



# COMMUNITY RISK IN CAIRNS

## A MULTI-HAZARD RISK ASSESSMENT

by

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*Cities Project*  
**Australian Geological Survey Organisation**

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## **FOREWORD**

### **COMMUNITY RISK IN CAIRNS A MULTI-HAZARD RISK ASSESSMENT**

**By The Hon. Warren Entsch MP, Parliamentary Secretary for Industry, Science and Resources.**

The Australian Geological Survey Organisation (AGSO) is Australia's premier National geoscience research body.

The Cities Project was established within AGSO in 1996 and since then has taken the leading role in researching a range of geohazards and how they impact upon local communities.

Geohazards exist almost everywhere. In layman's terms a geohazard is simply a 'natural hazard' that exists within the local environment and can be in the bush, in a town or a city. They include landslides and rapid erosion.

AGSO has taken up the challenge to develop a better understanding of geohazards and the relationships that exist when they impact upon urban communities. Cairns is the first in a series of 'case studies' to develop and test the science, the techniques, the information and the tools needed to analyse and assess such complex problems that exist in our everyday environment.

The results are very interesting. Having lived in and around Cairns for all of my life I was amazed to learn so much about a place that I thought I knew well.

This booklet provides an introduction to the Cairns multi-hazard risk assessment and contains some interesting results. I urge you to investigate the comprehensive information in the full report on the Compact Disk. This is important, groundbreaking work and I commend it to you.

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KG, TJ, ML & GS

# OVERVIEW

## Background

The AGSO *Cities Project* was established in 1996 to undertake research directed towards the mitigation of the risks faced by Australian urban communities that are posed by a range of geohazards. Geohazards are broadly defined to include all earth surface processes with the potential to cause loss or harm to the community or the environment. The ultimate objective is to improve the safety of communities, and consequently make them more sustainable and prosperous. To provide a realistic focus to this research, and to achieve practical outcomes, the *Cities Project* is using a series of case studies based on Queensland centres to develop and test its science and techniques. Cairns is the first of these multi-hazard case studies.

Cairns is the most northerly of Queensland's cities and one of the fastest growing communities in Australia. It is also an isolated community, located some 1 400 km from Brisbane (**Figure (i)**). Cairns has a resident population of approximately 120 000 and this total can exceed 150 000 at the height of the tourist season. An aerial image of Cairns city and inner suburbs viewed from the east is shown in **Figure (ii)** (reproduced by permission of Brian Cassey Photography).

This report is considered to be 'provisional' because the information, the techniques and the tools needed to undertake a task as complex as assessing community risk in a major urban centre are still evolving. Because this is the first *Cities Project* case study to be finalised, we have gone to some lengths to describe and explain the methodologies that have evolved. This report may, therefore, be seen as containing both a detailed risk assessment of Cairns and a worked-through example of the risk assessment techniques. Readers are encouraged to view the report as a starting point, rather than an end in itself.

At the heart of this research is the view that risk is the outcome of the interaction between a hazard phenomenon and the elements at risk within the community (the people, buildings and infrastructure) that are vulnerable to such an impact. The relationship is expressed in pseudo-mathematical form as:

$$\text{Risk}_{(\text{Total})} = \text{Hazard} \times \text{Elements at Risk} \times \text{Vulnerability}$$

This approach is not only elegant, it is also very practical given that it lends itself to quantitative, qualitative and composite analytical approaches. It also gives clear focus for our application of the risk management philosophy outlined in the standard *AS/NZS 4360-1995 Risk management*.

The vast majority of information, relationships and processes involved in understanding risk are spatial in nature. We have, therefore, made extensive use of geographic information system (GIS) to drive our analysis and assessment. *Risk-GIS*, as it has been christened in the *Cities Project*, is a fusion of the decision support capabilities of GIS and the philosophy of risk management expressed in the standard. The processes in which *Risk-GIS* are applied, and our understanding of the risk management process are summarised in **Figure (iii)**. These issues are described in **Chapter 1**.

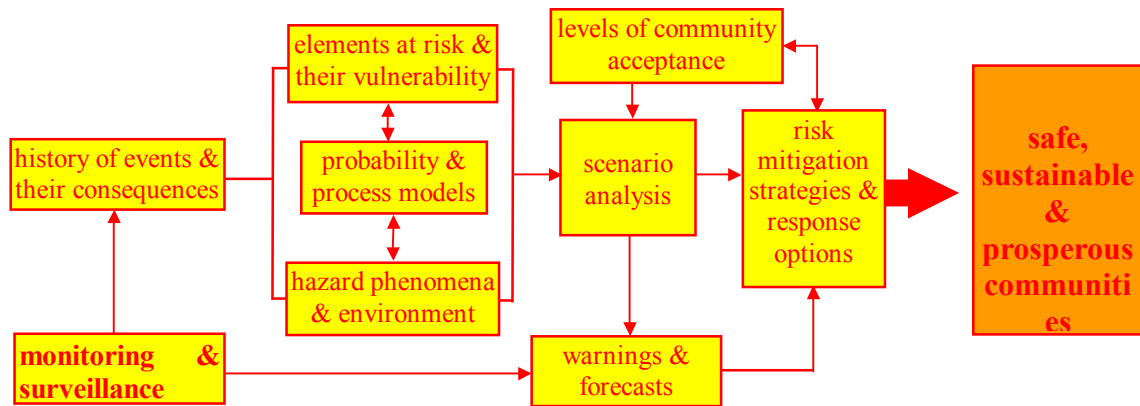


Figure (iii): *Cities Project* understanding of risk management and *Risk-GIS* processes

## Community Vulnerability

The elements at risk in the community and their vulnerability to hazard impact are described in detail in [Chapter 2](#) and [Chapter 3](#). We have adopted a systematic approach to this description, grouping the various elements into the five themes of setting, shelter, sustenance, security and society (the ‘five esses’). The topics addressed under these themes include:

- **Setting:** basic regional topics including the physical environment (climate, vegetation, geology, soils, land use, topography, elevation, etc), access (external links by major road, rail, air, marine and telecommunications infrastructures), population and administrative arrangements (local government, suburb and other administrative boundaries);
- **Shelter:** the buildings that provide shelter to the community at home, at work and at play. Access to shelter is also significant, so information on mobility within the community is included here. Particular attention is paid to the capacity and vulnerability of the road network and the availability of vehicles.
- **Sustenance:** modern urban communities are highly reliant on their utility and service infrastructures such as water supply, sewerage, power supply and telecommunications. These *lifelines* are significantly dependent on each other and on other logistic resources such as fuel supply. The community is also dependent on the availability of food supplies, clothing, medical supplies and other personal items.
- **Security:** the security of the community is measured in terms of its health and wealth and by the forms of protection that are provided. Physically, these may be assessed by the availability of facilities such as hospitals, nursing homes, industries, commercial premises, agricultural land use, ambulance stations, fire stations, police stations and

works such as flood retention basins and levees. Also important are socio-demographic and economic issues related to the elderly, the very young, the disabled, household income, unemployment, home ownership and the resources available at the fire and police stations.

- **Society:** here we find most of the more intangible measures such as language, ethnicity, religion, nationality, community and welfare groups, education, awareness, meeting places, cultural activities and so on. Some of these may be measured in terms of the facilities that they use, such as churches, meeting halls, sporting clubs, libraries and so on; however, the more meaningful measures, such as education, relate specifically to the individuals, families and households that make up the community.

Whilst these data provide a detailed quantitative description of specific aspects of the city's risk environment, they do not, of themselves, provide an adequate measure of overall community vulnerability. Nor do they individually reflect the relative levels of vulnerability across the city. To overcome these shortcomings we have developed an overall vulnerability profile of Cairns by which to identify those suburbs that provide a disproportionate contribution to community risk because of the number and nature of the elements at risk they contain. Details of the methodology developed to produce this composite view of community vulnerability is contained in [Appendix E](#).

**Figure (iv)** shows the distribution of suburbs according to their overall contribution to community vulnerability. The distribution strongly reflects the development history of the city, with the areas of greatest significance being the original city area, the original villages of Edmonton and Gordonvale to the south and the Yarrabah Aboriginal Community to the east.

## Earthquake risk

The earthquake hazard in Cairns is moderate by global standards, but it is not negligible. Over the past 100 years there have been at least 11 significant earthquakes reported within 200 km of Cairns, the most damaging being the Richter magnitude 4.3 event of 1896. In many places of Australia, probably including Cairns, moderate to strong earthquakes of Richter magnitudes 5 to 6 make up about 90% of the total contribution to the overall earthquake hazard. The occurrence of such an earthquake close to Cairns would be a rare event. However, its impact could be great. An earthquake in this magnitude range (Richter magnitude 5.6) near Newcastle in 1989 caused arguably Australia's most costly 20<sup>th</sup> Century natural disaster.

We have constructed earthquake urban hazard zonation maps and, from the building database, produced an inventory of buildings, by construction type and usage, in the zones in these maps. Any earthquake of a magnitude likely to cause damage in Cairns will have an effect across all suburbs. The amount of damage, and consequently risk, will increase with the intensity of the event.

Whilst all suburbs have some degree of exposure, *Risk-GIS* analysis of the earthquake hazard reveals that some 86% of Cairns buildings stand on 'soft' sediments of the coastal plains and riverine deltas, or the sands, silts and clays of the lower footslopes. These sediments amplify earthquake shaking. The extensive 'soft' sediments beneath the coastal suburbs, in particular, would aggravate the impact of any significant earthquake. These are also the suburbs that contain many of the critical facilities and have significant concentrations of people, buildings and

infrastructure. The remaining 14% of the buildings are mostly modern and are situated on the upper slope soils or rock of the hills where ground motions will be less damaging. Some of these buildings conform to the earthquake loading provisions of the Australian Building Code, and the majority conform to wind loading provisions.

In order to produce a suburb-by-suburb ranking of Cairns for earthquake risk from direct damage to buildings, we have introduced a vulnerability ranking of building construction types. The profile of risk exposure to earthquake and a total earthquake risk profile, which takes account of community vulnerability as well as the exposure to the hazard, are shown in **Figures (v) and (vi)**.

## **Landslide risk**

Until the 1996 Gracetown tragedy in Western Australia, when 9 people were killed by a coastal rockfall, and the 1997 Thredbo New South Wales landslide which demolished 2 ski lodges, killing 18, there had been little public recognition that landslides were a significant threat to life in Australia. Where landslides occur, their physical impact is typically confined to a few properties or a short length of road or railway. Their effect, however, can be disturbing and disruptive and occasionally fatal. Insurance policies in Australia do not normally cover landslide, and this can add to the anguish of property owners.

For Cairns, landslide has been, and remains, a significant risk, as evidenced by events such as the massive Ellis Beach debris flows that buried 10 km of the Captain Cook Highway in 1951, and the frequent impact on road and rail links to Kuranda and elsewhere.

Most landslides recorded in the Cairns area appear to be associated with disturbances of the natural surface by activities such as the construction of roads and the excavation of building sites. As development extends increasingly onto the hill slopes in areas such as the Freshwater valley, the risk of landslide impact will increase unless appropriate mitigation strategies and engineering design standards are adhered to. Experience over at least 70 years has demonstrated that flash flooding and/or debris flows in the Freshwater valley have the potential to severely dislocate the Cairns water supply.

The landslide study undertaken here is the first to follow an internationally recognised quantitative landslide risk assessment methodology to be undertaken in Australia. It has been conducted at a relatively broad reconnaissance level, however, and should not be interpreted, without more detailed geotechnical investigation, at the individual property level.

**Figures (vii) and (viii)** show the profile of exposure to landslide and the total risk (based on community vulnerability).

## **Flood risk**

Whilst flooding causes inconvenience and some dislocation in Cairns on average about once every 12 years, it poses a relatively limited threat to people and buildings because urban development has largely been excluded from the most flood-prone areas of the Barron River delta. This exclusion reflects the community's experience of at least seven episodes of major flooding since the establishment of the Trinity Inlet settlement in 1876.

The loss of sugar cane and damage to roads and other infrastructure on the delta and along Freshwater Creek carries with it a significant economic loss. The most significant inconvenience caused by moderate to major flooding in the Barron River system is the isolation of the northern beachside suburbs from downtown Cairns, with its critical facilities such as hospitals and airport. Road and rail access to Cairns can also be blocked from the south by flooding in the Mulgrave and Russell Rivers.

Limited flood mitigation works have been established, the main work being the levees that protect the airport. The flood warning system for the Barron River operated by the Bureau of Meteorology is very effective and provides residents in flood-prone areas with adequate time to prepare for flood and/or to evacuate if that is indicated. Formal land use planning constraints on development within the area likely to be affected by a flood with an average recurrence interval of 100 years have been in force since the early 1990s.

Flash flooding in the other catchments, especially the streams that flow into Trinity Inlet, is a potentially significant problem. Not only are there significantly more properties exposed to urban drainage surcharge in the downtown area than there are on the Barron delta, but also the risk to life is significant because of the rapid onset of flash floods and the propensity for careless or foolish behaviour by some people in and around floodwaters.

Using *Risk-GIS*, we have assessed the number of buildings, length of roads and area of cane land in each of the Barron River delta suburbs which would be affected by Barron River flood scenarios of various annual exceedence probabilities (average recurrence intervals). The impact on these communities, emergency management issues, and key facilities affected have been discussed. **Figures (ix) and (x)** show the flood risk exposure and total flood risk profiles for the Barron River.

## Cyclone risk

Tropical cyclones pose a considerable threat to Cairns. In the 123 years since the settlement was established there have been 53 cyclones that have had some effect on the town - that is, an average of a cyclone every two years. They bring with them the multiple threats of destructive winds, heavy rain and storm tide inundation.

Using *Risk-GIS*, we have assessed the suburbs in terms of wind risk exposure. We have also modelled various annual exceedence probability storm tide scenarios to quantitatively assess their impact on the elements at risk in the Cairns community.

The conventional response to an impending cyclone impact is for people to take shelter in their own homes. In those areas that would be subject to storm tide inundation, however, this is not an appropriate option as many people in such areas would be exposed to a significant risk of drowning, especially if the level of inundation exceed 1 m over floor level.

Evacuation of those people at risk must be completed before the winds reach 75 km/hr (typically six hours before the cyclone's eye reaches the coast), the strength at which it ceases to be safe for anyone to be out of doors. For storm tide events with annual exceedence probabilities of 1% or greater (an average recurrence interval of at most 100 years) the numbers of people involved are relatively small and could be easily managed with appropriate warning, planning and community awareness. Beyond that level, however, a considerable effort would be required to manage the

numbers of evacuees involved unless the vast majority were prepared to undertake their own evacuations beginning at least 24 hours before the forecast cyclone impact time. Delay in commencing a major evacuation process will increase the risk of people being caught in the open or in their transport when the cyclone hits because of gridlock on the roads leading out of the danger area.

Whilst a severe cyclone will have a major immediate impact on Cairns with potentially significant loss of life and massive damage, the long term impact will also be catastrophic. In an extreme event, most survivors would need to be evacuated to centres as far away as Brisbane and Sydney (as was the experience of Darwin following the impact of Cyclone *Tracy* in 1974). The loss of facilities on which the community relies would be such that the city would be virtually uninhabitable for an extended period.

The application of building code standards for domestic structures since 1982 and the inclusion of storm tide hazard as a constraint in the urban planning process in Cairns since the early 1990s have certainly slowed the rate at which risk would otherwise have increased. Significant reduction in risk will not be possible until the concentration of population, economic activity and community services in the highest risk areas of Aeroglen, Cairns North, City, Machans Beach, Manunda, Parramatta Park and Portsmith is reduced significantly. Some proposed developments, such as the creation of a major residential precinct in Trinity East, could, unless carefully implemented, exacerbate an already risk-laden situation. **Figures (xi) and (xii)** portray the wind exposure and total risk profiles and **Figures (xiii) and (xiv)** show the storm tide exposure and total risk profiles.

## Risk evaluation

There is no doubt that tropical cyclones pose the greatest threat to Cairns and that **the destructive winds accompanying cyclones pose the greatest level of risk**. Cairns has come within the radius of destructive winds at least 21 times since 1876. Not only do they have a high frequency of occurrence, they also have a wide-spread impact. The introduction of building construction standards for wind loads beginning in 1975 has proved to be a most effective form of mitigation. Very few buildings constructed since 1975 have suffered more than minor damage by winds in the 10 cyclones that have had an effect on Cairns since that time, though substantial damage has been done to vegetation and power lines. There is little, however, that can be done to reduce the risk of wind damage to sugar cane or tree crops such as banana and pawpaw.

Of the other hazard phenomena generated by cyclones, **storm tide clearly ranks second**. Destructive storm tides have been relatively rare events in Cairns history (only three or four instances over the past 123 years). There is absolutely no doubt, however, that they hold the greatest potential to cause major loss of life and to wreak widespread and massive damage. Their potential for destruction is derived largely from the large numbers of people, buildings and critical facilities that are located within the area in which storm tide impact would be greatest. All of this development pre-dates the introduction of planning constraints aimed at reducing storm tide risk, consequently it provides a substantial residual risk that will need to be addressed by other mitigation strategies.

Whilst earthquake is not widely recognised as a significant threat to Cairns, our research and the known record of seismic activity along the entire east coast of Australia leads us to conclude that **strong earthquake poses the third greatest risk to the Cairns community**. This risk is largely

derived from the geology of the region. Much of Cairns is built on thick sediments. In addition, the sediments that underlie much of the downtown area are classed as 'soft'. All these sediments are likely to significantly amplify strong ground motions, even from relatively distant earthquakes. Much of the major construction boom in Cairns took place after the publication of the first Australian earthquake loadings standard in 1979. However, this standard was not used widely in Queensland and, unlike its 1993 successor, it did not cover domestic buildings. Nonetheless, many Cairns buildings are earthquake-resistant to a degree, having been designed to comply with wind loading standards from around the late 1950s for engineered buildings and 1982 for domestic buildings.

Except in the event of a very strong earthquake we would not expect significant loss of life. Given the experience of the relatively moderate 1989 Newcastle earthquake (Richter magnitude 5.6), however, the catastrophic failure of one or more major buildings in the CBD, because of inappropriate design, poor construction and/or poor condition, can not be ruled out.

**Flooding of the Barron River delta is the fourth ranked risk** for Cairns. Major flood levels on the delta have been reached seven times since 1911 giving an average recurrence interval over the past 88 years of around 12 years. Even though planning constraints for development in the flood-prone areas of the delta were not introduced until the early 1990s, land use is predominantly agricultural. Urban areas in Caravonica, Holloways Beach, Machans Beach, Redlynch and Yorkeys Knob together with the road network which links them to the city centre are all susceptible to inundation. Flooding is, however, generally of short duration and the warning systems operated by the Bureau of Meteorology provide sufficient time for residents to take steps to protect their property and for emergency services to conduct evacuations if that course of action is indicated.

**Landslide and flash flooding share the fifth place** in terms of risk priority. Whilst these closely related hazards occur fairly frequently in Cairns, in developed localities they tend to affect only small areas and are a problem for only short periods. The experience of the massive 1951 Ellis Beach debris flows, however, is a clear indicator of what can happen along the Cairns escarpment in extreme circumstances. Our information, however, does not permit us to know with any certainty just how rare or extreme that event was. Even at the smallest scale, either phenomenon can be lethal because of its rapid onset and the lack of warning. Both flash flooding and debris flows in the upper Freshwater Creek valley hold the potential to disrupt the Cairns water supply by damaging the intake and pipeline.

## Is Cairns a risky place?

**For an isolated community of more than 120 000 people located in the wet tropics, Cairns has a relatively low level of risk exposure to most hazards within the 1% annual exceedence probability range (i.e. an average recurrence interval of 100 years or less). Whilst events within this range will cause some loss and put lives at risk, the warning systems and other mitigation strategies already in place should keep loss of life to virtually zero and economic loss to the community as a whole to nuisance, or at least tolerable, levels so long as the population is aware and prepared. There are cost effective steps that can be taken to reduce the current level of risk even further.**

**Importantly, there have been no fatalities directly attributable to the impact of a natural hazard in the Cairns community in the past two decades, in spite of this being a period of**

very rapid population growth. This record, in part, can be attributed to the fact that there were no significant earthquakes and very few major cyclone or flood impacts during that time. It can also be attributed to the implementation of hazard-based planning constraints, the introduction of building codes and an effective local emergency management capability. These risk mitigation strategies have minimised the exposure of new developments to hazards and maximised resilience of structures to the more common hazard impacts. Overall, we would assess Cairns as having a tolerable level of risk exposure to the more frequently occurring hazards.

The Cairns community does, none the less, have a very high level of residual risk exposure to the less frequent and more severe events, especially strong earthquakes, severe cyclones and major debris flows. Events with an annual exceedence probability of 0.2% or less (an average recurrence interval of 500 years or more) will inevitably cause significant economic harm and some (and potentially significant) loss of life. In these rarer and more extreme events, the loss of critical facilities, especially in Cairns North, City, Parramatta Park and Portsmouth, will add to the magnitude of the risk posed directly by the hazard event itself. These secondary risks are likely to have an effect for a considerable period of time after the initial impact.

It is clearly not possible, economic or rational to attempt to eliminate all risk. It is, however, feasible and economic to reduce the residual risk to even the most extreme event, over time, by implementing long-term planning strategies (such as the relocation of critical facilities) and by maintaining a vigorous campaign of community awareness and involvement in the community risk management process.

A wide range of risk mitigation strategies are available, many of them of a low cost and non-structural nature. These include the:

- development of a strong commitment to the process of risk management by the whole community;
- creation and maintenance of appropriate information to support risk management decision making;
- operation of effective hazard monitoring and warning systems;
- creation and maintenance of a strong level of community awareness through an ongoing program of risk communication;
- ongoing review and update of building and planning standards and codes;
- ongoing enhancement of emergency management plans, training and resources;
- implementation of effective plans to protect critical facilities, such as the hospitals, the loss of which will compound community hardship and risk; and,
- building of cost-effective structural defences.

The quicker these strategies are established, the sooner community risk will be reduced to an even more acceptable level. If this is done, Cairns will be one of Queensland's safest, most sustainable and most prosperous communities.