius of approximately 500 km from Townsville, the National Earthquake Database maintained by Geoscience Australia contains records of some 327 earthquakes, the earliest of which was on 11 November 1875; an M_L 4.5 event located in the Moranbah area approximately 350 km south-south-east of Townsville, whilst the largest on record was the M_L 5.7 'Ravenswood' event of 18 December 1913 located just 80 km south of the City. Shaking from the Ravenswood earthquake was felt in Townsville at MM IV level.

The epicentre locations are shown in Figure 2.23 and the isoseismal map for the Ravenswood earthquake is Figure 2.24.

The closest recorded earthquake to Townsville was a M_L 2.2 event on 9 May 1900 with an epicentre just south of the CBD, whilst the closest large event was the M_L 5.7 event of 1913 already mentioned.

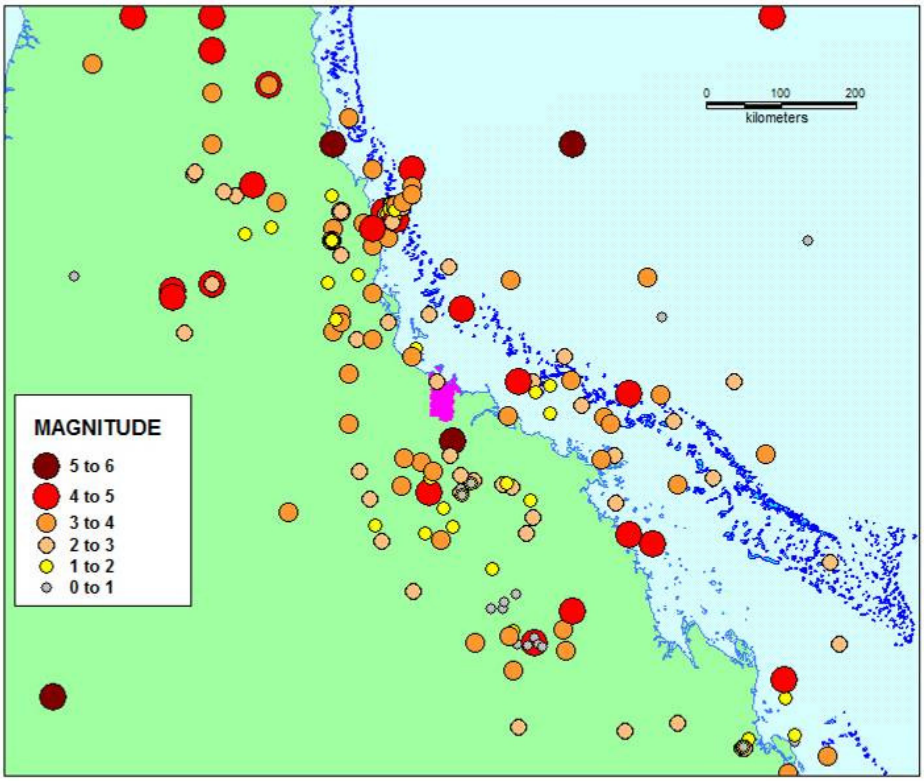

Figure 2.23: Earthquake epicentres (all events) within 500 km of Townsville City (Geoscience Australia data)

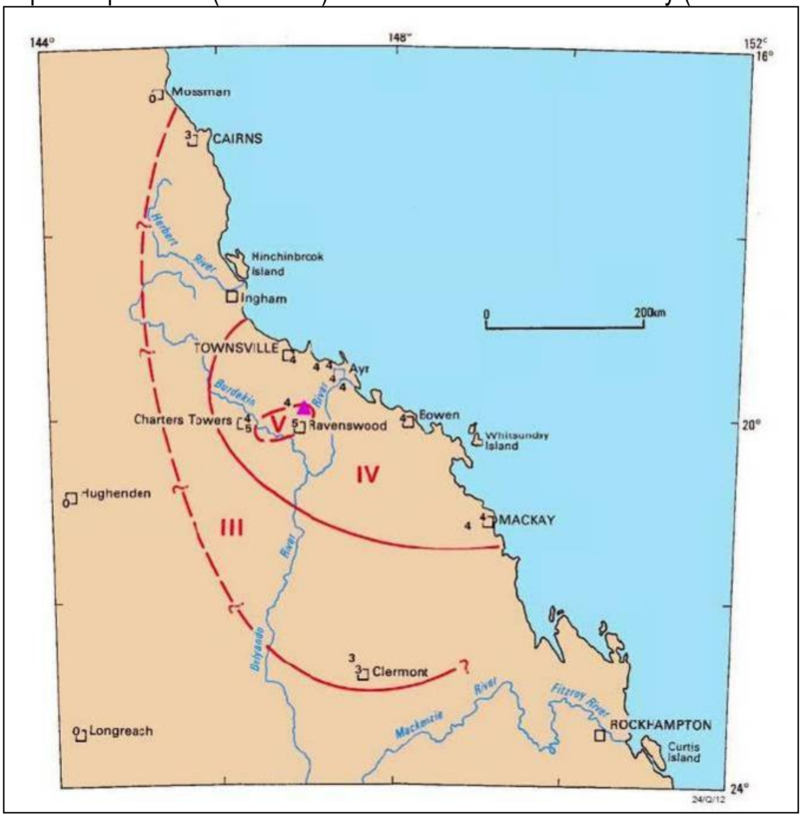

Figure 2.24: Isoseismal map of Ravenswood earthquake 18 December 1913 (Geoscience Australia)

2.7.3 The Earthquake Study

CERA (2006) provides the most comprehensive review of the earthquake hazard in the Townsville region. The approach taken is broadly consistent with well established seismological methods. Its conclusions are also broadly consistent with the earthquake hazard analyses in the AGSO *Cities Project* of studies of Cairns (Granger and others, 1999) and Mackay (Middlemann and Granger, 2000).

The broad conclusion is that by both global and national standards the earthquake hazard is low across the study area. That said, however, **no point in the study area is immune from earthquake impact**. On the basis of the historic record (not withstanding the uncertainty that exists in the knowledge of earthquake mechanisms in the region), it seems safe to assume that the risk of damage to buildings, and death or injury to people, throughout the study area, is relatively low.

CERA (2006) present two estimates of recurrence interval for the two source zones that appear to cover the Townsville region. They conclude:

> *that no definitive conclusions should be made as to the recurrence times (return periods) for earthquakes of any specified magnitude, specifically because of the extremely short time period of about 150 years (beginning of European settlement) for the region.*

The CERA however goes on to estimate ARI through to magnitudes of M_L 8.0. This is considered by IID to be an extremely unlikely level of earthquake magnitude for Australia, let alone the Townsville region. GHD (2005a), for example, suggest that a M_L 6.4 magnitude event (at an unstated distance from the dam site) has an ARI of 10,000 years. IID consider that an earthquake with a Richter magnitude of M_L 6.5 is **theoretically** possible within the Townsville region, whilst the Seismology Research Centre suggest that a ML 7 event within 50 km of Townsville has an ARI of 100,000 years (www.seis.com.au).

The estimated ARI for different levels of earthquake <u>impact</u> in South East Queensland are as given in Table 2.11 This assessment by Granger and Shorten (2004) is based on unpublished data used by Gaull and others (1990) to develop their probabilistic earthquake maps for Australia on which the current earthquake loading code is based.

Table 2.11: Approximate Modified Mercalli intensity levels in South East Queensland by ARI (Granger and Shorten, 2004):

ARI (years)	APPROXIMATE MM LEVEL*
100	IV-V
200	V
500	V-VI
1,000	VI
2,500	VI-VII
** Values relative to bedrock. Allow one level of MM intensity higher for deeper soft sediments*	

IID estimates that the potential intensity level regime in Townsville is likely to be a little higher than that in South East Queensland given that the earthquake 'hazard factor *z' (*or peak ground acceleration –

PGA)[7] for Brisbane is given in Table 3.2 of AS 1170.4 – 2007 (SA, 2007) as 0.05g, whereas Townsville is given as 0.07g. The PGA estimates in AS 1170.4 are based on the work of Gaull and others (1990), however, some authors, such as Cuthbertson and Jaume (1996), have estimated PGA across Queensland to be two to three times higher than previous studies.

The design standard established in AS 1170.4 – 2007 (i.e. a hazard factor of 0.07g for Townsville) is for an event with a 10% chance of being equalled or exceeded in any 50 year period (i.e. an ARI of 475 years – say 500 years).

These design factors relate to sites on hard rock. The effects of earthquake shaking, however, are amplified on softer soils depending on their depth and structure. AS 1170.4 identifies five classes of site sub-soil as follows:

Class A: Strong rock
Class B: Rock
Class C: Shallow soil
Class D: Deep or soft soil
Class E: Very soft soil

Such site classes were employed in the AGSO *Cities Project* studies to provide the base for their earthquake hazard mapping. The CERA (2006) report, however, does not provide such a mapping or a detailed discussion of site classes and their significance.

IID has analysed soil and geological mapping of the region and has allocated general site classes to soil types as shown in Table 2.12 and illustrated in Figure 2.25. A more detailed map of the urban areas is provided in Figure 2.26.

Table 2.12: Study area notional site class classification

CLASS	SOIL GEOMORPHOLOGY
B	soils of hilly and mountainous lands
C	soils of older alluvial plains; piedmont slopes and undulating uplands; soils of older alluvial plains
D	miscellaneous units (includes fill); soils of alluvial fans and channel infill; soils of the younger alluvial terraces and levees
E	Soils of the beach ridges and littoral

[7] The AS 1170.4 hazard factor for Townsville is equivalent to the 'peak ground acceleration (PGA)' of 0.07g, where 'g' is the acceleration experienced at the earth's surface under gravity.

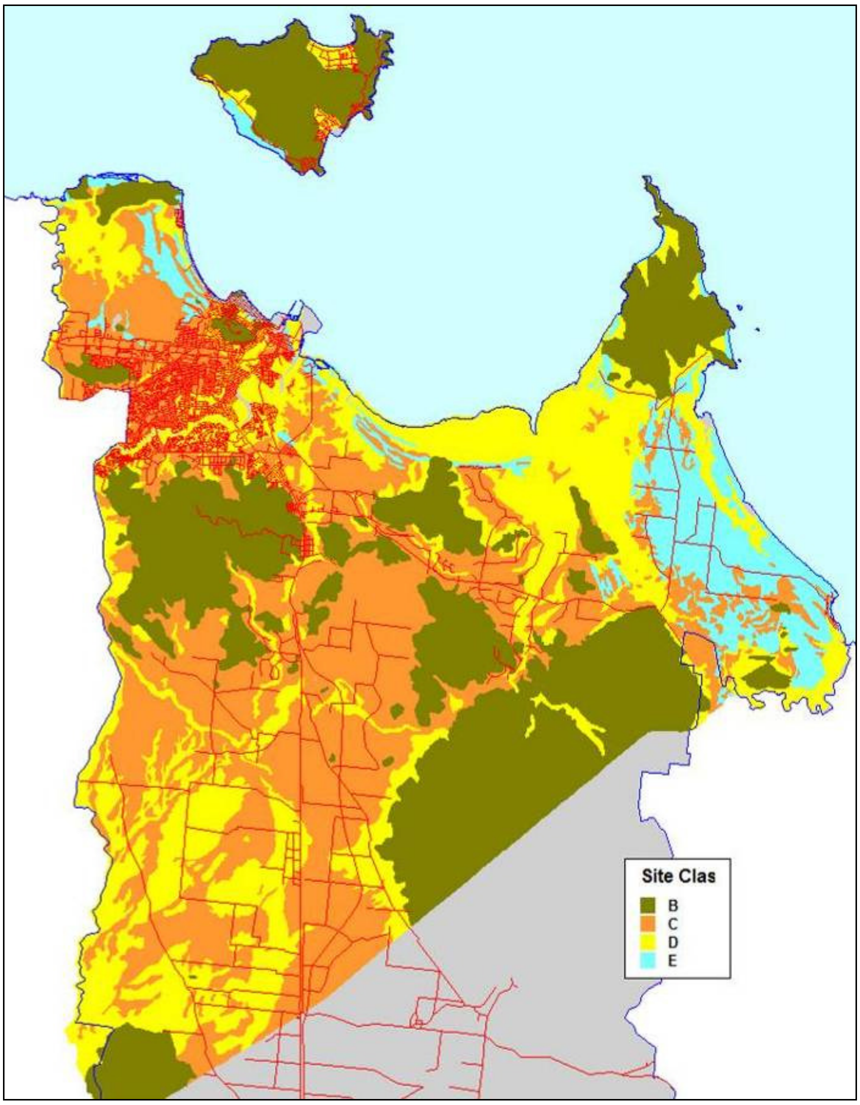

Figure 2.25: Study area notional earthquake site classes

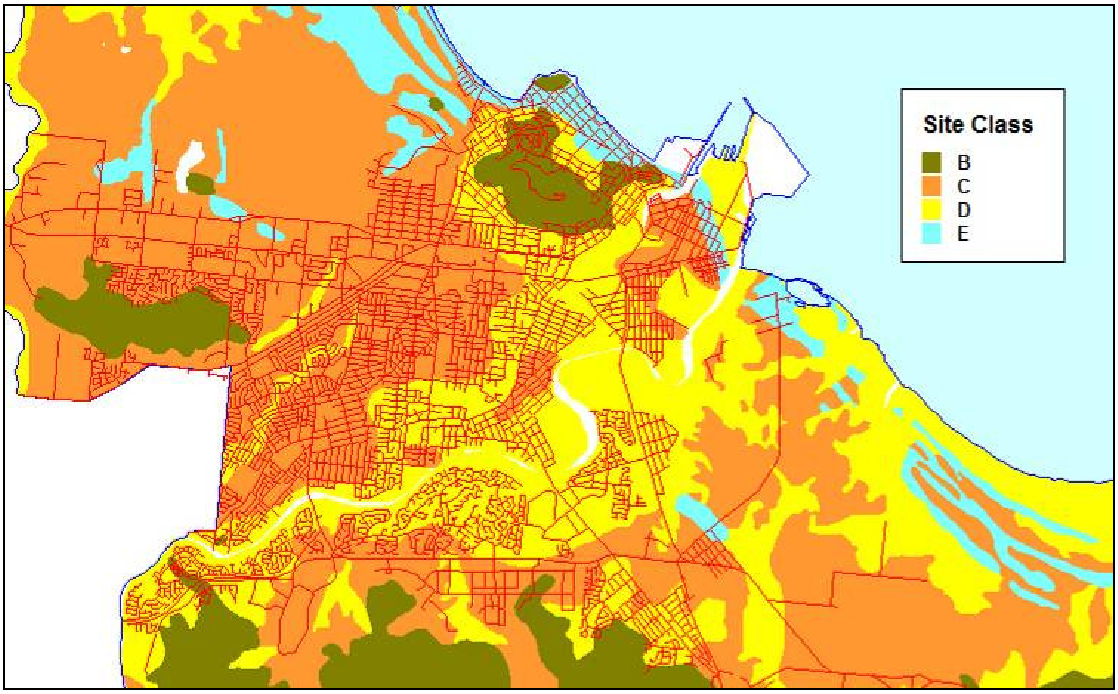

Figure 2.26: Townsville urban area notional earthquake site classes

2.7.4 Warnings

It is not possible to predict the occurrence of earthquakes and provide warnings other than broad, regional assessments of the likelihood of occurrence over time somewhere within that region.

2.7.5 Conclusions

Based on the historical record, the study area has a low level of earthquake hazard.

2.8 CLIMATE CHANGE

There is broad consensus that global mean temperatures have risen over the past century and that they will continue to rise as the result of Greenhouse-influenced climate change. An analysis published by the CSIRO's Atmospheric Research Division in 2002 (Walsh and others, 2002) specifically relating to the Townsville region includes the following estimates:

> *By 2030, projected annual mean temperature increases over Queensland range from 0.3 to 2.0 degrees Celsius over 1990 values. Much larger ranges are projected for 2070, with increases from 0.8 to 6.0 degrees.....*
>
> *Because of some disagreement between the projections of different climate models, the range of projected rainfall changes over Queensland is large, although the confidence in direction of change has improved. In general, projected annual rainfall over Queensland remains roughly the same or slightly decreases. The most recent CSIRO climate model (Mark 3) simulates slight increases in annual rainfall, although these results must at present be considered experimental. For strategic decision making, the consensus scenarios should be preferred.*

The consensus scenario predictions of little change in annual rainfall, combined with increases in temperature, imply a general decrease in soil moisture over Queensland in a warmer world. This decrease is most pronounced in the far interior. Drier soil conditions in the future will have implications for the grazing industry in the far interior and other agricultural production elsewhere in the State…..

By 2050, average electricity demand in Queensland is projected to rise 1-4% (assuming no technological improvement), with peak demand rising by 1.5-7%. This is a relatively small increase compared with the likely increase in demand due to non-climatic effects....

There is an emerging consensus that maximum tropical cyclone wind speeds are likely to increase by 5 to 10%, by some time after 2050. This will be accompanied by increases of 20 to 30% in peak tropical cyclone precipitation rates. Little change in regions of tropical cyclone formation is projected, however.

The UN-sponsored Intergovernmental Panel on Climate Change (IPCC) produced its most recent scientific basis forecasts and assessment of climate change in February 2007 (IPCC, 2007a). Amongst their key conclusions is the following:

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global mean sea level.

IPCC (2007b) also contains the following assessment:

Ongoing coastal development and population growth in areas such as Cairns and Southeast Queensland (Australia) and Northland to Bay of Plenty (New Zealand), are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050.

Table SPM-2 in IPCC (2007a) indicates that the estimates of sea level rise to 2090-99 relative to actual 1980-99 sea level, calculated by six different models ranges from 0.18 to 0.38m in the most conservative model to 0.26 to 0.59m in the least conservative model. Several local governments in South East Queensland have already adopted an allowance of 0.24m for sea level rise in their planning schemes.

Whilst there is still debate about the validity of some climate change forecasts and the degree to which human activity is responsible, it is prudent to adopt the 'precautionary principle' and take them into account in planning for future disaster risks. More intense episodes of precipitation will certainly increase the likelihood of flash floods, stormwater surcharge and landslides. Warmer and dryer conditions will clearly increase the likely incidence and severity of bushfires. The forecast increase in tropical cyclone intensity may also be significant to this Region. The increase in the number of hot days and the increasing demand on electricity greatly increases the likelihood of more severe heatwave impacts.

3 THE ELEMENTS AT RISK AND THEIR VULNERABILITY

The second ingredient required in the process of identifying the **risks** posed by natural hazards to the study area is an understanding of the things that are potentially **exposed** to hazard impacts and the degree to which those elements are susceptible to such an impact. Six main groups of element will be considered here: buildings and property, people, lifeline infrastructure, economic activity, the environment and institutional arrangements.

3.1 DATA SOURCES AND ASSUMPTIONS

To quantify the numbers of buildings, infrastructure and people exposed to natural hazards, data from a variety of sources have been integrated using geographic information system (GIS) techniques. All data have been integrated within GIS software using the MGA 84 Zone 55 datum (as specified by Townsville City Council). Given the lack of specific data to address some issues, however, a range of assumptions has been made and surrogates employed.

In quantifying the exposure and vulnerability of people, data from the 2006 national census have been relied on. Detailed tabulations are available at the Census Collectors District (CCD – neighbourhoods of approximately 200 households each) level only. The CCD boundaries do not closely align with other administrative boundaries used by Council such as the study area's 58 gazetted suburbs and localities. To simplify the analysis these localities have been grouped into the 14 *risk assessment zones* described in Chapter 1.

3.2 DEVELOPED PROPERTIES

Data interpreted from Council's rates and other administrative databases have been linked to the December 2007 version of the digital cadastral database (DCDB) to characterise each parcel as to its actual use. These data have been further edited using 2005 aerial photography to produce mapping that estimates the distribution of 'developed properties', that is, properties on which buildings, especially residential housing and commercial premises, are established. Road and rail easements are not included.

The assumption has been made that each 'developed property' has only one building, and that buildings are located at the centroid (i.e. the midpoint) of their respective land parcel. This assumption is reasonable for the vast majority of residential properties in suburban areas, however, in rural residential areas this assumption is perhaps less valid because of the larger parcel sizes. This assumption is also likely to be incorrect for non-residential properties such as schools where multiple buildings may be present and/or buildings are not located close to the parcel centroid. Conversely, some developed properties are made up of several land parcels but have only one building. In this case an attempt has been made to delete the superfluous 'buildings' based on field observation and other collateral material including high resolution digital ortho-photos acquired in 2005. This mapping is felt to provide a reasonable estimate of the distribution and numbers of buildings and their function.

Table 3.1 summarises the makeup of the developed properties throughout the study area. Classifications are based on the improvements identified in the December 2007 version of the DCDB provided by Council. The following classifications are used:

Business: commercial, industrial and professional facilities including factories, shops and offices – some of these are considered to be critical infrastructure[8];
Community: a wide range of community facilities including churches, halls, scout and guide huts, libraries, recreation facilities and government services;
Public safety: police, fire, ambulance, SES, and Defence Force facilities together with medical facilities including hospitals and nursing homes – all of these are considered to be critical infrastructure[9];
Residential: all detached private dwellings, duplexes, home units, flats, etc, including farm/residence properties on large land parcels;
Utility: All facilities to support the operation of telecommunications, power, water supply and sewerage – all of these facilities are considered to be critical facilities.

Table 3.1: Study area risk assessment zone developed properties

RISK ZONE	BUSINESS	COMMUNITY	PUBLIC SAFETY	RESIDENTIAL	UTILITY	TOTALS
Cungulla	0	0	1	251	1	257
Highway	10	6	0	656	2	689
Industrial East	97	70	1	395	13	635
Industrial West	861	71	138	921	30	2034
Institutions	37	215	400	6547	16	7222
Lakes	454	109	49	4859	13	5497
Lower Ross	321	87	7	3041	7	3469
Magnetic Island	69	38	8	1189	17	1325
National Parks	1	17	34	75	7	150
Pallarenda	0	17	3	329	2	352
Riverside	261	185	58	5441	10	5960
Strand-CBD	355	133	26	2168	20	2710
Upper Ross	6	30	18	382	17	570
Urban West	76	121	23	5732	8	5976
TOTALS	**2548**	**1099**	**766**	**31,986**	**163**	**36,562**

On this analysis, residential properties represent by far the greatest proportion (87.5%) of the number of developed properties in the study area.

3.2.1 Critical Facilities

A wide range of facilities, important to community safety and wellbeing before, during and after any emergency, exist throughout the study area that is. The loss or dislocation of these critical facilities would greatly exacerbate the impact on the community, both within the study area and beyond. Some

[8] 'Critical infrastructure' is described by the Commonwealth Government as follows: *The Government's critical infrastructure protection strategy covers those systems we all rely on in our day-to-day lives—communications networks, banking, energy, water and food supplies, health services, social security and community services, emergency services and transport. These are the physical facilities, supply chains, information technologies and communication networks, which, if destroyed or degraded, would adversely impact on Australia's social or economic wellbeing, or affect our ability to ensure national security.* (Australian Government, 2006)
[9] Accommodation buildings with the JCU campus and Lavarack Barracks were classified as educational and public safety respectively.

critical facilities are important to the economy of the State, whilst others are potentially significant to the wider national and international safety. They include:

- police and emergency service facilities (police stations, ambulance stations, fire stations, SES and other volunteer groups);
- Defence Force facilities including RAAF Garbutt and Lavarack Barracks;
- medical facilities (hospital, health centres, doctor's surgeries, pharmacies);
- telecommunication centres (telephone exchanges, microwave repeaters, cell phone towers);
- major power generation and supply control facilities (power stations, switching yards, sub-stations, transmission lines);
- water supply, treatment and reticulation facilities;
- sewerage treatment and pumping facilities;
- transport facilities (airfields, port facilities, train stations, bus terminals and depots, marinas, etc)
- fuel storage and supply; and,
- food processing, storage or distribution facilities.

Figures 3.1 to 3.4 illustrate some of the more significant critical facilities within the study area. The loss of any one of these facilities would have a major impact on community functions.

Figure 3.1: Mt Stuart TV and weather radar

Figure 3.2: Woodstock power supply substation

Figure 3.3: Port bulk fuel depots

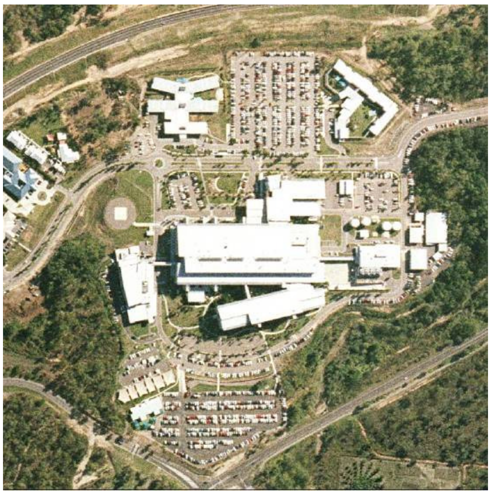

Figure 3.4: Townsville Base Hospital

3.2.2 Sensitive Facilities

A further range of facilities exist at which people, especially children or the elderly, may congregate or be concentrated. These include:

- child care centres, schools and other educational facilities;
- nursing homes, hostels and retirement villages;
- caravan parks and other forms of commercial accommodation;
- shopping centres;
- churches and community centres;
- social and recreational facilities such as clubs and sporting venues; and,
- prisons.

Figures 3.5 to 3.8 illustrate some of the more significant sensitive facilities located in the study area. Each of these facilities is periodically occupied by large numbers of people in a concentrated area.

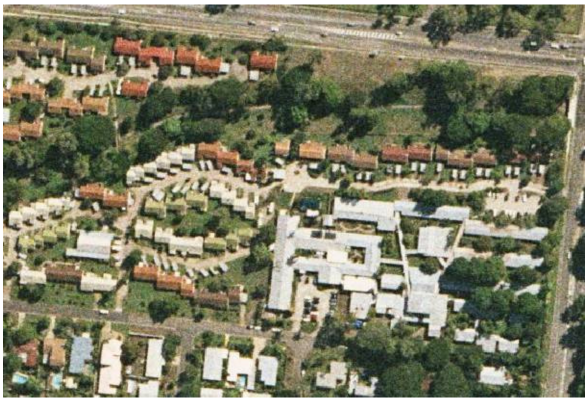
Figure 3.5: Retirement village and hospice


Figure 3.6: Major shopping centre


Figure 3.7: Stuart prison


Figure 3.8: TAFE and Pimlico High School

3.2.3 Associated Assets

In addition to the buildings constructed on these properties, consideration also needs to be given to the assets that are associated with, or stored within, them. These include assets such as swimming pools, vehicles and gardens.

Household contents are also exposed. These can including items of intangible value such as family photos, letters, heirlooms and memorabilia; legal documents including wills, passports, insurance policies and title deeds; pets; computer records; and so on. Commercial properties contain significant stock and business records. Fences, crops and livestock on rural properties also represent significant assets.

3.3 POPULATION DISTRIBUTION

Figures from the 2006 National Census show that in September 2006 the population of the study area was 95,464. This population is concentrated in the urban parts of the study area. The study area has an average population density of 51 persons per square kilometre. Densities across the 196 CCD used in the 2006 census, however, range from 3680 people per sq km in a Heatley CCD, to zero persons per sq km in the five CCD that have no population. Of the populated CCD the lowest density is in Stuart where one CCD has a density of 0.07 people per sq km. The distribution of population densities across the study area were shown in Figure 1.4 and for the urban area in Figure 1.5.

House and flat occupancy rates are also a useful indicator of population exposure. In the study area, at the 2006 census, house occupancies averaged 2.75 persons but ranged from as high as 3.7 persons in a CCD in Stuart to just under 2 persons in parts of Pimlico, South Townsville and Cape Cleveland. Flat occupancies averaged 1.7 persons, with a maximum of 5 persons in a Lake Louisa CCD.

3.4 LIFELINE INFRASTRUCTURES

The well being and safety of the community is also dependant on a range of lifeline infrastructure networks[10]. These include:

- the road network;
- the rail network;
- power reticulation services;
- water reticulation services;
- sewerage reticulation services;
- telecommunications services;
- logistic support facilities (e.g. fuel and food supply).

[10] All of these 'lifeline infrastructures' can also be classified as 'critical infrastructures'. They are treated separately here because they are all networks and share a wide range of features.

Table 3.2 indicates the nature of this interdependence. In this table, the loss of the lifeline in the left-hand column will have an impact on the lifelines across the row to a significant (S), moderate (M) or minor (blank) degree.

Table 3.2: Interdependence of lifeline assets (after Granger, 1997)

	POWER	WATER	SEWER	COMMS	ROAD	RAIL	AFLD	PORT	FUEL
POWER		**S**	**S**	**S**	**M**	**M**	**S**	**M**	**S**
WATER	**M**		**S**					**M**	
SEWER		**S**						**M**	
COMMS	**S**	**S**	**S**		**M**	**S**	**S**	**S**	
ROAD	**M**	**M**	**M**	**M**		**M**	**S**	**S**	**S**
RAIL					**M**			**S**	**S**
AFLD									
PORT									**S**
FUEL	**S**				**S**	**S**	**S**	**S**	

3.4.1 Roads

There are approximately 1567 km of constructed public roads within the study area. They range in importance from the multi-lane Bruce Highway to minor tracks.

There are also 'private' roads within areas such as the National Parks and institutions such as JCU and Lavarack Barracks.

The density of the road network provides a useful measure of the degree of connectivity of the network. This is significant in disaster management terms because the more dense the network the more alternative routes there tend to be should one segment be interrupted by flood, landslide, fire or for any other reason. Clearly the urban zones have the greatest network density. Table 3.3 provides the road statistics for each risk assessment zone.

Table 3.3: Study area road network by risk assessment zone

RISK ZONE	ROAD LENGTH (km)	ROAD DENSITY (km/sq km)
Cungulla	6.34	3.72
Highway	77.49	0.75
Industrial East	89.52	0.94
Industrial West	74.64	2.32
Institutions	168.72	5.52
Lakes	109.39	10.60
Lower Ross	88.70	5.67
Magnetic Island	58.76	2.41
National Parks	69.27	0.12
Pallarenda	9.73	3.80
Riverside	105.53	9.88
Strand-CBD	66.79	8.03
Upper Ross	523.52	0.55
Urban West	120.56	7.64
TOTALS	**1568.97**	**0.89**

3.4.2 Rail

There are 45.7 km of main-line rail crossing the study area. The main rail link between Brisbane and Cairns runs more-or-less from east to west, whilst the Mt Isa line runs north-south. There are spur lines to the port facilities and to rail freight depots in Townsville City and Stuart. None of this network is electrified.

Queensland Rail operates a major locomotive and rolling stock maintenance facility at Railway Estate, adjacent to the port area.

3.4.3 Airport

Garbutt is a military airfield which shares facilities with civil and general aviation services. It has a single sealed runway of approximately 2460 m and is capable of taking all regular civil and military aircraft operating in Australia. The airfield is shown in Figure 3.9.

Figure 3.9: Townsville International (Garbutt) airport (TCC photo 2005)

All three domestic carriers operate scheduled services to Townsville. Some 50 international carriers have rights to operate to Townsville but currently none are exercising those rights.

In the twelve months to 30 June 2007 Townsville handled almost 1.4 million passengers. The general aviation sector provides charter fixed wing and helicopter services throughout northern Queensland. A rescue helicopter service is operated by the Department of Emergency Services.

Defence Force units based at Garbutt (RAAF Townsville) include 35 Squadron and 38 Squadron Detachment B (RAAF) equipped with Caribou transport aircraft and the 5th Aviation Regiment (Army Aviation Corps) equipped with Blackhawk and Chinook helicopters. These units are supported by a range of administrative, logistic and maintenance elements.

3.4.4 Port

The Townsville port facilities are the third largest in Queensland (after Brisbane and Gladstone) and the most important in north Queensland. Townsville is a major port for the export of bulk commodities such as nickel ore, copper and zinc concentrates and raw sugar; and the import of petroleum products. It is also the most important general cargo and container port in the north.

Scheduled passenger and vehicle ferry services operate from the Ross Creek area of the port to Magnetic Island. Figure 3.10 shows the current layout of the port.

A major expansion plan has been developed that will greatly increase the capacity of the port (Department of Infrastructure, 2007). The key expansions are shown in Figure 3.11. Part of that upgrade will include major improvements to rail and road access to the secure port facilities.

Figure 3.10: Port of Townsville (TCC photo, 2005)

Figure 3.11: Port of Townsville expansion strategic plan (Department of Infrastructure, 2007)

3.4.5 Power

There is no base-load power station in the study area, though plans for a gas-fired station with a capacity of 370 MW were announced by AGL in October 2005. This project was declared a 'significant project' by the State Government in 2006 but has yet to commence construction. The Mt Stuart gas turbine power station, located within the study area, with a capacity of 288 MW, and the Yabulu 160 MW gas turbine station (in former Thuringowa City), provide peak load supplementation.

There are 40.7 km of 275 kV and 135.8 km of 132 kV power transmission line operated by Powerlink within the study area. This infrastructure forms part of the State and National grid and is all carried on steel towers. They are located within cleared and well maintained easements.

Reticulation of the power supply is operated by Ergon. There are 1836.3 km of high and low voltage power cables and lines within the study area supply reticulation network. Most of this infrastructure is above ground and carried on timber poles. Underground reticulation is confined to the Townsville CBD area and some of the more recent residential subdivisions. Supply to Magnetic Island is from the mainland via twin undersea cables with a combined length of 23.7 km.

Ergon operates 20 zone substations within the study area.

3.4.6 Water Supply

The urban areas and some non-urban residential areas of the study area are served by 1611.1 km of reticulation pipeline operated by the Townsville-Thuringowa Water Board (NQ Water). Pipes range in size from 1050 mm trunk mains to 32 mm reticulation conduits. The most common materials used are PVC, asbestos cement (AC) and concrete-lined iron. Water is reticulated by gravity from 28 reservoirs.

The water supply is sourced from the Ross River Dam within the study area and the Paluma Dam, located in former Thuringowa City. The Douglas water treatment plant is located in Mount Stuart, with a minor treatment plant for locally sourced bore water at Picnic Bay on Magnetic Island.

Most of the reticulation infrastructure is underground, though some trunk mains, including the supply trunk from the Paluma Dam, are above ground in some sections. Supply to Magnetic Island is via undersea trunk mains.

3.4.7 Sewerage

Sewerage reticulation is confined to the urban areas of the study area and the main infrastructure is underground. The majority of the 875.5 km of pipeline network uses PVC pipes with AC and vitreous china making up a significant percentage, especially in the older areas. There are five waste water treatment plants across the study area (Mount Saint John, Bohle, Stuart, Mount Stuart and Picnic Bay).

The distribution of power, water and sewer infrastructure across the study area is summarised in Table 3.4.

Table 3.4: Study area power, water and sewer infrastructure by risk assessment zone

RISK ZONE	WATER SUPPLY (km)	POWER SUPPLY (km)	SEWER (km)
Cungulla	4.56	3.13	0
Highway	21.47	113.7	0
Industrial East	66.93	158.57	34.35
Industrial West	132.98	132.43	86.43
Institutions	253.82	170.84	142.76
Lakes	221.82	152.12	128.69
Lower Ross	147.26	116.09	95.94
Magnetic Island	73.14	61.35	33.42
National Parks	6.95	85.87	14.11
Pallarenda	9.44	16.09	8.43
Riverside	223.66	141.62	111.78
Strand-CBD	139.37	131.54	90.29
Upper Ross	53.48	414.59	0
Urban West	202.83	139.55	129.27
TOTALS	**1557.71**	**1837.48**	**875.48**

3.4.8 Telecommunications

In urban areas the telephone network infrastructure, both copper wire and optical fibre, is under ground, however, in rural areas some sections are above ground. Telstra operate four telephone exchanges, and 16 cell phone towers and/or microwave repeaters within the study area. These are key nodes (and critical infrastructure). Details of the infrastructure operated by other carriers, such as Optus, were not available to this study.

Several major telecommunication facilities are operated by the Defence Force from sites within the study area. Numerous private networks are also operated by both public authorities (e.g. Police, Ambulance, QFRS, TCC, etc) and private enterprise bodies (e.g. taxis). The majority of these networks operate in the UHF band.

Broadcast TV and radio services also cover the study area with the main transmitter site located on Mt Stuart.

3.4.9 Logistic Facilities

Townsville is a major logistic supply centre. A large number of bulk warehouses, including cold stores, are located in the study area and serve outlets across the Far North Queensland region and beyond.

The most significant facilities, however, are the bulk fuel facilities located within the port area. These facilities provide fuel to a very large catchment including Mount Isa. Resupply of fuel is by tanker from either Brisbane or Singapore. There are 31 service stations throughout the study area providing retail distribution of fuels.

3.5 ECONOMY

Townsville was established to provide a port for the surrounding agricultural industries. Its status as a major transport hub and service centre continues today with road, rail, port and air transport services providing critical links to the inland mining centres of Mt Isa and Charters Towers, as well as to centres both north and south.

The transport infrastructure has also attracted the establishment of heavy industry including a major meat processing plant and the zinc refinery. It has also facilitated the development of major Defence Force facilities, as well as educational, research and medical facilities of national and international significance. Tourism plays a far less dominant role in the economy of Townsville than is the case in other northern centres such as Cairns.

Employment in the different industry sectors is a good indicator of the economic significance of that sector. Employment by industry at the 2006 census is given in Table 3.5. The largest employers are the public administration and safety; health care and social assistance services; and retail trade sectors.

A comparison with the industry proportions for Queensland as a whole is also included in Table 3.5. The economic sectors in which the study area has a disproportionally large representation are in the public administration and safety (because of the large Defence Force community) which is well above the State average; while agriculture, forestry and fisheries and manufacturing are well below the State average.

Table 3.5: Study area employment by industry sector (2006 census data)

INDUSTRY	EMPLOYED	PERCENT	STATE %
Agriculture, forestry and fishing	413	0.9	3.4
Mining	1112	2.3	1.7
Manufacturing	3573	7.5	9.9
Electricity, gas, water and waste services	647	1.4	1.0
Construction	4219	8.8	9.0
Wholesale trade	1422	3.0	3.9
Retail trade	4914	10.4	11.6
Accommodation and food services	3600	7.6	7.0
Transport, postal and warehousing	2297	4.8	5.1
Information media and telecommunications	845	1.8	1.4
Finance and insurance services	833	1.8	2.9
Rental, hiring and real estate services	896	1.9	2.1
Professional, scientific and technical services	2399	5.1	5.6
Administrative and support services	1261	2.7	3.1
Public administration and safety	6317	13.3	6.7
Education and training	4092	8.6	7.6
Health care and social assistance	5386	11.4	10.2
Arts and recreational services	660	1.4	1.3
Other services	1478	3.1	3.7
Not classified or not stated	1065	2.2	2.7
TOTAL	**47,429**		

3.6 ENVIRONMENT

3.6.1 Flora

The lengthy period of European occupation of the study area has seen much of the native vegetation removed or greatly modified. Significant areas of largely undisturbed vegetation are preserved in the National Parks on Magnetic Island, Cape Cleveland and Mt Elliot.

3.6.2 Fauna

The study area retains a wide range of terrestrial and marine fauna. They range from the larger mammals such as kangaroo, dolphin and dugong; to medium mammals such as koala and possum; and small mammals such as gliders, bandicoots and bats. There are perhaps 400 species of birds recorded as being found in the study area, many of them are migratory.

3.7 VULNERABILITY OF BUILDINGS

Vulnerability is defined as ‘the degree of susceptibility and resilience of the community and environment to hazards’ (EMA, 1998) and in this section, vulnerability to natural hazard impacts is considered holistically, rather than on a hazard-by-hazard basis. This is because there is very little differentiation between the things that make structures, lifelines and people susceptible to the impact of different hazards.

Because buildings are the most common form of protection for people and because much of the economy and community governance is conducted within buildings, the characteristics of buildings that make them more or less susceptible to damage or destruction deserves particular attention. The degree to which different building characteristics are relevant to the more important hazards is summarised in Table 3.6. In this table, the number of stars reflect the significance of each attribute's contribution to building vulnerability, where the greater the number of stars, the greater the relative contribution of an attribute to building vulnerability.

Table 3.6: Relative contribution of building characteristics to building vulnerability (after Granger, 2001)

CHARACTERISTIC	WIND	HAIL	FLOOD	FIRE	SLIDE	QUAKE
Building age	*****	***	***	*****	**	****
Floor height or vertical regularity	*		*****	****	*	*****
Wall material	***	*****	***	****	***	****
Roof material	****	*****		****		***
Roof pitch	****	***		*		
Large unprotected windows	*****	****	**	*****	**	***
Unlined eaves	***			*****		
Number of storeys	**		****	*	*	*****
Plan regularity	***		**	***	**	*****
Topography	****		*****	****	*****	***
Interior fittings and furniture			****	*****		

3.7.1 Engineering codes

The Building Code of Australia (BCA) is based on a number of standards designed to maximise the structural integrity of all buildings. Of particular significance are the standards that set design and construction parameters for severe wind and earthquake loads. A standard for construction in bushfire-prone areas has also been published (Standards Australia, 1991). There is no comparable standard for construction in landslide-prone areas or for inundation hazards.

Wind loading standards in Australia were first implemented by structural engineers in 1952. It was not until the experience of the severe destruction wrought by TC *Althea* (Townsville) in 1971 and TC *Tracy* (Darwin) in 1974 that efforts were made to strengthen building standards in Queensland and elsewhere in Australia, especially for domestic structures. Standard *AS1170.2 Minimum design loads on structures: Part 2 – Wind loads* was first published in 1973 and was subsequently revised in 1975, 1981, 1983 and 1989. The current (6th) edition was published in 2002 (Standards Australia, 2002).

The wind loads standard was first adopted under the *Queensland Building Act* in 1981, and had already become widely applied for domestic structures in Queensland by that time. *AS1170.2* is now encompassed by the BCA.

The wind loading code is based on a design event for which there is an ARI of 500 years for most structures. Note that this had been an ARI of 1000 years in the previous edition. For buildings designed to house large numbers of people the design threshold is an ARI of 1000 years and for buildings that are essential for post-disaster recovery (e.g. hospitals), the design threshold is an ARI of 2000 years.

A standard specific to houses has also been developed. That standard, *AS 4055 Wind loads for housing* was first published in 1992 and revised in 2006 (Standards Australia, 2006). Standards Australia and the

Insurance Council of Australia have also published guidelines for the upgrade of older buildings in both cyclone and non-cyclone-prone areas (Standards Australia & ICA, 1999a and 1999b).

Similar codes have been developed for earthquake loads over a similar time frame. The current codes are *AS1170.4-2007 Structural design actions Part 4: Earthquake actions in Australia* (Standards Australia, 2007). Earthquake loads are expressed as an 'acceleration coefficient' which relates to a 10% probability of exceedence in 50 years at 'rock' or 'firm' sites. This probability corresponds to an AEP of approximately 0.02%, or an ARI of approximately 500 years. Under the standard, Townsville City has an acceleration coefficient of 0.7g. Following the 1989 Newcastle earthquake a standard (AS3826) was developed to cover the upgrade of older buildings to modern earthquake-resistant standards (Standards Australia, 1998).

Dwellings constructed in bushfire-prone areas are subject to the provisions of *AS3959-1999 Construction of buildings in bushfire-prone areas* (Standards Australia, 1999). Further guidance on the siting and design of buildings in bushfire-prone areas is also provided in publications such as *Building in bushfire-prone areas – information and advice* (CSIRO/SA, 1993), *Bushfire prone areas- siting and design of residential buildings* (DHLGP/QFRS, 1994) and *Landscape and building designs for bushfire areas* (Ramsay and Rudolph, 2003).

3.7.2 Age of construction

The age of construction of all elements of the built environment is a key contributor to those element's vulnerability. Residential buildings constructed before 1982, for example, will not have been explicitly designed to comply with wind or earthquake loading standards of the Building Code; nor will those built before 1993 necessarily have taken into account the provisions of AS 3959 (bushfire-prone areas). Non-residential buildings constructed since 1976 will have been built to the wind loading code which will also provide them with a high degree of resilience to earthquake loads. Similar age thresholds also can be applied to other elements of the built environment including water supply, power supply and sewer infrastructure.

Some broad rule-of-thumb characteristics of dwelling structures can be linked to the age of construction as follows.

If built before the early 1950s:

- exterior and interior walls of timber and/or fibro;
- ceilings are timber or Caneite.
- interior cupboards and fittings in solid timber;
- high set on stumps generally 2 m or more above ground level;
- high pitched hip-ended metal roof;
- small windows shaded by verandas or awnings;
- brick walls are cavity brick construction.

If built in the 1960s or 1970s:

- greater mix of exterior wall material including brick and timber;
- greater proportion of internal walls and ceilings of Masonite, fibro or plasterboard;
- large areas of louvers for windows;

- windows shaded by small verandas or broad eaves;
- increased use of particle board in interior cupboards and fittings;
- floor levels above ground on piles up to 0.5 m above ground;
- high pitched metal roofs with an increase in gable ended shape;
- brick walls are brick veneer construction.

If built since 1980:

- increased use of brick in walls (brick veneer construction);
- interior walls of plasterboard (Gyproc);
- all interior cupboards and fittings of particle board;
- large windows and glass sliding doors;
- limited shading of windows by narrow eaves;
- high pitched metal roofs with a small proportion of tiled roofs;
- slab-on-ground construction.

To include structure age as a vulnerability factor in this risk assessment, the development history of the study area's road network has been developed using historic aerial photography flown approximately once a decade since 1941. The coverage of the photography was generally confined to the urban sections of the study area so an analysis of development in the rural areas has not been possible. In those risk assessment zones for which aerial photo coverage is not available an estimate of the road network that was in place in the periods for which no photo coverage is available has been made.

Table 3.7 details the percentage of the present-day road network in each risk assessment zone that was constructed by each time point. It should be understood that the vintage of the present-day buildings and infrastructure elements are likely to by different to the percentages in the table because of re-development and infrastructure upgrade programs has taken place (especially in the CBD and areas where unit development has proliferated). Figure 3.12 illustrates the growth of the study area since 1941.

Table 3.7: Study area built environment development age by risk assessment zone

RISK ZONE	% DEVELOPED BY 1941	% DEVELOPED BY 1951	% DEVELOPED BY 1961	% DEVELOPED BY 1971	% DEVELOPED BY 1982	% DEVELOPED BY 1992
Cungulla	63.09	63.09	78.86	78.86	78.86	100.00
Highway	11.06	12.90	25.81	38.71	51.62	64.52
Industrial East	25.43	25.43	29.97	32.02	43.08	45.54
Industrial West	28.87	44.20	51.88	58.56	77.33	98.09
Institutions	3.99	3.99	7.05	25.86	45.30	52.72
Lakes	57.87	72.46	84.01	91.35	94.49	97.70
Lower Ross	54.84	56.05	66.07	66.54	74.35	75.57
Magnetic Island	43.72	43.72	43.72	60.01	73.38	87.78
National Parks	54.04	54.04	54.04	54.86	64.97	79.40
Pallarenda	61.18	61.18	61.18	99.75	99.75	99.75
Riverside	28.44	43.75	65.06	91.08	99.37	99.40
Strand-CBD	65.18	74.41	76.82	84.50	85.97	91.22
Upper Ross	12.26	14.33	18.15	29.61	57.30	76.41
Urban West	13.36	16.32	24.83	46.41	66.21	75.66
TOTALS	**25.40**	**29.64**	**36.14**	**48.21**	**65.46**	**76.81**

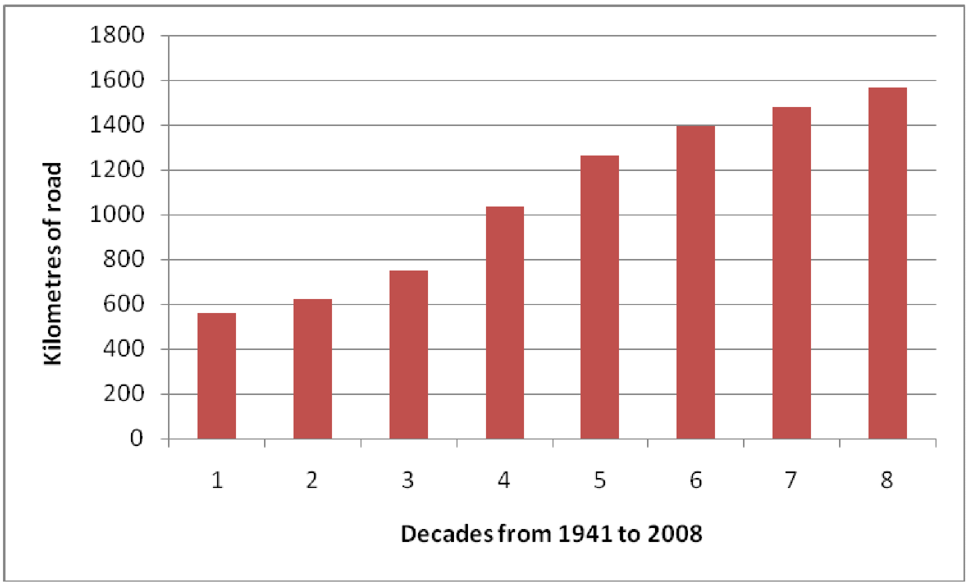

Figure 3.12: Study area progressive state of development 1941 to 2008

3.7.3 Construction features

The age-linked structural features described above provide an indication of the potential vulnerability of those buildings.

Most dwellings in the study area are constructed over a timber frame. Timber frame buildings behave in a ductile manner in earthquakes and strong winds, and can undergo relatively large displacements because of their non-rigid construction. Solid brick or masonry walls are more susceptible to damage because of their rigid construction.

Wall cladding is also important. Brittle materials such as fibro, Masonite and glass, as well as thin metal claddings such as aluminium, are likely to be susceptible to damage by wind-blown debris. Timber is obviously more flammable than brick, concrete and metal. However, the materials that are used for the walls and roof of a building make only a minor contribution to its vulnerability in bushfires, except where direct exposure to flames is made possible by other fuels in direct contact with the building. Experience shows that the majority of buildings destroyed in bushfires burn from the inside as a result of ember attack through openings such as broken windows or unsealed eaves, or through radiant heat igniting material inside the building. Moreover, well-built timber buildings perform better than other forms in earthquakes and slow-moving landslides

Roof material is a significant determinant of building vulnerability. Roofing, such as tiles and fibro are susceptible to hail and debris damage, whilst corrugated iron (especially older material) is susceptible to wind damage. Mahendran (1995), for example, reported that exposure of metal roofs to strong winds sets up fatigue around the fastening screws. Roofs in which fatigue has been established, and then exposed to further events, may subsequently fail in winds significantly lighter than those that they were originally designed to withstand.

Roof shape and pitch are also influential. In simple terms, gable ended roofs take the full force of the wind, whereas the wind flows more smoothly over hip ended roofs. Depending on wind direction, flat or low pitched roofs can experience greater levels of suction than do high pitched roofs. Hip ended roofs with a pitch of around 30^{o} tend to perform the best. The fastening of roofing material to trusses and the fastening of roof members to walls and foundations are also important. Complex roof shapes, especially where they involve valleys, can increase vulnerability to bush fires because such areas tend to accumulate leaf litter which can be ignited by wind-blown embers.

The great majority of residential buildings in the study area have metal roofs. The remainder are predominantly tile-clad, with a small number of older buildings with fibro roofing. By far the majority of roofs are high pitched and hip-ended; there were very few flat roofs.

Large unprotected windows also increase the vulnerability of buildings to wind damage and to bush fire radiant heat. Large windows are also susceptible to damage in earthquakes, and landslide. The glass manufacturer Pilkington has developed a glass (tradename 'Frontier') that has a transparent coating that greatly reduces the transfer of radiant heat into the building making it more suitable for use in bush fire-prone areas than ordinary glass.

Distance from the coast is also influential, especially where older buildings are concerned. Corrosion of metal fixings such as nails, screws, straps and bolts in the salt laden atmosphere within 15 km of the coast, may also reduce structural integrity over time.

The shape of the building can also affect how it stands up to wind impact and earthquake shaking. While the older high-set designs are especially well suited to the region's climate they are likely to be more susceptible to earthquake shaking. Most tall structures that are not engineered to withstand shaking from side to side can be damaged or toppled by the inverted pendulum effect – the amplitude of the shaking is greater at the top of the structure than at its base. So-called 'six pack' unit blocks which have a 'soft story' (i.e. the garages occupy the first floor level with no internal walls) are also very susceptible to failure under earthquake loads.

Interior walls of Gyproc and fittings of particle board are more susceptible to inundation damage than are solid timber or masonry walls.


Figure 3.13: Early post-war house


Figure 3.14: Contemporary housing

Figure 3.13 shows an early post-war house. It has a fibro roof that is susceptible to wind and debris damage but its small windows make it more resilient to severe wind damage; its timber frame makes it quite resilient to earthquake shaking; and its high set construction makes it resilient to inundation. The fibro roof could become a significant environmental hazard if it were damaged in a storm or earthquake.

Figure 3.14, by contrast shows contemporary houses. They have tiled roofs that are largely resilient to wind and debris damage; they have large areas of glass that make them susceptible to wind damage; their timber frames (under the brick veneer cladding) give them a degree of resilience to earthquake shaking; and their slab-on-ground construction could make them susceptible to inundation hazards.

3.7.4 Design, Landscaping and Maintenance

Subdivisional design can play a significant role in determining exposure to most hazards. In pre-war and early post-war subdivisions it was the practice to have houses elevated above ground level and allow storm water to run under the structure. In modern subdivisions, by contrast, the ground on which buildings (nor commonly slab-on-ground) are constructed has been engineered to be above a design flood level and streets designed to take any excess storm water that the pipe network cannot cope with. In bushfire-prone areas, subdivision design can be used to both provide a spatial buffer between the bush and houses and to ensure that emergency vehicles can safely access the area when needed.

A significant degree of bushfire (and perhaps also landslide) protection can be afforded by solid fencing (preferably metal) and by plantings of fire resistant trees to form a ‘green fire break’ around the property. Both can reduce the impact of radiant heat and ember attack. Conversely, landscaping with the more volatile native shrubs and trees close to the house will invariably increase exposure to flame and ember attack. Large trees close to buildings, especially over-mature remnants of the original eucalypt forests or woodlands, may also be susceptible to being toppled in high winds.

The probability of slope failure may be reduced by planting vegetation that lowers the water table and binds the soil, by installing good drainage, and by constructing properly engineered retaining walls.

The level of maintenance afforded both buildings and gardens can affect vulnerability significantly. A poorly maintained building with a significant accumulation of litter in gutters and roof gullies; a weed infested and unkempt garden that provides an unbroken path of fuel up to the building; stacks of flammable material, such as fire wood; close to the house; and, incorrectly positioned gas cylinders (i.e. with the vent facing the building) that will increase the susceptibility of the building to fire attack. Poorly maintained buildings may also be more susceptible to earthquake and landslide damage.

3.8 VULNERABILITY OF LIFELINE INFRASTRUCTURE

A wide range of engineering standards also apply to the construction and design of infrastructure elements such as drainage, water supply, sewerage and so on. These standards are applied within the study area.

3.8.1 Roads

Road pavements are very resilient to most hazards though they may be damaged by landslides, floods and severe earthquakes. They may be blocked by landslide debris, fallen trees (during bushfires or severe winds) and bushfire smoke. The most vulnerable points tend to be bridges and other choke points such as railway crossings. There are 28 level crossings within the study area – some are protected by boom gates; all of them have warning lights. The main north-south roads such as Hugh Street and Duckworth Street can both be blocked by the one train thus greatly restricting traffic movement between northern and southern sections of the study area.

3.8.2 Railways

Railway permanent ways are generally resilient to most hazards though rails and points may be affected by extreme heatwave conditions causing rail services to be slowed considerably. They may also be buckled by the more severe earthquakes and blocked by landslide debris or affected by embankment fill failures. Signalling and control equipment relies on electricity and telecommunications. As with roads, the most vulnerable points are level crossings, bridges, cuttings, embankments and overpasses.

3.8.3 Airfield

The airfield pavement is largely resilient to most hazards but may be blocked by flood waters (including storm tide) and debris from damaged buildings. Support facilities such as terminals and fuel systems could be damaged by destructive wind, earthquake and inundation hazards. The airfield will probably be closed in the face of a severe tropical cyclone where high winds make flying operations too dangerous.

3.8.4 Port

The port is vulnerable to damage from high seas and will probably be closed in the face of an approaching severe cyclone. On-shore port facilities are susceptible to damage by destructive winds and earthquake. Tall structures such as container cranes are especially vulnerable to being toppled. Given that the port facilities are built largely on filled estuarine deposits, the risk of liquefaction during an earthquake should be taken into account.

3.8.5 Power supply

The reticulation infrastructure is quite susceptible to fire and heat damage. Most of the poles that carry the lower voltage reticulation are wood and can burn out; the copper or aluminium cables that carry the power can melt, or at least stretch significantly, at relatively low fire temperatures, or be broken by high winds and falling branches; electronic control equipment is susceptible to high temperatures. Power poles can also be displaced or toppled by earthquakes or landslides.

High voltage transmission lines are susceptible to failure in dense bushfire smoke which permits the line to arc to the ground through the smoke. The experience of Victoria during severe bushfires in early 2007 is noteworthy. In those fires the main transmission line into the State grid from the Snowy Mountains hydro stations arced out in fire smoke and cause over a third of the State to be without power for an extended period.

Ground-mounted transformers will be vulnerable to inundation hazards.

If power is lost, the knock-on effect on other lifeline infrastructures, especially water supply, sewerage systems and telecommunications, can be great. Gravity feed water supply would continue to operate until power supply (either mains or stand-by generators) to the pumps resumed, unless their reservoirs were empty.

3.8.6 Water supply and sewerage

Most urban properties have access to reticulated supply, but in most rural areas supply (including fire-fighting water) is from rainwater catchment tanks, dams or swimming pools. Concrete, metal and some fibreglass tanks are quite resilient to high temperatures, however, PVC tanks can lose their rigidity and melt if exposed to the levels of heat associated with bushfires.

The use of PVC piping to carry water from tanks to the building can also be a problem, especially if it is exposed above ground level. In most areas where water supply is provided by tanks, water pumps are electric-powered and the loss of power during a fire can cut off the water supply. The availability of a petrol or diesel-powered backup pumping capacity greatly increases the ability to fight a fire.

The in-ground pipe networks are susceptible to damage during earthquakes and landslides, especially those older segments made of brittle material such as AC or cast iron. Above ground pipes can also be affected by landslides and probably earthquakes. Pumping equipment is dependent on the power supply.

Pumping stations for both water supply and sewerage systems are susceptible to damage if inundated or subject to high levels of radiant heat in bushfires.

3.8.7 Stormwater

The effectiveness of the stormwater system depends very largely on its design capacity, its level of maintenance and strategies to cope with surcharge. Experience shows that the best designed and maintained engineered stormwater network is susceptible to disruption by debris blocking pipes, culverts and other intake areas. Even the largest culverts can be blocked by objects such as vehicles and shipping containers. Such dislocation was experienced in Newcastle in 2007 leading to considerable increases in flood levels in localised areas with fatal consequences.

3.8.8 Telecommunications

The above-ground telecommunications infrastructure has similar vulnerabilities to that of the power supply network. In addition, dense smoke can block line-of-sight frequencies (UHF and VHF) which in turn will disrupt mobile phone and radio communications (including SCADA systems). These systems are also very heavily power-dependant.

Telstra land-line infrastructure is all underground reticulation. The system is therefore designed and installed to be robust against the ingress of water. The pit and conduit system is regularly inundated with water as part of the natural stormwater dissipation. The cable connection pillars, which are located above ground, are also sealed and positively pressurised to prevent the ingress of water. In-ground cables, especially optical fibre cable, are susceptible to damage by earth movements such as that experienced in earthquakes and landslides. Optical fibre cable, for example, will need to be replaced if it is stretched by only a few millimetres.

The weak links in the network are Telstra RIMs and exchanges. The RIMs are electronic devices installed in suburban areas in a weatherproof housing. These housings are not designed for submersion. The loss of the RIM or exchange will cause a loss of all communications connected to the exchange. This will affect a large area of the population and rectification will not be possible until the water levels return to normal.

It should also be noted that mobile phone base stations may be out of service due to high winds, therefore the use of mobile phones should not be relied upon during emergencies. The mobile network can also become overloaded when a large number of people try to make calls on the one local cell.

3.8.9 Logistic Facilities

Large metal fuel tanks are susceptible to damage caused by the liquid inside the tank sloshing from side to side under earthquake loads, thus placing stresses on the tank walls. Damage or failure, often referred to as 'elephant's foot failure', can result. Pipe connections to the tank can also suffer damage or be sheared off by differential movement. Figure 3.15 shows an example of 'elephant's foot' damage to a water tank in the USA following an earthquake. Domestic water tanks, particularly the traditional corrugated iron types, are also very susceptible to similar damage.

In-ground bulk fuel tanks are also susceptible during floods if they are not full. They have been known to 'float' in their pits and rupture pipelines.

Potentially more serious than these vulnerabilities is the potential for access by fuel tankers to the port facilities to be blocked by either damage to the unloading facilities or blockage of the shipping lane into the port. A blockage lasting more than a week would start to see Townsville and its service hinterland begin to run out of fuels.

Figure 3.15: 'Elephant's foot' damage to a large metal water tank caused by earthquake shaking (American Public Works Association photo)

3.9 VULNERABILITY OF PEOPLE

The degree to which people are likely to be affected by exposure to hazards depends on a wide range of factors. These are the factors that dictate their vulnerability to hazard impact.

A total of 14 measures are used to illustrate the distribution of characteristics that are likely to make people more or less susceptible to hazard impact.

3.9.1 Physical Vulnerability

The very young and the elderly are the main groups that are likely to be susceptible to disaster impact. At the 2006 National Census there were 5836 children under 5 years of age, or 6.1% of the study area population. That proportion, however, varied considerably between neighbourhoods. In three 'nappy valley' neighbourhoods in Urban West zone over 12% of the population is under 5 years. Of the risk assessment zones, Urban West has the highest proportion of children under five years of age (7.2%) and Upper Ross the lowest (3.6%).

The elderly (i.e. traditionally considered to be those 65 years of age and over) make up 10.9% of the population, i.e. 10,442 people. Their distribution is even more concentrated than the young, with the largest percentages in neighbourhoods dominated by nursing homes and/or retirement villages. One neighbourhood in Mundingburra has 60.0% of its population aged more than 64 years and one in Rowes Bay has 50.6% over 64 years. Four CCD have less than 1% of their populations over 64 years – in Douglas, Mount Stuart, Oonoonba and Mount Louisa. At the risk assessment zone level, Pallarenda with 20.1% has the greatest proportion of elderly while Upper Ross (5.1%) has the lowest.

The elderly who are living alone are especially vulnerable to the impact of most hazards, particularly heatwave. There are 2742 elderly in that situation, or 22.2% of all people over 64 years. Three CCD have more than 80% of their elderly people living alone – in Garbutt, Rosslea and Heatley. At the risk assessment zone level Industrial West, with 41.9% of its elderly living alone, is the highest; Pallarenda, with 7.8% is the lowest.

People with disabilities are also likely to be more susceptible to the impact of hazards than any other group in the community. The 2006 census provides (for the first time) the numbers of people with a 'profound or severe disability' by virtue of an identified need for assistance because of disability, long term health condition or old age. Across the study area there were 3387 people, or 3.6% of the population, classed as so disabled as to require assistance in one form or another. One CCD in Mundingburra that contains a large aged care facility and hospice had 33.5% of its total population with a disability. At the risk assessment zone level Pallarenda, with 13.2% of its population classed as disabled, has the greatest proportion.

Table 3.8 summarises the percentages of physical vulnerability measures by risk assessment zone and Figures 3.16, 3.17, 3.18 and 3.19 show the distribution of those measures at the CCD level across the study area.

Table 3.8: Study area physical vulnerability measures by risk assessment zone

RISK ZONE	% UNDER 5 YEARS	% OVER 64 YEARS	% OVER 64 AND LIVING ALONE	% DISABLED
Cungulla	4.04	17.00	14.29	5.67
Highway	6.13	7.75	17.74	2.88
Industrial East	4.09	6.71	22.36	2.00
Industrial West	5.47	19.79	41.91	6.83
Institutions	6.61	6.73	12.73	3.15
Lakes	6.09	12.86	34.04	3.42
Lower Ross	6.82	9.83	27.15	2.84
Magnetic Island	4.24	14.59	26.40	3.13
National Parks	4.92	7.92	19.51	2.51
Pallarenda	5.17	20.10	7.77	13.17
Riverside	6.41	14.42	25.82	4.50
Strand-CBD	4.16	10.05	28.84	2.19
Upper Ross	3.55	5.12	12.94	1.08
Urban West	7.24	10.57	24.64	3.64
TOTALS	**6.11**	**10.94**	**26.26**	**3.55**

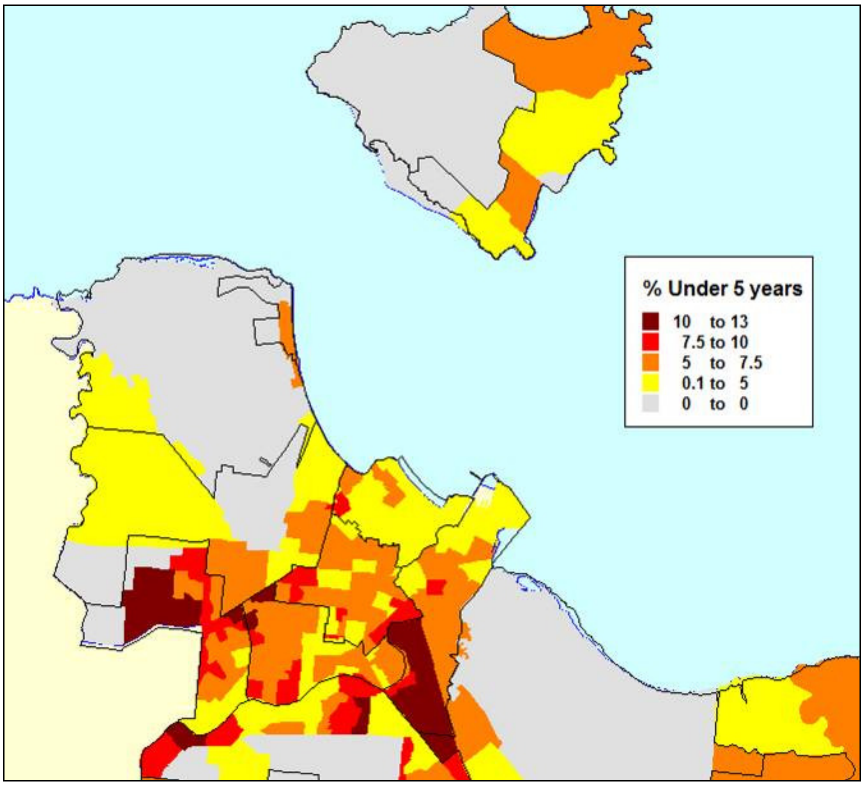

Figure 3.16: Urban area percent of 2006 population under 5 years (ABS, 2007 data)

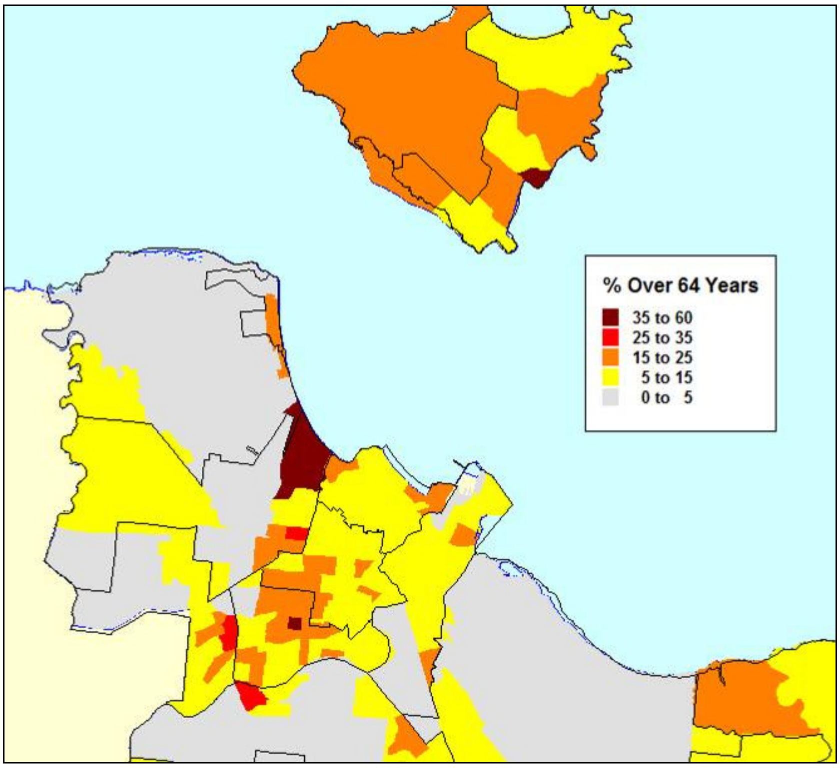

Figure 3.17: Urban area percent of 2006 population over 64 years (ABS, 2007 data)

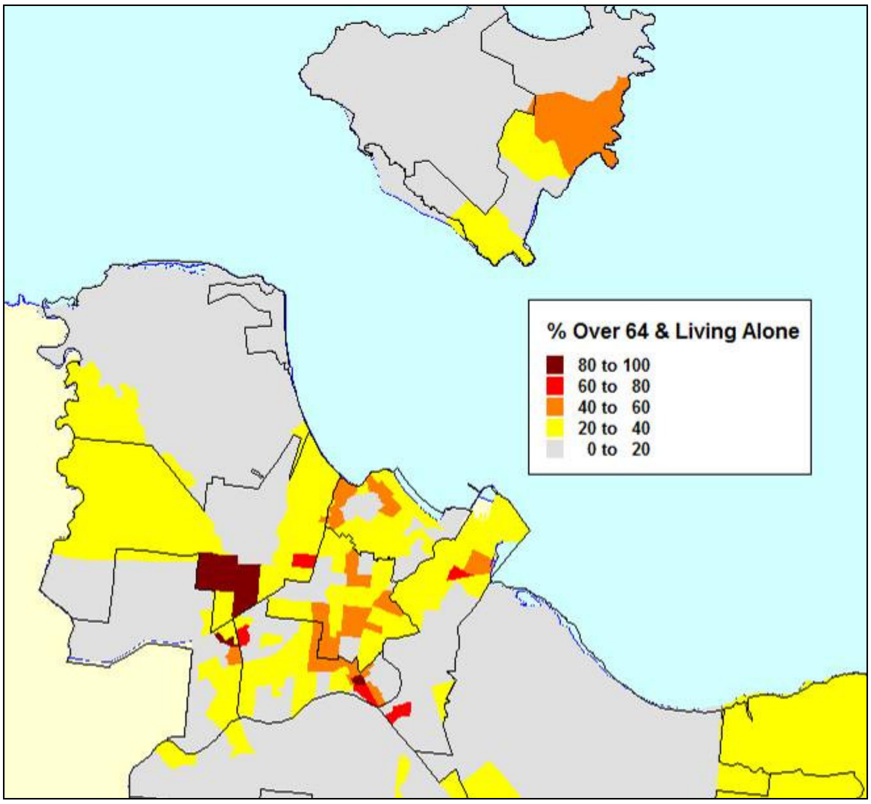

Figure 3.18: Urban area percent of over 64 years living alone (ABS, 2007 data)

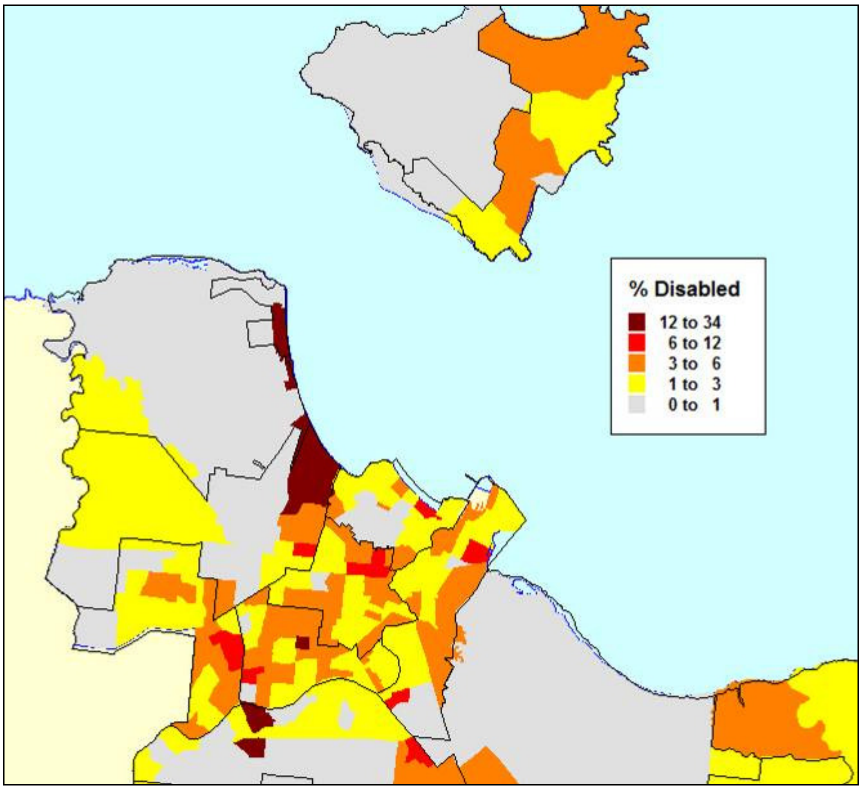

Figure 3.19: Urban area percent 2006 population disabled (ABS, 2007 data)

3.9.2 Social and Economic Vulnerability

The capacity to recover from the impact of any disaster is closely related to socio-economic well being. Less advantaged households, for example, will tend to be in rented accommodation; have no, or inadequate, insurance; and have difficulty replacing any losses. They will also be more likely to become unemployed should the businesses in which they work suffer damage in the event.

The percentage of people in the workforce who were unemployed at the 2006 census ranged from a high of 16.9% in a Heatley neighbourhood and 16.8% in a Heatley neighbourhood to a low of 0% in 15 CCDs. Taken across the risk assessment zones the greatest percentages are in Pallarenda (6.0%) whilst the lowest is in Highway (2.7%).

The proportion of households in rented accommodation is also an indicator of socio-economic vulnerability. These ranged from a high of 100% in two Douglas neighbourhoods (i.e. on the JCU campus) to lows of 0% in six CCD including those covering Lavarack Barracks and the Stuart Prison. There were 12,778 rented dwellings in all. At the risk assessment zone level, the greatest overall percentage is found in Strand-CBD (49.0%) whilst the lowest was in Highway (7.8%).

Families with low income (taken as less than $400 per week) are also susceptible to disaster impact. In Townsville in 2006 there were 2348 families that fell into that category. Percentages range from a high of 57.1% in a West Point neighbourhood, to lows of 0% in 27 CCD. Across the risk assessment zones Cungulla, with 18.3% of all households with low incomes has the highest proportion whilst Institutions (6.3%) has the lowest proportion.

There are numerous intangible social factors that can influence a community's relative vulnerability. Observations by experienced disaster managers, such as Silberbauer (2003), for example, suggest that a potentially critical factor is 'community cohesion'. Whilst there are many potential cleavages within communities, such as religion, ethnicity, social standing, employment, occupation and so on, communities in which these cleavages fail to divide are much more resilient than those in which they do divide. Community participation in sporting clubs, school groups such as P&C, service clubs (Rotary, Apex, QCWA, etc), cultural groups (choirs, dramatic societies, historical societies, etc) and volunteer organisations such as SES, is a strong indicator of community cohesion.

The 2006 census enumerated, for the first time, the contribution of volunteers. People over 14 years who undertook some unpaid work for an organisation or group in the 12 months prior to the census were counted. Of the total population over 14 years of 77,240, a surprisingly large number of 54,182 people (70.1%) had not done any voluntary work in the previous 12 months in the study area. The highly mobile nature of the younger population (especially university students and Defence Force personnel) may be a contributing factor in this. There were six CCD in which effectively every member of the over 14 year population had done voluntary work whilst there were five CCD in which less than 20% had done voluntary work. At the risk assessment zone level Upper Ross, with 78.1% not doing voluntary work had the lowest participation (and by implication the lowest level of community cohesion), while Industrial East with 53.6% of non-volunteers had the highest level of participation.

Details of the socio-economic vulnerability measures for each hazard precinct are given in Table 3.9 and their distribution illustrated in Figures 3.20 to 3.23.

Table 3.9: Study area socio-economic vulnerability measures by risk assessment zone

RISK ZONE	% UNEMPLOYED	% RENTING	% LOW INCOME	% NOT VOLUNTEERING
Cungulla	3.16	8.65	18.31	71.96
Highway	2.71	7.78	8.07	73.73
Industrial East	3.39	21.30	7.79	53.56
Industrial West	4.79	46.61	17.46	71.76
Institutions	3.55	32.59	6.43	71.66
Lakes	5.17	44.15	11.28	70.39
Lower Ross	4.86	37.90	8.63	70.00
Magnetic Island	3.54	37.23	17.59	64.47
National Parks	5.32	10.43	10.24	71.05
Pallarenda	6.00	32.10	8.14	72.60
Riverside	4.65	40.08	12.26	69.87
Strand-CBD	4.68	48.98	6.32	66.45
Upper Ross	2.96	12.90	11.34	78.07
Urban West	4.88	30.67	10.89	72.42
TOTALS	**4.23**	**37.49**	**9.93**	**70.15**

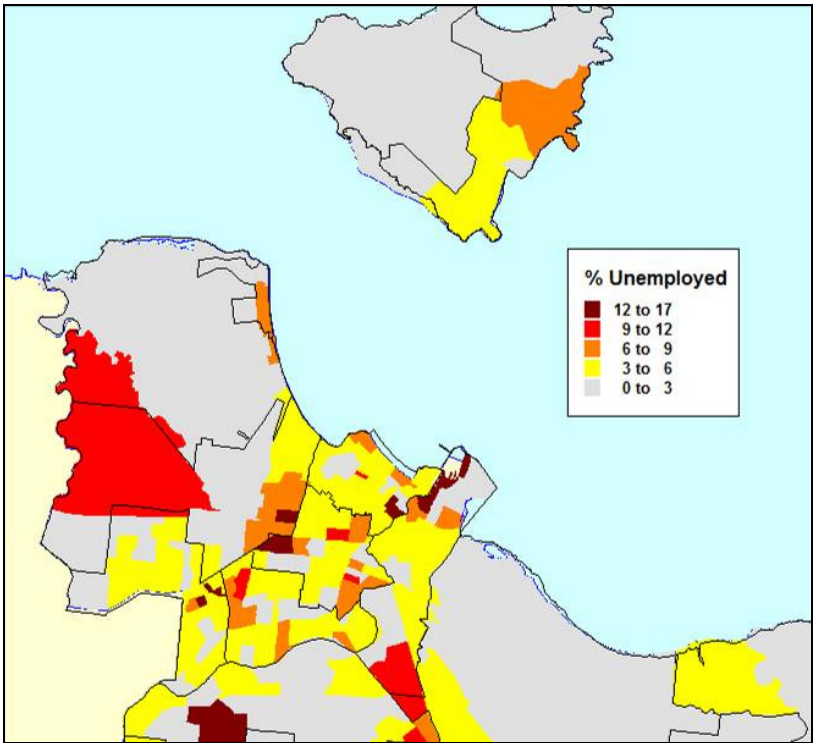

Figure 3.20: Urban area percent 2006 workforce unemployed (ABS, 2007 data)

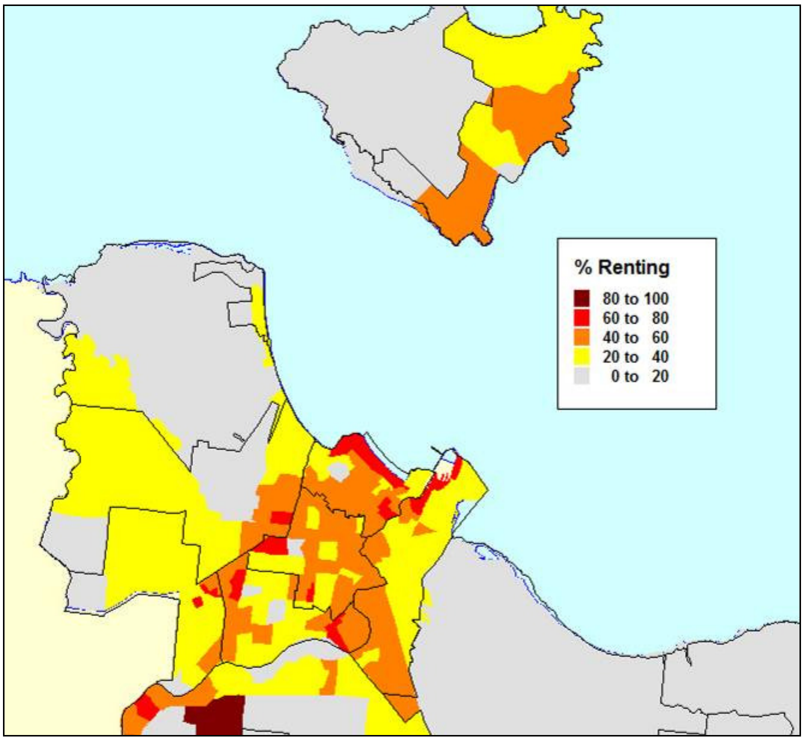

Figure 3.21: Urban area percent 2006 households renting (ABS, 2007 data)

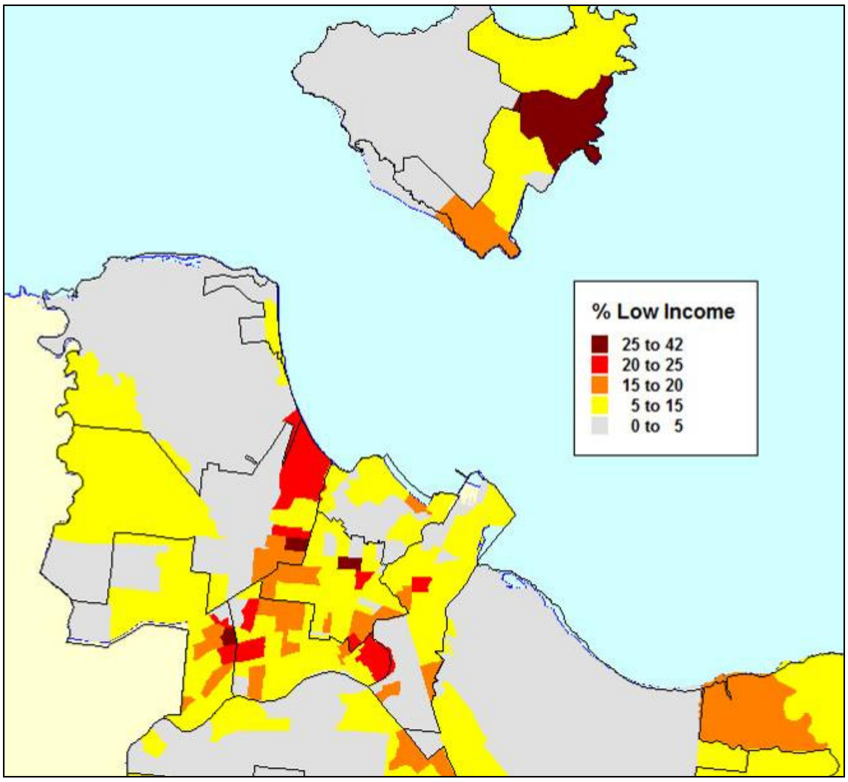

Figure 3.22: Urban area percent 2006 families with low income (ABS, 2007 data)

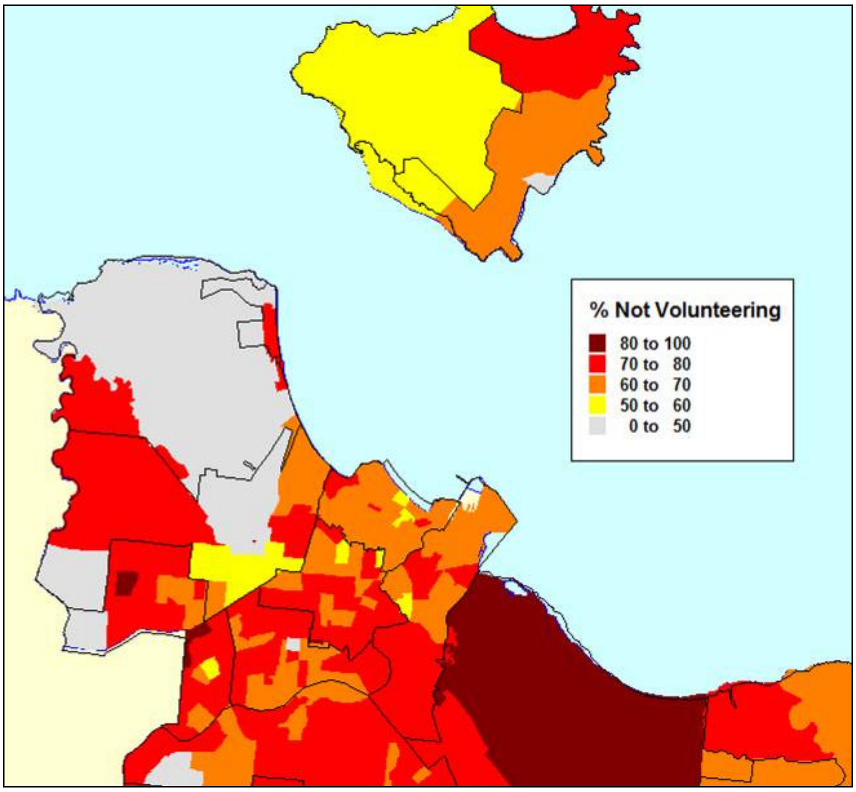

Figure 3.23: Urban area percent 2006 population over 14 not doing volunteer work (ABS, 2007 data)

3.9.3 Mobility Vulnerability

People who do not have independent means of transport are largely dependent on public transport, which is not widely or evenly available, or that provided by others. This makes them particularly susceptible in situations where evacuations may be required in the face of a rapidly evolving storm tide, flood or severe bushfire situation. Those who are particularly susceptible are in households that do not have access to a private car. There were 3040 households that did not have access to their own vehicle giving a study area-wide average of 8.9%. High percentages of carless households are found close to the airport where two neighbourhoods each have more than 33% of their households with no car. The lowest percentage is zero and that is found in 31 CCDs. At the risk assessment zone level proportions range from a high of 21.6% in Industrial West to a low of approximately 1.8% in Upper Ross.

Single parent households and large families are both at a disadvantage when it comes to taking emergency action such as an evacuation. At the 2006 Census there were 4093 single parent families in the City giving an average of 17.3% of all families. Percentages at the CCD level range from almost 50% in a Heatley neighbourhood to zero in 16 CCD. At the risk assessment zone level proportions range from 25.7% in Industrial West to a low of 9.2% in Upper Ross.

There were 2046 households that had three or more children at home giving an average of 6.0% across the study area. The greatest concentration was in Annandale where six CCD had greater than 13% of households meeting the ‘large’ criteria. There were 25 CCD with zero percent of large households. At the risk assessment zone level the values range from 10.1% in Institutions down to 2.9% in Cungulla.

Details of the mobility vulnerability measures for each hazard precinct are given in Table 3.10 and their distributions are illustrated in Figures 3.24 to 3.26.

Table 3.10: Study area mobility vulnerability measures by risk assessment zone

RISK ZONE	% NO CAR HOUSEHOLDS	% SINGLE PARENTS	% LARGE HOUSEHOLDS
Cungulla	2.91	14.08	2.91
Highway	2.65	10.35	6.70
Industrial East	4.49	20.08	7.32
Industrial West	21.25	25.65	3.88
Institutions	2.53	12.17	10.10
Lakes	12.66	20.46	4.05
Lower Ross	8.65	17.05	4.84
Magnetic Island	13.89	19.44	3.11
National Parks	1.88	13.65	7.53
Pallarenda	3.74	13.18	7.17
Riverside	9.70	21.80	5.17
Strand-CBD	10.86	13.02	3.26
Upper Ross	1.77	9.24	8.83
Urban West	7.86	18.17	7.75
TOTALS	**8.91**	**17.32**	**6.00**

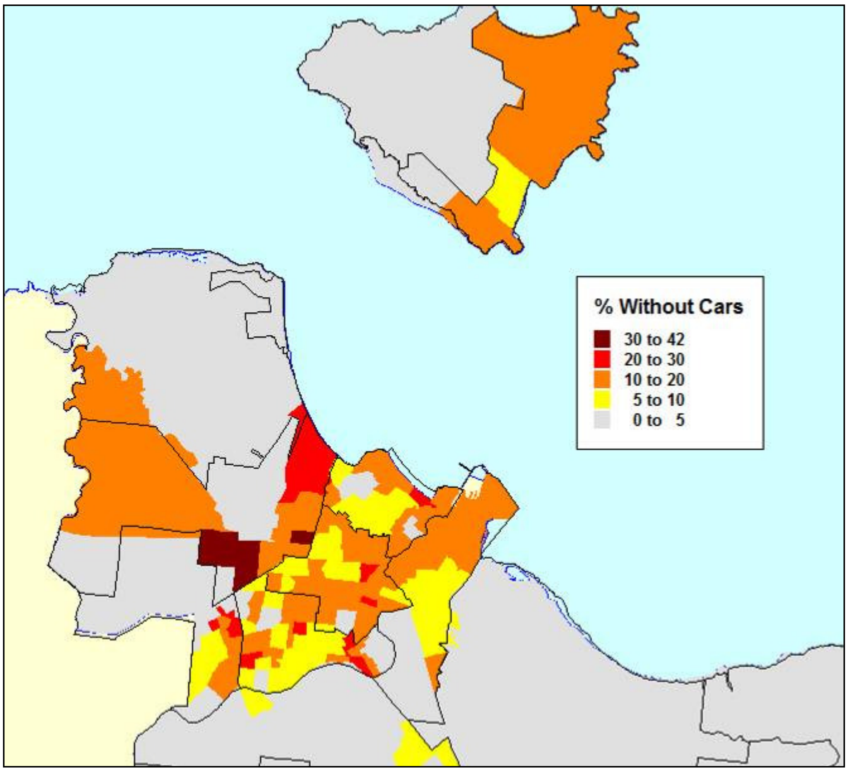

Figure 3.24: Urban area percent 2006 households with no car (ABS, 2007 data)

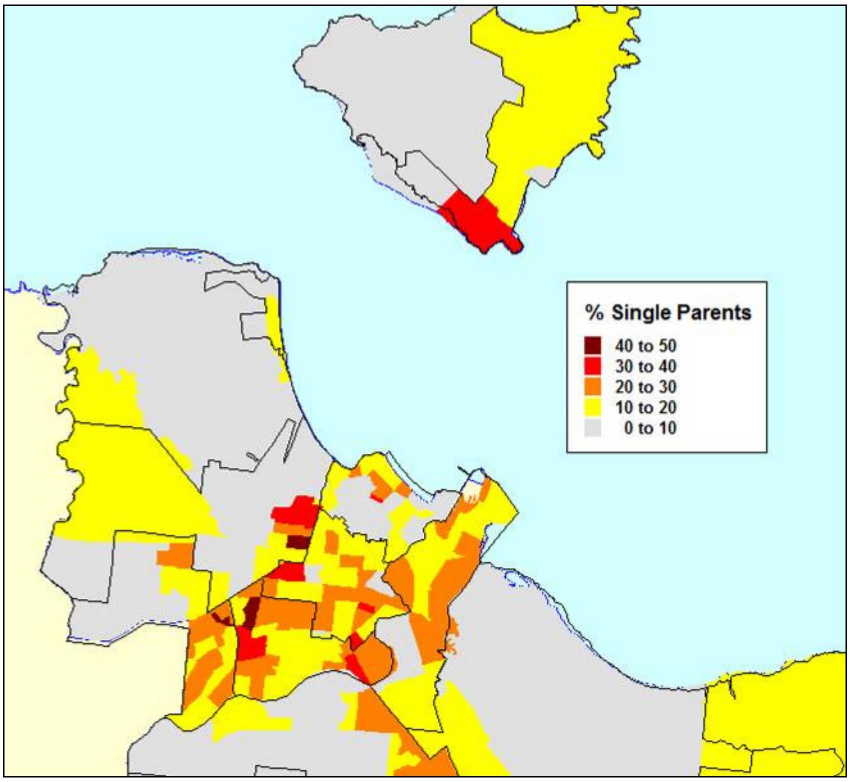

Figure 3.25: Urban area percent 2006 families with a single parent (ABS, 2007 data)

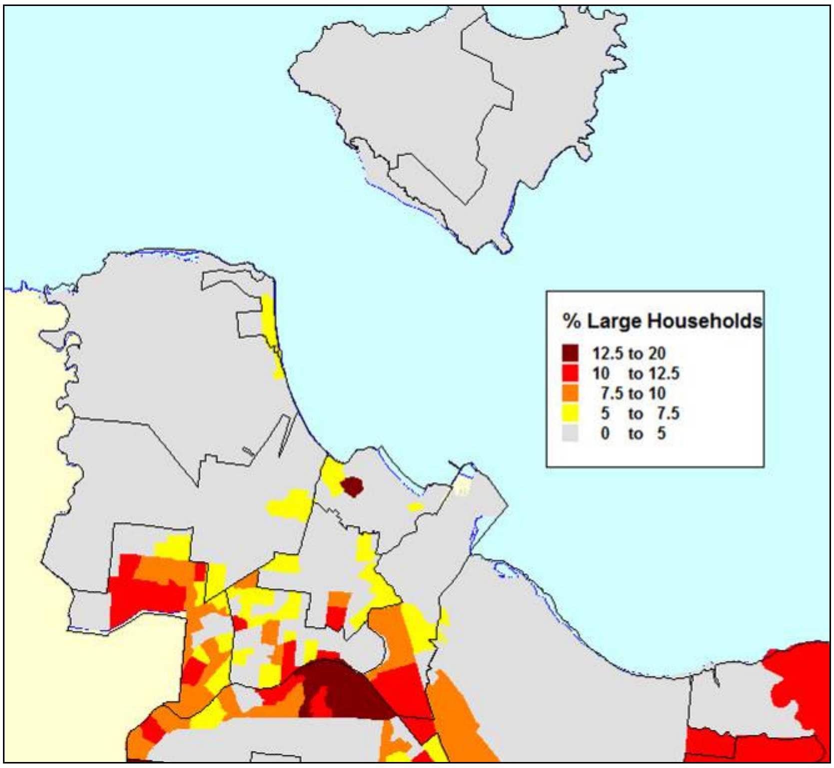

Figure 3.26: Urban area percent 2006 households with three or more children at home (ABS, 2007 data)

3.9.4 Awareness Vulnerability

A lack of awareness of the hazard threats, and how to cope with an emergency situation places people at greater risk than those who have a good level of knowledge and awareness. To cite the emergency services axiom, **'an aware community is a prepared community'**.

People who are new to the area tend to have a lower level of awareness than those who have lived there for a long time. Given the growth centre nature of the study area it is no surprise that some 44,851 of the study area's total population (or 47.0%) had lived at their census night address for less than five years. Some 60 CCDs (of the 196 in the City) have more than 50% of their population with less than five years residence. These neighbourhoods are particularly concentrated in Strand-CBD, Lakes and Urban West. There is also a high concentration in the Institutions zone reflecting the transient nature of the student and Army populations with one CCD having 90% new residents. At the risk assessment zone level proportions range from a high of more than 56% in Strand-CBD and Upper Ross to a low of 26.7% in the Industrial West zone.

All community awareness material and all warnings issued in the study area are in English so those people who do not speak English will be at a significant disadvantage. Only 367 people (0.4% of the total population) were recorded as having no English in 2006. Whilst the proportions are very small overall, the highest concentration is 4.38% in a Riverside neighbourhood. By contrast, a total of 124 of the 196 CCD have no people without English. At the broader risk assessment zone level all zones have less than 0.6% non-English speakers.

The use of the Internet is seen as a further indicator of awareness given that agencies such as the BoM post warnings and forecasts on the Web. In the study area there were 12,243 of the area's 34,085 dwellings (35.9%) that did not have Internet connection at the 2006 census. One small CCD (only four dwellings) had 100% absence of Internet connections whereas 12 CCD had better than 90% connection to the Internet. At the risk assessment zone level Industrial West with 52.1% of dwellings without Internet connection is the highest, with Institutions at 21.9% the most connected.

Details of the awareness vulnerability measures for each hazard precinct are given in Table 3.11 and the distributions across the Shire are shown in Figures 3.27 to 3.29.

Table 3.11: Study area awareness vulnerability measures by risk assessment zone

RISK ZONE	% NEW RESIDENTS	% WITH NO ENGLISH	% WITH NO INTERNET
Cungulla	37.25	0	40.38
Highway	32.52	0	29.56
Industrial East	26.81	0	36.11
Industrial West	33.58	0.19	52.14
Institutions	52.62	0.47	21.89
Lakes	46.18	0.28	43.66
Lower Ross	48.07	0.22	37.38
Magnetic Island	45.06	0.14	37.59
National Parks	33.88	0.29	39.30
Pallarenda	40.59	0	23.15
Riverside	44.16	0.56	40.98
Strand-CBD	56.38	0.39	32.69
Upper Ross	56.77	0.24	39.78
Urban West	45.66	0.50	34.62
TOTALS	**46.99**	**0.38**	**35.92**

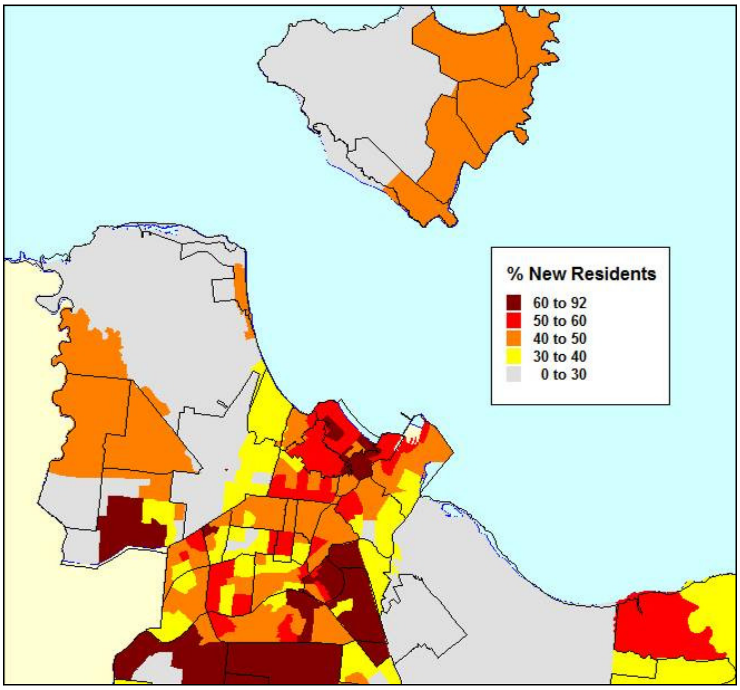

Figure 3.27: Urban area percent 2006 population less than 5 years resident (ABS, 2007 data)

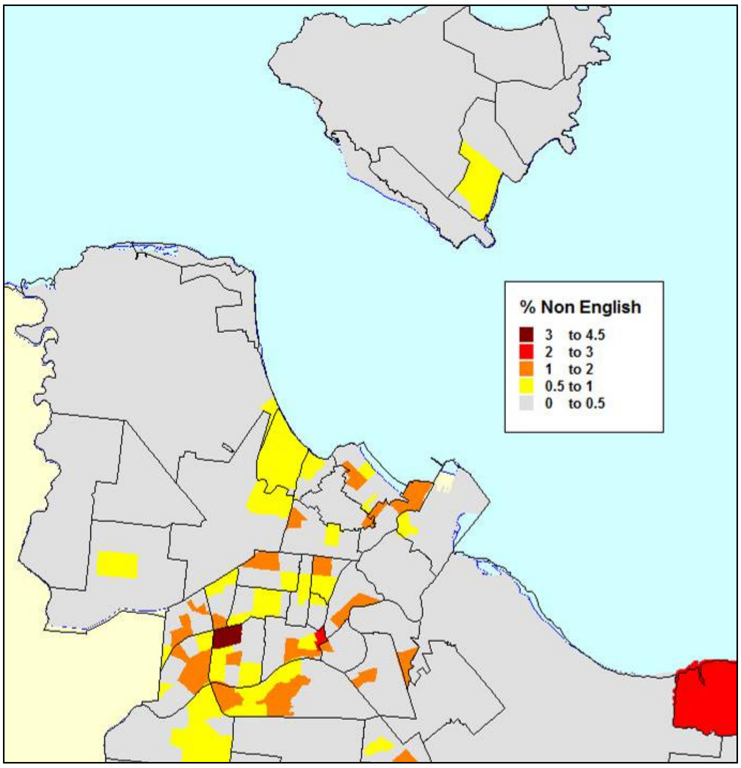

Figure 3.28: Urban area percent 2006 population with no English (ABS, 2007 data)

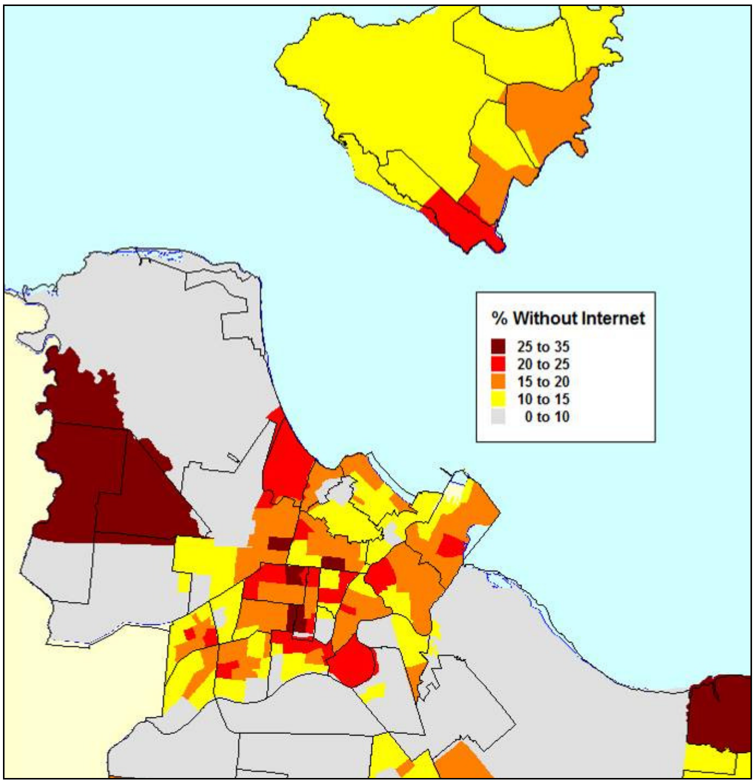

Figure 3.29: Urban area percent 2006 population who do not use the Internet (ABS, 2007 data)

3.9.5 Community Vulnerability Index

A combined index based on the values from the individual characteristics has been constructed to provide a **relative** measure of community vulnerability across the study area. The values for each characteristic have been divided by the largest value in the set so that the risk assessment zone with the highest vulnerability value has an index of 1. Those 14 indexes were then summed and expressed as a percentage of the maximum (14). On this basis it can be seen that Airport, and Riverside contain the greatest concentrations of people with characteristics that would make them more susceptible to the impact of a disaster. Table 3.12 provides the relative measures of community vulnerability at the risk assessment zone level. Figure 3.30 shows the vulnerability index at the CCD level and Figure 3.31 the index at the risk assessment zone level.

The risk assessment zone with the highest relative level of community vulnerability is Industrial West whilst the zone with the lowest relative level of vulnerability is Highway.

Table 3.12: Study area relative community vulnerability measures by hazard precinct

RISK ZONE	COMMUNITY VULNERABILITY INDEX
Cungulla	51.44
Highway	44.36
Industrial East	46.99
Industrial West	79.92
Institutions	57.84
Lakes	69.91
Lower Ross	62.45
Magnetic Island	63.08
National Parks	53.76
Pallarenda	60.61
Riverside	72.16
Strand-CBD	61.26
Upper Ross	50.20
Urban West	68.36

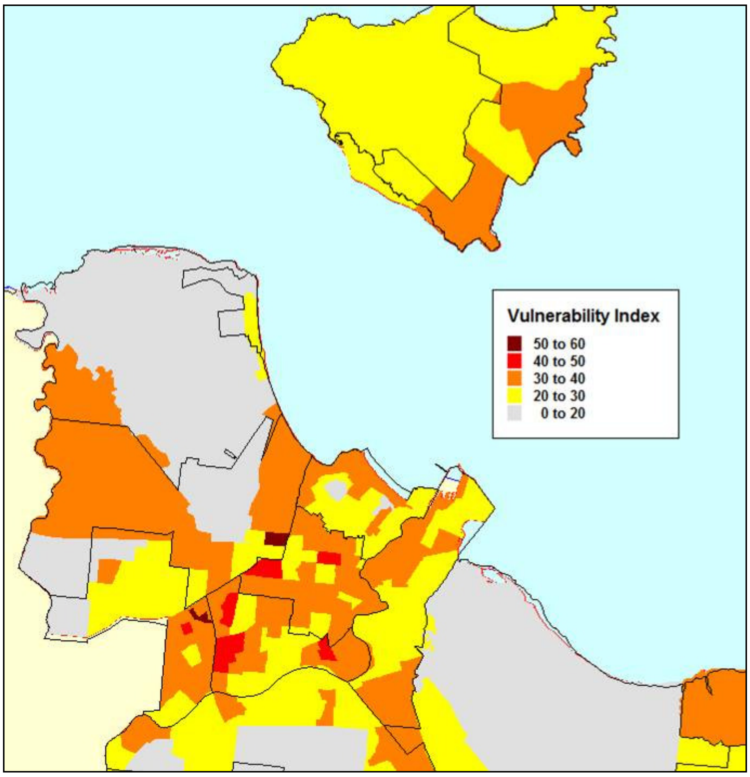

Figure 3.30: Urban area community vulnerability index at CCD level

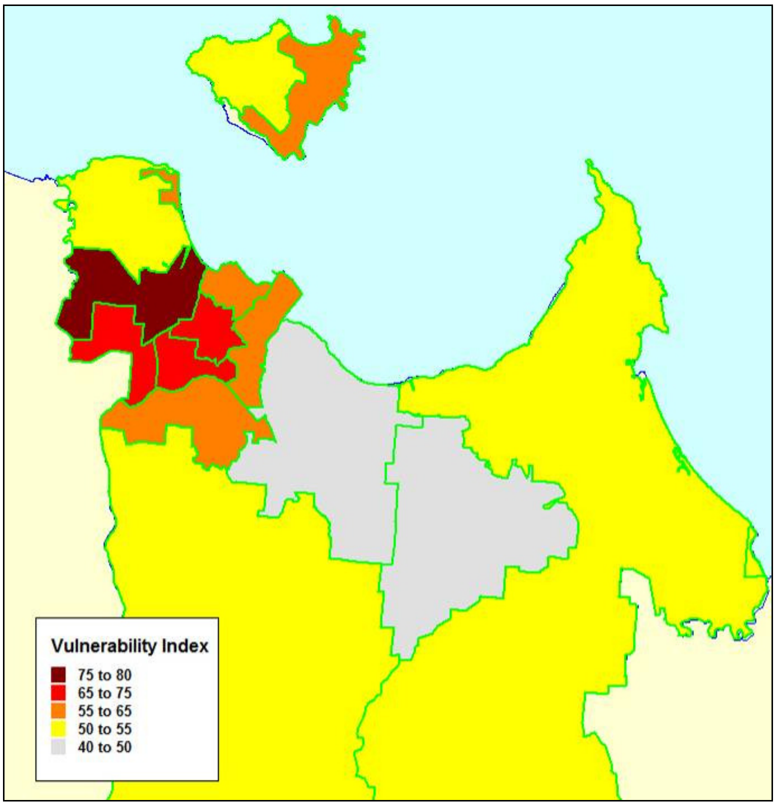

Figure 3.31: Study area community vulnerability index at the risk assessment zone level

The analytical model employed in the assessment of community vulnerability is shown in Figure 3.32.

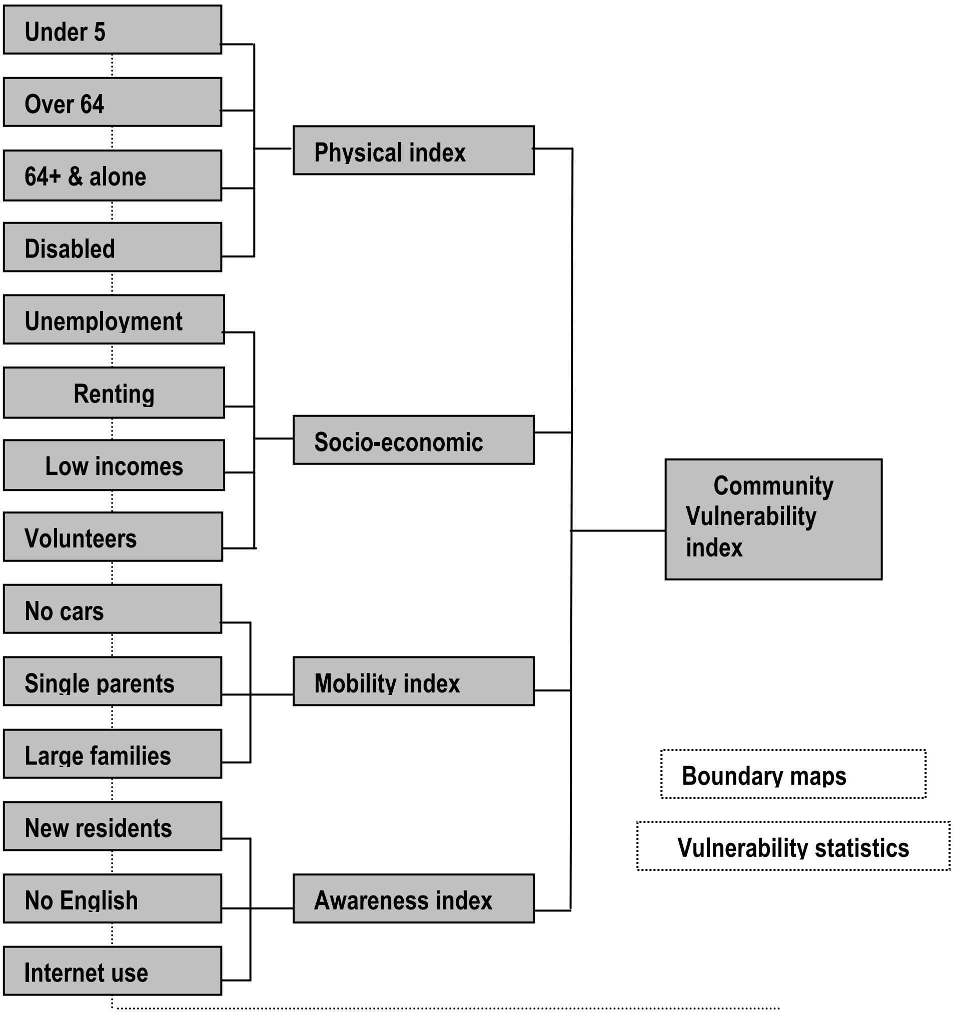

Figure 3.32: Community vulnerability analysis model

3.10 VULNERABILITY INTANGIBLES

Disasters and emergencies have a nasty habit of catching people unprepared. It is probably inevitable that many families will be caught out with vehicles with near-empty fuel tanks, stocks of food and other essentials enough for only a few days and essential medicines close to exhaustion. This situation is very evident in all urban centres like those in the study area where the convenience of ready access to a local service station, supermarket and pharmacy has developed significant complacency. This 'convenience store complacency' can erode community preparedness and self reliance.

There is also strong anecdotal evidence that the self reliance and independence that has traditionally been attributed to Australia communities appears to be giving way to an increasing dependence on outside assistance during emergencies. Again, anecdotal evidence from recent disasters in the study area and elsewhere in Queensland indicate that there is an increasing expectation (if not demand) that assistance will be provided by disaster workers, such as the SES placing tarpaulins on damaged roofs, when needed, rather than people taking a greater degree of responsibility for their own welfare and sustenance. Such attitudes, if they become entrenched, can only reduce community resilience.

3.11 INSTITUTIONAL VULNERABILITIES

The process of local government amalgamation contains many factors that may unintentionally increase community vulnerability until such time as the new Council and its many systems are truly integrated and operating as a cohesive unit.

Of the key factors identified during this study, the lack of a well integrated information infrastructure suitable to support emergency risk analysis has been most notable. So-called 'silos' of information exist in various agencies and sections of agencies such as the City Council. The degree to which those silos within TCC can be quickly connected appears to be well above the local government average in the experience of IID analysts. This was evident to some degree with spatial information used in this study's use of GIS analysis. It is yet to be demonstrated, however, whether they will be able to link quickly with comparable data sets held in former Thuringowa City Council.

Almost since its first articulation, the GIS concept has regularly been portrayed as a sequence of thematic layers, neatly arranged above each other in a three dimensional relationship as shown in Figure 3.33. In this approach, each overlay represents one theme of reality.

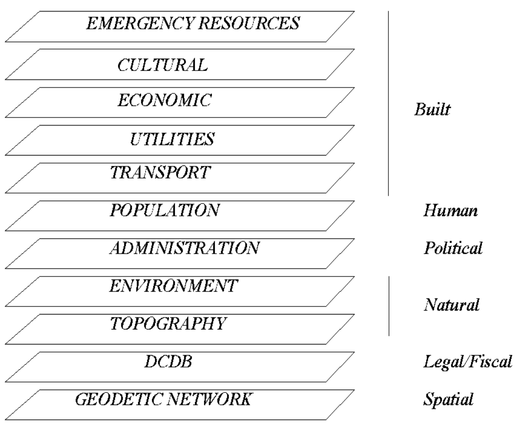

Figure 3.33: The idealised spatial information vision (Figure 6 from Granger, 1998)

Unfortunately this vision has not translated completely into the former Townsville City Council (and probably that of the former Thuringowa City Council as well) reality, given that each theme has tended to become an entity in its own right, controlled by interests that promote its separateness and/or uniqueness.

The focus is typically **within** each thematic layer rather than **between** layers. It has proven to be very difficult to integrate overlays to reconstruct a multi-dimensional, real world view. Indeed, in many instances it is difficult to even construct a two dimensional view. Figure 3.34 reflects (a somewhat exaggerated) view of the reality.

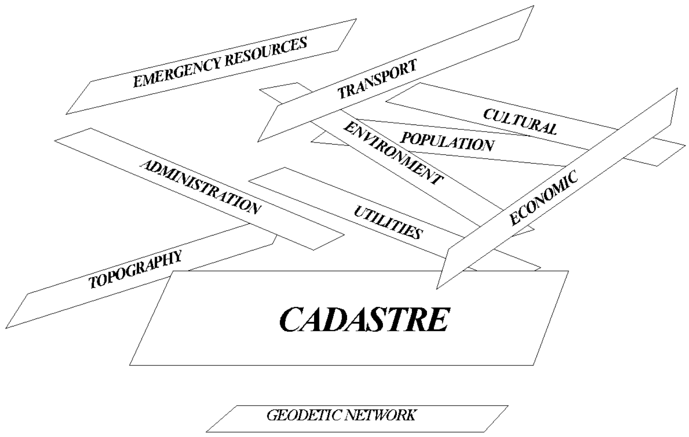

Figure 3.34: The information 'reality' (Figure 7 from Granger, 1998)

Clearly, a key test of the success of any information infrastructure is the degree to which it can overcome the 'reality' and conform with, if not mandate, at least the integrated, multi-dimensional vision. The experience of this study is that such a vision is yet to be completely developed amongst emergency managers in Townsville City. It will also take some time to integrate the information infrastructures of the two former local governments.

It was also apparent that an 'information culture' was not well developed amongst emergency managers – again there appears to be limited interchange of information at least as a matter of routine. Clearly, the information needed by emergency managers during an event is much wider and more 'real world' specific than a list of names and telephone numbers.

The study area has not experienced a major hazard impact for some years. Whilst there have been some localised flash floods and some landslides from ex-TC *Sid* in 1998 (and repeated more recently) There has been no tropical cyclone akin to TC *Althea* and its attendant wind damage and storm tide since 1971. The Townsville-Thuringowa LDMC has not been activated for an extended period to cope with a major disaster in the past decade, though it has been activated for short periods for less severe events. Whilst the individual members of the LDMC may be well experienced in their own agency operations, there appears to be a general lack of experience in joint operations and in operating the coordination centre in a real-life operational environment, especially in an emergency that lasts for more than 24 hours. Such experience can only be gained by actually doing the job.

This lack of operational experience is potentially exacerbated by an almost total lack of joint service training by which members of the different combat and supporting agencies can gain an appreciation of the capabilities, roles and procedures of other agencies with whom they will have to coordinate their activities.

At a more philosophical level, there does not appear to be an overt commitment to the objectives of emergency risk management, namely to foster safe and sustainable communities, by Townsville City Council in its Vision Statement or its Management Plan. The *City Safe* program in the former Vision Statement addresses only to 'prevent crime and promote greater safety in neighbourhoods and streets of Townsville'. There is no mention of promoting community safety from natural hazards.

This may, in part, reflect a lack of appreciation of the extent of the legislated responsibilities and common law obligations of local government where public safety and community risks are involved. Whilst this is probably seen as a minor issue by some, **it is critically important to provide a clear public recognition that emergency risk management is an integral part of overall community governance**.

Given the complexity of the full breadth of legislation, regulation and guidelines relating to emergency risk management in Queensland, and the obscurity of some material, it is not surprising that Councils generally have difficulty embracing the full scope of the issue. During this study several instances were encountered that indicated that the full ambit of the legal and 'duty of care' responsibilities of Council specifically associated with emergency risk management were not well understood or appreciated by some senior managers.

3.12 ECONOMIC VULNERABILITY

The vulnerability of the economy to the impact of hazards varies considerably. Obviously, if there is property loss or damage there is an economic impact and if those properties are either uninsured or underinsured, the impact will be significant. However, if properties are well insured, then sections of the economy, especially the building and allied industries, may in fact be given a boost as reconstruction of destroyed or damaged buildings and infrastructure becomes a focus.

The insurance industry itself may, perversely, gain a boost from the impact of some hazards. During and following fires in Sydney in 1994 and 2002, and Canberra in 2003, for example, the anecdotal evidence indicates that the insurance industry's income from new or increased premiums far outweighed their outlays for the losses caused by the fires. It was common for unaffected property owners to review the adequacy of their cover as a result of the fires. Those who were uninsured rectified that situation and those who were underinsured increased the level of their cover.

A key determinant in the magnitude of economic loss is the length of time it takes to recover the loss and/or to return to production. This is especially significant in rural industries. For the grazing industries, for example, the loss of feed can be temporarily replaced by importing fodder and the grass will come back following the next good rains. The horticultural industries could, however, lose a season of production if severe wind, hail, fires or floods occur before their crops are ready for harvest. The poultry industry would probably take only months to return to production. Orchards may be out of production for between five and seven years if they have to replant. In the non-agricultural sectors, small scale businesses are particularly susceptible to the impact of disasters. If not insured for such contingencies as business continuance, businesses will fail and people will be made unemployed. Such impacts may require many years for recovery.

3.13 ENVIRONMENTAL VULNERABILITY

3.13.1 Flora

Fire has played a major part in the evolution of the native vegetation of the study area. Much of that vegetation is a fire-climax type or fire-tolerant to a degree. The maintenance of vegetation diversity is, however, something of a balancing act. Severe bushfire (or too frequent burning) can destroy or retard the regeneration of most forms and open the way to the invasion of weeds and less fire-tolerant species. Conversely, the exclusion of fire for extended periods can lead to an expansion of some less fire tolerant rainforest species and reduce the biodiversity of the area.

Destructive winds associated with severe thunderstorms or tropical cyclones can damage the vegetation of the area, however, such damage is typically confined to relatively small areas. Wholesale destruction is unlikely.

Some climate change scenarios suggest that there may be a loss of species or an altitudinal migration to cope with higher mean temperatures. Given the small altitudinal range within the study area scope for such migration may be limited.

The biggest areas of largely undisturbed native vegetation are conserved in the National Parks, though significant areas remain on other public (especially Commonwealth) lands and on private holdings.

3.13.2 Fauna

Of all of the native fauna of the study area, the koala, and other small tree-dwelling mammals, such as possums and gliders, is probably the most susceptible to bushfire, especially severe fires that reach the crowns of the forest trees. Reptiles and frogs are also at a disadvantage during fire because they are particularly susceptible to the flames and heat. Birds, and the larger mammals such as kangaroos, can generally escape the flames.

Loss of habitat, either by too-frequent fire, <u>or by the exclusion of fire</u>, has a longer term impact, and species can/will be lost to the area. The elimination of regular burning of some forest areas for example, has changed the availability of fresh areas of grass, with the result that some species may disappear. The destruction of vegetation food sources following a severe cyclone impact will also have an impact on some species.

In the marine environment areas of the local reef systems may be destroyed or damaged by heavy seas and by flood run-off.

Climate change may also have an impact should there be significant changes to the habitat mix.

3.14 EXPOSURE TO SEVERE STORMS

As discussed in Chapter 2, no part of the study area is immune to the impact of destructive winds, hail or lightning brought by tropical cyclones or severe thunderstorms. Local features will, however, have some influence on the degree of exposure.

The wind loading standards (AS1170.2 and AS4055) under the Building Code of Australia recognises that the impact of severe winds will vary considerably from site-to-site because of the influences of local topographic factors. These relate primarily to:

- terrain ‘roughness’ (e.g. open sea, fields, trees, houses, etc);
- shielding or interference from adjacent objects (e.g. other buildings, dense vegetation, etc); and,
- acceleration on slopes and the tops of hills.

The wind loading code makes some allowance for these site factors and, following the approach of Harper (1999), four site classes can be applied, namely:

- foreshore (generally flat areas within 1 km of the coastline);
- hill slopes (elevated regions on slopes of 10% or more);
- town (generally flat areas where the density of housing provides shielding); and
- inland (generally open terrain more than 1 km from the coast).

All buildings have some degree of exposure to potentially damaging winds. Those that are located in the following locations have an elevated wind exposure:

- within 1 km of the coast;
- located on slopes of 10% or more; or,
- are not within a suburban area (i.e. on land parcels of less than 5000 sq m).

Table 3.13 lists the numbers of dwellings in each risk assessment zone that meets those criteria.

Table 3.13: Study area dwellings with a heightened exposure to wind damage by risk assessment zone

RISK ZONE	HEIGHTENED WIND EXPOSURE	% OF TOTAL
Cungulla	251	100.00
Highway	573	87.35
Industrial East	114	28.86
Industrial West	169	18.35
Institutions	205	3.13
Lakes	18	0.37
Lower Ross	576	18.94
Magnetic Island	1034	86.96
National Parks	75	100.00
Pallarenda	329	100.00
Riverside	71	1.30
Strand-CBD	1927	88.89
Upper Ross	376	98.43
Urban West	451	7.87
TOTALS	**6169**	**19.29**

The modelling undertaken by CTS and SEA (2003) reflect the significance of wind exposure to scenarios of differing severity. The results are summarised in Table 3.14 and the associated commentary from that study (CTS and SEA, 2003 p53).

Table 3.14: Townsville City estimates of houses sustaining wind damage (Table 7.2 in CTS and SEA, 2003)

DISTRICT	Constant wind speed applied to all districts				
	47 M/S	**55 M/S**	**59 M/S**	**69 M/S**	**74 M/S**
4810	7%	24%	35%	68%	83%
4811	4%	19%	29%	58%	75%
4812	2%	14%	24%	57%	75%
4814	3%	18%	28%	52%	66%
4815	2%	12%	20%	43%	59%
4817	2%	11%	18%	38%	53%
4818	2%	12%	21%	43%	58%
4819	8%	23%	32%	58%	75%
Total	**3%**	**16%**	**25%**	**51%**	**67%**

The effect of the higher percentage of older construction for model districts 4811 and 4812 is seen in the approximately 35% greater estimated number of houses damaged compared with the newer districts of 4815, 4817 and 4818. This difference would be even greater if it were not for the fact that 4811 and 4812 have greater proportions of houses ensconced in suburban terrain, with its lower impact wind velocity.

It is worth noting that the higher estimated number of damages for the district 4810 and the island district 4819 are due to the proportion of the houses in the district on elevated sloping terrain and in close proximity to coast. Although 4819 has a similar housing age proportion to 4815, its damage level is similar to the older suburb of 4811.

Commercial buildings and industrial structures are typically constructed to a much higher engineering standard than domestic buildings. They are, none-the-less still exposed to potentially damaging winds in the more exposed areas. Table 3.15 details the numbers and percentages of commercial and industrial buildings in each risk assessment zone.

Table 3.15: Study area commercial and industrial buildings with a heightened exposure to wind damage by risk assessment zone

RISK ZONE	HEIGHTENED WIND EXPOSURE	% OF TOTAL
Cungulla	0	0
Highway	10	100.00
Industrial East	67	69.07
Industrial West	278	32.29
Institutions	19	51.35
Lakes	77	16.96
Lower Ross	231	71.96
Magnetic Island	69	100.00
National Parks	1	100.00
Pallarenda	0	0
Riverside	40	15.33
Strand-CBD	251	70.70
Upper Ross	6	100.00
Urban West	48	63.16
TOTALS	**1097**	**43.05**

In addition to the dwellings that have an elevated exposure to damaging winds, there are significant numbers of critical and sensitive facilities that are also exposed. These include:

- Townsville airport and RAAF Garbutt and their supporting infrastructure;
- Lavarack Barracks;
- the Townsville, Mater and Wesley hospitals;
- police stations Picnic Bay, Belgian Gardens, South Townsville and Stuart;
- fire stations in South Townsville and Horseshoe Bay;
- SES headquarters in West End;
- the port facilities and fuel storage depots;
- most schools, shopping centres, aged care facilities and retirement villages (because of their larger block size and lack of screening).

All above-ground infrastructure, including power supply and tower-mounted telecommunications elements, are exposed to damage by strong winds and by wind-blown debris.

People are most likely to be exposed to severe wind hazards if they are caught in the open and are unable to reach a sheltered location, or leave shelter and venture out into the winds. Their exposure to lightning comes from similar situations.

Council's exposure: Council's exposure is probably confined to their own assets including buildings, plant and equipment. Council probably has only a very small legal exposure to claims originating from third-party wind damage.

3.15 EXPOSURE TO FLOOD

Maunsell (2005b) provides a detailed analysis of the exposure of properties and some key infrastructure elements to flood within the areas covered by that study. That study did not, however, cover all of the study area, for example there is no hazard modelling for the Houghton River catchment. Their flood modelling does cover the bulk of the urban areas and data from that study has been used to calculate the relative levels of exposure of buildings, roads and critical and sensitive facilities to events with recurrence intervals of 50 and 100 years as well as PMF[11].

Whilst there may be circumstances such as localised stormwater surcharge or a catastrophic dambreak where inundation may extend locally beyond the PMF level, the data available does not permit an adequate coverage of such scenarios. It is assumed, therefore, that the 'worst case' flood extent will be the modelled PMF level.

The Maunsell (2005b) study provides significant detail on the potential cost of damage likely to be experienced in floods of a given recurrence interval based on stage damage curves for both the structures and their contents. The relationship between structural damage and contents damage is illustrated in Figure 3.35 (Maunsell, 2005b, Figure 3).

[11] The spatial extent of the 100 year ARI modelling does not extend as far north as that for the 50 year ARI and PMF mapping so the exposure statistics in the following tables for the Industrial West and the Town Common portion of National Parks risk assessment zones for the 100 year ARI event are lower than they should be.

This study has not attempted to replicate the Maunsell (2005b) analysis because IID does not have access to essential attribute data for individual buildings including floor height and ground level height. Consequently, this study only considers exposure to buildings and road infrastructure where they lie within the mapped flood extent. This does not take into account depth of inundation or other factors such as velocity of flood waters. IID does not consider this to be a significant issue given that the objective of this study is to produce a comparison between the risks posed by all of the hazards considered.

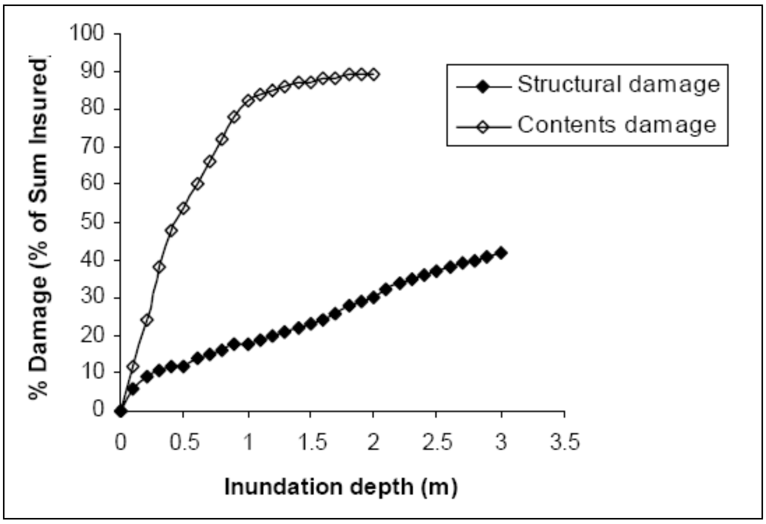

Figure 3.35: Potential loss curves for structural and contents damage (Maunsell 2005b, Figure 3)

Table 3.16 summarises the numbers of dwellings exposed to inundation by floods of any depth for three modelled event magnitudes. The statistics clearly show that Riverside and Lakes risk assessment zones have the greatest numbers of dwellings potentially exposed to floods up to the current design level (100 year ARI)[12]. Riverside risk assessment zone also has the greatest number at the PMF level.

Table 3.16: Study area dwellings exposed to inundation under three flood scenarios

RISK ZONE	50 YEAR ARI	% 50 YEAR ARI	100 YEAR ARI	% 100 YEAR ARI	PMF	% PMF
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	6	1.52	14	3.54	97	24.56
Industrial West	54	5.86	54	5.86	589	63.95
Institutions	17	0.26	19	0.29	1830	27.95
Lakes	425	8.75	568	11.69	3117	64.15
Lower Ross	128	4.21	155	5.10	2713	89.21
Magnetic Island	84	7.06	100	8.41	247	20.77
National Parks	0	0	0	0	0	0
Pallarenda	14	4.26	14	4.26	41	12.46
Riverside	652	11.98	841	15.46	3801	69.86
Strand-CBD	107	4.94	131	6.04	332	15.31
Upper Ross	0	0	0	0	0	0
Urban West	199	3.47	223	3.89	1490	25.99
TOTALS	**1686**	**5.27**	**2119**	**6.62**	**14,257**	**44.57**

[12] It should be noted that until recently the design flood level set for the study area was the 50 year ARI level.

Land use planning practices tend to concentrate commercial and industrial land uses into specific areas and that land is often land that is less desirable for development for residential uses. If commercial land uses are permitted on flood-prone land then the numbers exposed may be substantial. Table 3.17 details the numbers and percentages of commercial and industrial buildings on flood prone land. From this analysis the Lakes risk assessment zone clearly has the greatest exposure of commercial premises to a 100 year ARI flood.

Table 3.17: Study area commercial and industrial buildings exposed to inundation under three flood scenarios

RISK ZONE	50 YEAR ARI	% 50 YEAR ARI	100 YEAR ARI	% 100 YEAR ARI	PMF	%PMF
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	0	0	0	0	7	7.22
Industrial West	23	2.67	23	2.67	392	45.53
Institutions	1	2.70	1	2.70	11	29.72
Lakes	44	9.69	62	13.66	285	62.78
Lower Ross	12	3.74	12	3.74	168	52.34
Magnetic Island	6	8.70	7	10.14	20	28.99
National Parks	0	0	0	0	0	0
Pallarenda	0	0	0	0	0	0
Riverside	18	6.90	22	8.43	131	50.19
Strand-CBD	10	2.82	12	3.38	29	8.17
Upper Ross	0	0	0	0	0	0
Urban West	4	5.26	7	9.21	42	55.26
TOTALS	**118**	**4.63**	**146**	**5.73**	**1085**	**42.58**

Table 3.18 details the length of road that falls within the inundation zones for the three flood scenarios.

Table 3.18: Study area road segments exposed to inundation under three flood scenarios

RISK ZONE	50 YEAR ARI (km)	% 50 YEAR ARI	100 YEAR ARI (km)	% 100 YEAR ARI	PMF (km)	%PMF
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	11.07	12.36	11.61	12.97	21.84	24.39
Industrial West	14.25	19.09	14.25	19.09	51.60	69.13
Institutions	3.90	2.31	4.58	2.71	57.43	34.04
Lakes	21.68	19.82	25.63	23.43	78.27	71.54
Lower Ross	8.37	9.44	9.45	10.65	76.76	86.53
Magnetic Island	6.73	11.45	7.38	12.55	7.51	12.77
National Parks	0	0	0	0	0.76	1.10
Pallarenda	2.98	30.60	2.97	30.60	3.22	33.05
Riverside	33.67	31.90	37.16	35.21	83.09	78.73
Strand-CBD	6.72	10.06	7.22	10.81	13.78	20.63
Upper Ross	0	0	0	0	0	0
Urban West	20.63	17.11	22.20	18.41	50.55	41.93
TOTALS	**129.99**	**8.29**	**142.44**	**9.08**	**444.79**	**28.35**

A few facilities at RAAF Garbutt are affected by flood levels up to the 100 year ARI level, however, when extended to the PMF level the following critical and sensitive facilities would be exposed:

- Townsville airport and RAAF Garbutt facilities;
- Lavarack Barracks;
- the Wesley Hospital;
- the water police station in South Townsville;
- fire stations in South Townsville, Bohle and Horseshoe Bay;
- the ambulance station in Currajong;
- the port facilities;
- 10 service stations;
- more than 20 schools, together with several shopping centres, aged care facilities and retirement villages.

Segments of each major evacuation route may have minor levels of inundation in a 50 year ARI flood event. Somewhat more significant lengths of these routes will be inundated in a 100 year ARI flood. Those sections will also be inundated to a greater depth than in a 50 year flood. This flooding will be exacerbated where stormwater culverts become blocked during the flood.

A catastrophic dambreak would inundate a very similar area to that involved in a PMF event, but the damage potential would probably be significantly greater given the high velocity of flood waters and the likely very short warning time likely.

Council's exposure: Council's exposure to flood may extend well beyond the potential damage to its assets and the roads that would be inundated. In the event of floods involving engineered assets (stormwater surcharge or dambreak) Council may be seen as being responsible (at least in part) because it owns the assets that have 'caused' the flooding. That would expose Council to legal action by individuals and/or the insurance industry to recover their losses.

3.16 EXPOSURE TO STORM TIDE

GHD (2007) Table 8-3 provides estimates of the numbers of properties and people potentially exposed to the impact of storm tide across the study area for events with an ARI of 50, 100, 500 and 10,000 years. Their Table 8-4 provides estimates of the number of properties with more than 0.5 m of inundation and the potential loss of life for the same scenarios. The numbers of properties inundated was based on the land parcel data from the DCDB of *residential properties or commercial properties likely to house people during an event* rather than the actual location of buildings (as done by IID). It is not clear in GHD (2007) whether the land parcels needed to be fully within the flood extent to be selected or only part of the parcel needed to be involved.

The total numbers of properties identified in their modelling of 50, 100, 500 and 10,000 year ARI events was 15, 230, 2048 and 10,196 respectively. For properties with more than 0.5 m of inundation their results were (for the same scenarios) 0, 10, 1298 and 9352.

Their inundation totals are significantly lower than the IID results shown in Table 3.19. This may be explained by the fact that numerous land parcels with blocks of units, for example, have multiple buildings on the one land parcel and that IID used point data rather than polygon data.

As with the flood exposure analysis above, IID has extracted statistics on the numbers of dwellings, commercial premises and road segments that lie within the modelled extent of inundation for 50, 100 and 10,000 year ARI storm tide events. The results are shown in Tables 3.19, 3.20 and 3.21 respectively.

Table 3.19: Study area dwellings exposed to inundation under three storm tide scenarios

RISK ZONE	50 YEAR ARI	% 50 YEAR ARI	100 YEAR ARI	% 100 YEAR ARI	10,000 YEAR ARI	% 10,000 YEAR ARI
Cungulla	15	5.98	20	7.97	249	99.20
Highway	0	0	0	0	17	2.59
Industrial East	0	0	0	0	106	26.83
Industrial West	1	0.11	1	0.11	889	96.53
Institutions	1	0.02	1	0.02	696	10.63
Lakes	10	0.21	20	0.41	4017	82.67
Lower Ross	54	1.78	460	15.13	3010	98.98
Magnetic Island	4	0.34	4	0.34	128	10.77
National Parks	0	0	0	0	12	16.00
Pallarenda	0	0	0	0	301	91.49
Riverside	0	0	0	0	1064	19.56
Strand-CBD	0	0	8	0.37	527	24.31
Upper Ross	0	0	0	0	0	0
Urban West	0	0	0	0	21	0.37
TOTALS	**85**	**0.27**	**514**	**1.61**	**11,037**	**34.51**

Table 3.20: Study area commercial and industrial buildings exposed to inundation under three storm tide scenarios

RISK ZONE	50 YEAR ARI	% 50 YEAR ARI	100 YEAR ARI	% 100 YEAR ARI	10,000 YEAR ARI	% 10,000 YEAR ARI
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	0	0	0	0	2	2.06
Industrial West	6	0.70	7	0.81	397	46.11
Institutions	0	0	0	0	7	18.92
Lakes	0	0	1	0.22	389	85.68
Lower Ross	18	5.61	53	16.51	315	98.13
Magnetic Island	1	1.45	2	2.90	32	46.38
National Parks	0	0	0	0	0	0
Pallarenda	0	0	0	0	0	0
Riverside	0	0	0	0	71	27.20
Strand-CBD	1	0.28	3	0.85	132	37.18
Upper Ross	0	0	0	0	0	0
Urban West	0	0	0	0	31	40.79
TOTALS	**26**	**1.02**	**66**	**2.59**	**1376**	**54.00**

Table 3.21: Study area road segments exposed to inundation under three storm tide scenarios

RISK ZONE	50 YEAR ARI	% 50 YEAR ARI	100 YEAR ARI	% 100 YEAR ARI	10,000 YEAR ARI	% 10,000 YEAR ARI
Cungulla	1.29	20.32	1.29	20.32	6.24	98.45
Highway	0	0	0	0	5.85	7.55
Industrial East	4.91	5.48	5.75	6.42	22.13	24.72
Industrial West	0.78	1.04	2.45	3.28	53.11	71.15
Institutions	0	0	0	0	19.87	11.78
Lakes	0.20	0.18	0.72	0.66	90.02	82.29
Lower Ross	8.14	9.18	19.92	22.45	88.17	99.40
Magnetic Island	0.93	1.58	3.98	6.77	15.47	26.33
National Parks	1.69	2.43	1.89	2.73	5.11	7.38
Pallarenda	0.30	3.09	0.30	3.09	9.40	96.58
Riverside	0.27	0.26	0.27	0.26	24.86	23.56
Strand-CBD	0.67	1.00	1.92	2.87	18.82	28.18
Upper Ross	0	0	0	0	0	0
Urban West	0	0	0	0	3.76	3.12
TOTALS	**19.18**	**1.22**	**38.49**	**2.45**	**580.49**	**37.10**

It is clear that the Lower Ross risk assessment zone has by far the greatest degree of storm tide exposure for all levels of event. The degree of exposure at the 100 year ARI design level is very concerning. Not only is there a large number of dwellings exposed (and a population of perhaps 1100 people), a significant proportion of the zones roads would also be inundated. Emergency planning for storm tide will clearly need to consider widespread evacuations from that zone well in advance of the cyclone crossing the coast.

People in the open would generally be at far greater risk of injury from the destructive winds or wind-blown debris than from storm tide inundation. The storm tide peak would tend to be close to its peak at the same time that the eye of the cyclone crossed the coast. Some people may, consequently, venture outside during the lull in the winds and run the risk of crossing inundated roads or engaging in other foolhardy activities.

In addition to the dwellings that have an exposure to storm tide inundation at the 100 year ARI level, there are significant numbers of critical and sensitive facilities that are also exposed. These include:

- Townsville airport and RAAF Garbutt and their supporting infrastructure;
- the Townsville, Mater and Wesley hospitals;
- the fire station in South Townsville;
- the port facilities and fuel storage depots;
- one service station;
- one school, a few shopping centres, several aged care facilities and retirement villages.

Council's exposure: Council's current exposure to storm tide is likely to be confined to their own assets such as parks and roads. Should Council approve future developments within the 100 year ARI level they may be exposed to legal claims should people suffer losses as the result of storm tide inundation in such subdivisions.

3.17 EXPOSURE TO LANDSLIDE

The Coffey Geoscience (2001) landslide hazard zoning study did not include any analysis of the community elements potentially exposed to landslide and debris flow hazards within the wider urban area; and the Coffey Geoscience and Landmarc (2004) study undertook a very detailed risk analysis of the area surrounding Castle Hill only. It is important to repeat the observation in Chapter 2 that **landslides are individual events** and that the hazard mapping can only indicate the areas in which there is a potential for landslides to occur at some point and at some time.

With the hazard data available it is clear that the level of exposure to landslides is greatest in the Strand-CBD risk assessment zone where a total of 676 dwellings lie within either a debris flow, high or medium landslide hazard zone. The exposure in this zone comes from slides originating on Castle Hill. Urban West with 465 dwellings in one of the hazard zones has the next greatest level of exposure. The exposure in this zone comes from slides potentially originating on Mount Louisa. Magnetic Island has 212 dwellings within landslide zones. Most other risk assessment zones have a relatively low level of exposure. Table 3.22 provides the statistics for dwellings potentially exposed to landslide hazards. Only 26 commercial and industrial premises across the City are exposed to the same hazards.

Table 3.22: Study area dwellings exposed to three levels of landslide hazard potential

RISK ZONE	DEBRIS FLOW	% DEBRIS FLOW	SLIDE HIGH	% SLIDE HIGH	SLIDE MEDIUM	% SLIDE MEDIUM
Cungulla	0	0	0	0	0	
Highway	0	0	1	0.15	6	0.91
Industrial East	5	1.27	68	17.22	67	16.96
Industrial West	0	0	0	0	0	0
Institutions	2	0.30	187	2.86	148	2.26
Lakes	0	0	0	0	3	0.06
Lower Ross	0	0	0	0	0	0
Magnetic Island	5	0.42	174	14.63	33	2.78
National Parks	0	0	0	0	0	0
Pallarenda	0	0	0	0	0	0
Riverside	0	0	0	0	0	0
Strand-CBD	29	1.34	340	15.68	307	14.16
Upper Ross	0	0	1	0.26	13	3.40
Urban West	18	0.31	311	5.43	136	2.37
TOTALS	**59**	**0.18**	**1082**	**3.38**	**713**	**0.22**

Roads tend to have a relatively high degree of exposure because the batters cut to achieve the best gradient and the fill that some roads are built on are more likely to fail than is undisturbed ground. Batter failures can cause road blockages for a relatively short time though fill failure can require substantial and lengthy repair works. Table 3.23 summarises the road exposure in each risk assessment zone.

In-ground infrastructure such as water supply and telecommunications cabling probably has an even greater level of exposure to landslide hazards than do buildings and roads given that it only requires a small amount of movement to cause damage. Optical fibre cable, for example, is especially vulnerable and 'stretching' by only a few millimetres can require the whole section of cable to be replaced. A fracture in a water main, especially the older and more brittle AC pipes, can exacerbate the slide by saturating the soil that is already unstable.

Table 3.23: Study area road segments exposed to three levels of landslide hazard potential

RISK ZONE	DEBRIS FLOW (km)	% DEBRIS FLOW	SLIDE HIGH (km)	% SLIDE HIGH	SLIDE MEDIUM (km)	% SLIDE MEDIUM
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	0.29	0.33	2.86	3.19	11.01	12.30
Industrial West	0	0	0	0	0	0
Institutions	0	0	5.52	3.27	4.48	2.65
Lakes	0	0	0	0	0.18	0.17
Lower Ross	0	0	0	0	0	0
Magnetic Island	0.02	0.03	7.20	12.25	2.19	3.72
National Parks	0	0	0	0	0	0
Pallarenda	0	0	0	0	0	0
Riverside	0	0	0	0	0	0
Strand-CBD	0.46	0.69	10.10	15.11	8.19	12.26
Upper Ross	0	0	0	0	2.34	0.45
Urban West	0.32	0.27	6.13	5.08	1.62	1.35
TOTALS	**1.10**	**0.70**	**31.80**	**2.03**	**30.01**	**1.91**

Table 3.24 summarises the number of water supply nodes (i.e. joints in the pipe network) that lie within the three landslide hazard zones. Given that the sewer pipes and telecommunications cables are usually within the same general location, the water supply nodes provide a good illustration of the potential exposure of these critical infrastructures to landslide movement.

Table 3.24: Study area water supply network nodes exposed to three levels of landslide hazard potential

RISK ZONE	DEBRIS FLOW	% DEBRIS FLOW	SLIDE HIGH	% SLIDE HIGH	SLIDE MEDIUM	% SLIDE MEDIUM
Cungulla	0	0	0	0	0	0
Highway	0	0	0	0	0	0
Industrial East	0	0	2	0.08	38	1.48
Industrial West	0	0	16	0.22	0	0
Institutions	0	0	10	0.05	79	0.41
Lakes	0	0	9	0.05	12	0.07
Lower Ross	0	0	0	0	0	0
Magnetic Island	0	0	78	1.85	34	0.81
National Parks	0	0	0	0	0	0
Pallarenda	0	0	0	0	0	0
Riverside	0	0	0	0	0	0
Strand-CBD	24	0.25	332	3.42	1046	10.79
Upper Ross	0	0	1	0.13	8	10.4
Urban West	10	0.06	36	0.21	140	0.83
TOTALS	**34**	**0.03**	**484**	**0.45**	**1357**	**1.26**

Critical and sensitive facilities that have a potential exposure to landslide hazards include:

- police station in Stuart;
- ambulance station in Nelly Bay;
- three schools, the TAFE and JCU buildings.

Council exposure: Council has a small level of exposure to landslide hazards, mainly through damage to roads and streets. It does have a potentially significant legal and financial exposure where a damaging landslide originates from land that is under Council's control.

3.18 EXPOSURE TO BUSHFIRE

Trinity Software (1999) produced a hazard analysis for bushfires across the study area. As discussed in Chapter 2 the methodology employed has produced a relatively conservative (and now dated) analysis with far larger areas of high and medium hazard included than would result from an analysis using the methodology now provided in SPP 1/03. Until such an analysis is conducted the mapping undertaken by Trinity Software is all that is available. The exposure analysis provided here will consequently produce statistics that are, in some instances, clearly higher than the level of exposure that actually exists.

On the data available the Institutions risk assessment zone would appear to have the greatest level of exposure with 1452 dwellings within the high hazard zone. This is clearly wrong given that all of these dwellings are located in an area of Douglas that was developed after 1999. The 'new' Townsville Hospital is also included in Trinity Software's high hazard zone in that area. A similar situation exists with the dwellings in high hazard zones in the Mount Louise area of Urban West where those 'exposed' to high hazard were constructed after 1999.

With those limitations in mind the exposure of dwellings to the bushfire hazard, as mapped by Trinity Software, are tallied in Table 3.25.

Table 3.25: Study area dwellings exposed to bushfire hazard potential

RISK ZONE	HIGH FIRE	% HIGH FIRE	MEDIUM FIRE	% MEDIUM FIRE
Cungulla	21	8.37	225	89.64
Highway	0	0	654	99.70
Industrial East	0	0	263	66.58
Industrial West	0	0	11	1.19
Institutions	1452	22.18	223	3.41
Lakes	0	0	0	0
Lower Ross	0	0	438	14.40
Magnetic Island	5	0.42	1155	97.14
National Parks	37	49.33	38	50.67
Pallarenda	4	1.22	325	98.78
Riverside	0	0	0	0
Strand-CBD	0	0	264	12.18
Upper Ross	26	6.81	354	92.67
Urban West	103	1.80	426	7.43
TOTALS	**1648**	**5.15**	**4376**	**13.68**

From the field work undertaken by IID and knowledge of the vegetation of the study area it is clear that the main bushfire threat is from grass fires. The extensive rains of the 2007-08 'wet season' have given rise to very significant growth of grass across the study area so the bushfire threat will remain high for the rest of 2008. The main areas that would appear to have the greatest exposure to grass fires are the outlier suburbs of Pallarenda and Cungulla. Magnetic Island settlements also have a significant exposure given the greater penetration of forest into the settled areas.

Given the problems with the hazard mapping identified above it is not appropriate to list the commercial buildings or the critical and sensitive facilities that may be exposed. The above-ground infrastructure, especially power supply, will have significant exposure given that power poles are mostly timber, power lines can be damaged by fallen vegetation and roads can be closed because of smoke.

Council's exposure: There may be a few Council assets that could be exposed to bushfire, however, they would probably be easy to protect. There would also be a legal and financial exposure should a fire originate on Council controlled land and cause damage to neighbouring properties.

Fire Suppression Resources: Bushfire risks can be modified by the response of fire suppression resources including QFRS urban and QFRS Rural Fire Service units. The study area is served by eight rural and one urban brigade. They are shown in Figure 3.36. The rural brigades are listed with their identification numbers in Table 3.26.

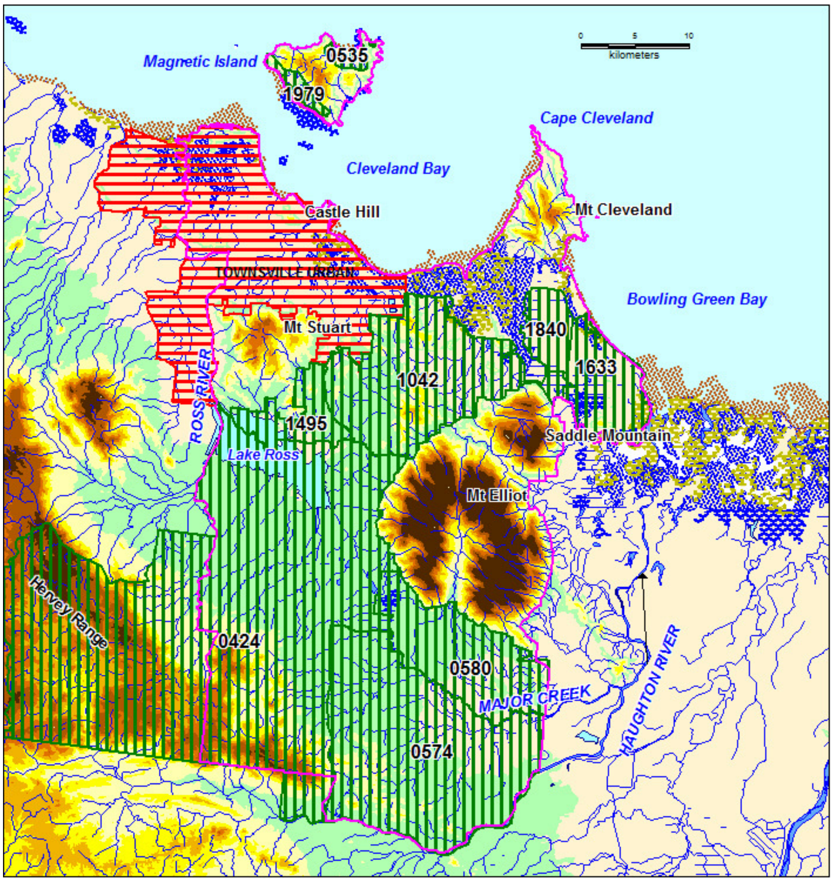

Figure 3.36: Study area QFRS urban stations and rural brigades

Table 3.26: Study area QFRS Rural brigades

ID	BRIGADE NAME
0424	Lime Hills Elliot Rural
0574	Reid River Rural
0580	Major Creek Rural
1042	Nome District Rural
1495	Oak Valley Rural
1633	Cungulla Rural
1840	Clevedon Rural
1979	West Point Rural

Urban brigades are funded from the urban fire levy collected for the State Government by Council along with the Council rates. The quantum of the levy is based on the nature of the property – high hazard properties such as chemical warehouses pay a higher levy than residential dwellings, for example. Staffing is by permanent and/or auxiliary fire fighters.

Rural brigades are funded in part by grants from the State Government (for capital equipment) and partly from the rural fire levy imposed and collected by Council. Staffing of rural brigades is by volunteers.

QPWS also maintains its own fire fighting resources to protect the National Parks within the study area and the Department of Defence is responsible for fire management within the Mount Stuart range area.

3.19 EXPOSURE TO EARTHQUAKE

Exposure to earthquake shaking is dependent on a wide range of factors including the magnitude and depth of the earthquake, its duration, the distance from the event epicentre and the depth and nature of the regolith on which the structure stands. Whilst no part of the study area is immune from earthquake shaking, it is not possible to differentiate exposure other than by the distribution of softer sediments and alluvial soils.

Some differentiation of the degree of potential exposure to earthquake across the risk assessment zones can be made by calculating the proportion of developed properties that are on the different Site Classes described in Chapter 2. These numbers and percentages of dwellings by Site Class are shown in Table 3.27 and the commercial and industrial premises by Site Class are given in Table 3.28.

Given that dwellings on Site Class E soils have a greater potential exposure to earthquake shaking the risk assessment zones that contain the greatest exposure are Strand-CBD, Pallarenda, Cungulla and Lower Ross.

Table 3.27: Study area dwellings located within four site classes

RISK ZONE	SITE CLASS B	% SITE CLASS B	SITE CLASS C	% SITE CLASS C	SITE CLASS D	%SITE CLASS D	SITE CLASS E	% SITE CLASS E
Cungulla	0	0	11	4.38	31	12.35	209	83.27
Highway	119	18.14	397	60.52	115	17.53	25	3.81
Industrial East	12	3.04	295	74.68	60	15.19	28	7.09
Industrial West	1	0.11	817	88.71	1	0.11	102	11.07
Institutions	137	2.09	1264	19.31	5146	78.60	0	0
Lakes	29	0.60	2455	50.52	2375	48.88	0	0
Lower Ross	0	0	847	27.85	1986	65.31	208	6.84
Magnetic Island	581	48.86	2	0.17	606	50.97	0	0
National Parks	5	6.67	0	0	20	26.67	50	66.67
Pallarenda	1	0.30	6	1.82	47	14.29	275	83.59
Riverside	0	0	2990	54.95	2451	45.05	0	0
Strand-CBD	744	34.32	126	5.81	744	34.32	554	25.55
Upper Ross	56	14.66	264	69.11	62	16.23	0	0
Urban West	199	3.47	4507	78.63	1026	17.90	0	0
TOTALS	**1884**	**5.89**	**13,981**	**43.71**	**14,670**	**45.86**	**1451**	**4.54**

Table 3.28: Study area commercial and industrial buildings located within four site classes

RISK ZONE	SITE CLASS B	% SITE CLASS B	SITE CLASS C	% SITE CLASS C	SITE CLASS D	%SITE CLASS D	SITE CLASS E	% SITE CLASS E
Cungulla	0	0	0	0	0	0	0	0
Highway	5	50.00	5	50.00	0	0	0	0
Industrial East	1	1.03	76	78.35	18	18.56	2	2.06
Industrial West	0	0	788	91.52	56	6.50	17	1.97
Institutions	1	2.70	13	35.14	23	62.16	0	0
Lakes	0	0	229	50.44	225	49.56	0	0
Lower Ross	0	0	142	44.24	125	38.94	54	16.82
Magnetic Island	26	37.68	0	0	43	62.32	0	0
National Parks	0	0	0	0	0	0	1	100.00
Pallarenda	0	0	0	0	0	0	0	0
Riverside	0	0	180	68.97	81	31.03	65	18.31
Strand-CBD	40	11.27	0	0	250	70.42	65	18.31
Upper Ross	3	50.00	2	33.33	1	16.67	0	0
Urban West	0	0	75	98.68	0	0	1	1.32
TOTALS	**76**	**2.98**	**1510**	**59.26**	**822**	**32.26**	**140**	**5.49**

In-ground infrastructure will also be exposed to earthquake shaking and those elements in the softer soils are more likely to be damaged than those in solid rock. There are 6575 water supply pipeline nodes within Site Class E soils and 47,344 nodes in Site Class D soils. Strand-CBD has the greatest number of nodes in the softest soils (Site Class E) followed by Lower Ross. Institutions risk assessment zone has by far the greatest number of nodes in Site Class D.

On a proportional basis, however, Pallarenda has 100% and Cungulla has 82.7% of their water supply nodes within the softer soils, while Institutions has 84.8% of its nodes in the Site Class D. The distribution of water supply network nodes by Site Class is detailed in Table 3.29.

Table 3.29: Study area water supply nodes located within four site classes

RISK ZONE	SITE CLASS B	% SITE CLASS B	SITE CLASS C	% SITE CLASS C	SITE CLASS D	%SITE CLASS D	SITE CLASS E	% SITE CLASS E
Cungulla	0	0	67	17.27	0	0	321	82.73
Highway	307	32.38	517	54.54	124	13.08	0	0
Industrial East	0	0	1623	63.20	701	27.30	244	6.50
Industrial West	52	0.71	6617	90.86	168	2.31	446	6.12
Institutions	355	1.84	2431	12.57	16,401	84.81	151	0.78
Lakes	387	2.30	8442	50.21	7954	47.31	31	0.18
Lower Ross	0	0	3043	27.24	7011	62.77	1116	9.99
Magnetic Island	2189	51.88	0	0	2030	48.12	0	0
National Parks	2	6.90	2	6.90	2	6.90	23	79.31
Pallarenda	0	0	0	0	0	0	746	100.00
Riverside	0	0	9444	55.94	7391	43.78	48	0.28
Strand-CBD	3134	32.32	242	2.50	2904	29.94	3418	35.24
Upper Ross	65	8.46	468	60.94	233	30.39	2	0.26
Urban West	312	1.85	14,081	83.58	2425	14.39	29	0.17
TOTALS	**6803**	**6.32**	**46,977**	**43.62**	**47,344**	**43.96**	**6575**	**6.10**

The police station in Belgian Gardens is located on Site Class E soils as are some of the facilities within RAAF Garbutt. Two service stations, one school and several aged care facilities are also located on Site Class E soils.

The exposure of people to earthquake is directly related to the vulnerability of the building in which they are located at the time of the event. As the engineering adage puts it *earthquakes don't kill people, poor buildings kill people*. Building vulnerability to earthquake shaking is discussed above.

Damage and loss of life associated with severe earthquakes are typically exacerbated by the impact of secondary hazards, especially fire, landslides, the loss of containment of hazardous materials and (rarely) dam failure. Fires are typically caused by ruptured gas lines and/or electrical short circuits. Where an earthquake is sufficiently severe to cause such damage it would also have caused damage to the water supply system and blocked some roads with fallen debris, thus making fires difficult to contain quickly.

Council's exposure: The most significant exposure of Council of earthquake damage is with the in-ground infrastructure of water supply and sewer. This exposure is greatest where the pipes are old and brittle. There may also be some exposure to other Council assets.

3.20 CONCLUSIONS

A detailed risk register, including an element-by-element risk assessment, for each hazard is contained in Appendix F.

4 ANALYSING THE RISKS

If you cannot measure it you cannot improve it.
William Thomson (Lord Kelvin)

4.1 BACKGROUND

In this Chapter the risks are measured (where possible), analysed and assessed by drawing together the information on the hazard phenomena, the elements in the community exposed to those hazards and the vulnerability of those elements to such an exposure[13].

AS/NZS 4360:2004 suggests that a level of risk is best determined by combining the 'likelihood' of an event happening with the 'consequences' of its outcome. This approach certainly satisfies most of the applications to which this generic standard is applied such as workplace safety, financial management and business management. In such applications the 'hazard' is typically a singular event that either happens or it does not happen. For natural hazards, by contrast, there is a statistical relationship between the frequency (i.e. likelihood) of an event happening and its severity or magnitude. For all intents and purposes the two terms may be viewed as being synonymous.

The likelihood/consequence (or frequency/severity) relationship can be used for analysing natural hazards, but only where one of the two dimensions is held constant, i.e. where an event of only a single likelihood is used, or a specific level of consequence is used. Such an approach is especially appropriate where the objective is to compare the risks posed by a range of hazards – as is the case in this study.

To provide a consistency of analysis across all six hazards, this study has adopted an event likelihood in the 50 to 100 year average recurrence interval (ARI) range (i.e. an event that might occur only once in a lifetime) against which to assess the current level of risk posed and to provide a benchmark against which to the develop risk reduction strategies. This threshold has been selected because it represents the 'design' level for inundation hazards (floods and storm tide) within the study area (see section 1.8).

In this study the term likelihood' has been preferred by the SAG. The definitions of likelihood and consequences employed are given in Tables 4.1 and 4.2 respectively.

[13] The analysis is undertaken at the risk assessment zone level and is based on indexes derived from percentages. Given the small amount of development (buildings and roads) within the National Parks risk assessment zone it will be excluded from the analysis.

Table 4.1: Definitions of frequency used in this study

DESCRIPTOR	DESCRIPTION	FREQUENCY
Almost certain	will happen numerous times during a person's lifetime	ARI up to 5 years
Likely	likely to happen up to three times in a lifetime (once in a generation)	ARI in the range 15 to 25 years
Possibly	likely to happen only once in a lifetime	ARI in the range 50 to 100 years
Unlikely	known to have happened only once in the recorded history of Australia and similar regions	ARI in the range 200 to 500 years
Rare	some evidence that such an event may have happened in pre-European times or deemed to be theoretically possible	ARI in excess of 1000 years

Table 4.2: Definitions of consequences used in this study

DESCRIPTOR	PEOPLE	PROPERTY, ENVIRONMENT, ECONOMY
Insignificant	No injuries or fatalities*; **and** Few if any people are displaced** and then only for short duration; **and** Little or no personal support required (support not monetary or material).	Inconsequential or no damage; **and** Little or no disruption to community; **and** No measurable impact on environment; **and** Little or no financial loss.
Minor	Small number of injuries but no fatalities*. First aid treatment required; **or** Some displacement** of people within the community (less than 24 hrs); **or** Some personal support required.	Some damage that is easily repaired with some disruptions (less than 24 hours); **or** Small impact on the environment but with no lasting effects; **or** Some financial loss.
Moderate	A small number of fatalities* possible, medical treatment required with some hospitalisations; **or** Localised displacement** of people within the community who return within 48 hours; **and** Personal support satisfied through local arrangements.	Localised damage that is rectified by routine arrangements. Normal community functioning with some inconvenience; **or** Some impact on the environment with no long-term effect or small impact on environment with long-term effect; **or** Significant financial loss leading to a small number of business failures and unemployment.
Major	Fatalities; **and/or** Extensive injuries, significant numbers hospitalised; **or** Large numbers of people displaced** within the community for up to a week; **and** External resources required for personal support.	Significant damage that is beyond the capacity of local resources and community only partially functioning; some services unavailable for a t least a week; **or** Some impact on environment with long-term effects including localised habitat destruction and possible extinctions; **or** Significant financial loss – some financial assistance required. Many business failures and much unemployment.
Catastrophic	Significant fatalities; **and/or** Large numbers of severe injuries and large numbers requiring hospitalisation for an extended period; **or** General and widespread displacement** of people to locations outside the community for an extended period.	Extensive damage requiring lengthy restoration; **or** Major impact on environment and/or permanent damage including local species extinctions; **or** Long term serious damage done to the local economy including business closures and extensive unemployment. Community unable to function without significant and lengthy external welfare support.

* does not include avoidable fatalities such as people who disregard warnings and place themselves in flood waters or other dangerous situations.
** displacement is taken to mean that people are not able to return to their normal place of residence until that place is made habitable.

Table 4.3 provides the likelihood/consequence relationships that produce a given level of risk employed in this study. The relationships adopted here were the result of significant discussion and debate within the SAG. Three models were considered: that suggested in Zamecka and Buchanan (1999) which is based on the 1995 and 1999 editions of AS/NZS 4360 – this model place a much greater weight on likelihood than on consequences; that suggested in AGO (2006) which provides a consistently even weight between the two ingredients of risk; and the relationships proposed originally by IID which placed a greater weight on consequences.

Table 4.3: Risk rating from levels of frequency and consequence used in this study (after AGO, 2002)

FREQUENCY	**CONSEQUENCES**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possibly	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

Whilst this approach provides a basic analysis of risk it does not take account of the wider range of issues, such as the range of hazard events other than that used as the 'design' event, that can be significant to the analysis of the risks posed by such complex phenomena as natural hazards.

In response to this limitation, the New Zealand Civil Defence Emergency Management Groups (CDEMG), for example, have adopted the 'SMUG' approach (seriousness, manageability, urgency and growth) specifically to provide:

> *a mechanism for a more detailed risk analysis process than a simple likelihood and consequence assessment as described in the Australian and New Zealand Risk Management Standard* (Cunningham, 2006).

The 'SMUG' approach is based on the SMAUG management model (the 'A' being 'acceptance') developed by US business management 'gurus' Kepner and Tregoe (1981). The 'acceptance' dimension is similar to the 'outrage' factor advocated by US academic and risk communicator Peter Sandman (www.psandman.com) to take account of the political dimension of emergencies, disasters and risk. Awareness of the risks posed – especially by the community – is yet another dimension of significance.

The seven dimensions of risk used by IID to provide a comprehensive analysis of risk in this analysis can be described as follows:

- **Frequency** – events that occur frequently are scored more highly than those that rarely occur;
- **Seriousness** – (essentially the same as 'consequences') events that have the potential for causing significant numbers of casualties and/or significant economic loss are scored more highly than those that produce few casualties or little loss;
- **Manageability** – those hazards that are difficult to control or manage by existing techniques, resources and warning systems are scored more highly than those that are more easy to manage;
- **Awareness** – hazards for which community understanding and awareness before the event have not led to active steps taken to reduce those risks are scored more highly than those for which risk reduction efforts have already been made. There are elements of voluntary versus involuntary risks in this assessment as well;

- **Urgency** – hazards that need to be addressed with some urgency because of a lack of preparedness, for example, are scored more highly than those that do not demand the implementation of risk reduction action so rapidly;
- **Growth** – hazards for which the risk is likely to grow either because the hazard could become more frequent or severe; or there is likely to be an increase in the number of community elements exposed; or there will be an increase in the vulnerability of those elements are scored more highly than those hazards that pose a more constant level of risk
- **Outrage** –the political dimension of risk is important because after the impact of an emergency, community outrage at what is perceived to have been a lack of preparedness or an inadequate response can generate unrealistic and unreasonable political demands rather than addressing the reality of community safety needs. Such hazards are scored more highly than those that tend to be seen as either voluntary risks or as being 'acts of God'.

To provide a consistent and systematic assessment of the risks which serves as a guide to what risk reduction strategies need to be considered, the 'five Rs' approach suggested in the COAG review of national bushfire risks (Ellis, Kanowski and Whelan, 2004) is followed. That approach is seen as an advance on the familiar PPRR approach that has been in use by emergency services in Australia since 1984.

The COAG report states:

> *A structured risk management process, consistent with the Australian Risk Management Standard, offers the best framework for making strategic and operational decisions about bushfire mitigation and management. Emergency management in Australia has adopted one form of this framework; its elements are Prevention, Preparedness, Response and Recovery, or PPRR.*
>
> *The Inquiry further developed and adapted the PPRR framework to a 5Rs framework—**R**esearch, information and analysis; **R**isk modification; **R**eadiness; **R**esponse; and **R**ecovery—which is a better basis for understanding the integrated elements of bushfire mitigation and management.*
>
> *Application of the 5Rs framework should be informed by a thorough understanding of the full range of assets that are threatened by bushfire—life and property, infrastructure and production systems, and environmental values.*

Like PPRR, this approach can be followed for any hazard.

4.2 TROPICAL CYCLONES AND SEVERE THUNDERSTORM RISKS

4.2.1 Severe Storm Risk Overview

The risks posed by destructive winds are summarised in the Table 4.4.

The benchmark likelihood for which the risks posed by each hazard are to be assessed is the 'once-in-a-lifetime' (possibly) event. That gives destructive wind from either tropical cyclones or severe thunderstorms a comparative risk rating of HIGH.

Table 4.4: Severe wind risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Almost certain	**Insignificant**: Low levels of wind damage reached in small areas – up to a few tens of buildings with minor damage. Roads and power supply may be affected for a short time by fallen trees.	**Medium**
Likely	**Minor**: Moderate levels of wind damage reached in small areas. Some older buildings may have major roof damage and up to 100 buildings with some damage. Roads, power supply and telecommunications infrastructure may be affected for a few hours by fallen trees or blown debris. Injuries likely.	**Medium**
Possibly	**Major**: Significant levels of wind damage reached in extended areas. Some buildings likely to lose roofs or suffer serious debris damage, with a few tens of buildings possibly destroyed and more than 100 severely damaged. Roads, power supply and telecommunications infrastructure will be affected for more than a day by fallen trees and blown debris. Widespread crop losses. Serious economic impact. Numerous injuries likely and loss of life possible.	**High**
Unlikely	**Catastrophic**: Severe wind damage over extensive areas. Many tens of buildings destroyed and several hundred more severely damaged. Roads, telecommunications and power supply infrastructure will be affected for up to a week by fallen trees and blown debris. Widespread crop losses. Major economic losses and long-term impact. Many injuries and loss of life likely.	**Medium**

The widest exposure to all of the hazards considered in this study is to the severe winds brought by both tropical cyclones and severe thunderstorms. Whilst no area of the study area is immune from the impact of destructive winds, there are some areas that have an elevated level of exposure. In addition to destructive winds, severe thunderstorms also bring hail and lightning. Any given thunderstorm, however, produces a relatively small footprint. Given their much greater extent, rural areas are more likely to suffer the impact of severe winds than is the urban area. When a severe storm does hit an urban centre, however, damage and economic losses can be considerable, with injury and even fatalities a possibility.

The lack of detailed information at the individual building level available to this study, especially construction data, does not permit a detailed assessment of wind risk. Given that all buildings and above-ground infrastructure are potentially exposed to damaging winds, some differentiation is possible, at least at the risk assessment zone level, using exposure statistics for residential and other buildings in areas of heightened exposure to potentially destructive winds. The general age of the built environment, as discussed in Chapter 3, is used as an indicator of structural vulnerability. The measures included and the weights applied are as follows:

• Percent residential buildings within heightened exposure zone	3
• Percent of construction before 1982	2
• Community vulnerability	1
Maximum score	**6**

The distribution is shown in Figure 4.1 and the statistics in Table 4.5. The model indicates that the highest relative risk is in the National Parks and Upper Ross risk assessment zones because of the lower urban density and the more exposed topography. Of the more urbanised zones Magnetic Island has the highest risk largely because of its higher proportion of buildings within 1 km of the coast.

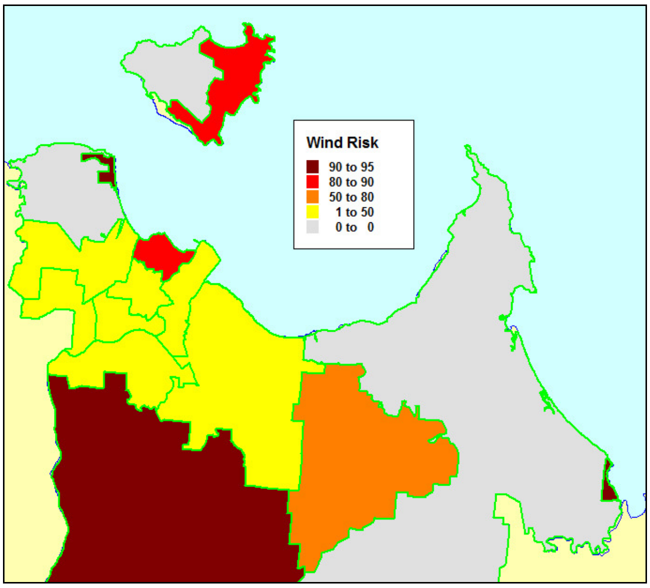

Figure 4.1: Study area relative risk of severe wind damage by risk assessment zone

Table 4.5: Study area wind risk index by risk assessment zone (% of possible score of 6)

RISK ZONE	WIND RISK
Cungulla	92.70
Highway	77.57
Industrial East	36.88
Industrial West	48.50
Institutions	26.36
Lakes	43.45
Lower Ross	44.90
Magnetic Island	82.23
National Parks	0
Pallarenda	94.23
Riverside	45.88
Strand-CBD	84.08
Upper Ross	90.20
Urban West	37.50

4.2.2 Secondary Hazards

The damage done by severe winds will produce very large volumes of debris including material such as fibro (AC sheeting and roofing material) and asbestos insulation that will require special management. In a very widespread event, with a large number of damaged properties, it may be necessary to adopt strategies such as damping down piles of debris to limit wind-blown spread of asbestos fibres until the hazardous materials can be safely collected and disposed of. The impact on Council's landfill resources could be significant.

The disruption of power supply for an extended period, with the knock-on failure of water supply and sewerage systems, would pose a public health risk. An extended power outage would pose an immediate risk to people on home dialysis, ventilators or defibrillators. The commercial impact of an extended loss of power supply would also be significant, for example the loss of refrigeration in supermarkets would generate a massive volume of putrescible waste – again the impact on Council's landfill capacity would be significant.

In areas of remnant natural vegetation the impact of a severe storm can dramatically increase the accumulation of bushfire fuels by bringing down leaf matter, branches and small trees to accumulate and dry out after the storm has passed. Similarly, in more urbanised areas remnant trees can pose a very significant secondary hazard where they can be brought down onto houses, cars and so on. The management of vegetation to reduce that form of risk tends to run into conflict with 'vegetation protection' regulations.

Damage by wind or wind-blown debris of sensitive elements of the telecommunications infrastructure could dislocate telephone and data services for some time. Restoration of services would depend on how widespread the damage and the availability of technicians and spares to carry out the necessary repairs. The social and economic dislocation that this would cause could become significant if services took more than 24 hours to restore.

4.2.3 Climate Change Implications

The climate change impact assessments published by CSIRO (Walsh and others, 2002) suggest a small increase in the frequency and severity of storms with damaging winds and that tropical cyclone wind velocities may increase by 5 to 10% by 2050.

4.2.4 Analysis

Frequency and Seriousness: Severe storms pose a potentially serious and relatively frequent threat to the study area's community. Coastal areas and locations along the developed hill slopes are most at risk from damaging winds.

Manageability: The threat is able to be managed to some degree by the application of appropriate building construction and maintenance standards. The large proportion of pre-code residential buildings, however, is a concern. Warning times are usually adequate for people to take shelter and to put movable assets, such as cars, under cover.

Awareness: The awareness of severe storms is generally widespread though the area has not experienced a severe tropical cyclone event for some years.

Urgency: Current arrangements and strategies are generally adequate for the management of storm risks, however, the absence of 'direct hits' by severe storms on the study area for some time may have created an element of complacency amongst both the general community and emergency managers.

Growth: The risks posed by severe storms will continue to grow, especially if retrofit of older buildings is not undertaken. Climate change may also slightly increase the incidence and severity of tropical cyclones and severe storm impacts.

Outrage: Considerable outrage will be experienced if warnings have been inadequate or the response by the SES and others is perceived to be too slow and/or inadequate. The media can play a significant role in influencing public opinion as to the adequacy of the response is it did in the 1999 Sydney hail storm.

4.2.5 Assessment

Research, information and analysis: A more detailed analysis of building attributes and building age than that provided by CTS and SEA (2003) would help improve the vulnerability content of the risk analysis. The addition of an analysis of commercial buildings and industrial facilities, as well as above-ground infrastructure elements (such as power transmission lines) would also enhance the risk assessment. The provision of a zonation map based on the Building Code of Australia (BCA) wind loading standard published as part of the TCC planning scheme would improve the community's understanding of wind damage risks and the need for appropriate construction and maintenance standards.

Risk modification: Appropriate application of the BCA wind loading code to new buildings is the most effective way to minimise any increase of severe storm losses in new buildings. Wider encouragement of building owners to apply the guidelines for the retrofit of older buildings to bring them closer to modern standards of resilience (Standards Australia & ICA, 1999a) would also reduce building vulnerability, especially where extensions or major renovations are to be undertaken.

Readiness: Emergency management of severe storm impacts is addressed in the Local Disaster Management Plan. The SES is the principal agency for severe storm response. Where building collapse is a consequence of severe storm impact the QFRS may assume responsibility for urban search and rescue operations. Police are responsible for most other storm-associated actions such as traffic control and property protection.

The BoM operates a very efficient and effective storm warning network. For tropical cyclones, warning times of several days are typically provided. Warnings for severe thunderstorms typically provide several hours notice, whilst an alert to the possibility of synoptic storm-producing conditions may be made up to 24 and even 48 hours in advance. Rapidly developing storm cells and microburst conditions, however, may impact without warning.

The use of the Standard Emergency Warning Signal (SEWS) to precede public messages warning of imminent severe storm impact is well known in those areas of the State that are subject to tropical cyclone impacts. The community's knowledge of its meaning or significance is generally well established in Townsville. There may be situations involving more localised storms in which the use of SEWS would also be appropriate, especially after a storm impact, to highlight warnings of secondary hazards such as downed power lines.

Response: Where the length of warning is adequate, consideration should be given to the relocation people living in housing that is vulnerable to wind damage such as caravans and temporary dwelling to more suitable places of shelter (DES & DPW, 2008). Unless there is compelling reasons to do so, all other people should be encouraged to shelter in their own homes, even if those dwellings were constructed before 1982. Should precautionary evacuation of people to 'safe haven' conditions before the impact of a storm be considered, the evacuation centres selected should be clearly immune to wind or debris impact.

Emergency managers should be aware of the significant risk of serious injury posed to emergency workers operating in the open when wind gusts of 75 km/h or more are likely to be experienced. All outside operations should be suspended and workers ordered into shelter when such conditions begin to be experienced. Under no circumstances should operations such as roof tarping continue under such conditions.

It is critical that the community be kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. It is important that the media be kept fully engaged in this process so that they provide positive support rather than become a source of ill-informed criticism of response activities.

Medical services should be prepared for a large number of injuries including potentially severe trauma cases caused by the impact of high velocity wind-blown debris.

Recovery: The operation of evacuation centres after a storm impact (perhaps better termed 'welfare centres') and/or the provision of relief housing may be required for extended periods. After the impact of very large or very severe storms the restoration of large numbers of damaged homes would be likely to take more than twelve months and some people may need to be relocated to centres outside Townsville.

Most comprehensive insurance policies provide cover for storm and tempest damage. Owners of damaged properties that are uninsured or underinsured may have to rely on public generosity through an organised appeal. The administration of any appeal needs to be well managed and coordinated and conform to the relevant Commonwealth guidelines. The demand for repair services for buildings and cars is likely to produce significant delays in work being undertaken.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of the risks posed by severe storms by improving the understanding of both the nature of the hazard itself, exposure of buildings in different situations (coastal versus suburban versus bush fringe) and the factors that influence building vulnerability. This should be undertaken as an integral part of the repair and reconstruction process and should be coordinated by the LDMG. The local studies section of the Townsville City Library should also be encouraged to collect and store all print and electronic media reporting of the event.

Following the more severe storms it is likely that there will be considerable interest expressed by academics, the insurance industry and public research agencies (such as the BoM, Geoscience Australia, CSIRO and the Cyclone Structural Testing Station) in studying the impact. It is important that this research activity be coordinated and that the resulting outcomes be made available to Council, the LDMG and the Townsville community.

4.3 FLOOD RISKS

4.3.1 Flood Risk Overview

The risks posed by river floods are summarised in the Table 4.6.

The 'design' flood level for the study area falls into the possibly likelihood, so the level of risk posed by flood can be classed as being MEDIUM.

The risk posed by a catastrophic failure of the Ross River Dam, whilst extremely unlikely (rare likelihood), must be classed as also posing a MEDIUM level of risk even if though the consequences of such an event would be catastrophic.

Table 4.6: Flood risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Almost certain	**Insignificant**: Nuisance flood levels reached in smaller urban catchments. Some minor roads cut and a few tens of properties isolated for hours. Minimal risk to urban communities.	**Medium**
Likely	**Minor**: Moderate flood levels reached in most urban catchments. Some roads cut for a few hours. Few if any urban properties with above-floor inundation but several hundred properties with water in the yard.	**Medium**
Possibly	**Moderate**: Major flood levels reached in all urban catchments and the Ross River. Up to 140 km of roads inundated, some cut for up to 24 hours and damaged. Power cuts certain and damage to infrastructure likely. Some evacuations likely. Up to 150 low-lying dwellings and 20 other buildings likely to be flooded over floor level. Loss of life possible but unlikely.	**Medium**
Unlikely	**Major**: Widespread road and infrastructure damage. Urban communities isolated for several days with virtually the entire population of the study area directly or indirectly affected. Evacuations will be required. Major economic losses. Loss of life likely.	**Medium**
Rare	**Catastrophic**: Floods approaching PMF or a catastrophic dam failure. Many hundred dwellings with over-floor flooding. Extensive and long-lasting economic harm. Fatalities certain. Large scale and long-term evacuations will be required.	**Medium**

Floods are clearly amongst the most potentially damaging of the single-event hazards encountered in the study area. Fortunately, the more frequently occurring levels of flood produce inconvenience rather than disaster. The inconveniences and losses brought by flooding are, to a large extent, offset in many rural areas by their replenishment of soil moisture and surface water.

Floods approaching PMF levels and/or a dambreak flood would be devastating and potentially lead to significant loss of life and extensive property loss. Such floods could, in fact, change the riverine landscape.

The relative risk model used for flood employs the following weights and is explained in Appendix H:

- Percent residential buildings in the 100 year ARI zone 3
- Percent commercial/industrial buildings in the 100 year ARI zone 2
- Percent roads in the 100 year ARI zone 1
- Percent of construction post 1982 3
- Community vulnerability 1

Maximum score 10

The risk assessment zones that represent the greatest relative risk are those in the lower reaches of the Ross and Bohle Rivers and the creeks of Magnetic Island. The Riverside, Lakes and Urban West risk assessment zones have the greatest level of flood risk. The spatial distribution of risk by hazard precinct is shown in Figure 4.2 and the risk index statistics in Table 4.7.

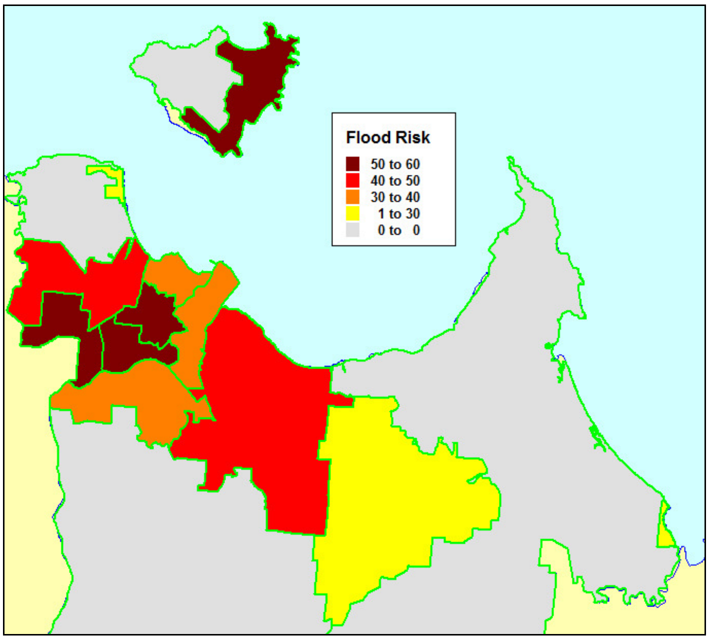

Figure 4.2: Study area relative flood risk by risk assessment zones

Table 4.7: Study area flood risk index by risk assessment zone (% of possible score of 10)

RISK ZONE	FLOOD RISK
Cungulla	5.14
Highway	16.35
Industrial East	45.26
Industrial West	40.54
Institutions	39.90
Lakes	59.06
Lower Ross	38.04
Magnetic Island	50.22
National Parks	0
Pallarenda	23.01
Riverside	59.79
Strand-CBD	33.18
Upper Ross	No data
Urban West	50.87

Note: The lack of flood modelling for the Houghton River catchment and the streams within the National Parks risk assessment zone means that the flood risk index for those areas is significantly understated, especially the risks to roads.

4.3.2 Secondary Hazards

The most significant secondary risks are probably to the environment, with contaminants such as oil being flushed off roads and driveways or carried away in drums, containers etc. Should businesses such as pool supply shops, hardware stores and plant nurseries be inundated, the probability of the various chemicals they normally have on-site, such as chlorine, acids, pesticides, herbicides and fertilizers, contaminating the flood waters would be very high.

Inundation of sewage treatment works or a break-down of the sewerage pumping system could lead to contamination of the flood waters by faecal material. Such contamination could pose a public health risk for some time after the flood waters recede.

In severe floods it is likely that the power supply will be disconnected in areas where elements such as substations, pad-mounted transformers and overhead cables are likely to come in contact with the flood waters. There could also be localised economic impacts, including the bankrupting of firms and consequent losses of employment.

Inundation of sensitive elements of the telecommunications infrastructure could dislocate telephone and data services for some time. Restoration of services would depend on how widely the flooding was experienced and the availability of technicians to carry out the necessary repairs. The social and economic dislocation that this would cause could become significant if services took more than 24 hours to restore as would be very likely.

4.3.3 Climate Change Implications

The climate change impact assessments published by CSIRO (Walsh and others, 2002) suggest a significant increase in the frequency and duration of intense rainfall episodes giving rise to a likely increase in the frequency and severity of flash flooding and storm water surcharge in study area.

Any increase of sea level will also have an influence on flood levels given that it raises the 'base' level. An increase of sea level by the 20 cm predicted to occur by 2040 under climate change scenarios would produce some increase in the flood level for any flood, though that influence would probably be undetectable in the upper reaches.

4.3.4 Analysis

Frequency and Seriousness: It is clear that large numbers of developed properties, both residential and commercial, lie within the 50 year ARI and 100 year ARI zones, thus indicating a level of risk that is potentially serious. For events of lower frequency risk levels can reach catastrophic levels. Modelling undertaken by TCC for the same flood scenarios using building data that included the estimated floor height indicates that of those properties not more than 150 dwellings would have over-floor flooding for a 50 year ARI event and perhaps 200 having above-floor flooding for a 100 year ARI event.

Manageability: The threat of flooding is difficult to manage because substantial development has been permitted in flood-prone areas. An ALERT flood warning network has been established on the Ross and Bohle Rivers. There are also flood gauges on the Houghton River to provide warnings to communities on the lower Houghton (outside Townsville City). The recent upgrade of the Ross River Dam to reduce its apparent failure potential during severe floods has also greatly improved the capacity for operators to control flood flows downstream.

Awareness: The experience of flash flooding episodes in Townsville over the past decade ensures that most people living in low lying areas are well aware of the risk. Lifestyle and other issues tend to outweigh the infrequent inconvenience or danger of inundation. There have been very few structural mitigation measures other than some houses in flood-prone areas being high set or built on raised pads to minimise flood damage or the engineering of newer subdivisions to have ground level at a specified level above the design flood. There are, however, a few tangible reminders of the flood threat such as historic flood height markers. There are flood depth markers along flood-prone road segments and at least one automatic illuminated flood warning sign on a road in suburban Annandale.

Urgency: Current response arrangements and strategies are generally appropriate for the management of flood risks although some improvements can be envisaged. In addition the absence of major flood events for some time in the Ross River may have created an element of complacency amongst both the general community and emergency managers.

Growth: The risks posed by floods are unlikely to grow significantly unless further development on flood-prone land is allowed. Climate change may increase the incidence and severity of flash floods and sea level rise would potentially exacerbate their impacts to a limited degree.

Outrage: Flooding itself, unlike the heavy rain that causes it, tends not to be seen as an 'act of God', and consequently people affected will seek to blame public authorities for their losses. Much of this outrage may be irrational, but in times of emergency rational thought is generally a scarce commodity. The outrage is likely to be exacerbated by the fact that most affected properties will not have insurance that includes flood cover. Even the provision of material aimed at informing the public about flood risks can be greeted with outrage. The publication of 'flood maps', for example, is likely to generate outrage where people perceive (generally without justification) that such information can have a negative impact on their property values. Any flood education that is carried out needs to be conducted with sensitivity.

4.3.5 Assessment

Research, information and analysis: The flood hazard studies that are currently available are based on industry-standard modelling techniques and tools and were underpinned by high resolution digital elevation models (DEM) with a vertical accuracy of 0.2 m or better. The data on buildings that are currently available, however, are not adequate. There are no comprehensive data on the height of floor levels above ground level, for example, that are necessary to enable accurate loss modelling to be undertaken. The stage damage curves employed to produce loss estimates should also be updated and enhanced based on the experience of floods in Townsville since 1998.

The recent upgrade of the Ross River Dam has significantly altered its capacity to control floods and has reduced its potential to fail. The impact of these changes is yet to be modelled.

There is also a need to undertake flood hazard modelling on the Houghton River catchment within the study area and some of the minor catchments flowing from Mt Elliot and along Cape Cleveland and to establish a rolling program of review and update of flood risk modelling as further areas are identified for urban or industrial development.

Risk modification: A $15 million flood mitigation capital works program based on the flood study recommendations has established a rolling program of upgrades to the storm water network. The $115 million upgrade of the Ross River Dam to reduce its risk of failure and improve its flood control capability has also been completed.

Readiness: The experience of flash floods in 1998 and subsequently has produced a good level of community awareness. The ALERT flood warning network established on the Ross and Bohle Rivers is adequate.

Response: Flood response plans are included in the Local Disaster Management Plan, but evacuation planning and community education activities need to be developed further, especially to cope with low frequency events. The 100 year ARI flood zone has been adopted as the defined flood event for the Townsville City Plan, though large parts of the study area were developed when the design level was the 50 year ARI event.

Recovery: The operation of welfare centres after a flood impact and/or the provision of relief housing may be required for some time after severe floods. In such events a few houses may be destroyed, and restoration of internal damage and renovation is likely to be required even in the aftermath of less severe floods.

In areas where the majority of properties at risk are businesses on which many people rely for both employment and the provision of services, a rapid recovery is essential. Specific business recovery plans may need to be developed for such high risk areas.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of flood behaviour and building and infrastructure vulnerability. This should be undertaken as an integral part of the clean-up and repair process and should be coordinated by the LDMG. The local studies section of the Townsville City Library might also be encouraged to collect and store all print and electronic media reporting of future flood events.

Following the more severe floods it is likely that there will be considerable interest expressed by academics, the insurance industry and public research agencies (such as the BoM, Geoscience Australia and CSIRO) in studying the impact. It is important that this research activity be coordinated and that the resulting outcomes be made available to Council, the LDMG and the community.

Few domestic comprehensive insurance policies provide cover for flood damage, though 'flash flooding' and stormwater surcharge may be interpreted as storm and tempest damage under some circumstances.

4.4 STORM TIDE RISKS

4.4.1 Storm Tide Risk Overview

The risks posed by storm tide are summarised in Table 4.8.

The 'design' level event is in the once-in-a-lifetime (possibly) category consequently the risk of storm tide is classed as being MEDIUM.

Table 4.8: Storm tide risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Almost certain	**Nil:** No damage likely.	**No risk**
Likely	**Insignificant:** Environmental impact only. Foreshore erosion likely.	**Low**
Possibly	**Minor**: Serious foreshore erosion likely. Inundation of fewer than 20 dwellings likely. Almost 20 km of roads will be affected for up to six hours. Few if any casualties.	**Medium**
Unlikely	**Major**: Major foreshore erosion certain. Up to 200 dwellings with some level of inundation. Prior evacuations warranted. Up to 40 km of roads likely to be affected by inundation for up to six hours.	**Medium**
Rare	**Major to Catastrophic**: Widespread and serious foreshore erosion. Around two thousand dwellings with significant inundation. Mass evacuations ahead of the cyclone mandatory to reduce the risk of fatalities.	**Medium**

Storm tide is a threat only in low-lying coastal areas and then only posed by very intense tropical cyclones. For the most part, storm tide including wave setup, will only cause environmental damage along the coastline for the more frequently experienced events. Intrusion into developed areas, however, may occur with events with severity that would be experienced with an ARI of between 50 and 100 years.

The model used to reflect relative storm tide risk (detailed in Appendix H) across the risk assessment zones uses the following weights:

- Percent residential buildings in the 100 year ARI storm tide zone 3
- Percent of roads in the 100 year ARI storm tide zone 1
- Percent of construction post 1982 3
- Community vulnerability 1

Maximum score 8

Where there are no buildings exposed, the risk rating is zero.

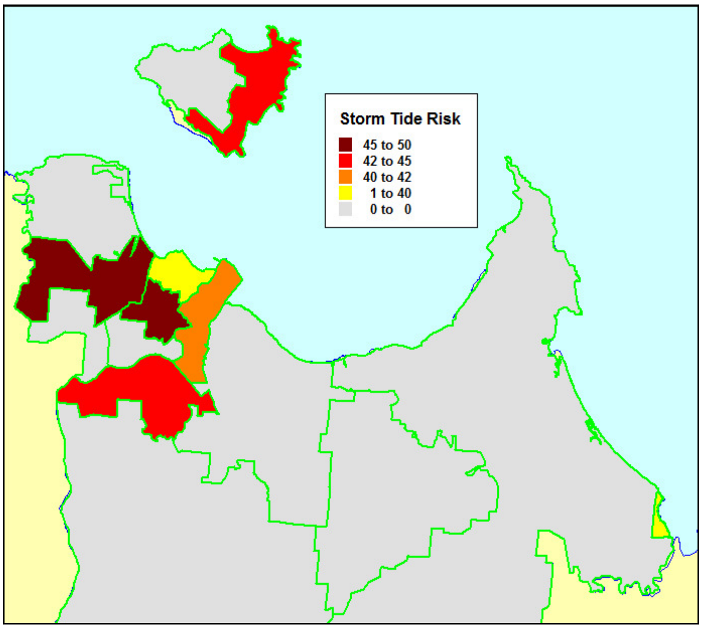

Figure 4.3: Study area relative storm tide risk by risk assessment zones

Table 4.9: Study area storm tide risk index by risk assessment zone (% of possible score of 8)

RISK ZONE	STORM TIDE RISK
Cungulla	6.43
Highway	0
Industrial East	0
Industrial West	45.79
Institutions	44.93
Lakes	48.83
Lower Ross	40.71
Magnetic Island	44.20
National Parks	0
Pallarenda	0
Riverside	0
Strand-CBD	35.28
Upper Ross	0
Urban West	0

Lakes risk assessment zone is clearly the zone with the greatest level of storm tide risk. Interestingly, Strand-CBD has amongst the lowest of all of the risk indexes. Pallarenda has zero risk on this analysis because there are no buildings within the zone that lie within the 100 year ARI storm tide inundation area.

4.4.2 Secondary Hazards

The secondary hazards posed by storm tide inundation will be similar to those posed by riverine and flash flood.

4.4.3 Climate Change Implications

Climate change forecasts suggest a possible small increase in the frequency and intensity of tropical cyclones capable of generating storm tide and causing significant coastal erosion and inundation of low-lying coastal areas. The uncertainties in this prediction are, however, large. Changes in sea level will also increase the potential for storm tide inundation and coastal erosion.

4.4.4 Analysis

Frequency and Seriousness: Storm tide poses a significant threat to the low-lying coastal areas of the study area in events with an ARI as low as 50 years. The very rare events (e.g. ARI of 10,000) years would have a catastrophic impact across much of the urban area.

Manageability: Given the significant number of properties potentially at risk, the development of mitigation works makes storm tide a largely unmanageable hazard. Warning times are likely to be long enough for significant reduction of the exposure of people. TCC has adopted the 100 year ARI as the defined storm tide event under the Townsville City Plan so future development in storm tide risk areas should not take place.

Awareness: There appears to be a general lack of awareness of the storm tide risk. To people along the coastline from Pallarenda to Cungulla and on Magnetic Island, the relatively low probability of storm tide impact is typically outweighed (if it is in fact appreciated) by their desire to have a 'waterfront' lifestyle, i.e. it is a voluntary risk.

Urgency: The absence of a major storm tide impact in the study area for more than 30 years is likely to have created an element of complacency amongst both the general community. The threat is, however, well understood by emergency managers.

Growth: The risk posed by storm tide is unlikely to grow unless further development on storm tide-prone land is allowed. Climate change may increase the incidence tropical cyclones capable of producing storm tides and sea level rise would undoubtedly exacerbate their impacts.

Outrage: The large number of properties likely to be impacted by storm tide will tend to create a high level of outrage, even though the hazard itself is readily seen as an 'act of God'.

4.4.5 Assessment

Research, information and analysis: The probabilistic storm tide and wave set-up model for Townsville City (GHD and SEA, 2007) employs industry standard modelling techniques, but there is considerable scope to upgrade the modelling of over-land inundation. The use of a seamless model that takes the surge/tide/wave setup component inland across the terrain and influenced by 'frictional' effects of vegetation and buildings should be employed where there is adequate data. The DEM employed in the study area is of an adequate resolution, but details on building characteristics, especially the height of the floor above ground level, are lacking. This makes it impossible to undertake any form of impact cost analysis.

Risk modification: Townsville City Council has adopted the 100 year ARI storm tide level as the defined event under the State Coastal Management Plan. Unfortunately, the development that has already taken place in the low-lying coastal zone tends to negate that planning process. Consideration should be given to establishing a higher design threshold (e.g. 500 year ARI) for critical infrastructure such as the port facilities and road/rail access to those facilities. Allowance should also be made for forecast sea level rise in the planning scheme.

Readiness: Storm tide is addressed in the Local Disaster Management Plan which follows the *Storm tide warning response system* guidelines (SCDO and BoM, 1997). The community, however, probably has a very low level of appreciation that storm tide is a significant risk, consequently few, if any, households will have prepared their own storm tide response plan.

It should be noted here that, during periods of active erosion of beaches and dunes, there is often pressure placed upon councils and other agencies (such as the SES) to carry out inappropriate and environmentally-deleterious 'mitigation' measures such as dumping rocks and old car bodies in at-risk locations (for example, in front of houses). Typically there is little time to consider the full implications of such measures, which may actually exacerbate the erosion in areas immediately adjacent to the material dumped, possibly leading later to litigation from the owners of property which was not protected.

Warnings of potential storm tide impact will normally be included as part of the BoM's severe weather warning covering the generating storm.

Response: Evacuation ahead of a predicted storm tide impact is essential for properties likely to be at risk. Such a large-scale evacuation needs to be very well planned and rehearsed and a high reliance on self evacuation will need to be factored into any evacuation plan. Evacuations ahead of storm tide impact must be completed before the wind speed associated with the storm reached a dangerous level (usually regarded as 75 km/h). Designated evacuation shelters identified for those people evacuated ahead of a storm tide must be resilient to the expected destructive wind level.

It is critical that the community be kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. It is important that the media be kept fully engaged in this process so that they provide positive support rather than become a source of ill-informed criticism of response activities.

Recovery: Where storm tide damage does occur to properties along the coastline, welfare housing may be required for an extended period. Such damage is not normally covered by insurance and rehousing or restoration may have to rely on public generosity or welfare assistance.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of storm tide behaviour. This should be undertaken as an integral part of the clean-up and repair process and should be coordinated by the LDMG. The local studies section of the Townsville City Library should also be encouraged to collect and store all print and electronic media reporting of the event.

Following damaging storm tide events it is likely that there will be considerable interest expressed by academics, the insurance industry and public research agencies (such as the BoM, Geoscience Australia and CSIRO) in studying the impact. It is important that this research activity be coordinated and that the resulting outcomes be made available to the LDMG and the City's community.

4.5 LANDSLIDE RISKS

4.5.1 Landslide Risk Overview

The risks posed by landslide are summarised in Table 4.10.

There is no 'design' level for landslides, however, if an intense rainfall episode with an ARI of 100 years (possibly likelihood) is taken as a reasonable recurrence interval for landslide the risk posed is MEDIUM. That risk is also confined generally to the slopes of Castle Hill and areas around Mt Stuart, Mt Louisa and on Magnetic Island. It is not a widespread risk.

If the spatial constraint is taken into account the level of risk to the whole study area could reasonably be discounted to LOW.

Table 4.10: Landslide risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Almost certain	**Nil:** No damage of significance likely.	**No risk**
Likely	**Insignificant**: A few small batter failures and localised slides.	**Low**
Possibly	**Minor**: A few medium size batter failures which cause minor road blockage. Small number of localised slides causing minor damage.	**Medium**
Unlikely	**Moderate**: Numerous batter failures causing extensive road blockage. Widespread slides, some of which will cause damage to in-ground infrastructure and some buildings. Small debris flows and rock falls possible. Injuries and fatalities possible.	**Medium**
Rare	**Major**: Numerous widespread batter failures blocking some roads for more than 24 hours. Widespread slides causing damage to roads, in-ground infrastructure and buildings. Damaging debris flows and rock falls likely. Injuries likely and fatalities possible.	**Low**

The hill-slope areas of the study area have a significant reputation for, and history of, landslides. Whilst a major rainfall event may give rise to multiple landslides, as witness by the 1998 and 2000 episodes, the vast majority occur in isolated and undeveloped areas. The risks to people, buildings and infrastructure are, consequently, relatively limited – though the direct impact of a landslide is invariably damaging and potentially lethal.

The model (detailed in Appendix H) used to reflect relative landslide risk across the risk assessment zones uses the following weights:

• Percent residential buildings in debris flow hazard zone	3
• Percentage of residential buildings in high landslide hazard zone	2
• Percentage of residential buildings in medium landslide hazard zone	1
• Percentage or road in debris flow hazard zone	2
• Percentage of road in high landslide hazard zone	1
• Percentage of road in medium landslide hazard zone	0.5
• Percentage of water supply network in debris flow zone	2
• Percentage of water supply network in high landslide hazard zone	1
• Percentage of water supply network in medium landslide hazard zone	0.5
• Percent construction after 1982	1
• Community vulnerability	1
Maximum score	**15**

Where there are no buildings exposed to landslide hazards then there is no risk.

The Strand-CBD risk assessment zone is by far the most at risk from landslide hazards. The distribution is shown in Figure 4.4 and the risk indexes in Table 4.11.

4.5.2 Secondary Hazards

There may be an increase in the number of traffic accidents caused by landslide debris on the road. There can also be stress-related health problems as a result of people's properties being affected by landslides. For example, in Tasmania in the 1970s, a man with heart problems died after being told that his house was being destroyed by a slow-moving landslide.

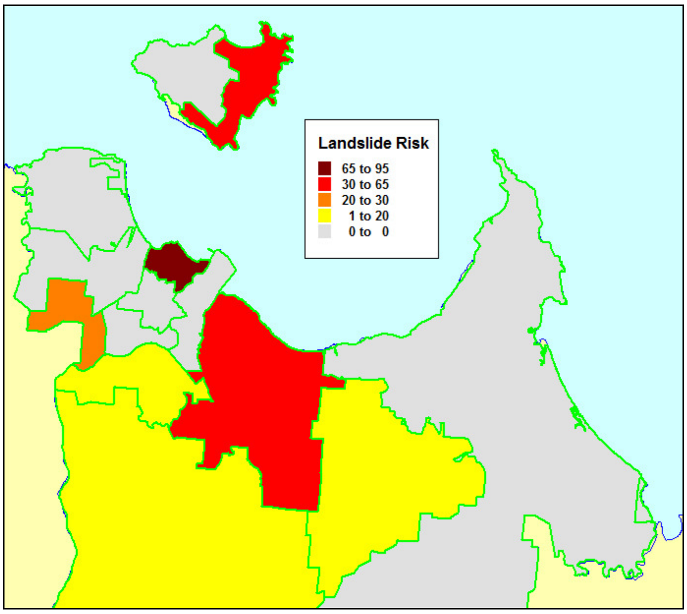

Figure 4.4: Study area hazard precinct levels of landslide risk

Table 4.11: Study area landslide risk index by risk assessment zone (% of possible score of 15)

RISK ZONE	LANDSLIDE RISK
Cungulla	0
Highway	6.08
Industrial East	60.36
Industrial West	0
Institutions	16.21
Lakes	0
Lower Ross	0
Magnetic Island	35.77
National Parks	0
Pallarenda	0
Riverside	0
Strand-CBD	90.07
Upper Ross	6.11
Urban West	29.94

4.5.3 Climate Change Implications

The climate change impact assessments published by CSIRO suggest a significant increase in the frequency and duration of intense rainfall episodes giving rise to a likely increase in the frequency and severity of slope failure.

4.5.4 Analysis

Frequency and Seriousness: Landslides are relatively infrequent events and tend not to affect more than a few properties or a few tens of metres of roads or in-ground infrastructure in any one event. Very large, and consequently serious, landslides involving several thousand cubic metres of material are unlikely to occur in the developed areas of the study area.

The risk of boulder fall from Castle Hill remains a significant threat with the potential to do serious damage and potential loss of life.

Manageability: The risk of landslides on developed land is readily managed by undertaking appropriate geotechnical investigations before development and then undertaking appropriate drainage and other engineering works. In areas such as Castle Hill a range or measures including catch fences and deflection walls have been used to reduce the risk to residential development. Warnings of potential landslide conditions may be included in general BoM severe weather warnings.

Awareness: The risk posed by slope failure is generally well understood by engineers and appropriate practices are well established by which the risk may be greatly reduced. The incorporation of *natural hazard management area (landslide)* mapping (based on Coffee, 2001) into the Townsville City Plan will greatly improve the level of awareness of the hazard and reduce inappropriate development in landslide-prone areas.

Urgency: The hazard appears to be appropriately managed at present, though routine monitoring of the more unstable areas of Castle Hill is warranted.

Growth: The risks posed by landslides will grow only if development in hazard-prone areas is carried out without appropriate geotechnical investigation and engineering. Climate change increases in episodes of intense rainfall may increase the incidence of landslides.

Outrage: Given the typically small size of landslides in the study area and the low probability of fatalities the general level of outrage is likely to be small. It will, however, be understandably high amongst those directly affected, especially if damage is seen as being the result of poor land use planning, engineering or building practice.

4.5.5 Assessment

Research, information and analysis: The *natural hazard management area (landslide)* mapping incorporated in the Townsville City Plan was developed using industry standard methods. Development in areas not yet covered by the Coffee (2001) mapping should not proceed until landslide hazard mapping, taking into account the combined influence of slope, lithology and vegetation, should is finalised. Ongoing monitoring of the Castle Hill boulder-fall problem is essential.

The risks posed by earthquake-induced rock falls from Castle Hill, whilst believed to have a very low probability, are largely unknown and specific research is probably warranted given the weathered nature of the rock on those steep slopes.

Risk modification: The *natural hazard management area (landslide)* mapping is now included to in the Townsville City Plan and all new development is required to take the hazard into account. Physical mitigation measures have been implemented in areas such as Castle Hill.

Readiness: While warnings specifically for landslides are not usually given, the BoM provides warnings of storms. These have been discussed under storm risk.

Response: Where building collapse is a consequence of landslide impact the QFRS is responsible for urban search and rescue operations. Police are responsible for most other landslide-response actions such as traffic control, with assistance from the SES. For landslides affecting roads, Council or the Department of Main Roads would be involved. Responders need to be very careful not to cause further slope instability when undertaking rescues in a landslide. Vibrations, putting extra weight on the head (uppermost part of the slide), or removing material from the toe (lowermost part of the slide) can trigger further movement.

Recovery: Evacuations would be limited, usually affecting only a small number of people. If buildings are destroyed, mitigation measures would need to be put in place before rebuilding could commence or the land may need to be quarantined from future development. Damage to people's property can trigger stress-related physical and mental health conditions, and the appropriate health professionals and possibly social workers may be required to aid in the recovery process.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of landslide behaviour and their impact on buildings and infrastructure. This should be undertaken as an integral part of the clean-up and repair process and should be coordinated by the LDMG. The local studies section of the Townsville City Library should also be encouraged to collect and store all print and electronic media reporting of the event.

4.6 BUSHFIRE RISKS

4.6.1 Bushfire Risk Overview

The risks posed by bushfire are summarised in Table 4.12.

Table 4.12: Bushfire risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Annual	**Nil**: Low intensity localised fires with limited spread. Limited threat to property. Easily controlled with small resources.	**No risk**
Almost certain	**Insignificant**: Small to medium intensity localised fires with some spread potential. Some property threat. Easily controlled with small resources.	**Medium**
Likely	**Minor**: Medium intensity, and possibly multiple, fires with some spread potential. Property likely to be damaged. Manageable by conventional methods.	**Medium**
Possibly	**Moderate**: Multiple severe intensity fires with significant spread potential. Property loss and injuries likely. Difficult to manage by conventional methods.	**Medium**
Unlikely	**Major**: Extreme fire intensity and major spread potential over an extended period. Property loss certain, fatalities likely. Very difficult to manage by conventional methods.	**Medium**

There is no 'design' level established for bushfire however a weather event with an ARI of around 50 to 100 years (possibly likelihood) would produce a risk posed by bushfire classed as MEDIUM.

As with landslide, the threat would never involve the whole study area at any one time and would be confined to rural areas and those developments on the urban fringe. That level of risk, if taken across the study area could be realistically discounted to LOW.

The principal ingredient for bushfires is the availability of ample fuel. The types of vegetation that can produce such fuels are found in broad areas of the City. Whilst fire is commonly used as a land management tool in rural areas, and communities in those areas are very familiar with the hazard and how to manage it, its management in more closely settled areas, however, is more problematical given a greater level of unfamiliarity with fuel management or fire control. There is some risk posed to standing crops and stock losses could be significant in more severe and rapidly developing fires. There is very little threat to suburban communities, but the risks posed by bushfire in rural residential areas can be considerable. Fire fighters are the most likely people to be injured or killed by bushfire.

The dated and conservative nature of the bushfire hazard modelling of the study area by Trinity Software does not make it appropriate to employ in a semi-quantitative risk assessment.

4.6.2 Secondary Hazards

Most of the harm caused by bushfires, such as damaged or destroyed property, disruption of power supply and the adverse health effects of smoke, are directly related to the hazard. Amongst the less direct hazards is a potential increase in the number of traffic accidents, typically caused by reduced visibility in smoke or the distraction of drivers by the sight of flames or fire fighting operations. The longer-term psychological impact on people closely involved may also require ongoing treatment.

Disruptions of telecommunications can occur at the result of above-capacity use of mobile phones in a local area and/or because microwave and cell phone transmissions can be disrupted by dense smoke. Such a loss of communications could lead to social isolation and increased anxiety and potentially have an impact on response management. Dense smoke can also disrupt SCADA systems controlling utility infrastructure including water and power supplies.

4.6.3 Climate Change Implications

The projected increase in spring and summer temperatures and episodes of drought are likely to have a significant influence on both the frequency and severity of fire weather events. Any flow-on affect on the frequency and severity of bushfires will be dependent on the frequency of fires and the amount of fuel that is regenerated between fires.

4.6.4 Analysis

Frequency and Seriousness: Bushfires pose a potentially serious and relatively frequent threat to those parts of the study area in proximity to the ‘bush interface’.

Manageability: The threat is, at least in theory, relatively easy to manage because the fire hazard can be reduced by appropriate fuel management throughout the year. Modern fire fighting techniques, such as the use of water bombing aircraft and helicopters to attack the fire in areas where conventional resources have difficult access, have also improved manageability. Warning times for bushfire weather conditions are typically long enough for those who may be both exposed to the fire and who are unable to cope with that experience to be evacuated well ahead of any fire emergency eventuating.

Awareness: Bushfires have become such a regular feature of life along Australia’s east coast that it is widely known to be an ‘inevitable’ threat. The awareness of the threat and the allocation of community resources to maintaining and supporting QFRS units (both urban and rural) also reflect a degree of acceptance that a significant risk exists. QPWS and the Department of Defence also have fire management plans and response resources available for the areas they control.

Urgency: The current quality of bushfire hazard potential mapping is not suitable as input to the *natural hazard management area (bushfire)* mapping employed in the Townsville City Plan; nor is it suitable for the development of threat assessments during the fire season. Current response arrangements and strategies are generally adequate for the management of bushfire risks.

Growth: The risks posed by bushfires are unlikely to grow significantly unless fuel management is not maintained and inappropriate and poorly designed development in interface areas is allowed. Climate change may increase the incidence and severity of bushfires.

Outrage: Bushfires are sufficiently common occurrences in the Townsville area that they tend not to generate a significant degree of outrage – unless they have been deliberately lit. There is considerable public anger generated where property loss, injuries and lives are lost (especially where it involves a fire fighter) as the direct result of arson. It is inevitable that some affected households or communities may voice anger after a fire at what they perceive to have been a slow or inadequate response should their properties be damaged.

4.6.5 Assessment

Research, information and analysis: The bush fire hazard mapping of the study area needs to be updated as a matter of urgency. That update should employ the SPP 1/03 methodology with modifications suggested in Chapter 2. It should also employ up–to-date vegetation mapping.

Risk modification: The risks posed by bush fire can be modified significantly if appropriate fuel management is undertaken – where possible. It is the responsibility of the land owner or occupier to manage the fuel on their property in such a way as to ensure that any fire that starts on the property does not endanger property beyond its boundary. Most of the larger areas of vegetation within the study area are on public land under the control of agencies such as QPWS and the Department of Defence.

Given the location of several areas of remnant bush in steeper gullies with residential development along all sides, the use of fire as a fuel management tool may not be accepted as an option by the community, even where other options such as slashing or grazing may not be practical. Establishing agreed target fuel loads for such areas (e.g. not to exceed 12 t/ha) would assist bushland estate managers in framing budgets and programming fuel management activities.

Owners of properties within the interface zone between bush and development should be encouraged to carry out appropriate fire maintenance before the onset of each fire season. Simple maintenance activities such as clearing gutters of leaf litter and cleaning up potential fuel close to buildings can greatly reduce the risk of fire from wind-blown embers.

Readiness: TCC does not have a dedicated position of Fire Control Officer to be responsible for fire management on Council-controlled land and to be the main point of contact with QFRS officers and rural brigades.

There are ‘fire danger’ warning signs outside most rural brigade sheds within the study area to provide a constant message of fire threat awareness. Placement of more signs in key urban interface areas should be considered by Council and QFRS.

The BoM issues fire weather warnings which typically lead fire authorities to impose restrictions or bans on lighting of fires in the open. During active fires, public warnings, including the use of the SEWS, will be broadcast over the ABC and commercial radio and TV stations.

People living in interface areas should be encouraged to prepare their own fire emergency plans. This should include deciding whether to evacuate well ahead of the approach of a fire front, or to stay and defend their property.

Response: During periods of high fire danger the general public should be encouraged to report fires as soon as possible to reduce response times. Bush fires can best be managed when they are attacked before they can become well established.

Health authorities will need to be prepared to cope simultaneously with several severe burns cases as well as a very high incidence of respiratory cases, especially severe asthma attacks caused by bush fire smoke.

It is critical that the community be kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. It is important that the media be kept fully engaged in this process so that they provide positive support rather than become a source of ill-informed criticism of response activities.

Power supply may be affected by fires within the major transmission line easements or from burnt-out poles, or trees falling onto power lines. The dislocation of power supplies may require NQ Water to limit water supplies to some areas in order to maintain supplies and pressure to those areas under threat from fires.

Should precautionary evacuation of people to ‘safe haven’ conditions before the impact of a bush fire be considered, the evacuation centres selected should be well clear of a potential fire front. Any evacuation should be undertaken only on the advice of the QFRS.

Recovery: The operation of evacuation/welfare centres after a fire impact and/or the provision of relief housing may be required for many months after a major fire event.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of fire behaviour and building and infrastructure vulnerability. This should be undertaken as an integral part of the clean-up and restoration process and should be coordinated by the LDMG. The local studies section of the Townsville City Library should also be encouraged to collect and store all print and electronic media reporting of the event.

Following the more severe fires it is likely that there will be considerable interest expressed by academics, the insurance industry and public research agencies (such as the BoM, the Bushfire Cooperative Research Centre and CSIRO) in studying the impact. It is important that this research activity be coordinated and that the resulting outcomes be made available to Council, the LDMG and the Townsville community.

Most comprehensive insurance policies provide cover for bush fire. The experience of fires around Sydney and other urban areas, such as Canberra, since 1994, however, indicate that under-insurance of both properties and their contents is common, and that the cost of demolition and removal of burnt buildings is not adequately taken into account. The demand for repair services for damaged or destroyed buildings is likely to produce significant delays in work being undertaken.

4.7 EARTHQUAKE RISKS

4.7.1 Earthquake Risk Overview

The risks posed by earthquake are summarised in Table 4.13.

An earthquake with an intensity likely to be experienced in the 100 year ARI range (possibly likelihood) would produce a risk level of LOW.

Table 4.13: Earthquake risk ratings

FREQUENCY	CONSEQUENCES	RISK LEVEL
Likely	**Nil**: Small intensity shaking to MM IV. Little if any damage.	**No risk**
Possibly	**Insignificant:** Small intensity shaking to MM V. Little if any damage.	**Low**
Unlikely	**Minor**: Moderate intensity shaking to MM VI. Minor damage to poorly constructed buildings possible. Injuries unlikely. Some damage to the more fragile in-ground infrastructure possible.	**Low**
Rare	**Major**: Strong intensity shaking to MM VII. Damage to older masonry and poorly constructed buildings likely. Some serious injuries likely and some fatalities possible. Some dislocation of in-ground infrastructure likely. Secondary hazards such as fire possible.	**Low**

The historical evidence suggests that whilst the impact of earthquakes may be experienced in all parts of the study area, they pose a relatively low level of risk overall.

The model (detailed in Appendix H) used to reflect relative earthquake risk across the risk assessment zones uses the following weights:

- Percent residential buildings on Site Class E — 3
- Percent residential buildings on Site Class D — 2
- Percent commercial/industrial buildings on Site Class E — 2
- Percent commercial/industrial buildings on Site Class D — 1.5
- Percent water supply nodes in Site Class E — 3
- Percent water supply nodes in Site Class D — 1.5
- Percent construction before 1952 — 3
- Percent construction between 1952 and 1982 — 2
- Community vulnerability — 2

Maximum score — 20

The distribution of earthquake risk across the risk assessment zones is shown in Figure 4.5 and the statistics in Table 4.14.

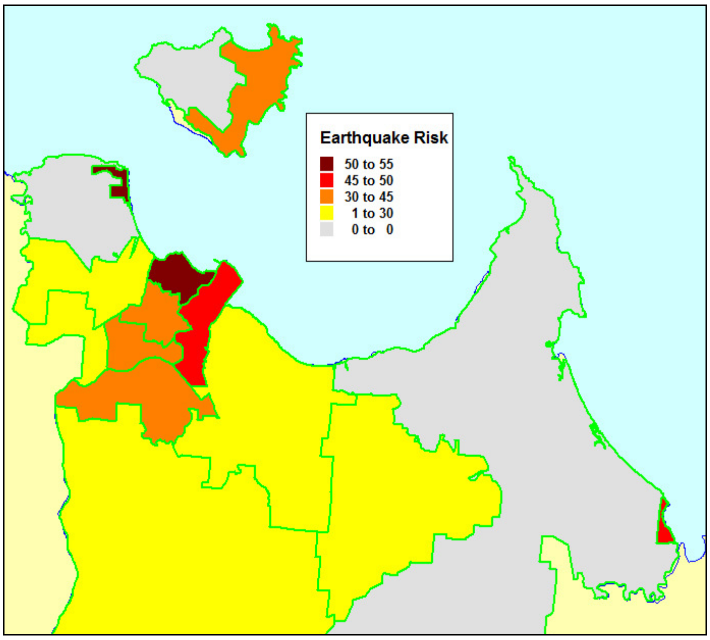

Figure 4.5: Study area relative earthquake risk by risk assessment zone

Table 4.14: Study area earthquake risk index by risk assessment zone (% of possible score of 20)

RISK ZONE	EARTHQUAKE RISK
Cungulla	49.07
Highway	19.68
Industrial East	21.03
Industrial West	24.14
Institutions	36.36
Lakes	36.67
Lower Ross	47.14
Magnetic Island	35.74
National Parks	0
Pallarenda	52.44
Riverside	34.46
Strand-CBD	53.30
Upper Ross	25.36
Urban West	20.51

4.7.2 Secondary Hazards

Earthquakes can give rise to a number of secondary hazards of which fires, caused by downed power lines or gas leaks, can be the most dangerous. This is especially so where water supply has been damaged and roads are blocked by debris making it difficult for fire services to reach and attack the seat of the fires.

Toxic material can leak from ruptured containers or pipes, adversely affecting the health of people, animals and the environment. Health problems can also arise from power outages, leaking sewage, interrupted water supply and from stress-related responses.

Very large earthquakes can trigger landslides. The risk of tsunamis being generated by earthquakes within 500 km of Townsville, however, is extremely low.

Traffic accidents can be caused by debris on roads and train derailments can occur where the tracks have been distorted by the earthquake or from debris on the lines.

4.7.3 Climate Change Implications

Earthquakes are not influenced by climate.

4.7.4 Analysis

Frequency and Seriousness: Damaging earthquakes are relatively rare in the Townsville region, but such an impact would have very serious consequences both in terms of people killed or injured and the economic losses that would be experienced.

Manageability: The threat is able to be managed to some degree by the application of appropriate building construction and maintenance standards. The large proportion of pre-code residential buildings, however, is a concern. There are no warnings.

Awareness: There is a very low degree of awareness that earthquakes pose a threat to the study area.

Urgency: The low frequency and limited seriousness indicates that there are few issues that require urgent attention.

Growth: The risks posed by earthquakes will grow if new construction is not to the standards required in the earthquake loading standard of the BCA and if retrofit and maintenance of older buildings to BCA standards is not continued. Fragility of in-ground infrastructure will continue to grow as it ages.

Outrage: Earthquakes are seen as an 'Act of God' hazard. Any perception that the response to earthquake damage and loss is slow or inadequate could, however, generate widespread outrage. It will also be significant where loss, especially in public buildings, is seen as being the result of poor quality construction and/or maintenance.

4.7.5 Assessment

Research, information and analysis: The area is adequately covered by both Queensland and national seismic monitoring sites. A more detailed site class study, possibly including a micro-tremor study like those undertaken in *Cities Project* studies, would improve the risk analysis. Detailed building construction data and building age data would also greatly improve the vulnerability input to the risk analysis.

Risk modification: The risk can be reduced by designing buildings to withstand a certain level of earthquake motion. Risk can also be lessened by teaching people what to do in an earthquake – taking shelter under strong pieces of furniture, for example, rather than running outside. Regular earthquake drills should be conducted in schools, starting at primary or even pre-school level so that people's response in an earthquake becomes rapid and automatic.

Readiness: At present, earthquakes can not be predicted so no warnings are available.

Response: It is critical that the community be kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. It is important that the media be kept fully engaged in this process so that they provide positive support rather than become a source of ill-informed criticism of response activities.

Recovery: The development of strategies to address infrastructure recovery, business recovery and community welfare need to be considered to ensure that the impact of an earthquake is not exacerbated by a lack of utilities, economic hardship and social dislocation. Lack of such services would prolong the community recovery process.

The operation of evacuation centres after an earthquake impact and/or the provision of relief housing may be required for extended periods. After the impact of a destructive earthquake the restoration of large numbers of damaged homes would be likely to take more than twelve months.

A post-event survey of the nature and distribution of damage is an essential step in improving the understanding of earthquake behaviour and building and infrastructure vulnerability. This should be undertaken as an integral part of the clean-up and restoration process and should be coordinated by the LDMG. The local studies section of the Townsville City Library should also be encouraged to collect and store all print and electronic media reporting of the event.

Following significant earthquakes it is likely that there will be considerable interest expressed by both national and international academics, the insurance industry and public research agencies (such as the Geoscience Australia and CSIRO) in studying the impact. It is important that this research activity be coordinated and that the resulting outcomes be made available to Council, the LDMG and the Townsville community.

Most comprehensive insurance policies provide cover for earthquake damage. Owners of damaged properties that are uninsured or underinsured may have to rely on public generosity through an organised appeal. The administration of any appeal needs to be well managed and coordinated and conform to the relevant Commonwealth guidelines. The demand for repair services for buildings and cars is likely to produce significant delays in work being undertaken.

4.8 THE RISKS COMPARED

Much of the analysis of the risks posed by the six hazards contained above is, fortunately, hypothetical or theoretical because the study area has had a rather benign history of major hazard impacts, the more recent exception being the impact of TC *Althea* in 1971. It is, none-the-less possible, using the knowledge of the various hazard phenomena and the experience of other communities in Australia and elsewhere, to make reasonable estimates of the 'what if' consequences of a wide range of event severities and recurrence intervals.

It is common to rate the severity of the risks posed by either the number of people killed or injured (e.g. Coates, 1996) or the economic cost of the event (e.g. BTE, 2001). Both approaches are considered here.

4.8.1 Personal Risk

The hazard with the most significant risk of a death toll is heatwave. Rather than producing large numbers of fatalities in a single event, heatwave kills relatively small numbers of people in each event, but there are frequent events over time. It is conceivable that more than 10 fatalities and as many as 500 hospitalisations due primarily to heatwave conditions can occur in the Townsville region in heatwaves of a severity that has an ARI of 10 years and a death toll of more than 50 people and 800 hospitalisations in events with an ARI of more than 25 years. The projected climate change effects are likely to reduce those recurrence intervals by as much as four times.

Severe storms, floods and bush fires appear to have roughly the same potential for producing fatalities with similar recurrence intervals. What makes them especially significant is that emergency workers (SES in the case of storms and floods and QFRS in the case of bush fires) are likely to be the most at risk. The average death toll over a decade would, however, be probably less than 5 for each hazard, though in extreme events (those with ARI of 100 years or greater) the death toll could be much greater.

Landslides probably pose a limited threat to people but their relative frequency of occurrence places them ahead of earthquakes based on the Australian record of natural hazard experience.

4.8.2 Economic Cost

Statistics compiled by Bureau of Transport Economics in their 2001 report *Economic costs of natural disasters in Australia* (BTE (2001) show that for Queensland as a whole the most costly natural hazard for the period 1967 to 1999 (on an annual average cost basis) was flood ($111.7 million), followed by cyclones ($89.9 million) and severe storms ($37.3 million), with bushfires occupying a distant fourth place ($0.4 million).

The complete analysis of the economic cost of disasters is extremely complex as the model proposed by the BTE in Figure 4.6 demonstrates.

It is unusual for this full model to be applied to the study of disasters. Most frequently the only costs addressed are the direct costs, and then they are typically confined to the insured losses to private property. This inevitably understates the true costs of disaster. Certainly the most thorough economic analysis of a disaster event in Queensland to date has been that undertaken for DES of the flooding associated with ex-TC *Sid* (DES, 2002). Most of the losses were confined to the former Townsville and Thuringowa City areas. This study calculated the direct losses to total $234.24 million; indirect losses totalled at least $6 million (with issues such as the indirect cost to tourism and agriculture unquantified); the intangible losses at $4.86 million; giving a total loss of at least $245.1 million. Against these costs recompense from insurance payouts ($69.35 million), Natural Disaster Relief Arrangement ($54.37 million) provided $121.91 million in 'benefits' giving a net loss of $123.19 million.

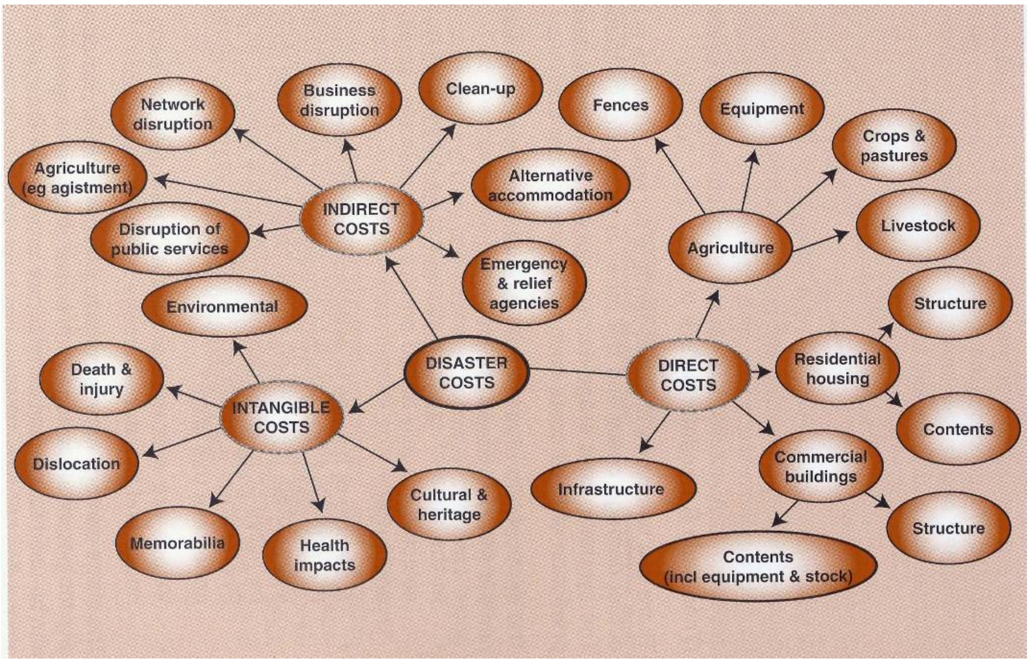

Figure 4.6: Disaster cost outline framework (BTE, 2001)

It is clear that any expenditure aimed at reducing the economic impact of any natural hazard on the community can be seen as an investment, rather than as a cost.

4.8.3 Risk Ranking

IID has applied a semi-quantitative approach to arrive at a comparative assessment of each hazard and their various sub-sets (e.g. flash flood as well as riverine flood). This approach allocates scores out of 5 for each element with the highest score going where that element contributes significantly to the total risk. The scenario-specific risk score is the sum score of likelihood and consequences. Whilst subjective, they are based on our knowledge of the hazards and the Townsville community.

The seven characteristics of the risks posed by each hazard have been used to provide a ‘risk rating’ in order to rank the risks. The characteristics used to analyse the relative risk and range of significance used are described below and summarised in Table 4.15:

Table 4.15: Scoring guide for relative contribution to risk level

RISK CHARACTERISTIC	SCORE				
	5	4	3	2	1
Frequency	Frequent	Occasional	Rare	Very rare	Extremely rare
Seriousness	Catastrophic	Major	Moderate	Minor	Insignificant
Manageability	Unmanageable	Difficult	Manageable	Easy	Very easy
Awareness	Total ignorance	Poor	Moderate	Reasonable	Widely known
Urgency	Most urgent	Very urgent	Urgent	Priority	Low priority
Growth	Extreme	High	Moderate	Low	Very low
Outrage	Extreme	High	Moderate	Low	Very low

Scored out of 5 have been allocated to each characteristic for each of the six hazards considered in this study and the scores summed to provide an overall ‘risk score’. Scores were allocated by IID research specialists. A high degree of consensus was achieved in that process. Those scores are shown in Table 4.16.

Table 4.16: Comparative multi-factor risk rating

HAZARD	SCENARIO RISK	MANAGE.	AWARE	URGENCY	GROWTH	OUTRAGE	TOTAL RISK
Destructive wind	6	3	2	2	3	3	19
River flood	5	3	2	3	2	4	19
Storm tide	5	3	3	3	3	4	21
Landslide	5	2	3	2	2	3	17
Bushfire	5	1	2	1	2	2	13
Earthquake	4	4	4	2	2	1	17

On this assessment of total risk IID considers storm tide to pose the greatest threat to the Townsville community, with destructive winds and riverine flood a close second. Bushfire poses the lowest overall level of risk.

5 TREATING THE RISKS

5.1 INTRODUCTION AND GUIDING PRINCIPLES

In this chapter, strategies that would help to reduce or eliminate emergency risks across the study area are identified and discussed. It is focused primarily, but not exclusively, on those strategies that might be adopted by TCC. Where they address issues that are the responsibility of either State or Commonwealth agencies, or individual property owners, they are expressed in terms of what Council might do to influence the adoption of treatment strategies by those who have the primary responsibility.

The current level of risk posed by the hazards included in this study and the effectiveness of the risk reduction strategies suggested in this Chapter, have been measured against the following criteria, in priority order, <u>for up to the once-in-a-lifetime (50 to 100 year ARI) event</u>. Those strategies, outlined in Chapter 1, and agreed by the Study Advisory Group, are:

1. reduce, and preferably eliminate, the risk of death or injury to emergency workers engaged in responding to any hazard impact;
2. reduce, and preferably eliminate, the risk of death or injury to the general population;
3. reduce, to an acceptable level, the risk of destruction or damage to public infrastructure and facilities;
4. reduce, to an acceptable level, the risk of destruction or damage to private property;
5. manage the impact of natural hazard impacts on cultural heritage and the natural environment to the extent that loss of heritage is minimised and the biodiversity of flora and fauna is maintained;
6. minimise the long-term impact on the local economy.

There is broad agreement that the protection of life and property will take precedence over environmental protection. This is consistent with the objective of all emergency risk management, namely **to provide safe and sustainable communities**. Whilst this objective is widely accepted, it is not often <u>explicitly</u> stated in such documents as the corporate plans of local governments or State agencies.

There is no single point of responsibility for emergency risk mitigation – **it is a total community responsibility**. Acceptance of that fact, however, is far from universal, especially after a tragic event. It is an unfortunate, but understandable, feature of disasters such as floods and bushfires that after the event, victims feel the need to allocate blame. Typically, that blame is directed towards the public sector – 'why did Council permit that development on the floodplain in the first place?'; 'if the National Parks people had managed their fuel, the fire would not have been so bad'; 'why didn't the SES get a tarpaulin on my damaged roof quicker?', and so on. The media reporting of the January 2003 fires in Canberra, the January 2005 Eyre Peninsula fires and the impact of TC *Larry* in north Queensland in 2006, for example, are full of such expressions.

The risk management standard *AS/NZS 4360:2004* identifies four broad options for risk treatment:

- eliminate the risk – whilst this is the theoretical ideal, this option is very difficult to achieve in practice because it would require one or more of the risk elements (hazard, exposure, vulnerability) to be reduced to zero;
- reduce the risk – this is typically the most practical option, however, it inevitably involves setting thresholds beyond which risk reduction is deemed to be either impractical or uneconomic. This involves the difficult and often contentious task of establishing what the community considers to be a level of 'acceptable' or 'tolerable' risk;
- transfer the risk – administratively, this is frequently done by a higher level of government passing responsibility to the next level down the line, or governments passing responsibility to individual property owners. When available, insurance is the most common strategy employed to transfer financial risk;
- accept the risk – where it is not possible to eliminate, reduce further, or fully transfer the risk, the residual risk is simply accepted or tolerated. Acceptance typically relates to those risks that are either relatively common, but their impact is more of an inconvenience than a significant threat (i.e. not worth worrying about); or those that may have a devastating impact but their occurrence is extremely rare (i.e. impossible to control or manage).

In the various hazard-specific studies on which this study is based a wide range of (mostly) structural treatment strategies have been recommended. Those strategies are being (or have been) implemented by TCC. They will not be further addressed in this study.

The more general strategies that are applicable to all hazards are dealt with first and are followed by strategies that relate to the specific hazards. Regardless of which strategy is adopted, it is important for risk managers to see emergency risk reduction activity as being **an investment rather than a cost**.

5.2 GENERIC RISK REDUCTION STRATEGIES

5.2.1 Context constraints – Council amalgamation

This study has been confined by its Terms of Reference (TOR) to the area administered by the former Townsville City Council. Since this study commenced that area has been amalgamated with its neighbouring Thuringowa City Council. While the two separate councils had operated their Local Disaster Management Group (LDMG) as a joint committee for several years, they had run very separate disaster risk management research programs and risk philosophies. Thuringowa City, for example had not undertaken any systematic studies covering bushfire, landslide or earthquake hazards, and the areas covered by their flood studies was not extensive.

The area administered by the New Townsville City Council is double that of the former council area covered by this study; and its population is 60% large than the population of the study area. The amalgamation of the two councils has established a situation where all of their separate statutory and operational systems, such as their planning schemes and their information infrastructures, as well as their separate administrative cultures, will need to be amalgamated.

Amalgamation provides an opportunity to establish a new approach to emergency risk management as well as a requirement to merge the statutory and operational systems. At the heart of the development of a new approach to emergency risk management is establishing a risk culture. In the *Cities Project* study of community risk in South East Queensland (Granger and Hayne, 2001b) the following observation is made:

> *At a philosophical level at least, one of the most potent forms of risk mitigation is the development and nurturing of a strong risk management culture across the community. It has, for example, been frequently observed that emergency risk management is most effective where it is an integral part of overall community risk management. Similarly, disaster planning is most effective where it is managed as an integral part of total community planning. In the vast majority of cases, however, these processes and activities tend to be divorced from the mainstream of community governance, even within organisations that are clearly committed to public safety, as is the* [TCC]. *The compartmentation and isolation of emergency risk management from the mainstream of community governance can best be attributed to the lack of a broad culture of risk management.*
>
> *A mature risk management culture will see the decisions made by the executive, administrative, public health, planning, environmental, engineering, fiscal, legal and emergency management elements become more integrated, consistent and coordinated. The outcome would see the interdependencies of strategic decisions in each of those areas acknowledged and their consequences taken into account in a more transparent and seamless process. Such an approach would also tend to widen the planning timeframe from the current two or three year, electorally-constrained horizon to one of 10, 20 or even 50 years.*

In short, a risk management culture is one in which the philosophy of providing safe and sustainable communities is clearly and consistently adhered to. The *Corporate Plan 2007-2012* of the former TCC does not mention natural hazards at all, nor does it identify a commitment to safe and sustainable communities. It does identify 'a safe community' as a strategic objective, but in the details, this objective is expressed as follows:

> *Central to our vision of building a better community are a range of practical initiatives aimed at improving public safety. Council is committed to increasing safety awareness and reducing the incidence of fear, crime and antisocial behaviour.*

***Generic strategy 1*: When establishing its new Vision Statement and Corporate Plan the New Townsville City Council consider the inclusion of a clear commitment to maintain a safe and sustainable community, especially in relation to the potential impact of natural hazards.**

To achieve such an objective it may be necessary to educate councillors and senior executives as to the central role of community safety in all aspects of community governance. LGAQ and DES, under their Disaster Management Alliance, have combined to produce an information workbook and companion CD resource under the title *Elected member's guide to disaster management* (LGAQ & DES, 2006). This resource provides comprehensive information tailored for elected councillors on their legal responsibilities primarily under the *Disaster Management Act*. At a higher level, the Local Government Association of Australia (LGAA) commissioned a study on land use planning and risk mitigation (SMEC & IID, 2006). It would be appropriate for all elected councillors and senior executives of the New Townsville City Council to receive a briefing on their responsibilities for emergency risk management within the first few months of an election and be provided with copies of supporting material such as those mentioned above.

***Generic strategy 2*: At an early stage in the life of each Council the LDMG arrange a briefing for all elected councillors and senior executives on their roles and responsibilities for emergency risk management. An information package to support such a briefing should contain material such as the LGAQ/DES resource *Elected member's guide to disaster management*.**

The *Elected member's guide* does not address the wider legislated and common law exposure of councillors and councils with regard to the various risks posed by both natural and anthropogenic hazards. It would be helpful to all local governments for the LGAQ and DES to commission research to compile an anthology of councils' legal obligations under both legislated and common law to guide and inform emergency managers at local level.

***Generic strategy 3*: Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.**

The two former councils have demonstrated an attachment to community-wide safety through maintaining a joint disaster management plan managed by a single combined Local Disaster Management Group (LDMG). This committee has been chaired by a councillor from one of the former councils on a rotational basis. Since amalgamation oversight of the LDMG has been transferred from the Infrastructure Committee, to the more appropriate Community Safety and Health Committee.

This study clearly demonstrates that a key to disaster risk reduction is a resilient community fostered and supported through a range of non-structural strategies. Templeman[14] and Bergin (2008), for example make the following observation:

> *A resilient community has the capacity to withstand a disaster and its consequences, return to its pre-disaster state quickly and learn from the disaster experience to achieve higher levels of functioning. For individuals, it's about the ability to function at a level far greater than expected given the individuals previous experiences.*

The development of resilience clearly lies beyond the ambit of a single Council committee. A whole-of-community approach would involve, in addition to the Community Safety and Health Committee, the Infrastructure Committee and the Planning and Economic Development Committee (as a minimum). The issues that fall within the ambit of those committees are also of critical importance to the process of disaster risk management.

***Generic strategy 4:* In the process of re-designing the functional arrangements for its amalgamated structure Council review the subordination of the LDMG to maximise its effectiveness as a risk management body.**

Another significant measure of a local authority's commitment to this culture is the degree to which it makes information on disaster risks available to the community. Information on flood, storm tide,

[14] David Templeman was Director-General of EMA from 2000 to 2006.

landslide and bushfire hazards have been made available to the public on the former TCC web site, but the same openness has not been the practice by the former Thuringowa City Council which has not made public its flood modelling. It is something of a paradox that in the management of hazardous materials the concept of 'community right to know' is enshrined in legislation yet in the management of natural hazards such a 'right' is widely denied. Along these lines, Templeton and Bergin (2008) make the following point:

> *A fundamental shift is required, however, in moving from a 'need-to-know' national security culture to a 'need-to-share' resilience culture to get the community fully engaged in understanding what our actual state of preparedness is and asking the community to be better prepared. A well-prepared public and a focus on information that will assist at the community level leads to national resilience.*

Generic strategy 5: **At an early stage in the amalgamation process the New Townsville City Council promotes a policy that facilitates public access to details of potential hazard impact zones, especially those involving inundation hazards.**

For this to be achieved it will be necessary for a multi-hazard risk assessment to be undertaken based on the new council boundaries to provide a current risk assessment on which to base a revision of the Local Disaster Management Plan.

Generic strategy 6**: Council commission a follow-up multi-hazard risk assessment, as Stage 2 of this study, to produce a disaster risk management strategy for the New Townsville City Council. That study should be based on updated City-wide hazard-specific studies for bushfire, landslide and earthquake (and possibly flood).**

Similarly, there is a need to establish consistent and appropriate policies relating to the potential risks of tree plantings or remnant mature trees in the urban environment. On the one hand, shade trees can be important in reducing the ambient temperature around housing if they produce a good heavy shade during the summer. Conversely, mature or over-mature remnant trees, especially eucalypts, close to houses pose a major threat during storms and bushfires. Encouraging people to plant appropriate trees that will provide shade in urban areas, and be less flammable than most native species, could reduce the risks and promote community amenity.

Generic strategy 7**: Council review its vegetation management strategies to manage remnant native trees and street tree planting to minimise their potential to do damage if brought down during storms or to provide bushfire fuel close to residences.**

5.2.2 Context constraints – the all-hazards approach

The other major constraint imposed by the TOR for this study was the range of hazards to be addressed. The hazards covered are those identified by the NDRRA guidelines, a constraint imposed by the funding criteria by the Commonwealth and State Governments for the Natural Disaster Mitigation Program (NDMP). Such a constraint is not imposed in some other jurisdictions, such as NSW and Victoria. In those states a more comprehensive 'all-hazards' approach to disaster risk management has been adopted as policy. In NSW, for example, local governments undertaking a multi-hazard risk study are required by the State Emergency Management Committee to take into account some 50 listed hazards (SEMC, 2001). This list can be simplified to that outlined in Table 5.1.

Only those hazards shown in bold in the table are covered under the NDRRA. Some of the others (such as coastal erosion or structural failure) can be covered if they are experienced as a consequence of a primary natural hazard.

Table 5.1: A typology of Australian hazard phenomena (from Granger, 2008a)

ATMOSPHERIC	EARTH	BIOLOGICAL	HUMAN
tropical cyclone	**landslide**	human epidemic	transport accident
east coast low	**earthquake**	animal epidemic	industrial accident
severe storm/tornado	**tsunami**	plant epidemic	structure failure
flood	subsidence		structure fire
storm tide	coastal erosion		hazardous materials
bush fire	**meteorite strike**		contamination/pollution
heat wave			space debris re-entry
drought			terrorism
fog and frost			
climate change			

The guiding principles of disaster or emergency risk management in Australia are based on four concepts:

- the comprehensive approach (i.e. the PPRR approach)
- the all-hazards approach
- the all-agencies approach
- the prepared community.

There is a clear need for State and Commonwealth authorities to better recognise this long-standing principle in the funding arrangements for emergency risk management studies including the NDMP. It should be noted that funding under the EMA-administered *Local Grants Scheme* does not impose such constraints.

This study has been extended slightly beyond the NDRRA scope to address the potential impact on the hazard environment of forecast climate change effects. It has also drawn attention to the 'secondary' risks, such as the loss of containment of hazardous materials, which are consequential to the impact of a primary hazard.

***Generic strategy 8*: Council, through LGAQ, request DES and EMA to review the limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.**

***Generic strategy 9*: Council seek future external funding to extend its multi-hazard risk assessment studies to address the full span of hazards, including heatwave, epidemics and anthropogenic hazards.**

5.2.3 Disaster information

Granger and Hayne (2001) make the following observation:

> *For a comprehensive risk management culture to flourish, it is necessary for it to be underpinned by a strong and effective information infrastructure. We see the development of such an infrastructure as being the most fundamental of all risk mitigation strategies. It is also one of the most cost effective strategies, given that most of the information required is already collected, maintained and used by* [a local government] *and the other authorities that have a role in community risk management.*
>
> *Whilst much of the basic information required for risk management (such as street layout, property information, land use and demographic aspects) is already available, there are several themes that we have found to be poorly addressed. Three themes stand out:*
>
> - <u>*historical information*</u>*: whilst the Bureau of Meteorology, and Geoscience Australia maintain their own information on hazard history and other bodies in the community such as the local or community papers each maintain collections on the community experience of disaster, there is no consolidated index or coordination of information about the* [local government area's] *history of disasters and the impact on the community;*

<u>Comment</u>: There is perhaps a role for groups such as the Townsville City Library and the local historical society to assist the LDMG to establish and maintain a disaster-specific historical material collection. There may also be scope for researchers with an interest in local history or oral history at James Cook University, for example, or history teachers in local secondary schools to be involved in such a program.

***Generic strategy 10*: The LDMG initiate discussions with the Townsville City Library, the Museum of North Queensland and local history groups to document the community's experience of and response to emergencies.**

> - <u>*modern event experience*</u>*:* Townsville City *has not experienced any* major *disaster impacts for several years, so there has been little need for* detailed City-wide *post-event research to be conducted …. Much of this post-event information, such as the recording of earthquake aftershocks,* and flood levels *is highly perishable – if it is not collected during the event it will be lost forever. Without such detail of real events it is not possible to reduce the uncertainty that exists in our models and input data. The requirement to collect key event information needs to be entrenched in the doctrine of disaster response, with appropriate resources identified in disaster plans and made available to undertake the collection and management of that information;…*

<u>Comment</u>: In developing this study, some difficulty was experienced in obtaining information on the recent (say the past ten years) of landslides, bushfires or severe storms. Council does not appear to maintain a consolidated database or information archive on such issues. Such a situation has the potential to place Council in a precarious legal position should repeat events occur and it can be shown that nothing was done to correct a known risk situation.

***Generic strategy 11*: The LDMG incorporate into its Local Disaster Management Plan the requirement to undertake and/or fund post-event surveys and studies from which to accurately assess the consequences (physical, economic, personal) of all significant hazard impacts.**

***Generic strategy 12*: The LDMG recommend to DES that guidelines be developed to standardise the conduct of post-event surveys and studies and incorporate those guidelines into the State Disaster Management Plan.**

Following significant hazard impacts, such as a major storm tide, earthquake or flood, there will inevitably be a considerable interest shown by both local and international academics, the insurance industry and various public research agencies such as the BoM, Geoscience Australia and the CSIRO, to undertake their own research into specific aspects of the disaster event. It is important that such research does not interfere with response and recovery operations and that the results of that research be returned to the local community. It would be appropriate for the LDMG to be the focus for the coordination of all such external research. It may also be appropriate for DES to develop guidelines for the conduct of post-event scientific investigations following major disasters along the lines of those developed by the international vulcanological scientific community (IAVCEI, 1999).

***Generic strategy 13*: The LDMG develop procedures and protocols by which to manage and coordinate post-event research by outside agencies following a major disaster.**

***Generic strategy 14*: Council, through the LGAQ, recommend to DES that guidelines be developed and circulated to the scientific community relating to the conduct of post-event studies.**

- *<u>technical information</u>: much background technical information is being routinely collected by commercial consultancies to meet the requirements of various standards such as the Australian Building Code. The collection and analysis of geotechnical information on which to base the design of building foundations is a case in point. This information is of great significance to improving the accuracy and relevance of risk assessments. Whilst there are obvious commercial (and possibly legal) sensitivities concerning such information, its value to the wider aspects of community safety is not being realised because there is no central inventory of the existence of such information – let alone an archive of the detail.*

  There has been significant public investment in the development of systems to monitor hazard phenomena and to provide warnings of an impending impact. This important investment has not, however, been matched by the level of investment in information that enables the warnings or risk forecasts to be translated into information of relevance to members of the community. There is clearly a need for a greater level of investment in risk information.

<u>Comment</u>: It has been observed (not without some truth) that one of the most common activities in emergency management is 'information-free decision making' (Granger and Johnson, 1994). This is largely because the key information is not available, or is out of date, or is in a form that is hard to use. There is also a significant reliance by emergency managers on personal local knowledge. Whilst local knowledge is important, it is not easily shared and is instantly perishable if the person who has it becomes a victim! Undoubtedly, one of the most significant strategies to reduce the risks faced by

emergency workers is to ensure that they have access to the right information, at the right time and in the right form.

Council operates the ESRI suite of GIS software in which a good range of data is maintained. It is also used routinely by a wide range of Council officers in their routine work. The GIS can provide an excellent base on which to build a strong emergency management information infrastructure along the lines described by Granger (1998 and 1999). Such an information infrastructure can facilitate the integration of a wide range of emergency-related information from DCDB and topographic data to census statistics and local knowledge. While this centralised system is well managed, there are 'silos' of data held by individual sections of Council, knowledge of which is not always made available to other Council elements that may have an interest in it.

The process of council amalgamation will undoubtedly draw attention to a wide range of inconsistencies and incompatibilities in the information infrastructures of the two original organisations. The major effort that will be required to draw together two disparate information infrastructures into a single corporate information infrastructure presents a perfect opportunity for it to be designed from the outset to facilitate emergency management.

Other supporting data that could be called on in times of emergency could also be introduced to the GIS or a GIS-supported emergency management information system. That information could include the location and availability of resources such as plant and equipment; contact details for private sector experts (such as engineers); amongst others. Given that emergency management ideally functions as a seamless part of overall community governance, it is important that the information systems used to underpin community governance are also suitable for, and available to, emergency managers.

***Generic strategy 15*: The LDMG recommend to Council that as part of the amalgamation of the two council information systems that it commissions a review of its amalgamated information infrastructure and its capacity to fully support the planning for and response to a major emergency.**

5.2.4 Monitoring and warning systems

The following relevant observation is also made in Granger and Hayne (2001):

> *For all of the hazards considered in this study, with the exception of earthquake, warnings of impending impact are already provided in one form or another. A report produced by the Institution of Engineers, Australia (Institution of Engineers, 1993) provides a useful hypothetical example of the benefits of this approach in the following terms:*
>
> > Flood warning systems now feature real time data collection networks linked to computer based flood models. These systems not only identify and track floods down a river but also enable emergency services to quickly assess the impact of various scenarios of increased or decreased rainfall, changing tidal conditions in the lower reaches of the river and varying tailwater effects at the river mouth due to storm surge and wave setup. Based on these scenarios, authorities can take more effective action to save lives and minimise damage to property. Even in a catchment with only one thousand flood prone homes, accurate advanced information on flood levels which

> enables residents to move contents and motor vehicles to locations above flood waters can result in a saving of $10 000 per household. **This $10M savings is a direct benefit to the community every time such a flood occurs.**
>
> *(emphasis in the original)*

> *The coverage and sophistication of most of the monitoring and surveillance systems is constantly improving. There are plans, for example, to introduce Doppler radar to measure wind speed in storms and cyclones and thus improve both warnings and our knowledge of extreme wind speeds. There is also significant scope to improve on the existing seismic monitoring network in the … Queensland region so that instrumental recording of the smaller and more frequent events can help build up our knowledge of the region's seismic environment.*
>
> *Nonetheless, warning systems will be much more effective if the community is aware of their existence and of the implications of warnings. Whilst there is some scope to improve the timeliness and accuracy of warnings, their value will only be increased when individuals are able to relate warning information to their own circumstances and translate that information into risk reduction action. To achieve this it is necessary to increase public awareness by combining appropriate risk information and warning information.*

Generic strategy 16: **Council enter into discussions with the BoM to upgrade the Mt Stuart weather watch radar to a Doppler radar and to review the effectiveness of the current flood warning system.**

5.2.5 Community awareness

Again, Granger and Hayne (2001) provide a relevant observation, as follows:

> *An effective strategy of risk communication is essential. For example, a typical public flood warning will be expressed in terms of a height on the reference flood gauge. Few people in urban areas can translate that level, with any certainty, to their own property in terms of how high the water would reach. The value of the warning is consequently diminished because few individuals know what action they should take in response.*

A considerable literature on risk communication has emerged over the past decade or so (see, for example, the review by Marra, 1998). One of the most coherent examples we have encountered is that promoted by the US Environmental Protection Agency (EPA). Their approach devolves from the basic tenet that, in a democracy, people and communities have a right to participate in decisions that affect their lives, their property, and the things they value. The EPA approach is based on the following 'seven cardinal rules' (quoted from EPA (US), 1988):

> Rule 1 – accept and involve the public as a legitimate partner: the goal of risk communication in a democracy should be to produce an informed public that is involved, interested, reasonable, thoughtful, solution-oriented, and collaborative; it should not be to diffuse public concerns or replace action.

Rule 2 – plan carefully and evaluate your efforts: there is no such entity as “the public”; instead, there are many publics, each with its own interests, needs, concerns, priorities, preferences, and organisations.

Rule 3 – listen to the public’s specific concerns: people in the community are often more concerned about such issues as trust, credibility, competence, control, voluntariness, fairness, caring, and compassion than about mortality statistics and the details of quantitative risk assessment.

Rule 4 – be honest, frank and open: trust and credibility are difficult to obtain. Once lost they are almost impossible to regain completely.

Rule 5 – coordinate and collaborate with other credible sources: few things make risk communication more difficult than conflicts or public disagreements with other credible sources.

Rule 6 – meet the needs of the media: the media are frequently more interested in politics than in risk; more interested in simplicity than in complexity; more interested in danger than in safety.

Rule 7 – speak clearly and with compassion: tell people what you cannot do; promise only what you can do, and be sure to do what you promise.

Governments, at any level, can only hope to reduce risk if their risk reduction strategies are accepted and supported by the community. Risk communication is the most democratic way of achieving that support.

Efforts to inform the community about risks are not always viewed with the same passion and altruistic values as those held by risk communicators. They are often met with opposition from small, but influential, sectors. The most common negative reactions relate to the belief that such information will have a negative impact on real estate values, and/or, will ‘scare away’ tourists or investment. Whilst there has been only limited research into the overall economic impact of risk communication, the anecdotal information that we have seen indicates that such negative beliefs are wrong. They do, nevertheless, excite levels of passion and political ‘outrage’ that typically leads to the dilution, if not termination, of public awareness efforts.

<u>Comment</u>: Further research has been published since completion of the GA studies, most notably that by Yeo (2003) and Vogt, Willis and Vince (2008). In particular Yeo draws attention to the work of Tobin and Montz (1994) who observe that residential property values ‘*reflect a complex interaction of spatial, temporal, economic, sociological and hydrologic variables*’. The public outrage in 2004 directed at Brisbane City Council over their refusal to release flood modelling done in 1998 was based largely on (largely irrational) fears about property values.

It is also important for community awareness programs to be sustained so that new residents, transients and tourists are also covered. Programs should be designed and resourced to cover these populations. Given the number of people in the study area for whom English is not their primary language, consideration should be given to producing a local version of the excellent Logan City Council publication *Preparing for natural disasters – a guide for residents living in Logan City* (LCC, nd) in languages that are widely spoken in the non-English-speaking community.

***Generic strategy 17*: The LDMG recommend to Council the development of a comprehensive emergency risk communications strategy, in association with the response agencies, including the production of a comprehensive guide to the development of household emergency management plans. That guide should be included in the 'welcome' information pack provided to new residents.**

The use of the electronic media to keep the community informed of an evolving emergency situation has become a fundamental tool for emergency managers. It can, however, be a double edged sword if media presenters or commentators are able to become a focus for criticism of the preparedness, response or recovery activities. Such criticism can have a seriously destructive impact on the morale of emergency workers who are already operating under extremely trying conditions.

SEWS has not been used to precede announcements for emergencies other than cyclones in Townsville City to date. It is unlikely that the community is aware of the wider use of the sound and its significance to other natural and anthropogenic emergency situations. The mobility of the Townsville community also indicated that many new residents will not even be aware of the relevance of SEWS preceding cyclone warning messages. There is a need to regularly inform the community as to the importance of SEWS and its use. An information campaign ahead of the bush fire or cyclone seasons, for example, would appear to be appropriate.

***Generic strategy 18*: The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.**

***Generic strategy 19*: The LDMG and Council establish a program of community awareness as to the importance of SEWS ahead of the annual bushfire and cyclone seasons.**

The use of currently topical issues, especially climate change, as a theme for public education programs would help to add both currency and significance to the message. The linking of messages relating to emergency risk issues to the potential growth of those risks due to climate change would help to both alert people to the possible future concern and reinforce the need to address the same issues now.

***Generic strategy 20*: Council use the current high degree of media interest in issues relating to climate change to promote messages of the linkage of climate and natural hazards both now and into the future.**

In developing such communications programs there is scope to emphasise the need for community members to take responsibility for their own safety rather than rely on a response by emergency workers or other public agencies. Templeton and Bergin (2008) for example observe:

> *No matter what the disturbance, Australians now appear to feel that somehow they will be looked after, even when caught up in overseas emergencies, such as the Lebanon war in 2006.*

We seem to have generated a community view of: 'don't worry, someone else will come and get you and fix the damage'.

Too many in our community believe that calling 000 will generate an instant response: 'just-in-time shopping with instant access to banking, goods and services has encouraged a sense of public complacency.

The Western Australian National Parks agency seek to discourage such an attitude by placing signs in areas such as gorges and rocky coastline areas that proclaim 'your safety is our concern but your responsibility'. A similar slogan might be employed in Townsville.

Generic strategy 21: **Before the start of each cyclone season Council run a community education program aimed at building community resilience and self reliance. To provide focus to that campaign Council could consider adopting a slogan along the lines of 'your safety is our concern, but your responsibility'.**

5.2.6 Emergency management

The emergency management process has been based on consideration of the prevention, preparedness, response and recovery phases of disasters (known as PPRR). Under the adaptation of AS/NZS 4360:2004 to emergency risk management, these traditional components of emergency management can be seen as risk treatment options. The emphasis is on the treatment of residual risks (i.e. the risks that can not be eliminated or reduced by other means), especially in the preparedness, response and recovery phases. Most risk reduction options, however, clearly focus on prevention.

The preparedness phase emphasises disaster planning, community awareness, training and exercising and the provision of appropriate resources such as communications equipment. It is important, therefore, for emergency planning to be based on sound risk assessments and realistic risk scenarios, otherwise plans may be inappropriate, awareness will be inadequate, training and exercises will not be based on realistic scenarios and resources may not be appropriate. Evacuation planning provides a good example. If such plans are based on an assessment that badly underestimates the numbers of people at risk and the timing for an evacuation, many people could be placed in serious jeopardy by reacting too late and with too few resources. Conversely, if the estimates are too conservative, large numbers of people who did not need to be evacuated could easily overwhelm evacuation resources and shelters.

(Granger and Hayne, 2001)

<u>Comment</u>: The detailed information provided to TCC as a result of the various hazard-specific studies can be used to produce threat-specific plans on which to base all aspects of the preparedness phase. They enable, for example, the development of disaster response and recovery plans for specific levels of storm tide or flood, well in advance of any event, and to use the scenarios on which they are based to run realistic exercises and training serials.

….Scenario modelling is also appropriate for rehearsing and planning for the recovery phase. There are examples in the literature of GIS being used to model the impact of a damaging earthquake and to forecast the requirements for short term and long term post-event shelter.

> *Similarly it is possible to model the physical impact on lifelines and the consequences of their loss on the community.*
>
> *Use of the scenario analysis technique develops 'future memory', i.e. disaster responders develop an understanding of what will happen when such an eventuality occurs so that their actions are based on 'experience' when it eventually does happen. This process could be reinforced by the development of role-play simulation 'games', such as SimCity, designed around real … urban centres.*

Observations: The practice that appears to be followed by the local emergency management community of activating the LDMG only in response to a significant emergency event greatly limits the experience of members (and member agencies) of managing a 'significant and coordinated multi-agency response'. Whilst the LDMG is activated in exercise situations, they are no substitute for being activated to manage real (albeit lower-level) events. The more frequent activation of the LDMG and the Local Disaster Coordination Centre (LDCC) would also greatly strengthen a culture of collective, multi-agency responsibility for emergency management.

***Generic strategy 22*: The LDMG consider activating the local LDCC in response to the more frequently occurring lower-level emergency situations to expand the experience of members and their agencies.**

All local governments in Queensland follow the classic PPRR approach to disaster management. It has been observed by several authors that they tend to focus largely on the second 'P' (prepare) and first 'R' (respond). The second 'R' (recovery) in particular tends to be left to other agencies. That approach leaves some significant gaps in the disaster management process. The most notable of these gaps are the lack of an infrastructure recovery sub-plan, a business recovery sub-plan and a community welfare sub-plan in many local disaster management plans. Development of model sub-plans by DES would provided LDMGs with appropriate guidance by which to better engage the important infrastructure, business and social welfare sectors of their communities more directly in the process and thus reinforce the holistic emergency risk management doctrine.

***Generic strategy 23*: The LDMG recommend to DES that model sub-plans be developed to provide guidance on planning for infrastructure recovery, business recovery and community welfare activities during and following an emergency.**

Major emergency impacts, such as a major cyclone or flood, inevitably give rise to the need to launch an appeal for public financial and other support, especially to assist households that are unable to cope financially with the impact. The coordination and administration of such appeals, if done poorly (as commonly happens), is a potential source of community outrage, and clear guidelines need to be established, based on the EMA manual *Economic and financial aspects of disaster recovery* (EMA, 2002).

***Generic strategy 24*: Council, through the LGAQ recommend to DES that it publish guidelines for the establishing, coordination and administration of public disaster appeals.**

Evacuation management is a key function of the emergency management process, whether it is ahead of a likely impact to 'safe haven' locations, or to shelter or welfare centres following an impact. The procedures for evacuation are detailed in the local disaster management plan. The role of evacuation in that process is described in the EMA *Evacuation planning* manual (EMA, 2005) as follows:

> *Evacuation is a risk management strategy which may be used as a means of mitigating the effects of an emergency or disaster on a community. It involves the movement of people to a safer location. However, to be effective it must be correctly planned and executed. The process of evacuation is usually considered to include the return of the affected community.*

It is essential to link considerations of evacuation with an understanding of the shelter that is required or is available, and the nature of the hazard involved. Evacuation and shelter are inextricably linked in the disaster/emergency risk management process. In essence there are three forms of evacuation-related shelter that may be required in a disaster or emergency.

Safe havens: shelter in which people can be kept safe while the hazard overwhelms their location. This type of shelter can range from the family home to purpose-built structures. In cyclones, for example, the safest option is for people to remain inside their homes so as to avoid the destructive winds and wind-driven debris outside. In a bushfire, it is safer to shelter inside the home rather than to be caught in the open as the fire front passes. In a toxic incident, it is safer to stay inside with closed doors and windows and shut-off air conditioning than to be outside in the hazardous atmosphere.

Under some circumstances, however, people may have to be evacuated to a safe haven because their regular shelter would be unsuitable as a refuge (e.g. in a caravan during a cyclone). As a general rule, however, **if people do not need to be moved they should not be moved.**

Relocation centres: shelter to which people can be moved to be out of harm's way ahead of or during a hazardous situation where the spatial extent (both horizontally and vertically) of that hazard impact can be adequately defined. Relocation may be required for only a few hours and could, in some circumstances, be undertaken within the same building (e.g. vertical evacuation ahead of a storm tide or flood); or the shelter used could require certain attributes (e.g. air conditioning and stand-by generators during a heatwave; kitchens and toilet facilities, etc). Under some circumstances, such as in major floods, relocation may be required for several days.

Recovery or welfare centres: shelter required to house people for an extended period after the hazard impact when their homes have become uninhabitable or isolated; or the local environment has been rendered unsafe to be rLDCCcupied. This is the type of shelter that would be required after a destructive earthquake, a major flood or cyclone, or as the result of the widespread failure of major infrastructure elements such as water and power supply.

The 'evacuation centre' locations within the study area provided by TCC to this study are virtually all public assets, most of them being schools. It is unlikely that such facilities would be suitable for most, if any, safe haven uses (they are not constructed to an adequate standard); relocation centres (very few have adequate air conditioning, toilet facilities or stand-by generators); or recovery centres (restoration of school activities should be a priority in the recovery stage). Some are also located within flood zones below the 100 year ARI level or would be difficult to access because surrounding roads are within the modelled flood zone.

***Generic strategy 25*: Before the onset of each cyclone season the LDMG should review and update the evacuation sub-plan of the Local Disaster Management Plan to take account of the risks identified in this study and to take account of best-practice evacuation planning methods.**

Perhaps the most difficult evacuation situation to plan for is that which involves retirement villages and aged care facilities. These facilities have concentrations of people with limited mobility, and in some cases people who will require medical assistance. They are, however, largely self-contained communities and the development of facility-specific emergency (and evacuation) plans can greatly enhance their resilience. The Maroochy SES Unit (now part of the Sunshine Coast Region SES Unit) developed an award-winning retirement village emergency planning process that is based on volunteer wardens in each village maintaining records of all residents and identifying those who would require assistance in the event of an emergency. The management of each village are also required to negotiate arrangements with 'sister' villages to provide emergency accommodate in the first instance.

***Generic strategy 26*: Townsville SES Unit investigate the development of a retirement village emergency and evacuation plan based on that operated by the Maroochy (Sunshine Coast Region) SES Unit.**

DES and the Department of Public Works have recently published a guideline on planning for evacuation and shelter for cyclone and storm tide impacts (DES & DPW, 2008). While this guideline has its limitations (e.g. it does not address evacuation ahead of floods) it does provide a base on which to develop evacuation plans.

The guideline does not provide any guidance on what types of buildings should be selected as public shelters or evacuation centres beyond stating that they should be constructed to provide protection from winds and debris (in the case of public shelters) and being suitable to provide temporary accommodation, food, water and sanitation. Prior to publication of the guideline Brisbane City Council had developed a sophisticated Internet-based evacuation centre management system that identifies mainly private properties (commonly sporting and social clubs) as being suitable for use in hazard-specific situations.

Notably, the Brisbane evacuation management system does not include schools. In some evacuation plans (including in Townsville) schools have been identified as being the first choice for an evacuation centre because they are public facilities and have lots of space. More modern thinking, however, exclude schools for several reasons, not least of which is that they will be needed to facilitate the recovery process by enabling children to return to school as soon as possible after a disaster to demonstrate that the community is returning to normal.

There are several software systems now available to assist in registering and tracking evacuees. One product (*Reg-evac* 2), produced by New Zealand company Resource Management Databases (RMD), has been acquired by a number of Australian local governments, including the former Maroochy Shire (now part of Sunshine Coast Regional Council), for to use for evacuation management, and a number of New Zealand local government Civil Defence units are also using it operationally.

***Generic strategy 27*: Council and the LDMG Welfare Committee examine the need and suitability of using 'off the shelf' software to support the registration and tracking of evacuees.**

5.2.7 Critical facility protection

> *The loss or isolation of critical facilities such as hospitals, airports, cold stores, fuel depots and emergency service facilities, will greatly magnify the impact of disaster on the community. Whilst such facilities remain exposed to disaster impact, plans to protect them are called for. Such protection may be as simple as ensuring the priority allocation of sandbags to the facility. It may be as routine as ensuring that the facility has an adequate uninterruptible power supply (UPS) or a stand-by generator with adequate fuel to cover the loss of reticulated power supply. Or it may embrace costly structural defences such as the construction of permanent protective berms or levees and the development of redundant capacity at other facilities to cope with the potential loss of one component in a critical system.*
>
> (Granger and Hayne, 2001)

Comment: The greater attention being given at National and State levels to critical infrastructure protection as a result of the perceived threat of terrorism should be exploited by those whose focus is on the far greater threat from natural hazards. For example, Templeman and Bergin (2008) observe:

> *The Critical Infrastructure Protection Modelling and Analysis Program (CIPMA) is an initiative of the Attorney-General's Department, working with CSIRO and Geoscience Australia, to protect critical infrastructure through modelling and simulating the dependency relationships of critical infrastructure systems. It provides an opportunity for owners and operators to understand interdependencies with other sectors and identify risks to the resilience of infrastructure.*
>
> *CIPMA has, however, focused mainly to date on terrorism risk. It should be regarded much more as a cost-benefit tool to enhance business resilience across the spectrum of risks. There is a tendency for business to view CIPMA only as part of the counter-terrorism world, not part of the world of enterprise risk management or broader economic security: that's the context in which the feedback should be provided to business. More could be done to make the information available to business in a useable form, even if it is sanitised and provided in a secure way.*

The future development of critical infrastructure, such as the Townsville port development and its associated road and rail access corridor should be designed with the present and potential future hazard environment in mind. It is important that all critical infrastructure, be it owned by public or private enterprises should have a degree of resilience that guarantees its availability during and after a disaster impact of at least a 500 year ARI level. Council may need to vigorously lobby the developers of such projects to ensure that community safety carries as much weight in the design process as does cost. The strength of Council's voice in these matters would be strengthened by establishing an ongoing dialogue with the proprietors of all public and private critical infrastructure facilities.

Geoscience Australia may be able to provide technical guidance on developing a critical infrastructure information system that is compatible with CIPMA.

***Generic strategy 28*: Council establish a dialogue with the public and private proprietors and operators of critical infrastructure to ensure that they understand their role in the local disaster management process and to encourage their support for the work of the LDMG.**

***Generic strategy 29*: The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.**

For effective response to and recovery from an emergency perhaps the most critical of all infrastructures is telecommunications. Both radio and telephone communications can be disrupted in a disaster. That disruption increases the vulnerability of victims because they cannot call for help; it also limits the response capacity of emergency workers. Under such circumstances it is beneficial to have a range of alternative networks such as that provided by volunteer radio operators of the Wireless Institute Civil Emergency Network (WICEN).

***Generic strategy 30*: The LDMG establish an arrangement with the local members of WICEN to provide communications support in the event of extended outages of telephone and other communications systems.**

5.3 TREATING SEVERE STORM RISKS

There is nothing that can be done to reduce thunderstorm or tropical cyclone hazards, nor is it possible to reduce exposure. Reducing the risks posed by severe storms, therefore, must rely largely on reducing vulnerability. The use of appropriate building design/construction standards and warning systems are the most effective strategies available.

5.3.1 Building design and construction

Advances made in wind resistant construction since the 1970s have resulted in improved building performance under wind loads. Houses built since 1982, or ones which have had their roofing systems upgraded to the new standards, should perform well under severe wind loads. Older buildings that have not been upgraded, and/or those that have been exposed to past severe wind episodes, will be more susceptible to damage.

In their oversight of construction standards, TCC applies the provisions of the *Building Act* and the *Building Code of Australia* (BCA), however, the vast majority of buildings in the study area were constructed before implementation of the wind loading code. Guidelines are available, however, for the retrofit of pre-code buildings to bring them up to modern wind resistant standards. Council could consider adopting these as regulations that make upgrade to modern standards mandatory for their own building assets and when any major renovation, alteration, addition or change of use is undertaken to private buildings. *SAA HB132.1* and *SAA HB132.2* (Standards Australia & ICA, 1999a and 1999b) contain recommendations for structural upgrade of dwellings for severe wind.

Responsibility for ensuring that construction conforms to the BCA wind loading standards is now vested in private certifiers rather than Councils. This 'reform' has greatly reduced the capacity of Councils to regulate and monitor construction standards. It has introduced the possibility of inconsistent construction standards depending on the training and professional competence of individual certifiers. This inconsistency could be greatly reduced by Council including in its planning scheme a 'wind loading' zoning map similar to that produced for Adelaide by Planning SA (1998) – reproduced in part in Figure 5.1.

The Planning SA zonation map also includes a 'corrosion line'. Under the SA Housing Code new construction within the 'corrosion line' requires elements such as straps, ties, screws, bolts and nails to be coated to resist corrosion from the salt-laden air close to the coast. These provisions are drawn from Table 3.3.3.1 of the BCA. A similar inclusion within the Townsville City Plan would make such a requirement more widely known by the general public.

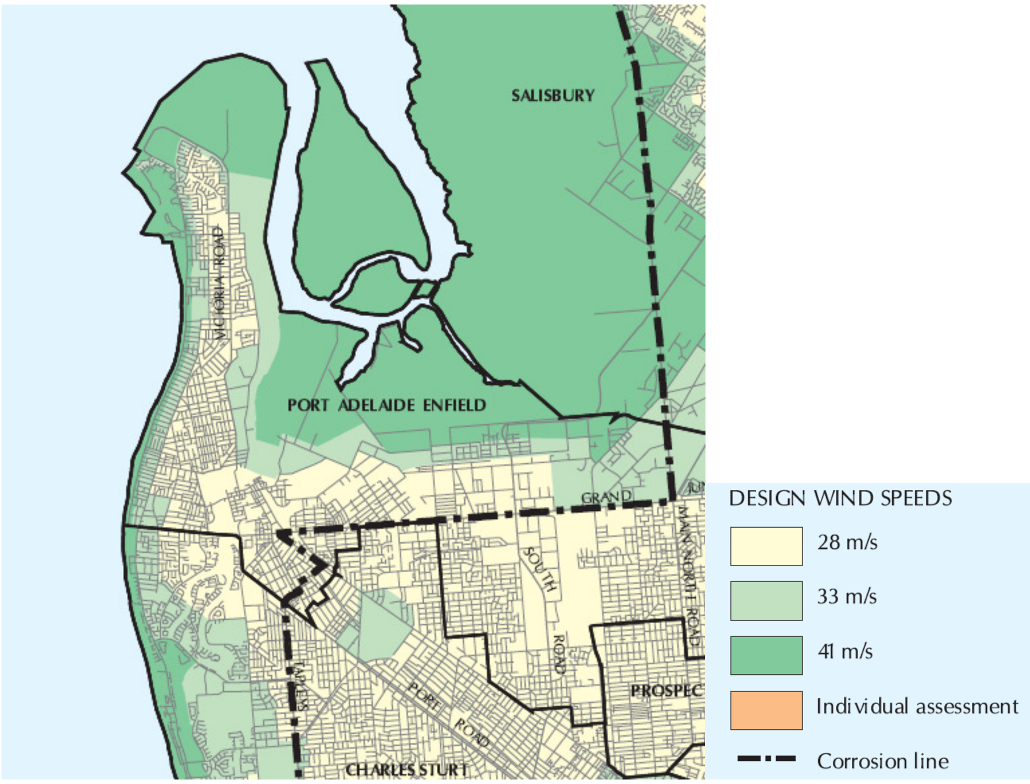

Figure 5.1: Port Adelaide Enfield wind-loading and corrosion zones (from Planning SA, 1998)

Historically, caravan parks tended to empty out well before the onset of the cyclone season. These centres are, however, increasingly taking on the role of low-cost residential centres with a large percentage of sites now permanently occupied. Caravans are very susceptible to damage, if not destruction, during severe winds and if not properly tied down they can become very large missiles. In comparable areas of Western Australia such as Port Hedland, all caravan parks have tie-down points incorporated into the concrete pads alongside each caravan site as shown in Figure 5.2.

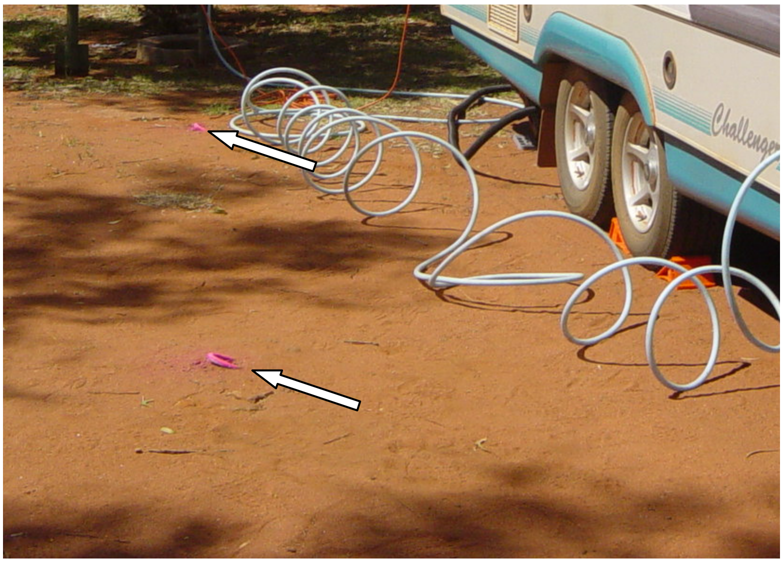

Figure 5.2: Caravan tie-down points Port Hedland (Western Australia)

5.3.2 Lifeline vulnerability

Above-ground infrastructure is clearly exposed to thunderstorm hazards including wind, lightning and hail. There is little that can be economically done to reduce this exposure or to strengthen its resilience in the short term. The placing of the power supply infrastructure underground progressively will, however, make that critical infrastructure significantly more resilient. Service providers should, however, take account of these risks when planning and equipping to undertake emergency repairs.

5.3.3 Warning systems

Some reduction to the overall losses from severe thunderstorms could be achieved if warnings of approaching storms could be provided in a timely fashion. The study area is well covered by the Mt Stuart weather radar operated by the BoM, however, even with that information, warning times may be short. An upgrade of the Mt Stuart radar to the modern Doppler technology would probably provide a marginal improvement on the warning time.

5.3.4 Treatment options for storm winds

***Storm treatment strategy 1*: Council maximise the likelihood that all new buildings conform with wind loading standards under the BCA by incorporating into the Townsville City Plan wind loading and corrosion line mapping based on the provisions of AS 1170.2-2002, AS 4550-2006 and BCA Table 3.3.3.1.**

***Storm treatment strategy 2*: Council encourage owners and builders to ensure that renovations and/or repairs to houses built before 1989 are upgraded to meet current wind code conditions in line with SAA HB1321 (SA & ICA, 1999a).**

***Storm treatment strategy 3*: Council run annual information sessions for private certifiers, builders and architects on the requirements of AS 1170.2 and the desirability of applying the retrofit strategies of HB1321.**

***Storm treatment strategy 4:* Council require operators of caravan parks to install tie down points for caravans and provide information to all caravan owners on caravan safety in high winds.**

***Storm treatment strategy 5*: Council establish a plan for the management of broken fibro and other asbestos-based products following storm damage. Identify appropriate disposal sites.**

***Storm treatment strategy 6*: Council continue to ensure that power supply in all new subdivisions is placed underground and establish a program with Ergon of placing power supply underground in areas of high exposure and/or frequent damage.**

5.4 TREATING FLOOD RISKS

It is not within the capacity of modern science and technology to have an impact on the flood hazard component. Flood risk reduction must, therefore, be achieved by affecting exposure and/or vulnerability. Reducing exposure is the approach most commonly adopted, with the planning process, building siting and design, warning systems and evacuations are the principal mediums used. Structural defences are also an option widely employed in NSW, for example, but are not as widely used in Queensland. Flood insurance is one of the few strategies available for reducing vulnerability to stormwater surcharge impact though insurance cover for riverine (and possibly flash) flood may not be available.

5.4.1 The planning process

Preventing inappropriate development in a floodplain is a very effective strategy by which to prevent the growth of <u>future</u> risks. In most circumstances, however, it can, by itself, have only limited impact on established development. Reducing exposure of existing development typically requires construction of works such as levees, detention basins, drainage systems and vegetation management, and/or the modification or relocation of existing structures. It may also be appropriate for the more flood-prone properties to be purchased by public authorities and the occupants relocated to flood-free property.

The planning process is now guided by SPP 1/03 (DLGP/DES, 2003a) which requires local governments to establish a 'natural hazard management area (flood)' for a 'Defined Flood Event'[3] (DFE) in their planning schemes under the *Integrated Planning Act*. Paragraph A3.2 of Annex 3 (p16) of SPP 1/03 states:

> *The Queensland Government's position is that, generally, the appropriate flood event for determining a natural hazard management area (flood) is the 1% Annual Exceedence Probability (AEP) flood. However, it may be appropriate to adopt a different DFE depending on the circumstances of individual localities. This is a matter that should be reviewed when preparing or undertaking relevant amendments to a planning scheme. Local governments proposing to adopt a lower DFE in their planning schemes to determine a natural hazard management area (flood) for a particular locality will be expected to demonstrate to the satisfaction of the Department of Emergency Services (DES) and the Department of Natural Resources and Mines (NR&M) that the proposed DFE is appropriate to the circumstances of the locality.*

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[3] Defined in SPP 1/03 as: 'the flood event adopted by a local government for the management of development in a particular locality. The DFE is rarely the full extent of flood-prone land.'

A footnote to this paragraph amplifies its advice as follows:

> *Local Governments are encouraged to adopt a DFE and identify natural hazard management areas (flood) in a planning scheme as soon as possible to enable the application of the SPP to development in flood prone areas.*

TCC has established the 100-year ARI level as their DFE for planning purposes, though this has only been increased from the 50 year ARI level very recently.

Appendix 2 of the Guidelines to SPP 1/03 (DLGP/DES, 2003b) provides guidance on the key issues to be considered when determining an appropriate DFE, including taking into account climate change. It is important to note that the Guidelines state that '*current best practice in floodplain management calls for an understanding of the full range of floods possible – up to and including the PMF* (the probable maximum flood)' (DLGP/DES, 2003b, A2.18). Modelling of the study area has been undertaken to the PMF level, however, its value, especially in the planning process, is somewhat questionable.

None-the-less, hydrological and hydraulic modelling of flood events with ARI beyond the 100 year range <u>are</u> required for the planning process when considering the siting of 'community infrastructure'[15] where longer ARI thresholds are required. Appendix 9 of the Guidelines state, for example, that hospitals, emergency service facilities and major power infrastructure should be able to function effectively during and immediately following a flood with an ARI of 500 years, whilst police facilities, valuable document archives and emergency shelters should be able to function at flood levels with an ARI of 200 years.

Such modelling is costly and needs to be underpinned by a DEM with a vertical accuracy that is appropriate to the sites being investigated. SPP 1/03 does not provide guidance on an appropriate vertical resolution, but the more recent Coastal Management Plan recommends a minimum vertical resolution of 0.25 m for modelling storm tide inundation. It may be appropriate for a resolution of 10 cm or better to be used in high-value existing or proposed urban areas. It is also important that inundation modelling be regularly revised to reflect changes in catchment land use and advances in modelling techniques.

It is important that flood modelling be reviewed and where necessary updated at least every five years to take account of new and/or proposed developments. Updates should also take account of the latest forecasts of climate change-caused sea level rise and changes to estimates of rainfall intensity and recurrence.

A program of collecting oral histories from residents who experienced these and earlier events and relating that material with attributes such as flood depth and duration of inundation, would also greatly enhance subsequent modelling and be valuable input to community awareness programs. Should a major flood event occur, every opportunity should be taken to gather accurate information on the behaviour of the flood. GPS measurements on the ground would provide the level of control that would

[15] Facilities that 'provide services that are vital to the wellbeing of the community' (see DLGP/DES, 2003a Appendix 1). The types of facility listed are essentially the same as those are now referred to as 'critical infrastructure'.

provide accuracies of a few metres, if not better. Implementation of such a data capture and analysis effort would, however, need to have been planned and resources identified well in advance.

5.4.2 Structural defences

For many years the most common response to a known or perceived flood threat has been to build defences such as levees, drainage works or detention basins. These defences are normally designed to provide flood immunity to a stated historic or modelled level of event that represents an 'accepted' level of risk. Structural defences are very effective at reducing risks posed by the more common levels of flood inundation. They can, however, engender a false sense of security. It is not uncommon for communities to adopt the attitude that because there is a levee, then all flood risks, regardless of stage height, have been eliminated. This can produce a false sense of security that will magnify residual risks if the levee is overtopped or if it fails, as happened in the NSW town of Nyngan in 1996.

In estuarine area such as the lower Ross River, levees can exacerbate stormwater surcharge where the storm water system is impeded by the flow of the main stream and backs up behind the levee. This proved to be the cause of major flood loss in Mackay in 2008.

The recent upgrade of the Ross River Dam, including the installation of flood gates, has been designed to reduce the threat of dam failure and to better manage the flow of flood waters downstream. The impact of those changes on the flood regime downstream is yet to be analysed so as to update the flood mapping employed in this study. The operators of the Ross River Dam (NQ Water) have also been amalgamated with the New Townsville City Council so it should be possible for the operating procedures that they have developed for managing flows through the dam to be incorporated into the local disaster management plan.

When considering structural defences it is also essential that 'escape' strategies also be considered such as identifying flood-free localities to which people could be evacuated before the levee fails.

5.4.3 Building siting and design

In planning schemes that have established '*natural hazard management areas (flood)*', exposure reduction is achieved through establishing <u>minimum</u> ground height and floor height levels above the DFE level. In areas not covered by a planning scheme, as in the rural sections of the study area, it is left to the building owner to incorporate strategies to minimise flood inundation by either siting their buildings on land that is thought to be flood-free (based on local knowledge of flood history), by constructing buildings on elevated mounds and/or constructing buildings on piles that elevate floor levels. In areas where flood velocities may pose an additional problem, building designs typically leave the ground level components open so that flood waters can flow through under the house with minimal resistance.

Many of the houses constructed in the study area before the mid-to-late 1980s were constructed with floor levels generally 0.5 to 0.8 m and up to 3 m above ground level. More modern houses, however, have adopted slab-on-ground forms of construction which provides minimal immunity if sited in flood-prone areas. Many of the older high-set dwellings, however, have had the under-house area filled in to provide additional accommodation or other domestic uses, effectively converting them to slab-on-ground dwellings.

Older houses tend to be less susceptible to damage if inundated because of the materials used. Homes in this category tend to have both external and internal walls, as well as fittings such as kitchen cupboards, of solid timber. Such material is quite resilient to inundation. More modern homes, by contrast, have plaster board internal walls and cupboards of chipboard, both of which materials suffer significant damage if inundated, especially if inundation lasts for more than a day.

5.4.4 Warning systems

Flood warning is an integral component of emergency management arrangements for a community at risk from flooding. The aim of a warning system is to minimise loss of life and property damage by warning people of the likelihood and size of a flood so that they can evacuate, shift property or stock to higher ground, or implement other temporary flood loss reduction measures, that is, by reducing the level of their exposure to the hazard. Warnings are of limited value unless they are delivered in a timely and effective manner and property owners and residents in the flood-threatened area have trust in the warning and take appropriate action in advance of being flooded. Figure 5.3 shows how experience and effective warnings can greatly reduce flood damage.

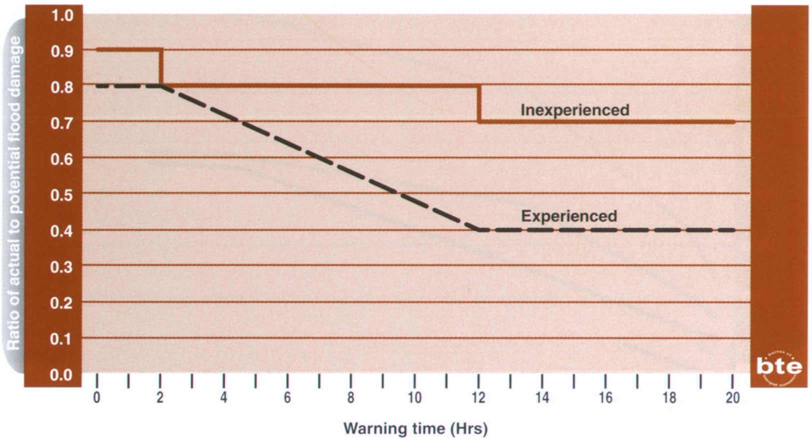


Figure 5.3: Affect of experience and warning time on actual flood damages (BTE, 2001).

The responsibility for flood forecasting and warning services in Australia rests with the BoM. In Queensland, the effectiveness of the flood warning system depends on the cooperative involvement of the BoM, State Government agencies and Local Government working with flood-threatened communities. The roles and relationships of the various agencies involved are outlined in Figure 5.4.

These flood warning services provide:

- river height bulletins which contain the latest observed river heights at selected locations within a catchment and are issued up to six times daily;
- flood warnings, which provide a summary of existing conditions within a catchment and predictions of river heights at key locations (towns, bridges, rural centres).
- professional advice and assessments of flood conditions to emergency agencies and local government officials;
- media briefings of radio, television and newspaper news services.

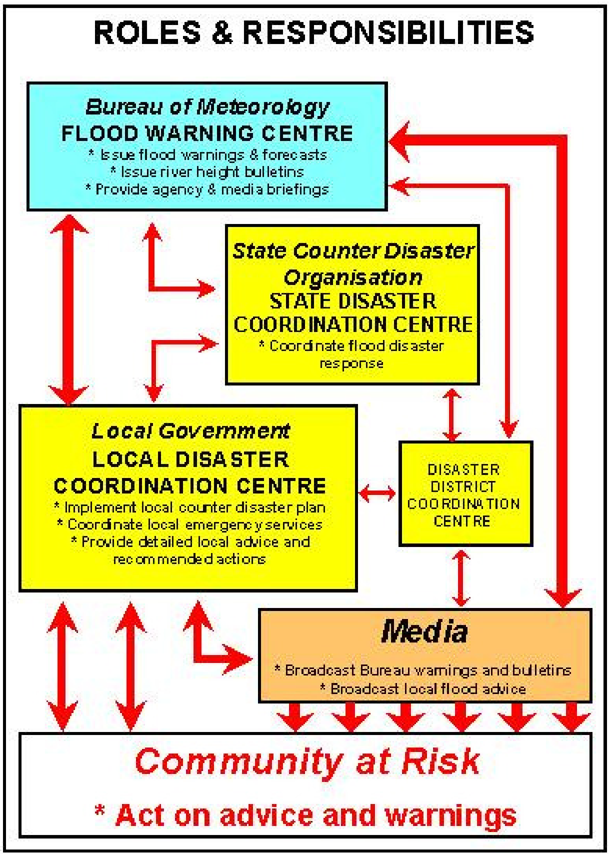


Figure 5.4: Roles and responsibilities within the flood warning system

The formal flood warning system relies on data from automatic weather recording stations and stream gauges, and reports from observers in the field. These data are incorporated into hydrological and hydraulic models of river behaviour to produce the forecasts included in the bulletins and warnings. Warnings are given as estimated stage heights likely to be reached within a given time frame. Effective use of this information, however, requires community members to be able to translate stage heights to flood heights on their own properties. In rural areas at least, most residents are experienced in making those translations and act accordingly. It is unlikely that urban dwellers have the same knowledge and scope exists for Council to incorporate such information in their community education work. An informal warning network also operates with property holders along the rivers keeping their neighbours, police and Council officers informed of actual flood behaviour and its impact (e.g. by reporting road closures).

Figure 5.3 shows the benefits if a longer warning time, however, in flash flood, storm water surcharge and other sudden-onset inundation such as dambreak flooding, a formal warning may not be possible. In those circumstances other means of alerting people at risk, such as sirens, may be required. The operation of flood gates on the Ross River dam which is in close proximity to developed property, for example, may need to be accompanied by such a warning system.

5.4.5 Movement in floodwaters

Many of the roads in the study area are susceptible to closure by flood waters. This will cause difficulties where people in isolated areas need to be evacuated, either for medical or other emergency reasons, or because their extended isolation poses an unacceptable risk. The depth and velocity of water are the critical determinants of trafficability as summarised in Table 5.2.

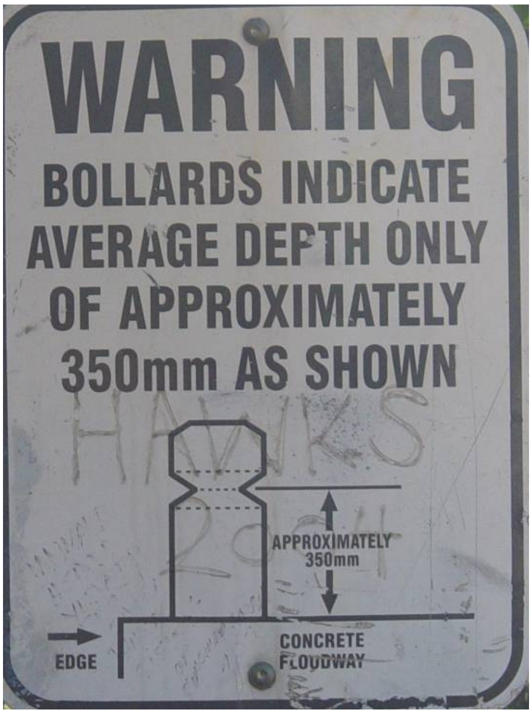
Where it can be anticipated that people in isolated areas will probably require evacuation in the event of a flood, for example, ladies at an advanced stage of pregnancy or people who rely on medical support such as home dialysis, precautionary evacuation before roads begin to go under water is preferable. Such vulnerable people should be identified and their details maintained by emergency managers with the assistance of local medical practitioners.

Table 5.2: Description of flood hazard categories (based on SCARM, 2000)

Hazard Category	Description
Low	If necessary, children and elderly people could wade to safety with little effort. Maximum flood depths and velocities along evacuation routes are low. Evacuation distances are short. Evacuation is possible by sedan-type cars or small vehicles. Ample time for flood forecasting, flood warning and evacuation. Evacuation routes remain trafficable for at least twice as long as the time required for evacuation.
Medium	Fit adults can wade to safety, but children and the elderly may have difficulty. Maximum flood depths and velocities are high. Evacuation routes are longer. Evacuation by sedan-type vehicle is possible in early stages, after which 4WD vehicles or trucks are required. Evacuation routes remain trafficable for 1.5 times as long as the time required for evacuation.
High	Fit adults have difficulty in wading to safety. Maximum flood depths and velocities are high (up to 1m and 1.5m/s) respectively. Evacuation is possible by 4WD or truck only in early stages of flooding. After this, boats or helicopters are required. Evacuation routes remain trafficable only up to the minimum evacuation time.
Extreme	Wading to safety is not an option due to rate of rise and velocity of floodwaters. Boats and helicopters are required for evacuation. Maximum flood depths and velocities are greater than 1m and 1.5m/s respectively.

Most fatalities in floods occur when people attempt to drive or wade across flooded waterways. The most immediate response to a developing flood threat is, therefore, to close those roads that are unsafe for traffic. Given the large number of low level bridges and flood-ways on the study area's roads it may not be possible for the SES and Council workers to staff all closure points. At the more frequently closed or remote crossings it may be worth considering the installation of automatic systems of booms and lights that can be remotely activated by emergency managers or become active when water reaches a given level.

As indicated in Table 5.2, water depth alone is not a good indicator of the risk involved in crossing flooded waterways – velocity is also critical. Depth indicators, however, are generally the only warning signs that are in common use. It may be worth exploring appropriate techniques, such as the bollards used extensively on low-level crossings in Western Australia and shown in Figure 5.5, for indicating the hazard more effectively taking account of the water velocity.



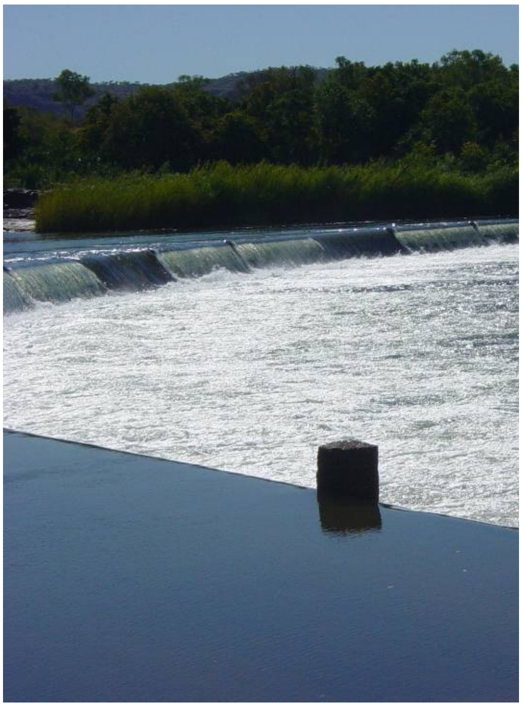


Figure 5.5: Flood depth and velocity warning bollards used in Western Australia

Council may also need to consider keeping some roads closed to traffic, especially by heavy vehicles, until the road surface and foundation has dried out adequately so as to avoid exacerbating damage.

5.4.6 Flood insurance

Until recently, flood insurance was available only for commercial premises and rural industries. It was not readily available for residential properties. This situation is changing due in part by public and political pressure on the insurance industry (see, for example, the papers contained in Smith and Handmer, 2002). Major insurers operating in Queensland now offer domestic flood insurance, typically as an option that attracts an additional premium. Suncorp, for example, offers such an option, but it is not available in areas where '*accurate, historical flood risk information is not available*' or where '*the risk of flooding is so high that we are not prepared to offer flood cover as an option*' (Suncorp, 2003).

5.4.7 Funding sources

EMA now administers the Natural Disaster Mitigation Program (NDMP) which incorporates the former Regional Flood Mitigation Programme (RFMP). Under this program funds are (according to the EMA web site) available for flood mitigation measures that:

- *protect the community and its existing infrastructure*
- *promoted community safety, and*
- *reduced the loss of life and property damage.*

This program was previously administered by the Department of Transport and Regional Development (DoTARS).

5.4.8 Flood treatment strategies

***Flood treatment strategy 1*: Council review the detailed flood risk treatment strategies identified by consultants Maunsell Australia in their 2005 report for inclusion in a new City floodplain management strategy.**

***Flood treatment strategy 2*: Council establish a rolling program to review and update flood modelling at ten or preferably five-year intervals, in urban areas and rural areas where significant development is planned to take place. Continue research and computerised flood impact modelling to support emergency management planning and operations.**

***Flood treatment strategy 3:* Council investigate the need to undertake an updated flood management study to take account of the upgrade of the Ross River Dam and to incorporate the NQ Water operational procedures for managing flows through the dam into the Local Disaster Management Plan.**

***Flood treatment strategy 4:* If indicated by the outcomes of *Flood strategy 3* Council investigate the installation of a siren warning system for properties immediately downstream of the dam to be used when flood waters are to be released from the dam.**

***Flood treatment strategy 5*: LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.**

***Flood treatment strategy 6*: Council records flood inundation information from major events in order to build up a database of records that can be used in responding to future flood events in flood prone areas.**

***Flood treatment strategy 7*: Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.**

5.5 TREATING STORM TIDE RISKS

It is not possible to reduce the hazard posed by storm tide, and vulnerability is difficult to influence in existing properties. Treating exposure must consequently be the main focus. For the most part, storm tide, including wave setup, will only cause environmental damage along the coastline at low recurrence intervals but intrusion into developed areas will undoubtedly occur with events with severity that would be experienced with ARI of less than 100-years.

5.5.1 Hazard mapping

The storm tide modelling of the study area is of a high standard. The on-shore impact modelling, however, could be improved. The on-shore modelling should seamlessly integrate the off-shore surge modelling, near-shore wave set up and onshore inundation (including depth limited wind waves), rather than the more common approach of modelling the event up to the shoreline using one model, then projecting that level on-shore with a different type of modelling technique.

The State Coastal Management Plan recommends a minimum vertical resolution of 0.25 m for the on-shore DEM used in such modelling. In high-value urban areas it may be appropriate to increase that resolution to 0.1 m.

Modelling should be reviewed and updated at least every five years to take account of proposed development and climate change-influenced sea level rise and the likely changes to cyclone recurrence and intensities.

5.5.2 Evacuations

Most of the evacuation strategies identified above to treat flood risks are relevant in treating storm tide risk, though storm tide inundation is usually a threat for only six or seven hours – that is, until the next low tide. Given this relatively short duration of inundation, shelter-in-place may be an effective response where the depth of inundation is unlikely to exceed one metre depth above floor level. Most modern residential buildings are likely to be able to withstand that depth of storm tide inundation.

If an evacuation is required, particularly of elderly or incapacitated residents, it must be completed well in advance of the cyclone crossing the coast given that the full force of destructive winds will start to be experienced up to 12 hours before the eye (and storm surge) reaches the coast. Movement outside in winds with a velocity of greater than 75 km/h by anyone, including emergency workers, should not be attempted.

A house-to-house door-knock of the relatively small number of properties that are likely to be affected would be the most appropriate way to disseminate a specific warning and to advise of evacuations.

5.5.3 Structural defences

It should be noted here that, during periods of active erosion of beaches and dunes, there is often pressure placed upon councils and other agencies (such as the SES) to carry out inappropriate and environmentally-deleterious ‘mitigation’ measures such as dumping rocks and old car bodies in at-risk locations (for example, in front of houses). Typically there is little time to consider the full implications of such measures, which may actually exacerbate the erosion in areas immediately adjacent to the material dumped, possibly leading later to litigation from the owners of property which was not protected.

The design and construction of sea wall defences should be undertaken only after careful engineering and environmental impact considerations have taken place.

5.5.4 Warnings

Warnings of potential storm tide impact will normally be included as part of the BoM’s severe weather warning covering the generating storm. The nature of the warnings is detailed in the *Storm tide warning-response system* manual (SCDO and BoM, 2006).

It is critical that the community be kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. It is important that the media be kept fully engaged in this process so that they provide positive support rather than become a source of ill-informed criticism of response activities.

5.5.5 Storm tide treatment strategies

***Storm tide treatment strategy 1*: Council establish a rolling program to review and update storm tide modelling at ten or preferably five-year intervals. Continue research and computerised inundation impact modelling to support emergency management planning and operations.**

***Storm tide treatment strategy 2*: The LDMG establish a program to encourage residents in potentially exposed locations to develop household emergency response plans for storm tide based on the existing modelling and storm tide warning system.**

***Storm tide treatment strategy 3*: LDMG to maintain specific evacuation plans for communities in storm tide-prone areas such as Cungulla and parts of South Townsville based on scenarios developed from the modelling.**

5.6 TREATING LANDSLIDE RISK

As with flood and storm tide inundation, there is nothing that can realistically be done to prevent landslides happening. There is also little that can be done to reduce the vulnerability of people, buildings or infrastructure to landslide impact. That leaves reducing exposure as the only effective strategy. Here again, SPP 1/03 establishes performance criteria for development in landslide-prone areas and guidelines for defining '*natural hazard management area (landslide)*'.

5.6.1 Hazard mapping

The *natural hazard management area (landslide)* mapping undertaken by Coffey Geoscience (2001) conforms to industry best practice and has been incorporated into the Townsville City Plan. That mapping does not, however, cover the whole study area so some areas earmarked for future development may not yet be covered. The GIS staff of TCC would be able to undertake such modelling with some professional guidance from an external consultant experienced in landslide hazard modelling.

The steep slope study of Castle Hill clearly identifies the risks posed in that small area and those risks must be kept under ongoing review.

5.6.2 Existing development

Where development has already occurred in areas that may be prone to landslide, engineering mitigation measures on slopes may be indicated. These might include, where necessary and appropriate:

- adequate drainage;
- retaining walls;
- planting of trees;

- appropriate siting of buildings on properties; and
- construction of catch fences or diversion barriers.

Useful diagrams illustrating good and poor hillside practice are shown on page 8 of the booklet, *Guidelines for control of slope instability within the City of Gold Coast*, prepared by Gold Coast City Council and SMEC (GCCC/SMEC, 1999).

In areas identified as having a landslide risk that are serviced by reticulated water and sewerage services, Council should consider the replacement of the older pipe network materials, such as AC or unlined cast iron that could be easily damaged, with more resilient materials as part of its ongoing maintenance program.

The uncertainties that exist with the potential for a moderate, but close earthquake to cause rock on the steep slopes of Castle Hill to topple should be the subject of more thorough research.

5.6.3 Public information

It may be appropriate and advisable for Council to inform the owners of those properties that lie within the higher hazard areas defined by the general landslide mapping and the steep slope hazard study of that fact. Council might also consider attaching a notice to the rates records of that fact to ensure that any prospective purchaser of such properties is aware of the hazard. They could also be encouraged, or in some instances required, to seek detailed site specific assessments and follow any professional geotechnical advice that might follow such an assessment.

5.6.4 Response advice

The risks posed by landslides also exist in the clean-up stage. There have been several fatalities in Australia caused by people attempting to clear a landslide and bringing more material down on themselves in the process. One such fatality occurred on the Paluma Road in 1998. It would be advisable for Council to prepare and keep current a list of local geotechnical specialists and other relevant people who can be contacted, day or night, to be available at short notice to give on-site advice in the event of a landslide emergency.

5.6.5 Warnings

There are currently no dedicated warning systems for landslide hazards in Queensland. The BoM may include a comment on the possibility of landslides during intense rainfall events such as tropical cyclones, but this is not a standard or consistent inclusion in such public warnings. Council might consider, in liaison with the LGAQ, an approach to the BoM to include specific landslide warnings when rainfall intensities approach levels that could give rise to landslides.

5.6.6 Landslide treatment strategies

***Landslide treatment strategy 1*: Stabilise potentially problematic batters or slopes on Council-controlled roads, or erect protective structures (such as mesh fences or bunds) and encourage DMR to undertake similar work on State-controlled roads.**

Landslide strategy 2: **Given the uncertainty that exists regarding the potential risks posed by rock falls from Castle Hill being initiated by a close earthquake of moderate or greater magnitude, Council, in conjunction with relevant State agencies, commission specific research to establish an appropriate management strategy.**

Landslide treatment strategy 3**: Council maintain an ongoing community education program warning about rock falls from Castle Hill and landslides from other steep slope areas such as Mount Louisa.**

Landslide strategy 4: **Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.**

Landslide strategy 5: **Council investigate technical options for monitoring areas of Castle Hill that have been identified as posing a particular threat from rock falls from steep rock cliffs.**

Landslide strategy 6: **Council establish a MOU with the State government as to their potential liability should major damage or injury result from a rock fall or landslide from Council-managed State land on Castle Hill.**

Landslide strategy 7: **Council commission City-wide landslide hazard potential mapping to SPP 1/03 standard. Council's GIS staff could undertake most of the work with guidance from an external consultant.**

Landslide strategy 8: **Incorporate the updated landslide potential hazard mapping done to SPP 1/03 standard into the new Townsville City Plan.**

5.7 TREATING BUSHFIRE RISK

Unlike the other hazards dealt with in this report, there are easily implemented strategies available by which to reduce the hazard, as well as strategies to reduce both exposure and vulnerability.

5.7.1 Managing the hazard

The bushfire hazard can be managed by reducing the fuel and by reducing the possibility of ignition occurring. The objective of fuel management is to mitigate fire risk by reducing fire intensity and spread (if there is no fuel there is no fire). Its objective is not, and cannot be, to eliminate fire. Whilst the priority in risk reduction is the protection of life and property, the management of fuel, particularly by prescribed burning, should be done in such a way as to have a minimal negative impact on biodiversity. There are two recognised forms of fire management to preserve biodiversity, namely:

- prescribed burning on a rotational basis to reduce fuel loads to an acceptable level, that is, burning carried out under selected conditions such that the fire will burn a predetermined amount of vegetation within predetermined boundaries. This method is generally used to reduce fuel throughout large areas; and,

- site-specific mechanical control such as slashing, hand removal of fuel and/or use of herbicides to remove growth. This technique is only viable in smaller sites, generally to establish fire-lines, or along roads and tracks.

In areas in which the preservation of biodiversity is less of a concern, two additional forms of fuel management can also be employed:

- grazing by stock in appropriate numbers to keep vegetation at a desired level. This can be effective across wide areas; and,
- the planting of low flammability species to protect built structures and fire sensitive vegetation types by creating a barrier to catch sparks and embers, and to shield them from radiant heat (so-called 'green fire breaks').

It is the responsibility of the land owner and/or land controller to manage the fire hazard on their land in a 'responsible manner'. Section 69 of the *Fire and Rescue Service Act* 1990 requires land owners to take measures to reduce the risk of fire and, in the event of a fire, the danger to persons, property and the environment through, *inter alia*:

- the maintenance or making of firebreaks;
- the removal of vegetation;
- the obtaining of fire fighting equipment;
- the provision of an adequate water supply;
- the suspension of operations.

The objective of fuel management should be to prevent any fire that may start on their land to spread beyond their boundaries.

The bushfire hazard can also be reduced by minimising the incidence of ignition. Whilst there is nothing that can be done to prevent lightning strike starting fires, there are strategies available to reduce the incidence of human-produced causes.

Fire weather warnings: When fire weather conditions become extreme (i.e. a combination of existing and forecast weather conditions, and estimates of fuel loads), under the Commonwealth *Meteorology Act*, the Severe Weather Section of the BoM's Regional Office in Brisbane is <u>required</u> to issue a public Fire Weather Warning. Where such a warning is issued, it is usual practice for a local fire ban to be declared over the areas likely to be affected.

Fire bans and states of fire emergency: Part 8 of the *Fire and Rescue Service Act 1990* provides the legislative base for the declaration of local fire bans (Division 1) and states of fire emergency (Division 2). Fire bans may be imposed by the Fire and Rescue Service Commissioner over an entire local government area, or part thereof, and will prohibit the lighting of all, or only certain types of fires. The duration of a local fire ban may not exceed 14 days and may be cancelled at any time after its declaration by the Commissioner. The declaration of a local fire ban revokes the authority of fire wardens and other authorities to issue permits to light fires.

A declaration of a state of fire emergency may be made by the Commissioner, with the approval of the Minister for Emergency Services, across the whole State or part thereof. It can impose restrictions on the lighting of fires similar to those in a local ban, but gives the Commissioner more flexibility in their application. The most important power given under a state of fire emergency is that the Commissioner may *"…requisition premises, plant, equipment, materials or substances for fire fighting or fire prevention."*

These legal provisions impose criminal sanctions to the lighting of fires during periods of significant and identified high fire threat. These usually relate to periods when episodes of fire weather are forecast or when unusual fuel conditions exist, e.g. after a cyclone has brought down large volumes of fuel.

Permits to burn: Section 65 of the *Fire and Rescue Service Act* establishes a system of 'permits to burn'. Under this section, a landholder wanting to light a fire greater than two metres on a side must apply either orally or in writing to their local fire warden. In making application information on: the land on which the fire will be lit; the names of all neighbouring landholders; the steps taken to notify every occupier of adjoining land of the intention to light the fire; and whether any of those adjacent occupiers has objected to the lighting of fire and the reasons for that objection, must be provided to the fire warden.

The 'permits to burn' system is aimed at managing the responsible use of fires as a land management tool in rural areas. Its successful application relies heavily on the experience and knowledge of the local fire warden.

Criminal sanctions: The *Fire and Rescue Service Act* (Sections 62 and 149) provides for fines or imprisonment for a range of offences, especially related to the lighting of fires without a permit. It also makes provision for offenders to be made responsible for costs associated with any fire that was lit without a permit. Arson is a crime under the Queensland *Criminal Code Act* and can carry a penalty of life imprisonment if it involves the destruction of a building or structure and 14 years if only involving vegetation.

Common law sanctions: Wright and Plumpton (1997) observe that '*the common law provides a number of courses of action in tort to persons who have suffered loss or damage as a result of bushfire'.* The common law claims most likely to arise in the context of bushfire are those relating to negligence or nuisance. A negligence action arises where there is a breach of duty of care, for example, to ensure that a fire lit on Council controlled land does not escape onto neighbouring land. Council is also responsible for preventing damage to lands under its control.

A nuisance action arises where the use of the land *'causes an unreasonable and substantial interference with a person's use or enjoyment of the land (private nuisance) or the right of the public at large to health, safety, property and equality of environment (public nuisance)* (Wright and Plumpton, 1997). Allowing the build up of flammable material and smoke from a fire may be considered as nuisance, if the person responsible has not taken reasonable steps to avoid or minimise the interference.

5.7.2 Managing the fire

The fire hazard can also be reduced by an effective response to a fire once it has started.

Detection and reporting: Experience has shown that the early detection of fire is essential if its spread, and impact, is to be minimised. In the study area, the detection of fire and its reporting to fire authorities depends largely on the vigilance and awareness of members of the public. An aware and informed public is, therefore, the best defence available. Awareness of the significance of fire smoke is greatest in rural areas. It is likely, however, that awareness is not as great amongst people living in urban areas; tourists are even less likely to be aware of the importance of reporting fires.

A critical element in a rapid response is in knowing where the fire is and how to get to it. This requires the availability of up-to-date and accurate maps, together with a spatial referencing system that is universally understood. Street, or rural road, address is by far the most widely used and understood form of spatial referencing available. TCC has implemented a rural road addressing process that generally conforms to the National standard for addressing. Allocating an address, however, is worthless unless the roads names and property addresses are adequately displayed, again, preferably in a standard form. Whilst signposting of most roads in the study area is excellent, there are some roads that are not signposted and the display of property number, in both rural and urban areas, is far from universal. This poses a significant problem for responding emergency services, especially those coming from out-of-area.

Fire Water: The application of water to both saturate and cool the fuel and to deny the fire oxygen is still the most effective means of fighting fire. Ready access to water is, therefore, essential for effective fire fighting. The urban areas of the study area are served with hydrants on the reticulated water supply mains. As long as there is water in the mains, these hydrants are available to be used directly for fire fighting or as a source to replenish the tanks of fire units. Hydrants can service up to 10 fire appliances at the one time. In rural areas, however, natural sources such as rivers and creeks, or developed sources such as dams and bores are relied on for fire water.

Under extended periods of dry weather or drought, the availability of water in dams and domestic tanks for fire fighting in areas not serviced by the reticulated water supply will inevitably be less than optimal. Landholders understandably will give priority to their own domestic requirements and their stock's need for water ahead of maintaining reserves for possible fire fighting.

Knowing where the available water is located is also important. A system of water mapping and the marking of water access points in rural areas would greatly aid in that process.

5.7.3 Managing exposure

Townsville City is amongst the local government areas specified in SPP 1/03 as required to take bushfire hazards into account in their planning process. The existing mapping by Trinity Software in 1999 does not meet the requirements of SPP 1/03. It is out of date, based on a superseded methodology and incomplete.

On established properties, managing exposure to bushfire is the responsibility of individual land owner and is best achieved by employing the fuel management strategies discussed above.

Evacuations: Where a severe fire is likely to threaten life, evacuation may be an appropriate strategy. This practice is, however, somewhat controversial and, if not properly managed, could place evacuees at greater risk than if they were permitted (or encouraged) to remain and protect their properties.

Section 8(d) of the *Public Safety Preservation Act* (PSPA) states that the police 'incident coordinator', following the declaration of an 'emergency situation', may:

a) direct the evacuation and exclusion of any person or persons from any premises and for this purpose may remove or cause to be removed (using such force as is necessary for the purpose) any person who does not comply with a direction to evacuate or any person who enters, attempts to enter or is found in or on any premises in respect of which a direction for the evacuation of persons has been given;
b) close or cause to be closed to traffic and pedestrians, any road, street, motorway, private road, private way, service lane, footway, right of way, access way or other way or close any place to which members of the public have access whether on payment of a fee or otherwise.

These are very sweeping powers indeed and may be enforced without reference to any other authority. In practice, however, close liaison is maintained between the QFRS (as the combat authority) and the police during a bushfire-based 'emergency situation' and police tend to act on the advice of the QFRS on-site commander. Where that advice is not available, however, it is standard operational procedure for the police to put the protection of life ahead of the protection of property, regardless of the individual circumstances. This can, and has, led to serious conflict, between police and landholders in the area affected, including the threat of arrest of landholders who have demanded to be allowed to defend their own property.

Role of radio and TV: Warning of the need to evacuate, or to take shelter, needs to be given as soon as possible. The experience of the residents of Canberra during the fire storm event there on 18 January 2003 provides a salutary example of inadequate warning, whilst the Sydney fires in early December 2002 provide a stark contrast. In Canberra there was little media coverage of the rapidly approaching fire threat other than over the local ABC station. On the day of the fire (a Saturday), TV coverage was concentrated on the Australian Open Tennis and other sporting events, however, no messages about the fire were provided via the 'crawler' message system used to intrude local messages without breaking into a program controlled from Sydney or Melbourne. Many people, especially elderly folk, had closed themselves into their houses to avoid the heat and smoke. Those who watched the TV were completely unaware of the approaching fire until warned by a police door-knock or by neighbours. The disruption of power supply, that accompanied the fire, cut off the excellent support provided by ABC local radio in the many households that did not have a battery-powered radio. Some people even resorted to using their car radios to keep themselves informed. Canberra was a demonstrably unprepared community.

During the Sydney fires in December 2002, by contrast, the media kept the community extremely well informed of the progress of the fires and their impact on the transport network. Talk-back radio proved to be an excellent forum for people to provide up-to-date first-hand reporting on fire outbreaks, road closures and so on. This intelligence greatly enhanced that being acquired by fire authorities and added significantly to the generally successful fire fighting effort. Given their experience of severe fires in the previous Christmas period, the Sydney community was a very aware community and the Sydney media very much attuned to fulfilling their community information role.

Townsville does have locally based TV and radio stations to provide appropriate, timely and locally-relevant public information during such an emergency. It may be appropriate for Council to work towards employing the local TV stations and local community radio as primary media for broadcasting warnings or advisory messages during a fire emergency.

The COAG bushfire report (Ellis, Kanowski and Whelan, 2004) includes the following recommendation (7.1) that has been endorsed by all States and Territory governments:

> *The Inquiry recommends that each state and territory formalise non-exclusive agreements with the Australian Broadcasting Commission as the official emergency broadcaster, providing an assured standing arrangement. Similar protocols with commercial networks and local media should also be established.*

Such an agreement was established between QFRS and the ABC in Queensland in early 2005.

SEWS and sirens: The Canberra experience has highlighted the need to provide a range of methods by which to communicate warnings of approaching fires. SEWS (the Standard Emergency Warning Signal) can be used to draw attention to urgent official emergency warning notices. Its use may only be authorised by the BoM (in the case of cyclones) or designated emergency management officials. Its success, however, depends on people being tuned in to radio or TV and understanding its significance. SEWS was used in Canberra but very few people understood its significance.

Safe havens: In some areas where evacuation routes can be cut by rapidly developing fires and/or the numbers of people potentially at risk is large and especially susceptible consideration might be given to the construction of 'safe havens'. These are structures in which people can take refuge during the critical few minutes when the fire front envelopes the area. Existing buildings can be made 'safe havens' by the installation of sprinkler systems, window shutters and so on. Once the fire front passes the sheltering people can rapidly return to defend their properties. In the more isolated homesteads, smaller-scale refuges might also be considered as shelter of last resort.

5.7.4 Reducing vulnerability

To re-state the emergency services adage – *an aware community is a prepared community*. A clear understanding of the risks being faced, and strategies by which to minimise their affect on individuals, families and households, has been demonstrated many time over to add greatly to community safety. Given that serious bushfire in the study area is a relatively infrequent event, maintaining an appropriate level of bushfire awareness is clearly a challenge.

A significant number of avoidable injuries are incurred by untrained and inexperienced people defending their own properties from bushfire attack. These injuries can be reduced by following simple guidelines, for example, wearing cover-all clothing of natural fibres (wool or cotton) and wearing eye, breathing and head protection. Working from exposed positions such as roof tops and under trees or power lines should also be avoided.

The media, especially the electronic media, have an important role to play in both supporting community awareness programs, in addition to their role of providing essential information during a bushfire disaster as discussed above.

Design and siting of buildings: The resilience of buildings and other structures constructed within fire-prone areas can be maximised by following the design guidelines contained in Australian Standard AS 3959-1999 *Building in bushfire prone areas* (Standards Australia, 1999). This Standard applies only to residential buildings (Classes 1, 2 and 3 of the Building Code of Australia). The fire-resisting construction measures of AS 3959 only lessen the risk of property damage and hence the risk to life, and then only if there is an adequate separation distance from a potential fire front. (NOTE: AS 3959 has been under review for several years and at least two amendments have been issued but a new version is still anticipated.)

Construction to AS 3959 standards is a significant improvement over some construction methods and designs employed before its introduction. There are certainly homes built in areas of high bushfire hazard that fall well below current standards of fire-resistance. It is clearly in the interests of owners and occupiers of such buildings to bring them up to current standards.

A detailed explanation of the construction and siting principles was produced jointly by CSIRO and Standards Australia to accompany the publication of the first edition of AS 3959 in 1993. This advisory publication (CSIRO/SA, 1993) should be referred to by everyone who has a responsibility for the development, siting and construction of residential properties in bushfire-prone areas. If these principles and standards are conformed with, then buildings constructed in bushfire prone land will be significantly more resilient to bushfire attack than will buildings that do not follow these principles.

Building and site maintenance: It is essential that buildings and their surrounds in bushfire-prone areas be well maintained. If simple housekeeping practices, such as keeping gutters clear of litter, are not followed, any fire-resistant properties afforded by construction to AS 3959 standards will be greatly compromised. Similarly, leaving a garden to become overgrown, especially with native plans, will compromise siting principles designed to provide a protection buffer between the building and the potential fire front.

Individual fire planning: The ultimate responsibility for reducing vulnerability to bushfire rests with the property owner or occupier, consequently the development of an individual fire plan is essential. There are several publications available that provide advice on property fire planning, for example the Southeast Queensland Fire and Biodiversity Consortium (FABC)-produced *Individual property fire management planning kit* (FABC, 2002) and the various publications produced by the QFRS.

It is important that individual property fire plans be lodged with Council and the local rural brigade so that they can be reviewed by fire management specialists and so that the information they contain, such as that relating to water supply and access, can be entered into the Council and brigade's information bases.

Insurance: Most properties carry some form of insurance against a wide range of risks ranging from accidental damage and theft to earthquake. Fire risk is a standard inclusion in most policies. Experience in fire disasters elsewhere, however, suggests that a small, but significant, number of property owners do not carry insurance or carry an inadequate amount of cover.

5.7.5 Bushfire treatment strategies

Fire strategy 1: Council commission an updated bushfire hazard mapping program to cover the New Townsville City area. Council's GIS staff has the necessary technical skills to undertake this work under the supervision of an external consultant that is skilled in bushfire hazard mapping.

Fire strategy 2: Incorporate the updated bushfire hazard potential mapping, done to SPP 1/03 standards, into the new Townsville City Plan.

Fire strategy 3: Council consider the immediate appointment of a Fire Management Officer to undertake the duties suggested by the 1994 State Bushfire Audit and to oversee the implementation of the bushfire management strategy for the study area.

Fire strategy 4: Council adopt as policy for managing fuel on Council-controlled land:

- **the fire management principles and practices identified by the FABC and QPWS which seek to strike a balance between community safety and preserving biodiversity;**
- **recognition of the principle that the need for fuel reduction to improve community safety will take precedence over consideration of smoke pollution from prescribed burning.**

Fire strategy 5: Conduct an annual audit of fuel conditions on Council-controlled land.

Fire strategy 6: Based on the results of those audits, allocate adequate human and equipment resources, including QFRS support, to initiate a sustainable program of fuel management on Council-controlled land, with the land with the greatest level of hazard being treated as soon as possible.

Fire strategy 7: Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.

Fire strategy 8: Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.

Fire strategy 9: Draw to the attention of building certifiers and developers operating in the City the existence of the _natural hazard management area (bushfire)_ mapping and the responsibility they bear to ensure that the provisions of AS 3959 with regard to design and construction standards within those areas designated as being fire-prone, together with appropriate subdivisional design and siting principles identified by CSIRO and others, are complied with.

Fire strategy 10: QFRS promote bushfire safety program in study area suburbs and localities with an identified fire threat. Households in those areas are to be encouraged to develop household fire plans.

Fire strategy 11: **QFRS consider installing and maintaining prominent 'fire danger' signage in urban interface areas to improve community awareness in periods of elevated fire danger.**

Fire strategy 12: **Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.**

5.8 TREATING EARTHQUAKE RISK

As with the other hazards, with the exception of bushfires, there is nothing that can be done to influence earthquake hazards. Also, given that earthquakes are a regional hazard there is nothing that can realistically be done to reduce exposure. That leaves vulnerability as the only effective risk element that can influence earthquake risk.

5.8.1 Building design and construction

Construction type and earthquake vulnerability in Australia appears to be closely correlated with building age. In part, this reflects the introduction of, and upgrades to, the BCA to address both wind and earthquake loads in the 1970s and 1980s. The BCA earthquake loading code aims to provide buildings that will not suffer catastrophic failure under design levels of earthquake load. For domestic construction that level of shaking equates to the level that would be experienced with an ARI of 500 years, whist public buildings have a design level of ARI of 1-2000 years. The philosophy is essentially one which aims for buildings to fail safely (thus reducing the risk of injury to occupants) rather than them to be immune from failure.

Even where buildings are constructed to BCA standards (or above) it is possible for some building components to fail and cause harm. For example, evaporative coolers mounted on the roofs of buildings may be dislodged.

The vast majority of buildings in the study area are of timber frame construction which has a good degree of inherent resilience because under earthquake loads they behave in a ductile manner and can undergo relatively large displacements because of their non-rigid construction. Many older buildings, however, are probably not in optimum condition, and their performance could be poor, particularly if they are not tied to their stumps or if their stumps are not cross-braced.

It would be appropriate for Council to seek structural engineering advice regarding their buildings, especially the older Council structures. It may also be appropriate for Council to advise owners of other critical and sensitive facilities (especially schools and hospitals) of the findings of this study.

5.8.2 Lifeline vulnerability

Water supply in particular, and sewer systems to a lesser degree, are vital to community well being. Brittle material, especially unlined asbestos cement (AC), may be particularly susceptible to fracture. A significant amount of such pipe has been used in the water supply reticulation networks in all areas served. Rupture of significant segments of the pipe network could reduce the availability of potable water to the community and fire fighting water to the emergency services. Widespread damage would take a considerable time for supply to be fully restored. As water and sewerage systems are progressively upgraded such brittle material should be replaced or lined with PVC to improve their resilience.

A key susceptibility for all utilities is in the resilience of their SCADA systems. They may fail initially because of the misalignment of their numerous antennae but such disruption should be quickly rectified.

Modelling of the tsunami risk to the east coast of Australia is being undertaken by Geoscience Australia. The results of that work for the Townsville area are not yet available at the time of writing.

5.8.3 Earthquake treatment strategies

Earthquake strategy 1: **Commission a detailed site class study of the urbanised area to improve the resolution and accuracy of the class zones suggested in this study. From that analysis identify specific building types that may be exposed to amplified earthquake shaking.**

Earthquake strategy 2: **Ensure all new buildings comply with the BCA earthquake loading code (AS1170.4) as modified by the revised acceleration factors. Encourage owners of existing buildings to upgrade their properties to current standards when undertaking structural renovations or extensions.**

Earthquake strategy 3: **Conduct an audit of all Council buildings and where appropriate retrofit all those deemed to be potentially unsafe in an earthquake of Richter magnitude 5.0 or greater.**

Earthquake strategy 4: **Educate the public about what to do in an earthquake.**

Appendix J summarises each of the recommended generic and hazard-specific treatment strategies detailed above and identifies the agency or agencies responsible and a rating of urgency for implementing the strategy.

5.9 CONCLUSIONS

The overall risks posed to the population of the study area are relatively small and infrequent. Heatwave poses the greatest threat to life, with floods and storms representing the most significant threats to property.

The risk treatment strategies suggested here have been designed to meet the criteria established in the context stage (Chapter 1). This has been achieved by adopting the following broad objectives:

1. protecting emergency workers: ensure that emergency workers have the right information at the right time and in the right form; ensure that they have appropriate training; ensure that they have appropriate resources.
2. protecting the general public: ensure that the general public receive the right information at the right time and in the right form; ensure that they know how to use that information to maximise their own safety; foster community resilience.

3. protecting public assets: ensure that all public critical infrastructure is sited, constructed and maintained to ensure that it will be available during and immediately after a disaster impact; if it is damaged ensure that it can be rapidly restored.
4. protecting community property: ensure that future development is located in areas with minimal exposure to inundation and other hazards; ensure that owners of existing property are aware of their potential exposure to hazards so that they may take steps to minimise their risk.
5. protecting the environment and heritage: ensure that all development is ecologically sustainable even under extreme conditions; ensure that heritage assets (including archives, historic buildings and cultural sites) are adequately protected.
6. protecting the economy: if all of the previous criteria are met the economy will largely look after itself.

By adopting these strategies the New Townsville City Council will go a long way to reducing the risks posed by natural hazards to a level that is as low as reasonably practicable in all but the most extreme events. Their adoption will also make Townsville City a safer and more sustainable community.

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REFERENCES

AFAC, 2001: *Position paper on community safety and evacuation during bushfires*, Australasian Fire Authorities Council Ltd, Box Hill.

AGS, 2000: *Landslide risk management concepts and guidelines*, Australian Geomechanics Society Sub-Committee on Landslide Risk Management.

Ahern A. and Chladil M., 1999: 'How far do bushfires penetrate urban areas?' in *Disaster prevention for the 21st Century*, conference proceedings, pp 21-26, Emergency Management Australia, Canberra.

AGO, 2006: *Climate change impacts and risk management: a guide for business and government*, Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

Australian Government, 2006: *Protecting Australia against terrorism 2006: Australia's counter-terrorism policy and arrangements*, Department of Prime Minister and Cabinet, Canberra.

Basher, R. E. and Zheng, X., 1995: 'Tropical cyclones in the Southwest Pacific: spatial patterns and relationships to southern oscillation and sea surface temperature', *Journal of Climate*, Vol 8, May, 1249-1260.

Benjamin and Cornell, 1970: *Probability, statistics and decision for civil engineers*, McGraw-Hill.

Binder D., 1992: *Legal liability for dam failures*, Association of US Dam Safety Officials.

BoM, 1995: *Severe storms – facts, warnings and protection,* brochure prepared by the Bureau of Meteorology in association with Emergency Management Australia, Canberra.

BTE, 2001: *Economic costs of natural disasters in Australia*, Report 103, Bureau of Transport Economics, Canberra.

CERA, 2006: *Final report on earthquake risk assessment for the City of Townsville*, consultant report for Townsville City Council by the Centre for Earthquake Research in Australia.

Chen K. and McAnerney J., 2004: 'Quantifying bushfire penetration into urban areas in Australia', *Geophysical Research Letters*, **18**(L12212).

Climate Institute Australia, 2007: *Briefing – International Panel on Climate Change report: implications for Australia*, Climate Institute (Australia) Ltd www.climateinstitute.org.au.

Coates L., 1996: 'An overview of fatalities from some natural hazards in Australia', pp 49-54, in R.L. Heathcote, C. Cuttler and J. Koetz (eds) *NDRS96 Conference on natural disaster reduction*, Institution of Engineers Australia, Canberra.

Coates L., Blong R. and Siciliano F.,1993: 'Lightning fatalities in Australia 1824-1991', *Natural Hazards*, 8 pp 217-233.

Coffey Geoscience, 2001: *Landslide hazard zoning study Townsville City area*, Coffey Geoscience P/L.

Coffey Geoscience and Landmarc, 2004: *Townsville steep slope risk assessment*, consultant report to Townsville City Council by Coffey Geoscience P/L and Landmarc P/L.

Crichton D., 1999: 'The risk triangle', in J. Ingleton (ed), *Natural disaster management*, Tudor Rose, London.

CSIRO/SA, 1993: *Building in bushfire-prone areas – information and advice*, Commonwealth Scientific and Industrial Research Organisation, Canberra and Standards Australia, Homebush.

CTS and SEA, 2003: *Development of a cyclone wind damage model for use in Cairns, Townsville and Mackay,* Report TS582, James Cook University Cyclone Testing Station in association with Systems Engineering Australia P/L.

Cunningham D., 2006: *The application of risk analysis tools in Civil Defence and Emergency Management Groups*, New Zealand Civil Defence, Wellington.

Cuthbertson R. and Jaume S., 1996: *Earthquake hazard in Queensland*, Queensland University Advanced Centre for Earthquake Studies, QUAKES Report #1.

Department of Infrastructure, 2007: *Townsville City port strategic plan*, Queensland Department of Infrastructure.

DES & DPW, 2008: *Mitigating the adverse impacts of cyclones: evacuation and shelter*, Department of Emergency Services and Department of Public Works, Brisbane.

DHLGP/QFRS, 1994: *Bushfire prone areas- siting and design of residential buildings*, Department of Housing, Local Government and Planning and Queensland Fire and Rescue Service, Brisbane.

DLGP, 2004: *Population and housing fact sheet: Caloundra City*, Planning Information and Forecasting Unit, Department of Local Government and Planning.

DLGP/DES, 2003a: *State planning policy 1/03: mitigating the adverse effects of flood, bushfire and landslide,* Department of Local Government and Planning and Department of Emergency Services, Brisbane.

DLGP/DES, 2003b: *State planning policy guideline: mitigating the adverse effects of flood, bushfire and landslide,* Department of Local Government and Planning and Department of Emergency Services, Brisbane.

DoTARS, 2007: *Natural disaster relief and recovery arrangements - Determination 2007*, Commonwealth Department of Transport and Regional Services, Canberra.

Dowrick, 1996: 'The Modified Mercalli Intensity Scale – revisions arising from recent studies of New Zealand earthquakes', *Bulletin of the New Zealand National Society for Earthquake Engineering* 29 (2), 92-106.

Ellis S., Kanowski P. and Whelan R., 2004: *National inquiry on bushfire mitigation and management*, Commonwealth of Australia, Canberra.

EMA, 1998: *Australian Emergency Management Glossary*, Emergency Management Australia, Canberra.

EMA, 2005: *Evacuation planning,* Manual 11, Australian Emergency Management Manual Series, Emergency Management Australia.

EPA (US), 1988: *Seven cardinal rules of risk communication*, pamphlet, US Environmental Protection Agency, Washington.

EPA, 2006?: *Mitigating the adverse impacts of storm tide inundation*, State Coastal Management Plan guideline, Environment Protection Authority, Brisbane.

FABC, 2002: *Individual property fire management planning kit*, Southeast Queensland Fire and Biodiversity Consortium, Brisbane.

Fournier d'Albe E.M., 1986: 'Introduction: Reducing vulnerability to nature's violent forces: cooperation between scientist and citizen' in Maybury, R.H. (ed.) *Violent forces of nature,* pp. 1-6, Lomond Publications, Maryland.

Fujita T.T., 1981: 'Tornadoes and downbursts in the context of generalised planetary scales', *Journal of Atmospheric Sciences*, Vol 38, No 8, Aug, pp 1511 - 1534.

Gaull B., Michael-Leiba M. and Rynn J., 1990: 'Probabilistic earthquake risk maps of Australia', *Australian Journal of Earth Sciences* Vol 37, pp 169-187.

GCCC/SMEC, 1999: *Guidelines for control of slope instability within the City of Gold Coast*, Gold Coast City Council and Snowy Mountains Engineering Corporation.

GHD, 2005a: *Ross River Dam upgrade study Part 3: design analysis inputs to risk analysis*, consultant report to TCC by GHD P/L.

GHD, 2005b: *Ross River Dam upgrade study Part 4: consequence analysis*, consultant report to TCC by GHD P/L.

GHD and SEA, 2007: *Townsville – Thuringowa storm tide study final report*, consultant report to Townsville and Thuringowa City Councils by GHD and Systems Engineering Australia P/L.

Granger K., 1997: 'Lifelines and the AGSO Cities Project', *The Australian Journal of Emergency Management,* Vol. 12, No. 1, pp. 16-18, Emergency Management Australia, Mt Macedon.

Granger K., 1998: *ASDI* (Australian Spatial Data Infrastructure) *from the ground up*, Australia New Zealand Land Information Council and AGSO, Canberra.

Granger K., 1999: *An information infrastructure for disaster management in Pacific Island Countries*, AGSO Record 1999/35, Australian Geological Survey Organisation, Canberra.

Granger K., 2005: *Heatwave risks in South East Queensland: a macro analysis*, report prepared for Brisbane City Council, Queensland Health and Queensland Ambulance Service.

Granger K., 2008a: 'MHFs [major hazard facilities] and emergency risk management', *Proceedings*, Major Hazards Facilities Conference, SafeWork SA, Adelaide.

Granger K., 2008b: 'Evacuation and shelter in disasters and emergencies – some observations on the theory and practice', unpublished IID working paper.

Granger K. and Johnson W., 1994: *Hazard management: better information for the 21st Century*, Emergency Management Australia and Australasian Urban and Regional Information Systems Association.

Granger K., Jones T., Michael-Leiba M. and Scott G. (1999), *Community risk in Cairns: a multi-hazard risk assessment*, Australian Geological Survey Organisation, Canberra.

Granger K. and Michael-Leiba M., (eds) 2001: *Community risk in Gladstone: a multi-hazard risk assessment,* Australian Geological Survey Organisation, Canberra.

Granger K. and Hayne M., (eds), 2001: *Natural hazards and the risks they pose to South-East Queensland*, Australian Geological Survey Organisation, Canberra.

Granger K. and Shorten G., 2004: *Earthquake risk assessment*, unpublished report prepared for Brisbane City Council Natural Disaster Risk Management Study.

Harper, B.A., 1998: *Storm tide threat in Queensland: history, prediction and relative risks*, Department of Environment and Heritage, Conservation Technical Report No. 10, Brisbane.

Harper, B.A., 1999: 'Numerical modelling of extreme tropical cyclone hazards', *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 83, pp. 35-47, Elsevier Science Ltd.

Harper B.A. and Holland G.J., 1999: 'An updated parametric model of the tropical cyclone', *Proceedings 23rd Conference on Hurricanes and Tropical Meteorology*, American Meteorology Association, Dallas Texas.

Hayne M. and Gordon D., 2001: 'Landslide risks', Chapter 10 in K. Granger and M. Hayne (eds), *Community risk in Gold Coast City: a multi-hazard risk assessment*, unpublished report to Gold Coast City Council, Australian Geological Survey Organisation, Canberra.

Holland G.J., 1980: 'An analytic model of the wind and pressure profiles in hurricanes', *Weather Monthly Review*, **108** (8), pp 1212-1218.

Holland G. J. 1997a: Personal communication to the authors of GHD and SEA (2007).

Holland G.J., 1997b: 'The maximum potential intensity of tropical cyclones', *J. Atmos. Sci.*, 54, Nov, 2519-2541.

Hopkins L.C. and Holland G.J., 1997: 'Australian heavy-rain days and associated east coast cyclones: 1958-92', *Journal of Climate*, 10, April, pp 621-635.

HSE, 1988: *The tolerability of risk from nuclear power stations*, Health and Safety Executive, HMSO Publishing, London.

IID, 2006b: *Lefevre Peninsula multi-hazard risk assessment study,* consultancy report for Port Adelaide Enfield City Council, Institute for International Development, Adelaide.

Institution of Engineers, 1993: *At what price data?* National Committee on Coastal and Ocean Engineering, Institution of Engineers Australia, Canberra.

IPCC, 2007a: *Climate change 2007: the physical science basis – summary for policy makers*, Intergovernmental Panel on Climate Change, Paris.

IPCC, 2007b: *Climate change 2007: impacts, adaptation and vulnerability– summary for policy makers*, Intergovernmental Panel on Climate Change, Paris.

Kepner C. and Tregoe B., 1981: *The new rational manager.* Kepner-Tregoe Inc., Princeton, NJ.

LCC, nd: *Preparing for natural disasters – a guide for residents living in Logan City*, Logan City Council, Logan Central.

LGAQ & DES, 2006: *Elected member's guide to disaster management – an information workbook*, Local Government Association of Queensland and Department of Emergency Services, Brisbane.

Mahendran M., 1995: 'Cyclone intensity categories' in proceedings of a workshop *Atmospheric Hazards: Process, Awareness and Response*, University of Queensland, Brisbane.

Maunsell, 2005a: *Townsville flood hazard assessment report: Phase 2 report flood hazard assessment*, consultant report to Townsville City Council by Maunsell Australia P/L.

Maunsell, 2005b: *Townsville flood hazard assessment report: Phase 3 report vulnerability assessment and risk analysis*, consultant report to Townsville City Council by Maunsell Australia P/L.

Maunsell McIntyre, 2001: *Ross River hydraulics study: downstream flood assessment report,* consultant report to NQ Water by Maunsell McIntyre Pty Ltd.

Marra F.J., 1998: 'Crisis communication plans: poor predictors of successful crisis management', in D. King and L. Berry (eds.) *Disaster management: crisis and opportunity*, pp. 296-306, conference proceedings (Cairns 1-4 November), Centre for Disaster Studies, James Cook University, Cairns.

Meyer P., 1997: *Tropical cyclone,* Swiss Reinsurance Co, Zurich.

Middelmann M. and Granger K. (eds) (2000), *Community risk in Mackay: a multi-hazard risk assessment*, Australian Geological Survey Organisation, Canberra.

Morgan G., 1997: 'A regulatory perspective on slope hazards and associated risks to life', in Cruden D. and Fell R. (eds) *Landslide risk assessment*, A.A. Balkema, Rotterdam.

Morris C., nd a: *Urban heat islands and climate change – Melbourne, Australia*, School of Earth Sciences, The University of Melbourne (www.earthsci.unimelb.edu.au/~jon/WWW/uhi-melb.html).

Meyer P., 1997: *Tropical cyclone,* Swiss Reinsurance Co, Zurich.

Nott J. And Hayne M., 2000: 'How high was the storm surge from Tropical Cyclone Mahina?', *Australian Journal of Emergency Management*, Autumn, pp 11-13, Emergency management Australia, Mt Macedon.

OESR, 2007: *Local government area profile – The Townsville (C) Region*, Office of Economic and Statistical Research, Brisbane.

Pielke R.A. (Jr) and Landsea C.W., 1999: 'La Niña, El Niño, and Atlantic hurricane damages in the United States', *Bulletin of the American Meteorological Society*, 80, 2027-2033.

Planning SA, 1998: *South Australian Housing Code: design wind speed map – Adelaide metropolitan area*, Planning SA, Department of Transport, Urban Planning and the Arts, Adelaide.

Power, S., Casey, T., Folland, C., Colman, A. and Mehta, V., 1999: 'Inter-decadal modulation of the impact of ENSO on Australia', *Climate Dynamics*, 15, 319-324.

QH, 2004: *Queensland heatwave response strategy*, Queensland Health, Brisbane.

Quelch P. and Byrne B., 1992: 'Lightning risk assessment based on flash intensity and distribution', *Proceedings Lightning Protection Workshop*, Institution of Engineers Australia, Hobart.

Queensland Transport, 2007a: *Notice to mariners 848 (Temporary) 2007: Townsville Pilotage Area*, Maritime Safety Queensland, Queensland Transport.

Queensland Transport, 2007b: *Semidiurnal tidal planes 2007*, Maritime Safety Queensland, (www.msp.qld.gov.au/Home/Tides/Tidal_planes) Queensland Transport.

Ramsay C. and Rudolph L., 2003: *Landscape and building design for bushfire areas*, CSIRO Publishing, Collingwood.

SA/SNZ, 1999: *Australia New Zealand Standard AS/NZS 4360:1999 Risk management,* Standards Australia, Homebush, and Standards New Zealand, Wellington.

SA/SNZ, 2004a: *Australia New Zealand Standard AS/NZS 4360:2004 Risk management,* Standards Australia, Homebush, and Standards New Zealand, Wellington.

SA/SNZ, 2004b: *HB436 Risk management guidelines: companion to AS/NZS 4360:2004*, Standards Australia, Homebush, and Standards New Zealand, Wellington.

SCARM, 2000: *Floodplain management in Australia: best practice principles and guidelines*, Standing Committee on Agriculture and Resource Management, CSIRO Publishing, Collingwood.

SCDO and BoM, 1997: *Storm tide warning-response system,* 3rd edition, State Counter-Disaster Organisation and Bureau of Meteorology, Brisbane.

SEMC, 2001: *NSW State Emergency Management Committee implementation guide for emergency management committees*, State Emergency Management Committee, Sydney.

Shorten G., Goosby S., Granger K., Lindsay K., Naidu P., Oliver S., Stewart K., Titov V. and Walker G., 2003: *Catastrophe insurance pilot study, Port Vila, Vanuatu: Developing risk-management options for disasters in the Pacific Region*. SOPAC Joint Contribution Report, **147**. 2 Volumes, SOPAC Secretariat, Suva.

Silberbauer G., 2003: 'Structural and personal social processes in disaster', *Australian Journal of Emergency Management*, Vol 18, No 3, Emergency Management Australia, Mt Macedon.

Smith D. and Handmer J., 2002: *Residential flood insurance: implications for floodplain management policy*, Water Research Foundation of Australia.

Standards Australia, 1989:

Standards Australia, 1991: *Construction of buildings in bushfire-prone areas AS 3959-1991*, Standards Australia, Homebush.

Standards Australia, 1998: *Strengthening existing buildings for earthquake (AS3826-1998),* Standards Australia, Homebush, NSW.

Standards Australia, 1999: *Australian Standard AS3959-1999: Building in bushfire prone areas*, Standards Australia, Homebush.

Standards Australia, 2002: *SAA Loading Code Part 2: Wind loads AS 1170.2-2002,* Standards Australia, Homebush.

Standards Australia, 2006: *AS 4055 - Wind loads for houses*, Standards Australia, Homebush.

Standards Australia, 2007: *AS 1170.4 – 2007 Structural design actions – earthquake actions in Australia,* Standards Australia, Homebush.

Standards Australia & ICA, 1999a: *SAA HB132.1 Structural upgrading of older houses part 1: non-cyclone areas.* Standards Australia and Insurance Council of Australia, Sydney.

Standards Australia & ICA, 1999b: *SAA HB132.2 Structural upgrading of older houses part 2: cyclone areas*. Standards Australia and Insurance Council of Australia, Sydney.

Stark, K., (ed), 1972: *Cyclone Althea: Part II storm surge and coastal effects*, James Cook University, Townsville.

Steadman R. G., 1979: 'The assessment of sultriness: Part I: A temperature-humidity index based on human physiology and clothing science', *Journal of Applied Meteorology*, 18, pp 861-873.

Steadman R. G., 1984: 'A universal scale of apparent temperature', *Journal of Climate and Applied Meteorology*, 23, pp 1674-1687.

TCC, nd: *The Townsville Region: a social atlas*, 5th edition, Community and Cultural Services Department, Townsville City Council.

Templeman D. and Bergin A., 2008: *Taking a punch: building a more resilient Australia*, Strategic Insights 39, Australian Strategic Policy Institute, Canberra.

Tobin G. and Montz B., 1994: 'The flood hazard and dynamics of urban residential land market', *Water Resources Bulletin*, Vol 30, No 4, pp673-685.

Trinity Software, 1999: *Bushfire hazard mapping: analysis of bushfire susceptibility based on vegetation type and slope*, consultant report to Townsville City Council by Trinity Software Australia P/L.

Vogt M., Willis K. and Vince J., 2008: 'Weighing up the risks – the decision to purchase housing on a flood plain', *The Australian Journal of Emergency Management*, Vol23, No 1, pp49-53, Emergency Management Australia, Mt Macedon.

Walsh K., Cai W., Hennessy K., Jones R., McInnes K., Nguyen K., Page C. and Whetton P., 2002: *Climate change in Queensland under enhanced greenhouse conditions – final report 1997-2002*, CSIRO Atmospheric Research, Aspendale.

Willmott W., 1983: *Slope stability and its constraints on closer settlement on the Mapleton-Maleny Plateau*, *Southeast Queensland*, Department of Mines Record 1983/9.

Wright I. and Plumpton V., 1997: 'Legal implications of bushfire management (Part 1), in *EcoInformation Source*, Logan and Albert Conservation Association (www.laca.org.au), Beaudesert.

WMO, 1997: *Tropical cyclone operational plan for the South Pacific and South-East Indian Ocean*, World Meteorological Organization TD-No. 292, Tropical Cyclone Programme Report No. TCP-24, Geneva.

Yeo S., 2003: 'Effects of disclosure of flood-liability on residential property values', *The Australian Journal of Emergency Management*, Vol18, No 1, pp35-44, Emergency Management Australia, Mt Macedon.

Zamecka A. and Buchanan G., 1999: *Disaster risk management*, Department of Emergency Services, Brisbane.

APPENDIX A

Significant Tropical Cyclone Events - Townsville

APPENDIX A: SIGNIFICANT TROPICAL CYCLONE EVENTS - TOWNSVILLE

This list of tropical cyclones has been compiled from several sources, most notably an unpublished list compiled by Jeff Callaghan of the Bureau of Meteorology (Callaghan, 1998), a database of cyclone tracks developed by the Bureau's Severe Weather Section in Brisbane (BoM, 1997) and Appendix 1 in Harper (1998).

2-3 March 1867	On 2nd, a tropical cyclone brought gales for 24 hours to Bowen with many buildings unroofed, verandas carried away and windows smashed. Boats smashed. The following day Townsville was hit with almost every building blown down.
20 February 1870	A tropical cyclone hit Townsville lasting 10 hours. The steamer Black Prince and schooner Wonder were wrecked. Nearly every house was damaged and several were completely unroofed. Large trees were torn up by the roots and streams were flooded.
17 February 1876	Severe gale reported at Townsville with much damage in the town.
21 March 1876	Heavy gale reported at Townsville. SS Banshee wrecked at Hinchinbrook Island with 17 people drowned.
24 March 1890	Tropical cyclone crossed the coast at Townsville and recurved over Fraser Island.
26 January 1896	TC *Sigma* passed just to the northeast of Townsville with a pressure of 991 hPa recorded at Townsville. Ships were wrecked in the harbour; fences were laid flat; and verandahs stripped off houses. Large trees were brought down. Falls of 510 mm of rain produced severe flooding. Flash floods and storm tide flooded lower parts of Townsville with over 1.8 m of water. Seventeen people were drowned and one sailor killed.
9 March 1903	TC *Leonta* recurved over Townsville with the barometer down to 965 hPa. Hurricane force winds caused much severe damage with flying roofing iron; buildings blown over and verandahs wrenched away. The Townsville hospital with 36 cm thick walls was wrecked by the wind and the brick Grammar School was destroyed. Eight people were killed in the hospital with another two deaths elsewhere.
23 March 1911	The SS *Yongala* sunk by an unnamed cyclone in Bowling Green Bay with a loss of 100 lives.
18 February 1940	Cyclone crossed the coast near Cardwell where pressure dropped to 965 hPa. Huge seas left a trail of damage along the Strand in Townsville. Three open baths, a memorial park and the sea wall were destroyed. Flood waters driven back by the storm tide isolated many parts of the City.
7 April 1940	Cyclone crossed the coast near Townsville causing disastrous flooding and loss of life. Worst damage was in the Ayr district with an estimated $1 million damage (in 1940 pounds).
2 March 1946	Cyclone recurved over Cairns and Townsville. Pressure of 983 hPa recorded at Cairns and Innisfail. Record flooding in the Burdekin River caused considerable damage and loss of life.
7 February 1954	Cyclone crossed the coast south of Townsville and produced severe flooding in the district.
6 March 1956	Category 3 TC *Agnes* passed directly over the Townsville Meteorology Office producing a barometric pressure reading of 961 hPa. The storm then moved northwards as far as Ingham before turning west. Maximum wind gusts of 73 knots at Townsville. Significant damage to buildings was reported. Flooding in the interior claimed four lives.
16 February 1959	TC *Connie* crossed the coast at Guthalungra (south-east of Townsville) where the pressure in the eye was recorded at 948 hPa. Severe wind damage at Ayr and Home Hill.
6 December 1964	Category 1 TC *Flora* crossed from the Gulf to enter the Coral Sea near Innisfail, and moved east-south-east. Cape Cleveland lighthouse recorded 75 knot gusts and paint was stripped off the lighthouse. On Palm Island power lines were blown down and palm trees snapped off or uprooted.
24 December 1971	Category 3 TC *Althea*, crossed the coast at Townsville, with a 106 knot gust recorded at the Townsville Met Office. There were three deaths in Townsville and damage costs in the region reached $50 million (1971 dollars). Many houses were damaged or destroyed by wind, including

	200 Housing Commission houses. On Magnetic Island 90% of the houses were damaged or destroyed. A 2.9 m storm surge was recorded at Townsville Harbour and 3.66 m at Toolakea (to the north-west). The storm surge occurred at low tide, even so the storm tide and waves caused extensive damage along the Strand and at Pallarenda.
19 December 1973	Category 1 TC *Una*, crossed the coast east of Townsville. Damage was restricted to trees and street signs in Townsville and Ayr, however, a home was unroofed in Home Hill.
31 January 1977	Category 1 TC *Keith* made landfall just to the east of Cairns before moving south to again cross the coast at Cape Cleveland. Only minor wind damage to buildings was reported, however, extensive loss of banana and sugar crops occurred.
1 March 1988	TC *Charlie* made landfall at Upstart Bay near Ayr. Cape Bowling Green recorded a pressure of 981 hPa and a one minute average wind speed of 75 knots. Losses of $15 million (1990 dollars) were caused to the agricultural sector mainly by flooding in the Burdekin and elsewhere.
4 April 1989	Category 4/5 TC *Aivu* crossed the coast near Ayr. A central pressure of 959 hPa was recorded 20 km inland at Fredericksfield. Damage was extensive, especially in the cane industry. Total damage was estimated at $90 million (1990 dollars). NOTE: A review of data and satellite imagery by Jeff Calaghan (BoM Brisbane) indicates that at one point during its approach to the coast a central pressure of 888 hPa was achieved. According to GHD and SEA (2007) such a central pressure is close to the maximum probable intensity (MPI) for an east coast cyclone.
22-25 December 1990	Category 4 TC *Joy* approached, and hovered, to within 120 km of Cairns before decreasing in intensity and moving south to cross the coast at Townsville as a much weaker system. Damage to infrastructure was widespread.
9-22 March 1997	Category 2 TC *Justin* was a very large system with a diameter of almost 1000 km. It produced very large seas and caused considerable coastal erosion between Townsville and Bundaberg. After making a large circle of the Coral Sea the cyclone crossed the coast at Cairns. Widespread torrential rain caused widespread flooding and landslides including several along the Paluma Range. One lady was killed by a landslide on the Paluma Road and the population of Paluma was evacuated by helicopter to Townsville.
10 January 1998	Ex TC *Sid* produced a rainfall of 549 mm in a 24 hour period producing severe flash flooding and landslides in Townsville and on Magnetic Island.
2 April 2000	Category 2 TC *Tessi* produced significant wind damage to the north of Townsville. An anemometer on Magnetic Island measured a 10-min average easterly wind of 59 kts at 1600 UTC 2nd which, in conjunction with some other data, indicated that Tessi's centre was about 40 km from Townsville at its closest approach. Tessi was responsible for setting new weather records for April at the Townsville Meteorological Office; highest wind gust (70 knots), highest daily rainfall (271.6mm) and the highest monthly rainfall(539mm to 27 April 2000). However official daily rainfall is measured up to 9am local (2300 UTC) and 423.4 mm was measured in the 24 hours up to 1500 UTC 3 April 2000. The cyclone caused widespread wind damage in Townsville mainly to trees and power lines. Most structural damage was due to falling trees though there were isolated reports of roof damage attributed to the wind itself. Widespread flooding occurred with the associated downpour, which also led to a severe landslide in one of the more affluent residential areas of Townsville on Castle Hill. There was also wave damage along the Strand at Townsville with several boats destroyed.

APPENDIX B

Wind Speed Conversion Table

IID
The Institute for International Development

APPENDIX B: WIND SPEED CONVERSION TABLE

Beaufort Scale	Specification of Beaufort scale for uses on land, based on observations made at land stations	Gust speeds [km/h]	Gust speeds [m/sec]	Gust speeds [knots]
0	Calm: smoke rises vertically	0	0	0
1	Light air: Direction of wind shown by smoke drift, but not by wind vanes	1-6	0.3-1.7	0.5-3.2
2	Light breeze: Wind felt on face; leaves rustle; ordinary vane moved by wind	7-14	1.9-3.9	3.8-7.6
3	Gentle breeze: Leaves and small twigs in constant motion; wind extends light flag	15-24	4.2-6.7	8.1-13.0
4	Moderate breeze: Raises dust and loose paper; small branches are moved	25-35	6.9-9.7	13.5-18.9
5	Fresh breeze: Small trees in leaf begin to sway; crested wavelets form on inland waters	36-48	10.0-13.3	19.4-25.9
6	Strong breeze: Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	49-61	13.6-16.9	26.5-32.9
7	Near gale: Whole trees in motion; inconvenience felt when walking against wind	62-76	17.2-21.1	33.5-41.0
8	Gale: Breaks twigs off trees; generally impedes progress	77-93	21.4-25.8	41.6-50.2
9	Strong gale: Slight structural damage occurs [chimney pots and slates removed]	94-110	26.1-30.6	50.8-59.4
10	Storm: Seldom experienced inland; trees uprooted; considerable structural damage occurs	111-129	30.8-35.8	59.9-69.7
11	Violent storm: Very rarely experienced; accompanied by widespread damage	130-146	36.1-40.6	70.2-78.8
12	Hurricane: … … … …	>146	>40.6	>78.8

Conversion Factors:

1 km/h = 0.2778 m/s
1 m/s = 3.6 km/h
1 knot = 1.852 km/h

1 km/h = 0.53996 knots
1 m/s = 1.944 knots
1 knot = 0.5144 m/s

APPENDIX C

Townsville Flood History

APPENDIX C: TOWNSVILLE FLOOD HISTORY

1870

26th February: Bowen: Country flooded for miles; river rose to a great height; flood worst experienced since settlement of the district. No communication with Townsville since 21st; telegraph line across the river Burdekin broken down for at least 31 chains, probably owing to heavy gale on night of 20th.

15 July: Townsville: Disastrous flood on the Flinders; all traffic stopped; one station lost 4,000 sheep.

16th November: Townsville: Very heavy rains; Burdekin River high; traffic stopped.

1872

1st February: Townsville: Wet season still continues; traffic seriously impeded, and in some directions entirely suspended.

1887

10th March: Heavy floods stopped all traffic on the Northern Railway at Townsville.

1892

25th January: A serious flood caused great damage at Townsville.

1894

17th January: The railway traffic at Townsville suspended owing to flood; water 6 feet above the Burdekin bridge.

20th January: Flood waters 22 feet over the rails of the Burdekin bridge.

1908

Extract from the Sydney Morning Herald, 10th January, 1908:

> *The train leaving Charters Towers for Townsville was blocked at Antill Plains; the water is 9 inches over the rails and rising fast. 625 points of rain fell at Townsville from 9 a.m. Tuesday (7th) till 6 p.m., Wednesday. The weather is now gusty. The glass at the Pilot Station fell to 29.64, and at 10 p.m. was still falling. At Geraldton all the low-lying parts of the district are flooded. The river was very high yesterday but is now falling.*

1911

6th January: Floods in the Cairns and Townsville districts.

1913

1st May: Mulgrave River flood; train services interrupted. Rail traffic between Townsville and Ayr was also interrupted by floods.

1916

1st to 4th February: Local heavy flooding in many districts, especially between Townsville, Charters Towers and Bowen, in the Charleville, Longreach and Brisbane districts and on the Downs. Two girls drowned near Charters Towers.

1918

19th to 22nd January: Disastrous and most severe flood on record at Mackay (associated with intense cyclone), where 24.70 inches rain fell in 24 hours. Twenty lives lost; enormous damage to property. All rivers between Townsville and Gladstone affected. Unprecedented floods in the Burdekin and Fitzroy Rivers. Highest flood on record at Rockhampton (31 ft. 11 in.); two or three lives lost. Man drowned at Townsville. Portion of Don River Bridge at Bowen washed away. High floods experienced in all tributaries of Fitzroy and Burdekin Rivers, especially the Dawson, Mackenzie, Comet and Nogoa Rivers.

9th to 11th March: Temporary, flooding of rivers between Cairns and Mackay from heavy rains associated with disastrous cyclone which crossed coast near Innisfail. Large part of Ingham inundated. Highest flood on record at Halifax.

1919

17th to 22nd January: Local heavy flooding in the north-west, central-east and south-east, chiefly in coastal rivers between Townsville and Rockhampton. Railway bridges between Ayr and Mackay damaged.

25th to 31st January: Local heavy floods in the north-west and between Townsville and Mackay. Flinders River at Hughenden in high flood.

1920

January From 5th to 8th the **Mary** and **Maroochy** rivers flooded and a man drowned at Kin Kin. During the period 17th to 22nd there was local heavy flooding in the north-west, central-west and south-east, chiefly in coastal rivers between Townsville and Rockhampton. Again, from 25th and 31st there were local heavy floods in the north-west and between Townsville to Mackay. The **Flinders River** at Hughenden was in high flood.

1925

February: Floods occurred in most rivers in the tropical portion of the State between 1st and 6th. Conditions were severe in some coastal streams between Mackay and Cairns, notably in the **Burdekin**, **Haughton**, **Herbert**, **Johnstone**, **Proserpine** and **Tully** rivers. There was extensive railway washaways between Cardwell and Bowen, and the bridge over the Burdekin at Inkerman collapsed with a section of some 75 metres being swept out of position. Floods in the Innisfail district caused early cessation of cane crushing operations, 26,000 tons of cane being left standing.

1930

January: From 5th to 9th heavy flooding of practically all rivers between Townsville and Cooktown. Complete dislocation of rail and road traffic, causing serious delays to mail, and much loss of crops. Innisfail isolated and some wharves submerged. A man drowned in **Liverpool Creek**.

From 20th to 31st floods over greater part of the State. However the Peninsula and far north-west rivers were not affected and floods were only slight in the Maranoa, Downs and the southern part of the South Coastal district.

Traffic between Townsville and Cairns again completely disorganised and low lying portions of Cairns inundated. Other districts experienced serious traffic interruptions and mail delays. These included Mackay-Townsville, Cloncurry-Mt Isa, Hughenden-Winton, Longreach-Aramac and Adavale-Charleville-Quilpie-Cunnamulla regions. Three railway passengers drowned whilst being ferried across the **Burdekin River** and drowning fatalities occurred in the **Warrego**, **Pioneer** and **Haughton** rivers.

October: On 4th there was heavy local flooding between Cooktown and Townsville, with the result being a train derailment near Bemerside. Business premises in Townsville were flooded. Further flooding between Hughenden and Winton caused another train derailment.

1931

February: Floods between Cairns and Ingham continued at the beginning of the month. From 2nd to 8th most coastal streams south from Townsville were affected. Only local flooding resulted from Townsville to Gladstone but the **Burnett** and all streams south from there had more serious flooding. All traffic was greatly disorganised and there were heavy losses caused by destruction of crops and drowning of stock. Streets of Bundaberg, Gympie and Maryborough were submerged.

December: From 26th to 29th there was flooding in coastal rivers between Port Douglas and Townsville with rail and road communication between Townsville and Innisfail interrupted.

1932

January: From 16th to 24th serious flooding occurred in the coastal districts north from St Lawrence, particularly between Cairns and Townsville, and Ayr and Mackay. Rail bridge over the **Elliot River** destroyed. There were two drowning fatalities, a child at Innisfail, and a man at Gordonvale. Houses in low lying parts of Innisfail and Tully submerged.

1934

January: On 1st and 2nd the end of December floods between Cairns and Townsville continued and rivers on the western side of the Atherton Tableland were also affected. General rail and road interruptions over the greater part of the north coast area. A cyclone in this part of the State caused more serious floods after 22nd. There was almost complete cessation of rail traffic between Cairns and Cardwell during the last week of the month. Homes were vacated at Ingham, Bemerside, Innisfail and Tully. A man drowned in the **Johnstone River** near Innisfail. By 31st the floods extended to the Townsville and Bowen districts. Rail traffic was suspended across the **Burdekin River** Bridge and a new weir on the **Ross River** near Townsville was extensively damaged.

1936

February: From 14th and 20th there was extensive flooding in coastal areas between Cooktown and Mackay. Some serious inundations occurred especially in the Innisfail district where considerable damage was reported to crops and roads, and a lad drowned. There were two people drowned at Townsville and transport services were disorganised. In the same period there was local flooding in parts of the north-west and south-west and wash-outs on the Hughenden-Winton line.

March: From 4th to 22nd there was some heavy flooding between Cardwell and Mackay. The **Burdekin River** at Ayr and the **Herbert River** at Ingham several times submerged bridges. Some creeks in the Mackay district reached the highest level on record and low lying areas of Mackay were submerged and homes partly inundated. Portion of the **Pioneer River** bridge was washed away. The **Ross River** was in high flood, country near Townsville was inundated and Sarina was isolated.

1939

February: From 8th to 14th flooding occurred between Cooktown and Mackay, especially in the area Cairns to Townsville. Cairns and Mossman were isolated. Low lying parts of Innisfail were submerged. A man drowned in Cairns and another in South Johnstone.

1940

February: Flooding in streams from north of Townsville to Rockhampton was mainly due to the cyclone. At Sellheim the **Burdekin River** peaked on 19th (third highest on record). In the tropical interior, under combined monsoonal plus cyclonic rains, extensive areas were inundated. Rail and other land traffic were held up for a few days at a time. Towns were isolated and Muttaburra had been without any communications for a fortnight at the end of the month.

April: Torrential rains, under cyclonic conditions, occurred on the central coast districts between Townsville and St Lawrence and west to Mt McConnell. Disastrous floods resulted in these districts, especially in the Home Hill - Ayr areas of the **Burdekin River**. Approximate damage one million pounds. Some lives were lost.

1941

January: North coast rivers and creeks were in flood. First Winton mail train since 11th. The Townsville / Ingham line experienced washaways. The Flying boat (Captain Koch) reported one wide sheet of water from Karumba to Townsville. The railway was under water between Bowen and Proserpine with traffic suspended.

23-1-41. The **Ross River** was flooding in Townsville.

1944

March: Local flooding on the far north coast and parts of the central coast. There were considerable traffic delays. The **Burdekin River** main stream was affected and parts of the northern tributaries of the **Fitzroy** system.

1945

March: Persistent and heavy local to stream flooding caused widespread damage especially in the first two weeks in coastal districts between Mackay and Cooktown and across the highlands to the eastern Carpentaria. Traffic delays were many.

On 8th the Burdekin rail bridge suffered heavy damage. A goods train was washed away and two lives were lost. The **Burdekin River** at Sellheim peaked on 7th and 13th. On 14th the railway bridge was some 4 metres under water with the river still rising.

1946

March: Under cyclonic influences extensive heavy to record flooding occurred during the first part of the month in all tropical coast streams between Cooktown and Rockhampton back to the adjacent highlands and eastern Carpentaria. Widespread damage, soil erosion and protracted traffic disabilities were reported. There was some loss of life and the town of Home Hill was out of communication for a couple of days.

The **Burdekin River** flooded from all catchment areas with record heights. These were Inkerman Bridge (4th), Sellheim (4th), Lornesleigh (7th), Einasleigh (4th). Townsville and Mackay also suffered considerable damage.

1947

February: The **Burdekin River** system showed rises in the first few days of the month and with peak periods about 6th and 12th, maintained an appreciable run-off until after 22nd.Floodwaters were over Inkerman Bridge from 5th to 18th with the highest report on 12th. This was higher than 1944 and 1945, but below the 1946 record.

1952

January: The 250 to 500mm rains in the third week on the tropical coast caused sharp flooding in coastal streams on the north coast and adjacent central coast and freshes in the **Burdekin River**. Rail traffic was temporarily suspended between Ayr and Townsville by **Haughton River** floodwaters, and at Halifax the **Herbert River** reached a height of 2 metres over the railway bridge on 22nd.

1954

February: Sustained and extensive widespread flooding in all main river systems reached record or near record levels in the **Burdekin**, **Fitzroy** and southern interior streams. Dislocation of traffic routes was fairly general, food drops being necessary in the central interior. At least 10 people lost their lives and hundreds of families had to be evacuated, particularly in the Rockhampton and Mackay areas. Bridges were swept away at Mitchell, Beaudesert and Ravenswood. The Marion Weir collapsed and the Burdekin River was over the Inkerman Bridge from 5th Feb. to 3rd March.

1955

March: Sustained and widespread flooding occurred throughout practically the whole of the States river systems during the month. Record or near record levels were reached in the **Burdekin**, **Fitzroy** , **Flinders** , **Thomson** and **Mary** rivers. Dislocation of road and rail traffic was fairly general, food drops being necessary in the central interior with homes evacuated and some stock lost.

1958

February: Traffic disabilities were widespread and communications were badly disrupted. In some areas these are still not restored and the full flood picture is not yet available. The main northern railway line was washed away at several places, many travellers were stranded and food shortages were reported in some of the isolated towns.

In the **Burdekin River** catchment, record floods were reported in the **Cape**, **Suttor** and **Sellheim** rivers, even higher than the 1918 floods. Some 90 years old stations were under water for the first time. At Lornesleigh the water reached to the second floor of the station homestead, whilst seven people were marooned on a hilltop for 11 days at Mt Elsie station. Near record flooding in the lower Burdekin caused the evacuation of parts of Ayr and Home Hill. The peak at Clare was at 0730 on 24th and at Inkerman Bridge at 1600 on 24th

March: Flooding in the **Haughton River** blocked the rail bridge at Giru and a goods train was derailed near Townsville, whilst some flooding was also reported in the upper reaches of the **Burdekin River**.

April: Subsequent flooding of the lower **Burdekin River** also broke all records. Goods were damaged when Home Hill and Ayr were inundated, the water being 2 metres deep in the main street of Home Hill at one time. Many cane farms were seriously damaged , three spans of the old railway bridge at Home Hill were washed away and approaches to the new high level bridge cut. Restoration of river banks on the Burdekin is expected to be costly. Record peaks were on the Bowen River at Birralee on 3rd , and on the Burdekin River at Dalbeg on 3rd , at Strathalbyn on 3rd and Home Hill [Inkerman Bridge] on 3rd.

1960

March: Heavy rains in the Townsville area on 10th and 11th caused dislocation of road and rail traffic, Townsville being isolated for a time. The **Bohle River** reached its highest level since 1946 and the **Haughton River** was well over the bridge at Giru. Disruption to traffic was also reported on the Bruce Highway south of Sarina at this time, with water covering the Prospect Creek bridge.

1971

December: Heavy rainfall, associated with the rain depression that was previously **Cyclone"Althea"**, caused minor to major flooding in many Queensland rivers and streams during the latter portion of the month. Flooding continued into January in most southern inland streams as the floodwaters moved downstream.
Flooding and traffic disabilities occurred in the following areas:

1. **Coastal** streams St. Lawrence to Townsville.
2. **Burdekin** catchment including Burdekin River and upper tributaries, and Bowen River.

1972

March: During the first two weeks of the month, heavy rainfall in the north of the State produced flooding in main streams and tributaries of the following rivers. **Herbert** [minor] , **Haughton** [minor] , **Flinders** [moderate to major] , **Burdekin** [minor] , **Diamantina** [moderate] , **Georgina-Eyre** [major] , **Thomson-Barcoo** [minor]. By the end of the month, flood waters in rivers in the far west had drained into South Australia border areas.

1976

December: Heavy rainfall on the coastal ranges between St. Lawrence and Cairns during the 4th week of the month caused floods and extensive traffic disabilities, especially in the vicinity of Giru on the **Haughton River**.

1990

March: Major flooding developed further south in the **Haughton River** on Sunday 25th

December: General southwest movement of Cyclone "Joy" and eventual landfall in the Ayr region, led to severe local flooding along the Central Coast. Major flooding occurred on the 27th in the **Pioneer, Don and Haughton** rivers, with minor flooding in the **Lower Burdekin** River.

1991

January: Continued heavy rainfalls caused by ex Cyclone "Joy" along coastal areas caused minor to moderate flooding to develop in all coastal streams between Cairns and Gladstone during January. Flooding in the **Tully, Herbert, Haughton, Lower Burdekin, Don, and Pioneer** Rivers caused widespread traffic hazards, flooding of low lying properties and isolation of towns for several days. Serious flooding occurred in the small township of Giru on the **Haughton River** as floodwaters broke their banks and flooded many houses and streets of the town in early January.

February: Flooding in the **Haughton River** also caused inundation of the small township of Giru several times during February. The Giru flooding was the worst in living memory for local residents.

1997

February: **Haughton River:** Moderate flooding also occurred in the Haughton River during the same period.

1998

January: **Ross and Black Rivers and Bluewater Creek**: Bluewater Creek and Black River responded very quickly to the torrential rainfall which commenced on the afternoon and evening of Saturday 10th. Flash flooding occurred in Townsville and the surrounds, with levels metres higher than previously recorded. Major flooding resulted in large areas of the city. Thuringowa was inundated with significant damage to houses and businesses. Due to the mitigating effect of the Ross River dam, flood levels in the Ross River below the Dam peaked some 48 hours after the heavy rainfall.

Haughton River: Intense rain on the afternoon and evening of 10th resulted in rapid rises in the Haughton River and major flooding at Giru. Floodwaters remained steady and above the major flood level at Giru from 11th to 13th before rapidly receding.

1998

August: **Haughton River** : The deep low that caused the floods in the Pioneer and Don rivers on the 29th slowly moved north and caused very heavy rains in the upper Haughton River catchment and sharp river rises in the Haughton River. An initial flood warning was issued on the 30th for minor to moderate flooding downstream to Giru. Further heavy overnight rain on the 30th resulted in renewed rises and the warnings were updated to major flooding at Giru. River levels in Giru peaked at 2.73 metres on the evening of the 31st with major flooding. The warning was finalised the following day.

September: **Haughton River**: The Haughton River at Giru peaked at major flood level on the evening of the 31st August and upstream water levels were falling rapidly. A final flood warning was issued on the 1st September with major flooding easing slowly at Giru.

2000

February: **Haughton River:** Flooding commenced in the Haughton River on 17th February and continued intermittently until the end of the month. Major flooding resulted in inundation of the township of Giru on two occasions with minor flooding continuing for long periods throughout the month.

March: **Haughton River:** Heavy rainfall overnight on 16th March, which continued during the 17th March, resulted in moderate to major flooding throughout the Haughton River. River levels at Giru reached 2.70 metres early morning on 18th March, with major flooding, the highest level since the start of records in 1978. The flood warning was finalised for the Haughton River on the 19th March when all river levels had fallen below the minor flood level.

April: **Haughton River:** Widespread heavy rainfall on 3rd April following ex tropical cyclone Tessi, caused rapid river rises throughout the Haughton River catchment. Minor to moderate flooding occurred in the upstream reaches, with river levels downstream at Giru reaching 2.85 metres on 4th April causing major flooding. This was the highest level since the start of records in 1978. The flood warning was finalised for the Haughton River on the 4th April when all river levels had fallen below the minor flood level.

2005

January: **Haughton River:** Rainfall totals of up to 200 mm occurred in the Haughton River catchment during 22 to 23 January with moderate to major developing from Flora Valley downstream to Giru during 23 January. Major flood levels continued at Giru during 24 January before slowly easing over the following few days.

2006

January: **Haughton River:** Heavy rainfall of up to 400 mm was recorded in the Haughton River catchment in the 72 hours from 25th January. This resulted in major flooding at Giru where the river level peaked at 2.7 metres on 27th January. The first warning was issued on the 26th January and was finalized on the 27th January.

2007

February: **Haughton River:** Widespread heavy rainfall across the upper Haughton River in early February resulted in major flooding quickly developing, and major flood warnings commenced on 1st February. The heaviest hourly rainfall of 35 mm was recorded at 5am at Upper Major Creek on 1st February.
Major flooding along the Haughton River resulted in peak flood levels at Giru of 2.95 metres early on 2nd February, with floodwaters flowing through the township. Flooding quickly subsided to the minor flood level on 3rd February, and flood warnings were finalised on 4th February.

Ross River: Widespread heavy rainfall across the Ross River basin in early February resulted in moderate to major flooding in the Bohle River and Stuart Creek area. The heaviest rainfall was recorded in the 2 hours to 2pm on 1st February with between 70 and 150 mm. Flood warnings were issued for the general coastal rivers between Townsville and Mackay on 2nd February.

Repeated daily storm events with renewed river rises resulted in multiple flash flood events on the Bohle River and Stuart Creek. Controlled flows from the Ross River Dam during this period saw below minor flooding downstream in the Ross River. General flood warnings were finalised on 4th February.

Black River: Widespread heavy rainfall across the Black River basin in early February resulted in only minor flooding, which was covered in the general flood warning for coastal rivers between Townsville and Mackay on 1st February.

APPENDIX D

Slope Conversion Tables

APPENDIX D: SLOPE CONVERSION TABLES

RATIO	PERCENT	ANGLE
1 in 33	3.0%	1.7 degrees
1 in 20	5.0%	2.9 degrees
1 in 15	6.6%	3.8 degrees
1 in 10	10.0%	6.0 degrees
1 in 8	12.5%	7.1 degrees
1 in 6	16.6%	9.4 degrees
1 in 4	25.0%	14.0 degrees
1 in 3	33.3%	18.5 degrees
1 in 2	50.0%	27.0 degrees
1 in 1.5	66.6%	33.5 degrees
1 in 1	100.0%	45.0 degrees

PERCENT	RATIO	ANGLE
3.0%	1 in 33	1.7 degrees
5.0%	1 in 20	2.9 degrees
7.0%	1 in 14	4.0 degrees
11.0%	1 in 9.1	6.3 degrees
12.5%	1 in 8	7.0 degrees
15.0%	1 in 6.7	8.5 degrees
17.5%	1 in 5.7	10.0 degrees
20.0%	1 in 5	11.5 degrees
25.0%	1 in 4	14.0 degrees
30.0%	1 in 3.3	17.0 degrees
35.0%	1 in 2.8	19.5 degrees

ANGLE	PERCENT	RATIO
2.0 degrees	3.5%	1 in 28.5
3.0 degrees	5.2%	1 in 19.2
5.0 degrees	8.7%	1 in 11.4
7.0 degrees	12.3%	1 in 8.1
10.0 degrees	17.5%	1 in 5.7
12.0 degrees	21.3%	1 in 4.7
15.0 degrees	26.8%	1 in 3.7
20.0 degrees	36.4%	1 in 2.7
25.0 degrees	46.6%	1 in 2.1
30.0 degrees	57.7%	1 in 1.7
45.0 degrees	100.0%	1 in 1

APPENDIX E

Modified Mercalli (MM) Scale of Earthquake Intensity
(after Dowrick, 1996)

APPENDIX E: MODIFIED MERCALLI (MM) SCALE OF EARTHQUAKE INTENSITY

(after Dowrick, 1996)

MM I

People: Not felt except by a very few people under exceptionally favourable circumstances.

MM II

People: Felt by persons at rest, on upper floors or favourably placed.

MM III

People: Felt indoors; hanging objects may swing, vibrations may be similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake.

MM IV

People: Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building.

Fittings: Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock.

Structures: Walls and frame of building are heard to creak, and partitions and suspended ceilings in commercial buildings may be heard to creak.

MM V

People: Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed.

Fittings: Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate.

Structures: Some windows Type I cracked. A few earthenware toilet fixtures cracked.

MM VI

***People*:** Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily.

Fittings: Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or “easy glide” drawers may open (or shut).

Structures: Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall.

Environment: Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides.

MM VII

People: General alarm. Difficulty experienced in standing. Noticed by drivers of motorcars who may stop.

Fittings: Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings.

Structures: Unreinforced stone and brick walls cracked. Buildings Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick gables, and architectural ornaments fall. Roofing tiles, especially ridge tiles, may be dislodged. Many unreinforced chimneys damaged, often falling from roof-line. Water tanks Type I burst. A few instances of damage to brick veneers and plaster or cement-based linings. Unrestrained water cylinders (Water Tanks Type II) may move and leak. Some windows Type II cracked. Suspended ceilings damaged.

Environment: Water made turbid by stirred up mud. Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, or weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).

MM VIII

People: Alarm may approach panic. Steering of motor cars greatly affected.

Structures: Buildings Type I, heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structures Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundation may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down.

Environment: Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.

MM IX

Structures: Many buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V. Houses not secured to foundations shifted off. Brick veneers fall and expose frames.

Environment: Cracking of the ground conspicuous. Landsliding general on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.

MM X

Structures: Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). Dams, dykes, and embankments seriously damaged. Railway lines slightly bent. Cement and asphalt roads and pavements badly cracked or thrown into waves.

Environment: Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.

MM XI

Structures: Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

MM XII

Structures: Most Buildings Type III destroyed. Many Structures Type IV destroyed. Structures Type V heavily damaged, some with partial collapse. Structures Type VI moderately damaged.

Construction types

Buildings Type I: Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete, or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to Buildings Type I–III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I).

Buildings Type II: Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers.

Buildings Type III:	Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed in detail to resist earthquake forces.
Structures Type IV:	Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid 1930s to c. 1970 for concrete and to c. 1980 for other materials).
Structures Type V:	Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials.
Structures Type VI:	Structures dating from c. 1980 with well defined foundation behaviour, which have been especially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high (value) contents, or new generation low damage structures.

Windows

Type 1:	Large display windows, especially shop windows.
Type II:	Ordinary sash or casement windows.

Water Tanks

Type 1:	External, stand mounted, corrugated iron water tanks.
Type II:	Domestic hot-water cylinders unrestrained except by supply and delivery pipes.

APPENDIX F

RISK REGISTERS

APPENDIX F: TOWNSVILLE CITY RISK REGISTERS

Table F.1A: Large-scale storm destructive wind overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Almost certain (ARI up to 2-5 yrs) wind speeds to 100 km/h	**Insignificant:** Minor to moderate levels of wind damage reached in more exposed areas – a few tens of buildings damaged by falling branches, trees etc. Roads and power supply may be affected for a short time by fallen trees. Power supply may also be affected briefly by lightning strike or wind-blown debris. Some injuries can be expected but fatalities are unlikely.	**Medium**	Within capacity of local SES, though with some involvement of out-of-area SES units and other agencies possible to ensure response is completed speedily. Activation of LDCC unlikely. BoM warnings for at least 24 hours for cyclones. SEWS possibly needed to advise of after-storm dangers e.g. downed power lines
Llikely (ARI ~10-20 yrs) wind speeds to 166 km/h	**Minor:** Moderate levels of wind damage reached in more exposed coastal and ridge-top areas – up to 100 buildings with some damage. Roads, power supply and telecommunications infrastructure may be affected for a few hours by fallen trees, blown debris and/or lightning strike. Some older buildings may lose their roofs; some houses may be temporarily uninhabitable. Serious injuries can be expected and fatalities are possible. Quantities of fibro and asbestos insulation may need safe disposal.	**Medium**	Capacity of local SES stretched; QFRS assistance needed along with considerable support from out-of-area SES units. LDCC activated. Local medical services adequate. Restoration of power a priority and within local capacity. Short-term activation of evacuation centres likely.
Possibly (ARI ~50-100 yrs) winds to 212 km/h	**Major:** Significant levels of wind damage reached in broad areas – a few tens of buildings possibly destroyed and more than 100 severely damaged. Roads, power supply and telecommunications infrastructure will be affected for more than a day by fallen trees and blown debris. Some buildings likely to lose roofs or suffer debris damage. Serious economic impact. Numerous serious injuries likely, including serious trauma cases, and loss of life possible. Quantities of fibro and asbestos insulation may need safe disposal. Some public health risks if power supply remains out for more than 24 hours.	**High**	External resources required to assist local SES, QFRS and Police. LDCC and DDC activated. Local health service capacities stretched. Restoration of power supply and telecommunications likely to require State-wide assistance. Activation of evacuation centres for an extended period likely. BoM warnings for at least two days. Disaster appeal likely to be launched.
Unlikely (ARI ~250 yrs or greater) winds greater than 212 km/h	**Catastrophic:** Severe wind damage over extensive areas. Many tens of buildings destroyed and several hundreds or thousands severely damaged. Roads, telecommunications and power supply infrastructure will be affected for up to a week by fallen trees and blown debris. Some people possibly cut off and in need of urgent help. Major economic losses. Many injuries including severe trauma and loss of life likely. Large volumes of fibro and asbestos insulation may need safe disposal. Serious public health risks if power supply remains out for more than 48 hours.	**Medium**	LDCC, DDCC and SDCC activated. Commonwealth resources likely to be required. Local health service capacities exceeded and evacuation of serious cases to external hospitals required. Restoration of power supply and telecommunications likely to require interstate assistance. Activation of evacuation centres for an extended period likely. SEWS used.

Table F.1B: Large-scale storms element-by-element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	Almost certain	Medium	Exec Officer keep members informed of situation and activity by response agencies Keep community informed via electronic media Consider activation of LDCC and implementation of local disaster management plan	Routine Routine Routine
	Likely	Medium	Request assistance from DDC and/or State-level agencies by combat agency Review and update local disaster management plan after event	Routine High
	Possibly	High	Request assistance from DDC and/or State-level agencies if sought by combat agency Provide focus for post-event surveys and research activities by outside agencies	High Medium
	Unlikely	Medium	More of the same	
Buildings	Almost certain	Medium	Ensure that all new buildings conform to wind loading standards SES available for roof tarping once wind gusts consistently below 75 km/h Small number of property damage claims on insurance Collect and dispose of any damaged asbestos material according to OH&S standards	Routine Routine Routine High
	Likely	Medium	Survey and record damage for further analysis Require repairs and encourage retrofit of older buildings to meet current BCA standards	High Medium
	Possibly	High	Large number of property damage claims on insurance	Routine
	Unlikely	Medium	Very large number of property damage claims on insurance	Routine
Infrastructure	Almost certain	Medium	Ongoing maintenance of all above-ground infrastructure Local repair crews placed on standby when warnings issued Public warning of danger from downed power lines	Routine Routine High
	Likely	Medium	Implement infrastructure recovery plan Review and update infrastructure recovery plan Power lines to be put underground in new subdivisions and progressively in high risk areas	High High Medium
	Possibly	High	Regional repair crews placed on standby when warnings issued Large capacity stand-by generators required for critical facilities including hospitals Priority restoration of supply to critical infrastructures including water supply Activate WICEN and CREST volunteer radio networks until telecommunications restored	Routine High High High
	Unlikely	Medium	A lot more of the same	
Critical Facilities	All events	Medium to High	Restore operational capacity as soon as possible If restoration not possible move operational activities to alternate facility Review impact on critical services and identify strengths/ weaknesses in systems	High High High

People	Almost certain	Medium	Health system alerted to a potential increase in injury and trauma cases Short-term emergency accommodation provided to small numbers of people	Routine High
	Likely	Medium	Implement community welfare plan Small number of households require long-term emergency accommodation Small numbers of households need short-term financial assistance Review and update community welfare plan	High High High High
	Possibly	High	Health system alerted to potentially very large numbers of injury and trauma cases Short-term emergency accommodation provided to large numbers of people Moderate numbers of households need short-term financial assistance	Routine High High
	Unlikely	Medium	Large number of households require long-term emergency accommodation or relocation Large numbers of households need short-term financial assistance	High High
Environment	All events	Medium	Pruning, removal and disposal of damaged vegetation required Injured animals may need treatment	Routine Routine
Economy	Almost certain	Medium	Small number of business continuity claims and property claims on insurance	Routine
	Likely	High	Implement business recovery plan Review and update business recovery plan	High Medium
	Possibly	Medium	Significant number of business continuity claims and property damage claims on insurance Initiate and manage disaster appeal Coordinate and prioritise repair and reconstruction program	Routine High High
	Unlikely	Medium	Very large number of business continuity claims and property damage claims on insurance	Routine

Table F.2A: Flooding overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Almost certain (ARI up to 5 yrs)	**Insignificant:** Nuisance to minor flood levels reached in smaller urban catchments. Some minor roads cut and a few tens of properties isolated for up to a few hours.	**Medium**	SES on surveillance to effect evacuations if necessary. Close flood-affected roads and redirect traffic. Limited sandbagging possible; people affected checked on by doorknockers and helped to evacuate if necessary. Possibly no warnings; warnings of severe weather by BoM may note possibility of very heavy rain leading to flash flooding.
Likely (ARI up to 25 yrs)	**Minor:** Moderate to major flood levels reached. Some roads cut, perhaps as many as 50 properties isolated for up to a day. Power cuts and property losses likely, especially in low-lying areas where water ingress to buildings may occur.	**Medium**	SES on surveillance to effect evacuations if necessary. Close flood-affected roads and redirect traffic. Limited sandbagging possible; people affected checked on by doorknockers and helped to evacuate if necessary.
Possibly (ARI up to 100 yrs)	**Moderate:** Major flood levels reached. Many roads cut and damaged. Power cuts certain and damage to infrastructure likely. At least scores of properties isolated for more than a day; building, contents and equipment damage likely. Evacuations very likely. Potentially extensive property losses. As many as 150 low-lying dwellings and 20 other properties likely to be flooded over floor level. Loss of life possible but unlikely.	**Medium**	SES carry out evacuations by boat and assistance given to evacuees. Possibly no warnings of flash flood or storm water surcharge; warnings of severe weather by BoM may note possibility of very heavy rain leading to flash flooding.
Unlikely to rare (ARI greater than 250 to 500 yrs)	**Major to Catastrophic:** Extreme flood levels reached. Widespread road and infrastructure damage. Virtually the entire population of the City directly or indirectly affected. Evacuations will be required. Extensive property losses, with many dwellings and commercial premises experiencing over-floor inundation, especially in lower reaches of former creeks and swamplands. Major economic losses. Loss of life probable.	**Medium**	Rescue activity needed; assistance given to evacuees who may be moving upwards within multi-storey buildings where available. Much of this assistance could only be provided by local commercial firms to customers. If reliable indications of severity are available, warning of possible severe flash flooding may be provided by BoM.

Table F.2B: Flooding element-by-element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	Almost certain	Medium	Exec Officer keep members informed of situation and activity by response agencies SES to keep community kept informed and advised via electronic media and by doorknocks if needed and possible SES to be activated Consider activation of LDCC and implementation of local disaster management plan	Routine Routine Routine Routine
	Likely	Medium	Implement catchment-specific response plans where appropriate Review and update catchment-specific response plan and local disaster management plan Provide focus for post-event surveys and research activities by outside agencies	High High Medium
	Possibly	Medium	Request assistance from DDC and/or State-level agencies by combat agency	High
	Unlikely	Medium	Request assistance from State-level agencies and/or Commonwealth by combat agency	High
Buildings	Almost certain	Medium	SES to sandbag threatened buildings and installations if possible	Routine
	Likely	Medium	Survey and record damage for further analysis Commission high resolution hydraulic modelling and revise flood plan Implement engineering mitigation activities identified as necessary from new modelling Review land use planning scheme Consider acquisition of properties that have a demonstrated serious risk of inundation	High High Medium Medium Medium
	Possibly	Medium	More of the same	High
	Unlikely	Medium	Lot more of the same	High
Infrastructure	Almost certain	Medium	Close flood-affected roads and divert traffic	High
	Likely	Medium	Implement infrastructure recovery plan Manage power supply to minimise threat to SES and other emergency workers	High High
	Possibly	Medium	More of the same	High
	Unlikely	Medium	Lot more of the same	High
Critical Facilities	All events	Medium	Restore operational capacity as soon as possible If restoration not possible move operational activities to alternate facility Review impact on critical services and identify strengths/ weaknesses in systems	High High High
People	Almost certain	Medium	SES to carry out surveillance in case of need to evacuate or rescue people	High
	Likely	Medium	Open evacuation centres	High
	Possibly	Medium	More of the same	High
	Unlikely	Medium	Lot more of the same	High

Environment	All events	Medium	Pollution of waterways monitored and remediated if necessary	High
Economy	Almost certain	Medium	Small number of business continuity claims on insurance	Routine
	Likely	Medium	Significant numbers of business continuity claims on insurance Implement business recovery plan Review and update business recovery plan	Routine High Medium
	Possibly	Medium	Coordinate and manage public disaster appeal	High
	Unlikely	Medium	More of the same	High

Table F.3A: Storm tide and beach erosion overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Likely (ARI ~20 yrs)	**Insignificant:** Localised beach erosion likely. Some foreshore inundation and dunal recession possible.	**Low**	Within capacity of local SES and Council. Activation of LDCC unlikely. BoM warnings of at least 24 hours.
Possibly (ARI 30-50 yrs)	**Minor:** Major beach erosion certain and dunal recession likely. Inundation of fewer than 20 dwellings likely. Almost 20 km of roads will be affected for up to six hours. Few if any casualties.	**Medium**	Within capacity of local SES and Council. Activation of LDCC unlikely. Precautionary evacuation and possible sandbagging of exposed properties advisable. BoM warnings of at least 24 hours. Door-knock of some properties required.
Unlikely (ARI 50-100 yrs)	**Major:** Major foreshore erosion certain. Up to 200 dwellings with some level of inundation. Prior evacuations warranted. Up to 40 km of roads likely to be affected by inundation for up to six hours.	**Medium**	Within capacity of local SES and Council. Activation of LDCC unlikely. Precautionary evacuation and evacuation of exposed properties essential; assistance with removal and storage of belongings needed where houses are in danger of being damaged. BoM warnings of at least 24 hours. Door-knock of some properties required.
Rare (ARI >500 yrs)	**Major to Catastrophic:** Widespread and serious foreshore erosion. Several thousand dwellings with significant inundation. Mass evacuations ahead of the cyclone mandatory to reduce the risk of fatalities.	**Medium**	Beyond the capacity of local SES and Council. Precautionary evacuation and evacuation of exposed properties essential; assistance with removal and storage of belongings needed where houses are in danger of being damaged. BoM warnings of at least 24 hours. Door-knock of many properties required.

Table F.3B: Storm tide and beach erosion element-by-element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	Likely	Low	Exec Officer keep members informed of situation and activity by response agencies Keep community informed via electronic media	Routine Routine
	Possibly	Medium	Implement local disaster management plan and activate LDCC	Routine
	Unlikely to rare	Medium	Implement area-specific response plans for Pallarenda and Cungulla Review and update storm tide response plan and local disaster management plan Provide focus for post-event surveys and research activities by outside agencies	High High Medium
Buildings	Likely	Low	Nothing required	
	Possibly	Medium	Some sandbagging of buildings in Cungulla	High
	Unlikely to rare	Medium	Some sandbagging of buildings	High
Infrastructure	Likely	Low	Nothing required	
	Possibly	Medium	Close potentially affected roads	High
	Unlikely to rare	Medium	More of the same	High
Critical Facilities	Unlikely to rare	Medium	Some sandbagging required	
People	Likely	Low	Nothing required	
	Possibly	Medium	Voluntary evacuation of a small number of people by SES ahead of event	Medium
	Unlikely to rare	Medium	Ordered evacuation of many households	Medium
Environment	All events	Medium	Repair and restore beach erosion	Low
Economy	All events	Medium	Nothing required	

Table F.4A: Landslide overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Likely	**Insignificant:** Small slides from batters affecting roads. Partial or total blockage of, and isolated damage to, a few roads may occur. Possible rare injuries or fatalities due to debris on roads or rock falls from cliffs.	**Low**	Within capacity of Council. Activation of LDCC unlikely. Warnings unlikely except as a result of real time surveillance noting signs of movement.
Possibly	**Minor:** A few medium size batter failures which cause minor road blockage. Small number of localised slides causing minor damage. Possible rare injuries or fatalities due to rock falls from cliffs.	**Medium**	Within capacity of Council. Activation of LDCC unlikely.
Unlikely	**Moderate:** Numerous batter failures causing extensive road blockage. Widespread slides, some of which will cause damage to in-ground infrastructure and some buildings. Small debris flows and rock falls possible. Possible injuries or fatalities due to debris on roads, impact of landslides on houses, or rock falls from cliffs.	**Medium**	Within capacity of Council. Activation of LDCC unlikely.

Table F.4B: Landslide element-by-element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	All events	Medium	Keep community informed via electronic media Activate landslide sub-plan Review and update local disaster management plan if necessary Provide focus for post-event surveys and research activities by outside agencies	Routine Routine Routine Routine
Buildings	All events	Medium	If buildings are affected: Survey and document damage. Repair or demolish damaged buildings. Undertake engineering mitigation measures. Review planning scheme zonation.	High High
Infrastructure	All events	Medium	Close or partly close affected roads. Repair damaged infrastructure and document damage. Implement engineering mitigation measures.	High High High
Critical Facilities	All events	Medium	Repair damaged facilities and document damage. Implement engineering mitigation measures.	High High
People	All events	Medium	Counselling of affected people Treat any injuries. Document injuries.	High
Environment	All events	Medium	Probably none required	
Economy	All events	Medium	Probably none required	

Table F.5A: Bushfire overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Almost certain	**Insignificant:** Low intensity localised fires with limited spread. Limited threat to property. Easily controlled with small resources.	**Medium**	Well within the capacity of QFRS. Possible fire weather warnings.
Likely	**Minor:** Medium intensity, and possibly multiple, fires with some spread potential. Property likely to be damaged. Manageable by conventional methods.	**Medium**	Within the capacity of QFRS and immediately neighbouring RFS. Possible fire weather warnings.
Possibly	**Moderate:** Multiple severe intensity fires with significant spread potential. Property loss and injuries likely. Difficult to manage by conventional methods.	**Medium**	Beyond the capacity of local QFRS. Significant support by neighbouring QRFS units and aerial attack resources required. LDCC activated. Selective evacuation of some areas likely. Fire weather warnings issued. Fire bans in force. Use of SEWS probably required.
Unlikely	**Major:** Extreme fire intensity and major spread potential. Property loss certain, fatalities likely. Very difficult to manage by conventional methods.	**Medium**	Well beyond the capacity of local QFRS. Significant support by State-wide QRFS units and aerial attack resources required. Evacuation of some areas required. Fire weather warnings issued. Fire bans in force. Use of SEWS essential.

Table F.5B: Bushfire element-by element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	Possibly to unlikely	Medium	Keep community informed via electronic media Implement local disaster management plan and activate LDCC Review and update local disaster management plan if necessary Provide focus for post-event surveys and research activities by outside agencies	Routine Routine Routine Routine
Buildings	Possibly to unlikely	Medium	Property owners prepare buildings and grounds for fire threat Process all insurance claims for property loss/damage and business continuity	High High
Infrastructure	Possibly to unlikely	Medium	Manage water supply to maximise availability to fire fighters Manage power supply to minimise risks to fire fighters Close roads and divert traffic where smoke hazards exist	High High High
Critical Facilities	Possibly to unlikely	Medium	If in bush interface areas keep fuel load within 500 m to less than 12 t/ha at all times Review impact on critical services and identify strengths/ weaknesses in systems	High High
People	Possibly to unlikely	Medium	Implement household bush fire management plan Evacuate at-risk individuals well ahead of fire to centres well removed from likely fire threat People remaining to defend property prepare clothing and equipment and monitor radio	Routine High High
Environment	Possibly to unlikely	Medium	Recover and care for injured wildlife	Routine
Economy	Possibly to unlikely	Medium	Review and update business recovery plan Coordinate and manage public disaster appeal	High High

Table F.6A: Earthquake overview

LIKELIHOOD	CONSEQUENCES	RISK LEVEL	RESPONSE
Likely	**Nil:** Small intensity shaking to MM IV. Little if any damage.	**Low**	Within capacity of local SES and Council. Activation of LDCC unlikely. No warnings.
Possibly	**Insignificant:** Small intensity shaking to MM V. Little if any damage.	**Low**	Within capacity of local SES and Council. Activation of LDCC unlikely. No warnings.
Unlikely	**Minor:** Moderate intensity shaking to MM VI. Minor damage to poorly constructed buildings possible. Injuries unlikely. Some damage to the more fragile in-ground infrastructure possible.	**Low**	Within capacity of local SES and Council. Activation of LDCC likely. No warnings.
Rare	**Major:** Strong intensity shaking to MM VII. Damage to older masonry and poorly constructed buildings likely. Some serious injuries likely and some fatalities possible. Some dislocation of in-ground infrastructure likely. Secondary hazards such as fire possible.	**Low**	External resources required to assist local SES, QRFS and Police. LDCC, DDCC and SDCC activated. Commonwealth resources required. Local health service capacities exceeded and evacuation of serious cases to external hospitals required. Restoration of power supply and telecommunications require interstate assistance. Activation of evacuation centres for an extended period likely. No warnings.

Table F.6B: Earthquake element-by-element risk assessment

ELEMENT	LIKELIHOOD	RISK LEVEL	TREATMENT OPTIONS	PRIORITY
LDMG	Unlikely to rare	Low	Request assistance from State-level agencies and/or Commonwealth	High
Buildings	Unlikely to rare	Low	Lot more of the same	Routine
Infrastructure	Unlikely to rare	Low	Lot more of the same	High
Critical Facilities	Unlikely to rare	Low	Restore operational capacity as soon as possible If restoration not possible move operational activities to alternate facility Review impact on critical services and identify strengths/ weaknesses in systems	High High High
People	Unlikely to rare	Low	Lot more of the same	High
Environment	Unlikely to rare	Low	Pollution of waterways monitored and remediated if necessary	High
Economy	Unlikely to rare	Low	Significant numbers of business continuity claims on insurance Implement business recovery plan Review and update business recovery plan Coordinate and manage public disaster appeal	High

APPENDIX G

RISK TREATMENT PLAN

APPENDIX G: RISK TREATMENT PLAN

In the following tables the risk reduction strategies that have been detailed in Chapter 5 are drawn together to form the basis for a risk treatment plan. Three tables are provided. The first simply lists the strategies in the order that they appear in Chapter 5. The agencies that should be involved in their implementation are identified and a priority for their implementation has been suggested. The second table arranges the strategies in priority order. The third series lists strategies according to the agencies responsible.

The suggested priorities can be interpreted as follows:

Ongoing:	activities that are already established as an operational activity
High:	should be commenced within six months
Medium:	should be commenced within 12 months
Low:	should be commenced within 18 months

Table G.1: Risk treatment strategies in Chapter 5 order

STRATEGY NUMBER	STRATEGY	RESPONSIBLE AGENCY	PRIORITY
Generic 1	When establishing its new Vision Statement and Corporate Plan the New Townsville City Council consider the inclusion of a clear commitment to maintain a safe and sustainable community, especially in relation to the potential impact of natural hazards.	TCC	High
Generic 2	At an early stage in the life of each Council the LDMG arrange a briefing for all elected councillors and senior executives on their roles and responsibilities for emergency risk management. An information package to support such a briefing should contain material such as the LGAQ/DES resource *Elected member's guide to disaster management*.	LDMG, TCC	High
Generic 3	Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.	TCC, LGAQ, DES	Medium
Generic 4	In the process of re-designing the functional arrangements for its amalgamated structure Council review the subordination of the LDMG to maximise its effectiveness as a risk management body.	TCC, LDMG	High
Generic 5	At an early stage in the amalgamation process the New Townsville City Council promotes a policy that facilitates public access to details of potential hazard impact zones, especially those involving inundation hazards.	TCC	High
Generic 6	Council commission a follow-up multi-hazard risk assessment, as Stage 2 of this study, to produce a disaster risk management strategy for the New Townsville City Council. That study should be based on updated City-wide hazard-specific studies for bushfire and earthquake (and possibly flood).	TCC	High
Generic 7	Council review its vegetation management strategies to manage remnant native trees and street tree planting to minimise their potential to do damage if brought down during storms or to provide bushfire fuel close to residences.	TCC	Ongoing
	Council, through LGAQ, request DES and EMA to review the		

Generic 8	limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.	TCC, LGAQ, DES, EMA	Low
Generic 9	Council seek future external funding to extend its multi-hazard risk assessment studies to address the full span of hazards, including heatwave, epidemics and anthropogenic hazards.	TCC	Low
Generic 10	The LDMG initiate discussions with the Townsville City Library, the Museum of North Queensland and local history groups to document the community's experience of and response to emergencies.	LDMG	Medium
Generic 11	The LDMG incorporate into its Local Disaster Management Plan the requirement to undertake and/or fund post-event surveys and studies from which to accurately assess the consequences (physical, economic, personal) of all significant hazard impacts.	LDMG	Ongoing
Generic 12	The LDMG recommend to DES that guidelines be developed to standardise the conduct of post-event surveys and studies and incorporate those guidelines into the State Disaster Management Plan.	LDMG, DES	Low
Generic 13	The LDMG develop procedures and protocols by which to manage and coordinate post-event research by outside agencies following a major disaster.	LDMG	Low
Generic 14	Council, through the LGAQ, recommend to DES that guidelines be developed and circulated to the scientific community relating to the conduct of post-event studies.	TCC, DES	Low
Generic 15	The LDMG recommend to Council that as part of the amalgamation of the two council information systems that it commissions a review of its amalgamated information infrastructure and its capacity to fully support the planning for and response to a major emergency.	LDMG, TCC	Ongoing
Generic 16	Council enter into discussions with the BoM to upgrade the Mt Stuart weather watch radar to a Doppler radar and to review the effectiveness of the current flood warning system.	TCC, BoM	Medium
Generic 17	The LDMG recommend to Council the development of a comprehensive emergency risk communications strategy, in association with the response agencies, including the production of a comprehensive guide to the development of household emergency management plans. That guide should be included in the 'welcome' information pack provided to new residents.	LDMG, TCC	Ongoing
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	LDMG, TCC, SES, QFRS, QAS, QPS	Ongoing
Generic 19	The LDMG and Council establish a program of community awareness as to the importance of SEWS ahead of the annual bushfire and cyclone seasons.	TCC, community groups	Ongoing
Generic 20	Council use the current high degree of media interest in issues relating to climate change to promote messages of the linkage of climate and natural hazards both now and into the future.	TCC	Ongoing
Generic 21	Before the start of each cyclone season Council run a community education program aimed at building community resilience and self reliance. To provide focus to that campaign Council could consider adopting a slogan along the lines of 'your safety is our concern, but your responsibility'.	TCC	Ongoing

Generic 22	The LDMG consider activating the local LDCC in response to the more frequently occurring lower-level emergency situations to expand the experience of members and their agencies.	LDMG	Ongoing
Generic 23	The LDMG recommend to DES that model sub-plans be developed to provide guidance on planning for infrastructure recovery, business recovery and community welfare activities during and following an emergency.	LDMG, DES	Medium
Generic 24	Council, through the LGAQ recommend to DES that it publish guidelines for the establishing, coordination and administration of public disaster appeals.	TCC, LGAQ, DES	Low
Generic 25	Before the onset of each cyclone season the LDMG should review and update the evacuation sub-plan of the Local Disaster Management Plan to take account of the risks identified in this study and to take account of best-practice evacuation planning methods.	LDMG	Ongoing
Generic 26	Townsville SES Unit investigate the development of a retirement village emergency and evacuation plan based on that operated by the Maroochy (Sunshine Coast Region) SES Unit.	SES	Ongoing
Generic 27	Council and the LDMG Welfare Committee examine the need and suitability of using 'off the shelf' software to support the registration and tracking of evacuees.	TCC, LDMG	Medium
Generic 28	Council establish a dialogue with the public and private proprietors and operators of critical infrastructure to ensure that they understand their role in the local disaster management process and to encourage their support for the work of the LDMG.	TCC	Medium
Generic 29	The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.	LDMG, DES, Geoscience Australia	Medium
Generic 30	The LDMG establish an arrangement with the local members of Wireless Institute Civil Emergency Network (WICEN) to provide communications support in the event of extended outages of telephone and other communications systems.	LDMG, WICEN	Ongoing
Storm 1	Council maximise the likelihood that all new buildings conform with wind loading standards under the BCA by incorporating into the Townsville City Plan wind loading and corrosion line mapping based on the provisions of AS 1170.2-2002, AS 4550-2006 and BCA Table 3.3.3.1.	TCC	Ongoing
Storm 2	Council encourage owners and builders to ensure that renovations and/or repairs to houses built before 1989 are upgraded to meet current wind code conditions in line with SAA HB1321 (SA & ICA, 1999a).	TCC	Ongoing
Storm 3	Council run annual information sessions for private certifiers, builders and architects on the requirements of AS 1170.2 and the desirability of applying the retrofit strategies of HB1321.	TCC	Medium
Storm 4	Council require operators of caravan parks to install tie down points for caravans and provide information to all caravan owners on caravan safety in high winds.	TCC	High
Storm 5	Council establish a plan for the management of broken fibro and other asbestos-based products following storm damage. Identify appropriate disposal sites.	TCC	Ongoing
	Council establish a requirement for power supply in all new	TCC,	

Storm 6	subdivisions to be placed underground and establish a program with Ergon of placing power supply underground in areas of high exposure and/or frequent damage.	Powerlink, Ergon	Medium
Flood 1	Council to review the detailed flood risk treatment strategies identified by consultants Maunsell Australia in their 2005 report for inclusion in a new City floodplain management strategy.	TCC	Ongoing
Flood 2	Council establish a rolling program to review and update flood modelling at ten or preferably five-year intervals, in urban areas and rural areas where significant development is planned to take place. Continue research and computerised flood impact modelling to support emergency management planning and operations.	TCC	Ongoing
Flood 3	Council investigate the need to undertake an updated flood management study to take account of the upgrade of the Ross River Dam and to incorporate the NQ Water operational procedures for managing flows through the dam into the local disaster management plan.	TCC	Medium
Flood 4	If indicated by the outcomes of *Flood strategy 3* Council investigate the installation of a siren warning system for properties immediately downstream of the dam to be used when flood waters are to be released from the dam.	TCC	Medium
Flood 5	LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.	LDMG, SES, QPS	Ongoing
Flood 6	Council records flood inundation information from major events in order to build up a database of records that can be used in responding to future flood events in flood prone areas.	TCC	Ongoing
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	TCC, LGAQ, DES	Low
Storm tide 1	Council establish a rolling program to review and update storm tide modelling at ten or preferably five-year intervals. Continue research and computerised inundation impact modelling to support emergency management planning and operations.	TCC	Ongoing
Storm tide 2	The LDMG establish a program to encourage residents in potentially exposed locations to develop household emergency response plans for storm tide based on the existing modelling and storm tide warning system.	LDMG	High
Storm tide 3	LDMG to maintain specific evacuation plans for communities in storm tide-prone areas such as Cungulla and parts of South Townsville based on scenarios developed from the modelling.	LDMG	Ongoing
Landslide 1	Stabilise potentially problematic batters or slopes on Council-controlled roads, or erect protective structures (such as mesh fences or bunds) and encourage DMR to undertake similar work on State-controlled roads.	TCC, DMR	Ongoing
Landslide 2	Given the uncertainty that exists regarding the potential risks posed by rock falls from Castle Hill being initiated by a close earthquake of moderate or greater magnitude, Council, in conjunction with relevant State agencies, commission specific research to establish an appropriate management strategy.	TCC, State agencies	Low
Landslide 3	Council maintain an ongoing community education program warning about rock falls from Castle Hill and landslides from other steep slope areas such as Mount Louisa.	TCC	Ongoing

Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	TCC, LGAQ, DES, DLGP	Medium
Landslide 5	Council investigate technical options for monitoring areas of Castle Hill that have been identified as posing a particular threat from rock falls from steep rock cliffs.	TCC	Ongoing
Landslide 6	Council establish a MOU with the State government as to their potential liability should major damage or injury result from a rock fall or landslide from Council-managed State land on Castle Hill.	TCC	High
Landslide 7	Council commission City-wide landslide hazard potential mapping to SPP 1/03 standard. Council's GIS staff could undertake most of the work with guidance from an external consultant.	TCC	High
Landslide 8	Incorporate the updated landslide potential hazard mapping done to SPP 1/03 standard into the new Townsville City Plan.	TCC	High
Fire 1	Council commission an updated bushfire hazard mapping program to cover the New Townsville City area. Council's GIS staff has the necessary technical skills to undertake this work under the supervision of an external consultant that is skilled in bushfire hazard mapping.	TCC	High
Fire 2	Incorporate the updated bushfire hazard potential mapping, done to SPP 1/03 standards, into the new Townsville City Plan.	TCC	High
Fire 3	Council consider the immediate appointment of a Fire Management Officer to undertake the duties suggested by the 1994 State Bushfire Audit and to oversee the implementation of the bushfire management strategy for the study area.	TCC	Medium
Fire 4	Council adopt as policy for managing fuel on Council-controlled land: – the fire management principles and practices identified by the FABC and QPWS which seek to strike a balance between community safety and preserving biodiversity; – recognition of the principle that the need for fuel reduction to improve community safety will take precedence over consideration of smoke pollution from prescribed burning.	TCC	Medium
Fire 5	Conduct an annual audit of fuel conditions on Council-controlled land.	TCC	Ongoing
Fire 6	Based on the results of those audits, allocate adequate human and equipment resources, including QFRS support, to initiate a sustainable program of fuel management on Council-controlled land, with the land with the greatest level of hazard being treated as soon as possible.	TCC, QFRS	Ongoing
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	TCC, QPWS, DoD, QFRS	Medium
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	LDMG, QFRS, QPWS, DoD, Powerlink, Ergon	Medium
Fire 9	Draw to the attention of building certifiers and developers operating in the City the existence of the *natural hazard management area (bushfire)* mapping and the responsibility they bear to ensure that the provisions of AS 3959 with regard to	TCC	Low

	design and construction standards within those areas designated as being fire-prone, together with appropriate subdivisional design and siting principles identified by CSIRO and others, are complied with.		
Fire 10	QFRS promote bushfire safety program in study area suburbs and localities with an identified fire threat. Households in those areas encouraged to develop household fire plans.	QFRS	Ongoing
Fire 11	QFRS consider installing and maintaining prominent 'fire danger' signage in urban interface areas to improve community awareness in periods of elevated fire danger.	QFRS	Medium
Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	TCC, LGAQ, DES, DLGP	Low
Earthquake 1	Commission a detailed site class study of the urbanised area to improve the resolution and accuracy of the class zones suggested in this study. From that analysis identify specific building types that may be exposed to amplified earthquake shaking.	TCC	Low
Earthquake 2	Ensure all new buildings comply with the BCA earthquake loading code (AS1170.4) as modified by the revised acceleration factors. Encourage owners of existing buildings to upgrade their properties to current standards when undertaking structural renovations or extensions.	TCC	Low
Earthquake 3	Conduct an audit of all Council buildings and where appropriate retrofit all those deemed to be potentially unsafe in an earthquake of Richter magnitude 5.0 or greater.	TCC	Low
Earthquake 4	Educate the public about what to do in an earthquake.	TCC	Medium

Table G.2: Risk treatment strategies in priority order

STRATEGY NUMBER	STRATEGY	AGENCY	PRIORITY
Generic 7	Council review its vegetation management strategies to manage remnant native trees and street tree planting to minimise their potential to do damage if brought down during storms or to provide bushfire fuel close to residences.	TCC	Ongoing
Generic 11	The LDMG incorporate into its Local Disaster Management Plan the requirement to undertake and/or fund post-event surveys and studies from which to accurately assess the consequences (physical, economic, personal) of all significant hazard impacts.	LDMG	Ongoing
Generic 15	The LDMG recommend to Council that as part of the amalgamation of the two council information systems that it commissions a review of its amalgamated information infrastructure and its capacity to fully support the planning for and response to a major emergency.	LDMG, TCC	Ongoing
Generic 17	The LDMG recommend to Council the development of a comprehensive emergency risk communications strategy, in association with the response agencies, including the production of a comprehensive guide to the development of household emergency management plans. That guide should be included in the 'welcome' information pack provided to new residents.	LDMG, TCC	Ongoing
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	LDMG, TCC, SES, QFRS, QAS, QPS	Ongoing
Generic 19	The LDMG and Council establish a program of community awareness as to the importance of SEWS ahead of the annual bushfire and cyclone seasons.	TCC, community groups	Ongoing
Generic 20	Council use the current high degree of media interest in issues relating to climate change to promote messages of the linkage of climate and natural hazards both now and into the future.	TCC	Ongoing
Generic 21	Before the start of each cyclone season Council run a community education program aimed at building community resilience and self reliance. To provide focus to that campaign Council could consider adopting a slogan along the lines of 'your safety is our concern, but your responsibility'.	TCC	Ongoing
Generic 22	The LDMG consider activating the local LDCC in response to the more frequently occurring lower-level emergency situations to expand the experience of members and their agencies.	LDMG	Ongoing
Generic 25	Before the onset of each cyclone season the LDMG should review and update the evacuation sub-plan of the Local Disaster Management Plan to take account of the risks identified in this study and to take account of best-practice evacuation planning methods.	LDMG	Ongoing
Generic 26	Townsville SES Unit investigate the development of a retirement village emergency and evacuation plan based on that operated by the Maroochy (Sunshine Coast Region) SES Unit.	SES	Ongoing
Generic 30	The LDMG establish an arrangement with the local members of Wireless Institute Civil Emergency Network (WICEN) to provide communications support in the event of extended outages of telephone and other communications systems.	LDMG, WICEN	Ongoing
	Council maximise the likelihood that all new buildings conform with wind loading standards under the BCA by incorporating into		

Storm 1	the Townsville City Plan wind loading and corrosion line mapping based on the provisions of AS 1170.2-2002, AS 4550-2006 and BCA Table 3.3.3.1.	TCC	Ongoing
Storm 2	Council encourage owners and builders to ensure that renovations and/or repairs to houses built before 1989 are upgraded to meet current wind code conditions in line with SAA HB1321 (SA & ICA, 1999a).	TCC	Ongoing
Storm 5	Council establish a plan for the management of broken fibro and other asbestos-based products following storm damage. Identify appropriate disposal sites.	TCC	Ongoing
Flood 1	Council to review the detailed flood risk treatment strategies identified by consultants Maunsell Australia in their 2005 report for inclusion in a new City floodplain management strategy.	TCC	Ongoing
Flood 2	Council establish a rolling program to review and update flood modelling at ten or preferably five-year intervals, in urban areas and rural areas where significant development is planned to take place. Continue research and computerised flood impact modelling to support emergency management planning and operations.	TCC	Ongoing
Flood 5	LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.	LDMG, SES, QPS	Ongoing
Flood 6	Council records flood inundation information from major events in order to build up a database of records that can be used in responding to future flood events in flood prone areas.	TCC	Ongoing
Storm tide 1	Council establish a rolling program to review and update storm tide modelling at ten or preferably five-year intervals. Continue research and computerised inundation impact modelling to support emergency management planning and operations.	TCC	Ongoing
Storm tide 3	LDMG to maintain specific evacuation plans for communities in storm tide-prone areas such as Cungulla and parts of South Townsville based on scenarios developed from the modelling.	LDMG	Ongoing
Landslide 1	Stabilise potentially problematic batters or slopes on Council-controlled roads, or erect protective structures (such as mesh fences or bunds) and encourage DMR to undertake similar work on State-controlled roads.	TCC, DMR	Ongoing
Landslide 3	Council maintain an ongoing community education program warning about rock falls from Castle Hill and landslides from other steep slope areas such as Mount Louisa.	TCC	Ongoing
Landslide 5	Council investigate technical options for monitoring areas of Castle Hill that have been identified as posing a particular threat from rock falls from steep rock cliffs.	TCC	Ongoing
Fire 5	Conduct an annual audit of fuel conditions on Council-controlled land.	TCC	Ongoing
Fire 6	Based on the results of those audits, allocate adequate human and equipment resources, including QFRS support, to initiate a sustainable program of fuel management on Council-controlled land, with the land with the greatest level of hazard being treated as soon as possible.	TCC, QFRS	Ongoing
Fire 10	QFRS promote bushfire safety program in study area suburbs and localities with an identified fire threat. Households in those areas encouraged to develop household fire plans.	QFRS	Ongoing
Generic 1	When establishing its new Vision Statement and Corporate Plan the New Townsville City Council consider the inclusion of a clear	TCC	High

	commitment to maintain a safe and sustainable community, especially in relation to the potential impact of natural hazards.		
Generic 2	At an early stage in the life of each Council the LDMG arrange a briefing for all elected councillors and senior executives on their roles and responsibilities for emergency risk management. An information package to support such a briefing should contain material such as the LGAQ/DES resource *Elected member's guide to disaster management*.	LDMG, TCC	High
Generic 4	In the process of re-designing the functional arrangements for its amalgamated structure Council review the subordination of the LDMG to maximise its effectiveness as a risk management body.	TCC, LDMG	High
Generic 5	At an early stage in the amalgamation process the New Townsville City Council promotes a policy that facilitates public access to details of potential hazard impact zones, especially those involving inundation hazards.	TCC	High
Generic 6	Council commission a follow-up multi-hazard risk assessment, as Stage 2 of this study, to produce a disaster risk management strategy for the New Townsville City Council. That study should be based on updated City-wide hazard-specific studies for bushfire and earthquake (and possibly flood).	TCC	High
Storm 4	Council require operators of caravan parks to install tie down points for caravans and provide information to all caravan owners on caravan safety in high winds.	TCC	High
Storm tide 2	The LDMG establish a program to encourage residents in potentially exposed locations to develop household emergency response plans for storm tide based on the existing modelling and storm tide warning system.	LDMG	High
Landslide 6	Council establish a MOU with the State government as to their potential liability should major damage or injury result from a rock fall or landslide from Council-managed State land on Castle Hill.	TCC	High
Landslide 7	Council commission City-wide landslide hazard potential mapping to SPP 1/03 standard. Council's GIS staff could undertake most of the work with guidance from an external consultant.	TCC	High
Landslide 8	Incorporate the updated landslide potential hazard mapping done to SPP 1/03 standard into the new Townsville City Plan.	TCC	High
Fire 1	Council commission an updated bushfire hazard mapping program to cover the New Townsville City area. Council's GIS staff has the necessary technical skills to undertake this work under the supervision of an external consultant that is skilled in bushfire hazard mapping.	TCC	High
Fire 2	Incorporate the updated bushfire hazard potential mapping, done to SPP 1/03 standards, into the new Townsville City Plan.	TCC	High
Generic 3	Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.	TCC, LGAQ, DES	Medium
Generic 10	The LDMG initiate discussions with the Townsville City Library, the Museum of North Queensland and local history groups to document the community's experience of and response to emergencies.	LDMG	Medium
Generic 16	Council enter into discussions with the BoM to upgrade the Mt Stuart weather watch radar to a Doppler radar and to review the effectiveness of the current flood warning system.	TCC, BoM	Medium
Generic 23	The LDMG recommend to DES that model sub-plans be developed to provide guidance on planning for infrastructure recovery, business recovery and community welfare activities	LDMG, DES	Medium

	during and following an emergency.		
Generic 27	Council and the LDMG Welfare Committee examine the need and suitability of using 'off the shelf' software to support the registration and tracking of evacuees.	TCC, LDMG	Medium
Generic 28	Council establish a dialogue with the public and private proprietors and operators of critical infrastructure to ensure that they understand their role in the local disaster management process and to encourage their support for the work of the LDMG.	TCC	Medium
Generic 29	The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.	LDMG, DES, Geoscience Australia	Medium
Storm 3	Council run annual information sessions for private certifiers, builders and architects on the requirements of AS 1170.2 and the desirability of applying the retrofit strategies of HB1321.	TCC	Medium
Storm 6	Council establish a requirement for power supply in all new subdivisions to be placed underground and establish a program with Ergon of placing power supply underground in areas of high exposure and/or frequent damage.	TCC, Powerlink, Ergon	Medium
Flood 3	Council investigate the need to undertake an updated flood management study to take account of the upgrade of the Ross River Dam and to incorporate the NQ Water operational procedures for managing flows through the dam into the local disaster management plan.	TCC	Medium
Flood 4	If indicated by the outcomes of *Flood strategy 3* Council investigate the installation of a siren warning system for properties immediately downstream of the dam to be used when flood waters are to be released from the dam.	TCC	Medium
Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	TCC, LGAQ, DES, DLGP	Medium
Fire 3	Council consider the immediate appointment of a Fire Management Officer to undertake the duties suggested by the 1994 State Bushfire Audit and to oversee the implementation of the bushfire management strategy for the study area.	TCC	Medium
Fire 4	Council adopt as policy for managing fuel on Council-controlled land: – the fire management principles and practices identified by the FABC and QPWS which seek to strike a balance between community safety and preserving biodiversity; – recognition of the principle that the need for fuel reduction to improve community safety will take precedence over consideration of smoke pollution from prescribed burning.	TCC	Medium
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	TCC, QPWS, DoD, QFRS	Medium
	Consider formation of the Townsville City Fire Management		

Fire 8	Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	LDMG, QFRS	Medium
Earthquake 4	Educate the public about what to do in an earthquake.	TCC	Medium
Generic 8	Council, through LGAQ, request DES and EMA to review the limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.	TCC, LGAQ, DES, EMA	Low
Generic 9	Council seek future external funding to extend its multi-hazard risk assessment studies to address the full span of hazards, including heatwave, epidemics and anthropogenic hazards.	TCC	Low
Generic 12	The LDMG recommend to DES that guidelines be developed to standardise the conduct of post-event surveys and studies and incorporate those guidelines into the State Disaster Management Plan.	LDMG, DES	Low
Generic 13	The LDMG develop procedures and protocols by which to manage and coordinate post-event research by outside agencies following a major disaster.	LDMG	Low
Generic 14	Council, through the LGAQ, recommend to DES that guidelines be developed and circulated to the scientific community relating to the conduct of post-event studies.	TCC, DES	Low
Generic 24	Council, through the LGAQ recommend to DES that it publish guidelines for the establishing, coordination and administration of public disaster appeals.	TCC, LGAQ, DES	Low
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	TCC, LGAQ, DES	Low
Landslide 2	Given the uncertainty that exists regarding the potential risks posed by rock falls from Castle Hill being initiated by a close earthquake of moderate or greater magnitude, Council, in conjunction with relevant State agencies, commission specific research to establish an appropriate management strategy.	TCC, State agencies	Low
Fire 9	Draw to the attention of building certifiers and developers operating in the City the existence of the *natural hazard management area (bushfire)* mapping and the responsibility they bear to ensure that the provisions of AS 3959 with regard to design and construction standards within those areas designated as being fire-prone, together with appropriate subdivisional design and siting principles identified by CSIRO and others, are complied with.	TCC	Low
Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	TCC, LGAQ, DES, DLGP	Low
Earthquake 1	Commission a detailed site class study of the urbanised area to improve the resolution and accuracy of the class zones suggested in this study. From that analysis identify specific building types that may be exposed to amplified earthquake shaking.	TCC	Low
	Ensure all new buildings comply with the BCA earthquake loading code (AS1170.4) as modified by the revised acceleration factors.		

Earthquake 2	Encourage owners of existing buildings to upgrade their properties to current standards when undertaking structural renovations or extensions.	TCC	Low
Earthquake 3	Conduct an audit of all Council buildings and where appropriate retrofit all those deemed to be potentially unsafe in an earthquake of Richter magnitude 5.0 or greater.	TCC	Low

Table G.3A: Risk treatment strategies by responsible agency and priority – **TCC**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 7	Council review its vegetation management strategies to manage remnant native trees and street tree planting to minimise their potential to do damage if brought down during storms or to provide bushfire fuel close to residences.	Ongoing
Generic 15	The LDMG recommend to Council that as part of the amalgamation of the two council information systems that it commissions a review of its amalgamated information infrastructure and its capacity to fully support the planning for and response to a major emergency.	Ongoing
Generic 17	The LDMG recommend to Council the development of a comprehensive emergency risk communications strategy, in association with the response agencies, including the production of a comprehensive guide to the development of household emergency management plans. That guide should be included in the 'welcome' information pack provided to new residents.	Ongoing
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing
Generic 19	The LDMG and Council establish a program of community awareness as to the importance of SEWS ahead of the annual bushfire and cyclone seasons.	Ongoing
Generic 20	Council use the current high degree of media interest in issues relating to climate change to promote messages of the linkage of climate and natural hazards both now and into the future.	Ongoing
Generic 21	Before the start of each cyclone season Council run a community education program aimed at building community resilience and self reliance. To provide focus to that campaign Council could consider adopting a slogan along the lines of 'your safety is our concern, but your responsibility'.	Ongoing
Storm 1	Council maximise the likelihood that all new buildings conform with wind loading standards under the BCA by incorporating into the Townsville City Plan wind loading and corrosion line mapping based on the provisions of AS 1170.2-2002, AS 4550-2006 and BCA Table 3.3.3.1.	Ongoing
Storm 2	Council encourage owners and builders to ensure that renovations and/or repairs to houses built before 1989 are upgraded to meet current wind code conditions in line with SAA HB1321 (SA & ICA, 1999a).	Ongoing
Storm 2	Council encourage owners and builders to ensure that renovations and/or repairs to houses built before 1989 are upgraded to meet current wind code conditions in line with SAA HB1321 (SA & ICA, 1999a).	Ongoing
Storm 5	Council establish a plan for the management of broken fibro and other asbestos-based products following storm damage. Identify appropriate disposal sites.	Ongoing
Flood 1	Council to review the detailed flood risk treatment strategies identified by consultants Maunsell Australia in their 2005 report for inclusion in a new City floodplain management strategy.	Ongoing
Flood 2	Council establish a rolling program to review and update flood modelling at ten or preferably five-year intervals, in urban areas and rural areas where significant development is planned to take place. Continue research and computerised flood impact modelling to	Ongoing

	support emergency management planning and operations.	
Flood 6	Council records flood inundation information from major events in order to build up a database of records that can be used in responding to future flood events in flood prone areas.	Ongoing
Storm tide 1	Council establish a rolling program to review and update storm tide modelling at ten or preferably five-year intervals. Continue research and computerised inundation impact modelling to support emergency management planning and operations.	Ongoing
Landslide 1	Stabilise potentially problematic batters or slopes on Council-controlled roads, or erect protective structures (such as mesh fences or bunds) and encourage DMR to undertake similar work on State-controlled roads.	Ongoing
Landslide 3	Council maintain an ongoing community education program warning about rock falls from Castle Hill and landslides from other steep slope areas such as Mount Louisa.	Ongoing
Landslide 5	Council investigate technical options for monitoring areas of Castle Hill that have been identified as posing a particular threat from rock falls from steep rock cliffs.	Ongoing
Fire 5	Conduct an annual audit of fuel conditions on Council-controlled land.	Ongoing
Fire 6	Based on the results of those audits, allocate adequate human and equipment resources, including QFRS support, to initiate a sustainable program of fuel management on Council-controlled land, with the land with the greatest level of hazard being treated as soon as possible.	Ongoing
Generic 1	When establishing its new Vision Statement and Corporate Plan the New Townsville City Council consider the inclusion of a clear commitment to maintain a safe and sustainable community, especially in relation to the potential impact of natural hazards.	High
Generic 2	At an early stage in the life of each Council the LDMG arrange a briefing for all elected councillors and senior executives on their roles and responsibilities for emergency risk management. An information package to support such a briefing should contain material such as the LGAQ/DES resource *Elected member's guide to disaster management*.	High
Generic 4	In the process of re-designing the functional arrangements for its amalgamated structure Council review the subordination of the LDMG to maximise its effectiveness as a risk management body.	High
Generic 5	At an early stage in the amalgamation process the New Townsville City Council promotes a policy that facilitates public access to details of potential hazard impact zones, especially those involving inundation hazards.	High
Generic 6	Council commission a follow-up multi-hazard risk assessment, as Stage 2 of this study, to produce a disaster risk management strategy for the New Townsville City Council. That study should be based on updated City-wide hazard-specific studies for bushfire and earthquake (and possibly flood).	High
Storm 4	Council require operators of caravan parks to install tie down points for caravans and provide information to all caravan owners on caravan safety in high winds.	High
Landslide 6	Council establish a MOU with the State government as to their potential liability should major damage or injury result from a rock fall or landslide from Council-managed State land on Castle Hill.	High
Landslide 7	Council commission City-wide landslide hazard potential mapping to SPP 1/03 standard. Council's GIS staff could undertake most of the work with guidance from an external consultant.	High

Landslide 8	Incorporate the updated landslide potential hazard mapping done to SPP 1/03 standard into the new Townsville City Plan.	
Fire 1	Council commission an updated bushfire hazard mapping program to cover the New Townsville City area. Council's GIS staff has the necessary technical skills to undertake this work under the supervision of an external consultant that is skilled in bushfire hazard mapping.	High
Fire 2	Incorporate the updated bushfire hazard potential mapping, done to SPP 1/03 standards, into the new Townsville City Plan.	High
Generic 3	Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.	Medium
Generic 16	Council enter into discussions with the BoM to upgrade the Mt Stuart weather watch radar to a Doppler radar and to review the effectiveness of the current flood warning system.	Medium
Generic 27	Council and the LDMG Welfare Committee examine the need and suitability of using 'off the shelf' software to support the registration and tracking of evacuees.	Medium
Generic 28	Council establish a dialogue with the public and private proprietors and operators of critical infrastructure to ensure that they understand their role in the local disaster management process and to encourage their support for the work of the LDMG.	Medium
Storm 3	Council run annual information sessions for private certifiers, builders and architects on the requirements of AS 1170.2 and the desirability of applying the retrofit strategies of HB1321.	Medium
Storm 6	Council establish a requirement for power supply in all new subdivisions to be placed underground and establish a program with Ergon of placing power supply underground in areas of high exposure and/or frequent damage.	Medium
Flood 3	Council investigate the need to undertake an updated flood management study to take account of the upgrade of the Ross River Dam and to incorporate the NQ Water operational procedures for managing flows through the dam into the local disaster management plan.	Medium
Flood 4	If indicated by the outcomes of *Flood strategy 3* Council investigate the installation of a siren warning system for properties immediately downstream of the dam to be used when flood waters are to be released from the dam.	Medium
Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	Medium
Fire 3	Council consider the immediate appointment of a Fire Management Officer to undertake the duties suggested by the 1994 State Bushfire Audit and to oversee the implementation of the bushfire management strategy for the study area.	Medium
Fire 4	Council adopt as policy for managing fuel on Council-controlled land: – the fire management principles and practices identified by the FABC and QPWS which seek to strike a balance between community safety and preserving biodiversity; – recognition of the principle that the need for fuel reduction to improve community safety will take precedence over consideration of smoke pollution from prescribed burning.	Medium
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland	Medium

	interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	
Earthquake 4	Educate the public about what to do in an earthquake.	Medium
Generic 8	Council, through LGAQ, request DES and EMA to review the limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.	Medium
Generic 9	Council seek future external funding to extend its multi-hazard risk assessment studies to address the full span of hazards, including heatwave, epidemics and anthropogenic hazards.	Low
Generic 14	Council, through the LGAQ, recommend to DES that guidelines be developed and circulated to the scientific community relating to the conduct of post-event studies.	Low
Generic 24	Council, through the LGAQ recommend to DES that it publish guidelines for the establishing, coordination and administration of public disaster appeals.	Low
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	Low
Landslide 2	Given the uncertainty that exists regarding the potential risks posed by rock falls from Castle Hill being initiated by a close earthquake of moderate or greater magnitude, Council, in conjunction with relevant State agencies, commission specific research to establish an appropriate management strategy.	Low
Fire 9	Draw to the attention of building certifiers and developers operating in the City the existence of the *natural hazard management area (bushfire)* mapping and the responsibility they bear to ensure that the provisions of AS 3959 with regard to design and construction standards within those areas designated as being fire-prone, together with appropriate subdivisional design and siting principles identified by CSIRO and others, are complied with.	Low
Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	Low
Earthquake 1	Commission a detailed site class study of the urbanised area to improve the resolution and accuracy of the class zones suggested in this study. From that analysis identify specific building types that may be exposed to amplified earthquake shaking.	Low
Earthquake 2	Ensure all new buildings comply with the BCA earthquake loading code (AS1170.4) as modified by the revised acceleration factors. Encourage owners of existing buildings to upgrade their properties to current standards when undertaking structural renovations or extensions.	Low
Earthquake 3	Conduct an audit of all Council buildings and where appropriate retrofit all those deemed to be potentially unsafe in an earthquake of Richter magnitude 5.0 or greater.	Low

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Table G.3B: Risk treatment strategies by responsible agency and priority – **LDMG**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 11	The LDMG incorporate into its Local Disaster Management Plan the requirement to undertake and/or fund post-event surveys and studies from which to accurately assess the consequences (physical, economic, personal) of all significant hazard impacts.	Ongoing
Generic 15	The LDMG recommend to Council that as part of the amalgamation of the two council information systems that it commissions a review of its amalgamated information infrastructure and its capacity to fully support the planning for and response to a major emergency.	Ongoing
Generic 17	The LDMG recommend to Council the development of a comprehensive emergency risk communications strategy, in association with the response agencies, including the production of a comprehensive guide to the development of household emergency management plans. That guide should be included in the 'welcome' information pack provided to new residents.	Ongoing
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing
Generic 22	The LDMG consider activating the local LDCC in response to the more frequently occurring lower-level emergency situations to expand the experience of members and their agencies.	Ongoing
Generic 25	Before the onset of each cyclone season the LDMG should review and update the evacuation sub-plan of the Local Disaster Management Plan to take account of the risks identified in this study and to take account of best-practice evacuation planning methods.	Ongoing
Generic 30	The LDMG establish an arrangement with the local members of Wireless Institute Civil Emergency Network (WICEN) to provide communications support in the event of extended outages of telephone and other communications systems.	Ongoing
Flood 5	LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.	Ongoing
Storm tide 3	LDMG to maintain specific evacuation plans for communities in storm tide-prone areas such as Cungulla and parts of South Townsville based on scenarios developed from the modelling.	Ongoing
Generic 2	At an early stage in the life of each Council the LDMG arrange a briefing for all elected councillors and senior executives on their roles and responsibilities for emergency risk management. An information package to support such a briefing should contain material such as the LGAQ/DES resource *Elected member's guide to disaster management*.	High
Generic 4	In the process of re-designing the functional arrangements for its amalgamated structure Council review the subordination of the LDMG to maximise its effectiveness as a risk management body.	High
Storm tide 2	The LDMG establish a program to encourage residents in potentially exposed locations to develop household emergency response plans for storm tide based on the existing modelling and storm tide warning system.	High
Generic 10	The LDMG initiate discussions with the Townsville City Library, the Museum of North Queensland and local history groups to document the community's experience of and response to emergencies.	Medium

Generic 23	The LDMG recommend to DES that model sub-plans be developed to provide guidance on planning for infrastructure recovery, business recovery and community welfare activities during and following an emergency.	Medium
Generic 27	Council and the LDMG Welfare Committee examine the need and suitability of using 'off the shelf' software to support the registration and tracking of evacuees.	Medium
Generic 29	The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.	Medium
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium
Generic 12	The LDMG recommend to DES that guidelines be developed to standardise the conduct of post-event surveys and studies and incorporate those guidelines into the State Disaster Management Plan.	Low
Generic 13	The LDMG develop procedures and protocols by which to manage and coordinate post-event research by outside agencies following a major disaster.	Low

Table G.3C: Risk treatment strategies by responsible agency and priority – **SES**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing
Generic 26	Townsville SES Unit investigate the development of a retirement village emergency and evacuation plan based on that operated by the Maroochy (Sunshine Coast Region) SES Unit.	Ongoing
Flood 5	LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.	Ongoing

Table G.3D Risk treatment strategies by responsible agency and priority – **QFRS**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing
Fire 6	Based on the results of those audits, allocate adequate human and equipment resources, including QFRS support, to initiate a sustainable program of fuel management on Council-controlled land, with the land with the greatest level of hazard being treated as soon as possible.	Ongoing

Fire 10	QFRS promote bushfire safety program in study area suburbs and localities with an identified fire threat. Households in those areas encouraged to develop household fire plans.	Ongoing
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	Medium
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium

Table G.3E: Risk treatment strategies by responsible agency and priority – **QPS**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing
Flood 5	LDMG ensure that local SES and QPS staffs are made familiar with management arrangements for local flood issues, conduct on-site briefings on the management of the flood threat at identified flash flooding hotspots, especially where road closures are required.	Ongoing

Table G.3F: Risk treatment strategies by responsible agency and priority – **QAS**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 18	The LDMG, in conjunction with Council and response agencies engage with the local electronic media outlets to establish procedures to manage communications with the community, including messages in languages other than English, to provide authoritative information ahead of, during and after an emergency.	Ongoing

Table G.3G: Risk treatment strategies by responsible agency and priority – **DES**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 3	Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.	Medium
Generic 23	The LDMG recommend to DES that model sub-plans be developed to provide guidance on planning for infrastructure recovery, business recovery and community welfare activities during and following an emergency.	Medium
Generic 29	The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.	Medium

Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	Medium
Generic 8	Council, through LGAQ, request DES and EMA to review the limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.	Low
Generic 14	Council, through the LGAQ, recommend to DES that guidelines be developed and circulated to the scientific community relating to the conduct of post-event studies.	Low
Generic 24	Council, through the LGAQ recommend to DES that it publish guidelines for the establishing, coordination and administration of public disaster appeals.	Low
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	Low
Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	Low

Table G.3H: Risk treatment strategies by responsible agency and priority – **DLGP**

STRATEGY NUMBER	STRATEGY	PRIORITY
Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	Medium
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	Low
Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	Low

Table G.3I: Risk treatment strategies by responsible agency and priority – **DMR**

STRATEGY NUMBER	STRATEGY	PRIORITY
Landslide 1	Stabilise potentially problematic batters or slopes on Council-controlled roads, or erect protective structures (such as mesh fences or bunds) and encourage DMR to undertake similar work on State-controlled roads.	Ongoing

Table G.3J: Risk treatment strategies by responsible agency and priority – **QPWS**

STRATEGY NUMBER	STRATEGY	PRIORITY
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	Medium
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium

Table G.3K: Risk treatment strategies by responsible agency and priority – **Powerlink**

STRATEGY NUMBER	STRATEGY	PRIORITY
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium

Table G.3L: Risk treatment strategies by responsible agency and priority – **Ergon**

STRATEGY NUMBER	STRATEGY	PRIORITY
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium

Table G.3M: Risk treatment strategies by responsible agency and priority – **LGAQ**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 3	Council, through the LGAQ, request DES to task its legal advisors to compile and disseminate a statement of the legal, administrative and common law responsibilities of Queensland local governments for emergency risk management.	Medium
Landslide 4	Recommend to LGAQ that they negotiate with DES and DLGP to review the SPP 1/03 guidelines relating to landslide with the particular suggestion that the 'default' landslide threat zonation of 15% slope be revised to require specific reference to the lithology.	Medium
Flood 7	Recommend to LGAQ that they negotiate with DES and DLGP a review of SPP 1/03 guidelines relating to flood with the particular suggestion that guidance be included on an appropriate resolution for DEM used in flood modelling.	Low

Fire 12	Recommend to LGAQ that they negotiate with DES and DLGP for a review of SPP 1/03 guidelines relating to bushfire with the particular suggestion that guidance be included on an appropriate resolution for modelling in interface area. It would also be advantageous to publish more appropriate weights for aspect to reflect wind direction in local fire weather events and a more comprehensive list of hazard potential scores vegetation or ecosystem types than is currently available.	Low

Table G.3N: Risk treatment strategies by responsible agency and priority – **EMA**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 8	Council, through LGAQ, request DES and EMA to review the limitation of NDMP projects to those hazards covered under the NDRRA so that Queensland local governments can more effectively develop a genuine all-hazards approach to emergency risk management.	Low

Table G.3O: Risk treatment strategies by responsible agency and priority – **BoM**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 16	Council enter into discussions with the BoM to upgrade the Mt Stuart weather watch radar to a Doppler radar and to review the effectiveness of the current flood warning system.	Medium

Table G.3P: Risk treatment strategies by responsible agency and priority – **Geoscience Australia**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 29	The LDMG and DES commission specific research and analysis of the full range of critical infrastructure, especially in areas identified as information gaps in this study. Liaise with Geoscience Australia to ensure that this research is modelled on the approach employed in Commonwealth-led Critical Infrastructure Protection, Management and Analysis (CIPMA) program so that the information developed could be exchanged between the two systems.	Medium

Table G.3Q: Risk treatment strategies by responsible agency and priority – **Dept of Defence**

STRATEGY NUMBER	STRATEGY	PRIORITY
Fire 7	Council, QPWS and Department of Defence, in consultation with QFRS, adopt a maximum desirable fuel loading in bushland interface areas within the study area (e.g. 12 t/ha). Develop strategies to monitor and maintain that loading level, especially in areas adjacent to critical infrastructure and the urban interface.	Medium
Fire 8	Consider formation of the Townsville City Fire Management Committee with representation from QFRS, QPWS, Defence, Powerlink and Ergon as a sub-committee of the LDMG.	Medium

Table G.3R: Risk treatment strategies by responsible agency and priority – **WICEN**

STRATEGY NUMBER	STRATEGY	PRIORITY
Generic 30	The LDMG establish an arrangement with the local members of Wireless Institute Civil Emergency Network (WICEN) to provide communications support in the event of extended outages of telephone and other communications systems.	Ongoing