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REPORT

TOWNSVILLE CITY COUNCIL

TOWNSVILLE FLOOD HAZARD ASSESSMENT STUDY

Phase 3 Report
Vulnerability Assessment and Risk Analysis

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AN AECOM COMPANY

Townsville Flood Hazard Assessment Study

Phase 3 Report

Vulnerability Assessment and Risk Analysis

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	08/03/06	Final Issue	Brian Wright Manager Environment NQ	Original signed by Brian Wright

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Executive Summary

Townsville City Council received funding under the Natural Disaster Risk Management Studies Program to undertake a Disaster Risk Management Study specific to flooding including a preliminary assessment of storm surge. Primary objectives of the Study included:

- quantifying flood and storm surge inundation in Townsville, Magnetic Island and Cungulla,
- determining the flood hazards and the vulnerability of community and infrastructure, and
- identifying possible risk mitigation measures and strategies to allow proper and effective management of the identified risks.

The Project Plan identified three distinct yet inter-related phases to the Study. This report addresses Phase 3, which required a Vulnerability Assessment, Risk Analysis and Mitigation Strategies, based on the results of Phase 2 modelling and investigation. Phase 3 of the Study was carried out in accordance with the principles contained in the Risk Management Standard (AS/NZS 4360:1999), the Queensland Department of Emergency Services (DES) Guidelines for Disaster Risk Management, and the guiding principles contained in the Consultancy Brief.

The following sections provide a brief overview of the investigations undertaken in Phase 3:

Establishing the Context

The primary aim of the Study was to determine those areas within the urban areas of Townsville that may be affected by the 50 Year and 100 Year ARI flood events, and use this information to:

- assess the vulnerability of the community, expressed in terms of people, properties, businesses, public assets and essential services,
- review town planning controls over infill development in flood prone areas to ensure long-term sustainable growth,
- implement an improved flood warning network and refined evacuation procedures that target areas most at risk,
- enhance the Counter Disaster Plan,
- determine flood damage estimates,
- assess flood mitigation program currently under review, and
- assess potential structural and non-structural treatment options to mitigate the impacts of flooding and develop a prioritised action plan.

A risk management team (Study Advisory Group) was established at the onset of the Study, to administer, guide and review the risk management process. The Project Plan was reviewed and proposed methodology adapted during the course of the investigation.

Identifying Risks and Hazard

The Study was mainly restricted to the analysis of the risks associated with the hazard of flooding of existing properties in the Townsville Floodplain and Magnetic Island areas. In addition, due to budgetary constraints, preliminary assessment of storm surge and tidal inundation of coastal areas including the communities of Pallarenda and Cungulla was also completed in lieu of a full flood investigation of these areas. Various events (10 Year ARI, 50

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Year ARI and extreme flood event of January 1998) were assessed for flooding, and storm surge and tidal inundation mapping was reviewed for 50 Year ARI and the synthetic extreme storm surge scenario of Cyclone Althea coincident with a high tide.

Due to the limited extent of the flood hazard study area, the study has not investigated the issue of future development in flood prone areas in any great detail. A separate investigation will be required to consider this issue.

The risk evaluation process is used to establish whether a risk can be deemed acceptable or unacceptable. Preliminary risk evaluation criteria were developed in consultation with the Study Advisory Group and used to compare the likelihood and consequence of a hazard against a set of criteria, to assign a level of seriousness to the risk. Hazard maps were produced using MIKE21 model outputs of depth and velocity for the same range of flood events detailed in Volume 2 of the Phase 2 Report. Flood hazard mapping identifies flood hazard zones and other areas that are susceptible to unacceptable levels or frequency of inundation.

Community Vulnerability Assessment

Vulnerability relates to a community's susceptibility to a hazard, and its resilience in coping with the hazard. A vulnerability profile for the community was developed and critical facilities and engineering lifelines were mapped. A detailed access route analysis was also undertaken to access the risk of isolation of communities and loss of evacuation routes. **Table 1** shows an example of the risk register for the 50 Year ARI event detailing the communities susceptibility to flood damage.

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Table 1
Risk Description – Townsville – 1 in 50 Year ARI Event

Hazard – Flooding (1 in 50 Year ARI Event)		
Vulnerable Elements	**Risk**	**Consequence**
People	▪ A population of 573 is at risk of inundation by flooding, in the following additional areas: ▪ City: Garbutt, West End, Hyde Park, Hermit Park, Mysterton, Currajong, Aitkenvale, Heatley. ▪ South Townsville: Railway Estate. ▪ Annandale: Annandale.	▪ People may be injured and require medical treatment. ▪ People may be displaced from their homes for short period (eg 24hrs). ▪ People may require local services. ▪ People may be able to work with some inconvenience.
Buildings	▪ Approximately 177 residential buildings are at risk of inundation by flooding, in the following additional areas: ▪ City: Garbutt, West End, Hyde Park, Hermit Park, Mysterton, Currajong, Aitkenvale, Heatley. ▪ South Townsville: Railway Estate. ▪ Annandale: Annandale.	▪ Buildings may suffer some damage (contents). ▪ Temporary loss of power, telecommunications and sewerage. ▪ Property owners may incur some clean-up costs.
Business	▪ 12 businesses are at risk of being affected by flooding, in the following additional areas: ▪ City: Garbutt, Hyde Park, Hermit Park, Aitkenvale. ▪ Mt Louisa: Mt Louisa. ▪ Fairfield: Stuart.	▪ Businesses operate with some inconvenience. ▪ Temporary loss of power, telecommunications and sewerage. ▪ Some clean-up costs. ▪ Damage to caravan parks.
Engineering Lifelines	▪ Engineering lifelines (water, sewerage, power and communications) may suffer damage by flooding within the following additional areas (>300mm): <u>Pump Stations</u> ▪ City: Hugh Street, Douglas Street/Lancaster Street, Sussex Street, Hugh Street/Chandler Street, Mariners Drive. ▪ Annandale: Marabou Drive.	▪ Sewerage, power and telecommunications may fail temporarily.
Critical Facilities	Some critical facilities in the following additional areas are at risk from flooding (>300mm): <u>Evacuation Areas</u> ▪ Fairfield: Area at Mervyn Crossman Drive flooded. ▪ City: Access to area at the showgrounds restricted at Kings Road and portion of area inundated. ▪ City: Access restricted to area at Fulham Road/Swanson Street intersection. ▪ Annandale: Access restricted to area on Yolanda Drive/Oleander Street and area inundated.	▪ Inconvenience to local goods distribution. ▪ Local clinics operate with some inconvenience. ▪ Hospital may operate with some inconvenience. ▪ Some delay in the response of emergency services (fire, police, ambulance) due to road access restrictions.

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Flood Damages

A comprehensive flood damage assessment was undertaken for the Townsville urban area using MIKE FA, a GIS based add-on for the MIKE suite of programs developed to allow economic assessment of flood losses and mitigation options. This process utilised flood level data (outputs from Phase 2), stage-damage curves (developed following detailed investigations to provide supplementary information) and GIS databases of floor levels and building type. A detailed GIS property database existed with zoning information and property type/size however additional investigations were required to assess building floor levels.

Although the flood damage assessment applied industry standard guidelines, a number of shortcomings became evident during the course of the study. These include no existing information on building floor levels and no information on damages curves for different property types. Consequently, it was difficult to make an accurate assessment of flood damages.

Such inaccuracies are not unusual. For example, the direct residential losses estimated for North Queensland by the Department of Emergency Services following the 1998 event ranged from $26 million to in excess of $152 million, a factor greater than 5.

To improve the estimation of flood damages in the study, direct damages from flood inundation were calibrated against actual damages recorded for the 1998 event. This process required some manual manipulation of the input data sets to achieve a reasonable damage estimate. The GIS based flood damages estimates for the January 1998 event are shown below in **Table 2**.

Table 2
Estimate of 1998 Flood Damages

Property Zoning	Damages (1998 Flood Event)
R1	$9.91m
RH100	$0.35m
RH80	$5.28m
RH60	$8.49m
RH40	$9.54m
RH20	$1.14m
COM	$9.63m
IND	$9.37m
OS	$0.27m
PD	$0.04m
SP	$0.51m
TOTAL	$54.53m
Total Residential	$34.72m

Damage estimates were prepared for the full range of flood events (2 year ARI up to PMF) and two storm surge events (Cyclone Althea and the extreme event of Cyclone Althea coincidental with a high tide). The results are shown below in **Table 3**.

Table 3
GIS Damage Estimates for All Events*

Property Zoning	Flooding							Surge	
	2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	PMF	Cyclone Althea	Cyclone Althea + MHWS
R1	$0.55m	$1.79m	$1.81m	$2.88m	$3.86m	$4.61m	$5.57m	$0.00m	$0.00m
RH100	$0.00m	$0.03m	$0.04m	$0.11m	$0.14m	$0.16m	$1.06m	$0.00m	$0.00m
RH80	0.08	$0.15m	$0.23m	$1.18m	$1.58m	$2.05m	$5.96m	$0.81m	$19.52m
RH60	$0.14m	$0.33m	$0.47m	$3.56m	$4.05m	$4.61m	$36.03m	$0.00m	$1.01m
RH40	$0.24m	$0.38m	$1.18m	$1.62m	$2.41m	$3.34m	$90.76m	$0.18m	$14.00m
RH20	$0.00m	$0.00m	$0.01m	$0.15m	$0.23m	$0.34m	$18.06m	$0.00m	$0.00m
COM	$0.03m	$0.05m	$0.06m	$1.37m	$2.12m	$3.26m	$54.96m	$0.00m	$6.44m
IND	$0.08m	$0.09m	$0.7m	$2.62m	$2.86m	$3.19m	$74.58m	$0.00m	$1.65m
OS	$0.04m	$0.04m	$0.05m	$0.12m	$0.15m	$0.17m	$1.13m	$0.04m	$0.26m
PD	$0.01m	$0.02m	$0.03m	$0.07m	$0.08m	$0.10m	$0.54m	$0.00m	$0.00m
SP	$0.04m	$0.06m	$0.09m	$0.15m	$0.19m	$0.23m	$3.25m	$0.05m	$0.48m
TOTAL	$1.22m	$2.94m	$4.04m	$13.77	$17.59m	$21.98m	$395.72m	$1.09m	$43.38m
Total Residential	$1.02m	$2.67m	$3.75	$9.51	$12.26m	$15.12m	$261.26m	$1.00m	$34.54m

*(for legend, see Section 5.3.1)

These estimates are based on a number of assumptions which may result in the estimates varying by a factor of five. See page 49 **Section 5 – Flood Damages**.

The damage estimates indicate that Townsville generally has a less than 20 year ARI channel capacity at which the overland flow component becomes more significant and causes significant damage.

Risk Analysis, Evaluation and Treatment Options

Using the assigned likelihood and consequence levels, the level of risk was estimated, ranging from Low (managed by routine procedures) to High (works identified and included in forward works program). No immediate action is required to address a perceived Extreme Risk). Hazards were further evaluated from greatest to least risk so that a priority of treatment can be assigned. Risks are generally described as acceptable, unavoidable, undesirable or unacceptable, and have been evaluated for a range of recurrence interval flood events and storm surge levels (where appropriate). A register of prioritised unacceptable risks was developed.

The final step in the risk management process involved the selection of appropriate strategies that will minimise the potential for harm to the community. The process involved the identification, evaluation and selection of treatment options to deal with unacceptable risks, using the following framework for the selection of risk treatment options:

- Prevention/mitigation measures: seek to reduce the consequences of the event, and can be structural and non-structural.
- Preparedness measures: seek to reduce the harm caused by a hazard by reducing community vulnerability (eg. community awareness programs)

- Response measures: seek to reduce the harm to the community by ensuring that well trained resources are available to respond to a hazard situation.
- Recovery measures: seek to minimise the medium to long-term harm to a community.

Disaster Mitigation Plan

An endorsed treatment strategy was developed for the Study Area, further details of which are provided in **Section 7** and **Tables 35**, **36** and **37** in **Appendix A**. The strategy includes general recommendations like town planning measures and updates to the Counter Disaster Plan, as well as detailed recommendations with respect to flood warning and structural improvements to achieve at least 20 Year ARI immunity. Where appropriate, schematic drawings have been provided showing the location of key mitigation strategies proposed. Preliminary cost estimates have been prepared for most options, with discussion provided on other factors that affect the benefit to the community of undertaking the works. **Table 4, Legend: H** – High Priority, M – Medium Priority, L – Low Priority

Table 5 and **Table 6** show some of the mitigation works proposed for Townsville, Magnetic Island and Pallarenda and Cungulla respectively.

NOTE:
Since this report only investigates the hazards of flooding and a preliminary assessment of storm surge, it is intended that Council may adapt the information contained herein for inclusion in an all-hazards risk management document (i.e. that includes other hazards to the City of Townsville such as windstorm, bushfire and earthquake). The report also identifies that a more comprehensive assessment of storm surge risk is required.

Table 4 - Treatment Strategy Development - Townsville

Ranking (Priority)	Endorsed Treatment	Responsible Agency	Complete Implementation Timeframe	Estimated Cost	Funding Source(s)
1 (H)	Continue to implement current Townsville West Flood Mitigation Project (Stage 1 and 2).	Townsville City Council	0 – 5 years	$7.20 million	Council Budget, External Funding Sources
2 (H)	Develop town planning policy on flood and storm surge prone areas.	Townsville City Council	0 – 5 years	$5000 (Time and Materials)	Council Budget
3 (H)	Upgrade existing flood warning system for Townsville.	Townsville City Council	0 – 5 years	$25,000	Council Budget, External Funding Sources
4 (H)	Review and Update Counter Disaster Plan	Townsville City Council	0 – 5 years	$5000 (Time and Materials)	Council Budget
5 (H)	Wandella Crescent/Cranbrook Park Diversion to Ross River	Townsville City Council	0 – 5 years	$6.0 million	Council Budget, External Funding Sources
6 (H)	Killara Street Diversion to Ross River.	Townsville City Council	0 – 5 years	$11.80 million	Council Budget, External Funding Sources
7 (M)	Widening of the primary drainage path in the area immediately downstream of Abbott Street.	Townsville City Council	5 - 10 years	$2.40 million	Council Budget, External Funding Sources

Legend: H – High Priority, M – Medium Priority, L – Low Priority

Table 4 Continued

Ranking (Priority)	Endorsed Treatment	Responsible Agency	Complete Implementation Timeframe	Estimated Cost	Funding Source(s)
8 (M)	Widening the Woolcock Canal between Kings Road and Parkes Street, and culverts under Kings Road to match.	Townsville City Council	0 – 5 years	$1.60 million	Council Budget, External Funding Sources
9 (H)	Relocate the exposed section of the western suburb outfall main that crosses the Ross River.	Townsville City Council	0 – 5 years	$1.00 million	Council Budget, External Funding Sources
10 (H)	Raise section of Bruce Highway (between Abbott St and Stuart Drive).	Department of Main Roads	0 – 5 years	$0.10 million	State Government

Legend: H – High Priority, M – Medium Priority, L – Low Priority

Table 5
Treatment Strategy Development – Magnetic Island

Ranking (Priority)	Endorsed Treatment	Responsible Agency	Complete Implementation Timeframe	Estimated Cost	Funding Source(s)
1 (H)	Establish two rainfall stations on Magnetic Island (Nelly Bay and Horseshoe Bay).	Townsville City Council	0 – 5 years	$10,000	Council Budget, External Funding Sources
2 (M)	Upgrade culvert and drain along Apjohn Street (Horseshoe Bay).	Townsville City Council	5 – 10 years	$0.50 million	Council Budget, External Funding Sources

Legend: H – High Priority, M – Medium Priority, L – Low Priority

Table 6
Treatment Strategy Development – Pallarenda and Cungulla

Ranking (Priority)	Endorsed Treatment	Responsible Agency	Complete Implementation Timeframe	Estimated Cost	Funding Source(s)
1 (H)	Upgrade Heatley Parade (Evacuation Route from Pallarenda).	Townsville City Council	0 – 5 years	$0.55 million	Council Budget, External Funding Sources
2 (H)	Install dedicated storm surge sirens at Pallarenda and Cungulla.	Townsville City Council	0 – 5 years	$10,000	Council Budget, External Funding Sources

Legend: H – High Priority, M – Medium Priority, L – Low Priority

The existing Townsville Thuringowa Counter Disaster Plan is a comprehensive document however some recommendations have been made for upgrading the plan to incorporate the findings of Phase 2 of the this flood study.

1 Introduction

Introduction

1.1 Study Area

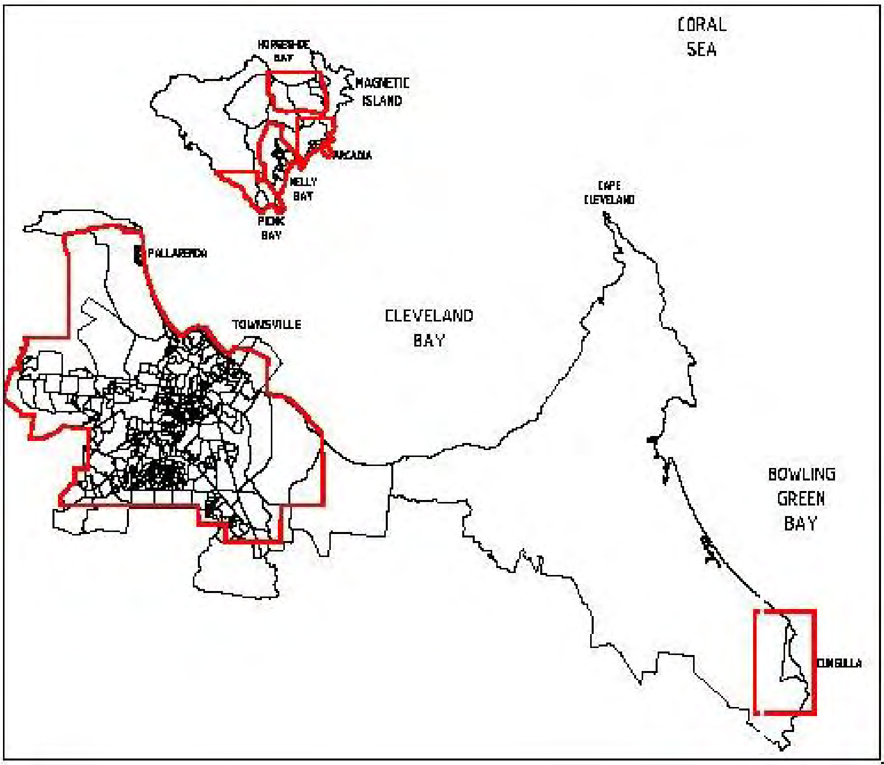
The Study Area, comprised of twelve (12) sub-areas, is shown graphically in **Figure 1** below. The most significant zone within the Study Area is that described as the Townsville floodplain and combines the sub-areas of the City, South Townsville, Fairfield, Annandale, Mt Louisa and Sandfly Creek. The Study Area also incorporates the four major bays of Magnetic Island, namely Horseshoe Bay, Arcadia, Nelly Bay and Picnic Bay, and the two coastal communities of Pallarenda and Cungulla.

For the purposes of this Vulnerability Assessment and Risk Analysis, the Study Area was grouped as follows:

- Townsville
- Magnetic Island
- Pallarenda and Cungulla
- Other Components

This breakdown was adopted throughout the Study, including the Risk Registers presented in the Disaster Risk Management Tables (attached as an Appendix). "Other Components" covers issues that are common to all areas, like the potential for environmental degradation.

Figure 1
Study Area



Introduction

1.2 Scope of the Study

Townsville City Council received funding under the Natural Disaster Risk Management Studies Program to undertake a Disaster Risk Management Study specific to flooding and storm surge. Primary objectives of the Study included:

- quantifying flood and surge inundation in Townsville, Magnetic Island and Cungulla,
- determining the flood hazards and the vulnerability of community and infrastructure, and
- identifying possible risk mitigation measures and strategies to allow proper and effective management of the identified risks.

The Project Plan identified three distinct yet inter-related phases to the Study as follows:

Phase 1 – Digital Terrain Model (DTM) Preparation
Undertaken under a separate consultancy (Schlencker Mapping Pty Ltd), Phase 1 involved provision of detailed ground surface data (0.2 m contours) covering the greater part of Townsville, four inhabited bays of Magnetic Island, and the coastal communities of Pallarenda and Cungulla (in all, twelve separate sub-areas). Each sub-area was provided progressively on a priority basis, as well as an overall combined DTM of the Townsville floodplain.

Phase 2 – Flood Study
A comprehensive flood study of Townsville and Magnetic Island, using both 1-D and 2-D hydraulic modelling techniques, culminating in inundation mapping of design flood events ranging from 2 Year ARI to Probable Maximum Flood (PMF). Included tidal and storm surge inundation assessment in coastal areas including Magnetic Island, Pallarenda and Cungulla. Using the results of the flood analysis, hazard mapping of flood and surge inundation was undertaken to identify vulnerable areas and engineering lifelines.

Phase 3 – Vulnerability Assessment and Risk Analysis
Using a risk based approach to ranking and prioritising the identified hazards, possible mitigation options and strategies were identified and investigated. Phase 3 culminates in recommendation and implementation of strategies for the management of the identified flood risks.

This Draft Report presents the findings of Phase 3 – Vulnerability Assessment and Risk Analysis.

1.3 Acknowledgments

Maunsell Australia Pty Ltd (MAPL) gratefully acknowledge the following agencies and individuals that provided information and advice during the course of the Study:

- Townsville City Council who provided population statistics, GIS layers of all critical facilities and free access to all relevant documentation.
- The Steering Committee comprising engineering staff and Council representatives, and the Study Advisory Group representing the wider community and emergency service providers.
- Mr Ken Durham, previously of Department of Emergency Services, who provided valuable guidance on the Disaster Risk Management process and chaired the Risk Management Workshop.

2 Establishing the Context

2 Establishing the Context

2.1 Summary of Project Plan

The vulnerability of Townsville to flooding was highlighted in the flood event of January 1998 (ex-Tropical Cyclone Sid), when considerable inundation of property, damage to infrastructure and disruption to essential services occurred. In recent years, Council has embraced the movement towards more effective natural disaster risk management and has identified flooding as the most dominant form of natural disaster hazard facing the Townsville community.

In 2001, Townsville City Council successfully applied for funding under the Natural Disaster Risk Management Studies Program to undertake a Disaster Risk Management Study to assess the risk due to flooding. Flooding can result from a number of sources; riverine, storm surge and dam breach. The Study's primary focus was to quantify risks associated with riverine flood inundation; however, a preliminary assessment has also been made of the risk from storm surge.

NOTE:
Flooding resulting from a breach of Ross River Dam has been identified as a serious threat to the community and has been addressed in the Counter Disaster Plan for the Townsville and Thuringowa region. However, dam breach and other natural hazards have not been addressed in this Study; rather a separate overall Disaster Risk Management Study is proposed to address these issues.

Phase 3 of the Townsville Flood Assessment Study involved assessing the vulnerability of the community based on the results of the Flood Study (Phase 2), with consideration to demographic information, built and natural environment, and critical services. The following sections discuss the qualitative risk assessment undertaken to address all of the risks recognised during the course of the Study.

The Phase 3 deliverables do not in themselves constitute a Disaster Risk Management Report and Disaster Mitigation Plan. As this Study relates only to the risks imposes by flooding, outputs will form a component of the overall Disaster Risk Management documentation. The description of risks and risk treatment options has been done in a format consistent with the aforementioned guidelines, so that Council can readily incorporate the outcomes and recommendations into an overall Disaster Risk Management Report and Disaster Mitigation Plan, to satisfy the requirements for continued eligibility for Natural Disaster Relief Arrangements.

2.1.1 Study Aims and Scope

The primary aim of the study was to determine those areas within the urban areas of Townsville that may be affected by the 50 Year ARI - 6 hour flood event of major flow paths, and to use this information to:

- assess the vulnerability of the community, expressed in terms of people, properties, businesses, public assets and essential services,
- review town planning controls over infill development in flood prone areas to ensure long-term sustainable growth,
- implement an improved flood warning network and refined evacuation procedures that target areas most at risk,

2 Establishing the Context

- enhance the Counter Disaster Plan,
- determine flood damage estimates,
- assess flood mitigation program currently under review, and
- assess potential structural and non-structural treatment options to mitigate the impacts of flooding.

The project aims were confirmed at the first meeting of the SAG, and the proposed methodology detailed by Maunsell in a presentation was endorsed as appropriate.

It is recognised that the true 50 Year ARI level has not been determined at every location. This task requires examination of what is the critical duration event for every sub-catchment within the city and to apply all the different duration storm events across the city.

2.2 The Study Structure

2.2.1 Risk Management Team

The establishment of a risk management team is fundamental to the success of the risk management process, to administer, guide and review the process as required. A risk management team was therefore formed and members are listed in **Table 1** of **Appendix A**. The Risk Management Team was established at the onset of the Study, comprising key Council personnel and emergency services representatives, and was responsible for monitoring the progress and direction of the Study, and developing the risk evaluation criteria for the project.

2.2.2 Physical and Time Boundaries

The physical and time boundaries of the study, terms of reference, goals and objectives of the study, and an expression of expected outcomes are presented in **Table 2** of **Appendix A**.

Significant delays were experienced during Phase 1 (Digital Terrain Model) and Phase 2 (Flood Study) that meant that the original timeframe for delivery of Phase 3 (June 2003) was unachievable. Phase 2 delays occurred primarily due to the very technical nature of flood modelling investigations, which were largely unforseen at commencement of the project.

2.2.3 Communication Plan and Consultation

Communication between the consultant and the Study Advisory Group was facilitated by the Study Manager (Mr Brian Milanovic) and Assistant Study Manager (Mr Bob Neunhoffer). Townsville City Councillors not directly involved with the Study Advisory Group were provided with briefings on the progress of the study at normal Council meetings, and Council managers and staff were briefed at critical stages as required.

Community and stakeholder consultation is an integral component in all stages of the development of the disaster risk management program. The Consultancy Brief provided direction in terms of stakeholder consultation requirements and consultation was undertaken with relevant stakeholders throughout the study period as required. Much of the liaison with stakeholder groups was undertaken through representatives on the Study Advisory Group; however separate meetings were held as required with external agencies not represented. Key consultation activities undertaken included a Flood Questionnaire distributed to a group of targeted residents who were aware of flooding issues in their immediate area. A Mitigation Workshop was also undertaken to canvass all stakeholders on issues relating to community vulnerability and identifying unacceptable risks.

Risk management strategies will also need to be effectively communicated to the community, and it is proposed that Council conduct public displays and prepare press releases for the local newspaper to seek community opinion and feedback.

2.3 The Study Context

The initial step in the disaster risk management process involves developing and understanding of the legislative, regulatory, political and social environment. A description of the scope and nature of issues that compromise the Study Context is provided in **Table 3** of **Appendix A**, including a Problem Definition statement relating specifically to flooding.

3 Identifying Risk and Hazard

3 Identifying Risk and Hazard

3.1 Preliminary Risk Evaluation Criteria

AS/NZS 4360:1999 Risk Management defines risk as:

> "The chance of something happening that will have an impact upon objectives, measured in terms of likelihood and consequences".

The main aim of the risk evaluation process is to establish whether a risk can be deemed *acceptable* or *unacceptable.* This is achieved by analysing the consequences and likelihood of the risk, and then assigning a level of seriousness to the risk. The determination of risk evaluation criteria enables the comparison of the likelihood and consequence of a hazard against a set of criteria. The preliminary risk evaluation criteria developed for this study (in consultation with the Study Advisory Group) is shown in **Table 7**.

Table 7
Preliminary Risk Evaluation Criteria

Criteria	Description
Human and Social Factors	Loss of life and serious injury is unacceptable in any predictable event up to the 1 in 100 year Annual Exceedance Probability (AEP). Significant damage to existing housing causing homelessness in events up to the 1 in 20 year AEP is unacceptable. Loss of employment opportunities by any member of the community is unacceptable for events less than the 1 in 10 year AEP. Significant damage to cultural or heritage sites is undesirable.
Built and Natural Environment	Loss of engineering lifelines, including critical transport routes, for more than 24 hours for events less than the 1 in 100 year AEP is unacceptable. Damage to buildings or infrastructure is unacceptable for events less than the 1 in 100 year AEP. Damage to critical facilities that makes them inoperable/unavailable at any time is unacceptable. Long-term deterioration of water or soil quality is unacceptable. Release of untreated wastewater to the environment in a predictable event is unacceptable. Significant loss of ecological habitat is unacceptable. Loss of threatened or endangered species is unacceptable.
Economic Loss	Economic loss by an existing business is unacceptable for events less than the 1 in 10 year AEP. Major long-term economic loss to the community is unacceptable.
Risk Escalation	It is unacceptable that new developments occur in areas below the 1 in 20 year AEP flood level. The floor levels of all future housing developments will be constructed at least 300mm above the 1 in 50 year AEP level.
Risk Frequency	It is unacceptable that local flood inundation events similar in magnitude to a 1 in 5 year AEP event isolate individuals or communities (eg Pallarenda, Cungulla, Magnetic Island). It is unacceptable for persons to be isolated for more than 6 hours when floodwaters exceed depths of 300mm.
Legal and Social Justice Implications	It is unacceptable that dependent people within the community are exposed to greater risk than the general community.
Political Implications	It is unacceptable that any sectional interest receives preferential treatment.
Manageability	It is unacceptable that works that have been identified as necessary to mitigate risks are not prioritised and included in Councils forward works programs.

Note: Adapted from *Disaster Risk Management,* Zamecka and Buchanan (2000)

3 Identifying Risk and Hazard

Through consultation with Townsville City Council and the Study Advisory Group the 1 in 100 year Annual Exceedance Probability (AEP) event was adopted as the upper limit on the magnitude of an event that may be reasonably expected to occur during a person's lifetime. It is noted that the January 1998 flood event has been approximated as a 1 in 500 year AEP event (Phase 2 – Flood Study), and it is considered unreasonable to expect that the risks associated with such an extreme event could be mitigated effectively.

3.2 Identify Risks

This study is mainly restricted to the analysis of the risks associated with the hazard of flooding in the Townsville Floodplain and Magnetic Island areas. In addition, due to budgetary constraints, a preliminary assessment of storm surge and tidal inundation for coastal areas including the communities of Pallarenda and Cungulla was also completed. In identifying these risks, it is important to develop not only an understanding of flooding, but also an understanding of the vulnerability of the community and to find out what risks are faced by the community. The outcomes of the risk identification process are outlined in this section.

3.2.1 Identification and Description of Flood Hazard

A description of flooding hazard is contained in **Table 4** of **Appendix A**. Simplistically, riverine flooding is defined as the result of heavy rainfall, of either short or long duration and typically brought about by a tropical cyclone or severe storm. Riverine flooding is the most frequent hazard to be experienced by the community of Townsville. The low-lying and flat topography of the coastal plain on which the majority of Townville's suburbs are located means that many parts of the community are vulnerable to local catchment inundation rather than flooding from the Ross River. The magnitude of flood flows and hence the incidence of riverine flooding from the Ross River has been substantially reduced following the construction of the Ross River Dam upstream of Townsville in the early 1970's.

Local flooding remains a large problem in many parts of Townsville. Many of the older suburbs have little to no defined stormwater surcharge paths, with the drainage paths that do exist considerably undersized. The flat topography and the complications associated with post-development installation or remediation make adequate drainage works costly and/or difficult to achieve. The area has experienced problems with cyclones, storms and floods in the past, and a considerable amount of natural disaster relief funding has been allocated in the aftermath of some of these events. Notable events that have occurred in the Townsville region (or impacted on the Study Area) are further described below.

Ross River Flooding

The largest recorded flood of the Ross River occurred in March 1946 with a flow in the order of 11,000 m^3/s (BoM, personal correspondence). Before construction of Ross River Dam, large floods in the order of 1,500 m^3/s generally occurred about once in every five to ten years (JCU, 1971). The most recent large flood of the Ross River occurred in 1968, with a peak flow at Black Weir of 1,862 m^3/s. However, as noted previously, major flooding has not occurred since the construction of the dam in the early 1970s, which has a substantial attenuating effect on peak flows. The largest river flow since then occurred in January 1998 with a peak flow of 600 m^3/s, generated solely by local catchment downstream of the dam. This is much less than the generally agreed capacity of Ross River which has been estimated to be in the order of 1500 m^3/s. Ross River Dam was not spilling at the time of the river peak, with spillway releases peaking at 300 m^3/s some days afterwards.

Local Catchment Flooding
There have been a number of recent flood events that have highlighted Townsville's vulnerability to flooding from local runoff and smaller watercourses and drains. The largest of these was the event of January 1998, in which 549 mm fell in 24 hours at Townsville Airport, the highest on record, with unofficial gauges recording in excess of 700 mm. This included 121 mm in one hour and 205 mm in two hours.

Severe local flooding of most urban areas of Townsville resulted, with the stormwater drainage system greatly overwhelmed. It has been estimated that over 7000 houses in Townsville and Thuringowa experienced flooding above floor height (King, 1998), resulting in extensive damage to houses and property. Considerable damage to businesses, roads and other infrastructure also occurred. Most roads in the city were untrafficable during the event. The Bruce Highway and rail links were closed both north and south of the city, as was the Townsville Airport. Numerous cars were damaged by flooding, and up to 50% of the houses in Townsville lost power at some stage. Damages to Local Government infrastructure were high.

3.2.2 Identification and Description of Storm Surge Hazard
A description of storm surge and tidal inundation hazard is contained in **Table 5** of **Appendix A**. Simplistically, storm surge is defined as the increase in coastal water levels resulting from a reduction in atmospheric pressure combined with the effects of surface wind stress and wave action, typically brought about by a tropical cyclone or severe storm and can cause extensive destruction and land degradation. The combined storm surge and normal tide level is often referred to as a storm tide.

Townsville has experienced problems with cyclones and storm surge events in the past. Notable storm surge events that have occurred in the Townsville region (or impacted on the Study Area) are further described in the below extracts from correspondence and documentation provided by the Bureau of Meteorology Severe Weather Centre detailing the impacts of cyclones of the Queensland coast.

Tropical Cyclone Sigma (26 January 1896)
TC Sigma passed just to northeast of Townsville, and the bar at Townsville dropped to 991 hPa. Ships were wrecked in the harbour, fences were laid flat and verandahs stripped off houses. Trees 6 ft in circumference were blown down. Seas were enormous and 510 mm of rain fell in Townsville during the cyclone. Floods and storm surge flooded the lower parts of Townsville with over 1.8 m of water. 3 miles of suburbs became an inland sea with large waves breaking on the banks. Seventeen people drowned as a result and one sailor was killed.

Tropical Cyclone Althea (24 December 1971)
TC Althea crossed the coast just north of Townsville with a 106 knot wind gust being reported at the Townsville Met Office. There were three deaths in Townsville and

damage costs in the Townsville region reached $50 million (1971 dollars). Many houses were damaged or destroyed (including 200 Housing Commission homes) by the winds. On Magnetic Island, 90% of the houses were damaged or destroyed. A 2.9 m storm surge was recorded in Townsville Harbour, however the maximum storm surge of 3.66 m was to the north at Toolakea. This storm surge occurred at low tide, however the surge and large waves caused extensive damage along the Strand and at Cape Pallarenda.

A series of severe storms and unnamed tropical cyclones impacted the Townsville area in the late 1800's and early 1900's, and more recently, Tropical Cyclone Tessi (2000) caused damage to the foreshore areas and flooding inland. The impact of storm surge on coastal areas was considered to provide Council with information regarding the expected impacts of tidal inundation, namely the number of inundated properties, extent of potential land degradation due to salt water inundation and foreshore erosion.

3.2.3 Elements of Flooding

It is necessary to split complex hazards such as flooding and surge inundation into their component parts to ensure all aspects of inundation are identified and adequately addressed in the risk management process. Some of the associated features of flooding and surge inundation are:

- Depth of inundation.
- Velocity of flood waters and the impact on homes and infrastructure.
- Area of inundation and associated impact on the community
- Duration of inundation.
- Warning time (less than six hours) - necessary to determine appropriate evacuation procedures and routes.
- Evacuation routes.
- Debris: impact of silt from steep erosive slopes - potential to block stormwater systems; impact of floating debris - potential to block culverts and damage infrastructure.

A series of maps have been generated showing the frequency and extent of flooding and surge inundation in the Study Area (refer to Volume 2 of the Phase 2 Report). For the purposes of the risk assessment, 10 Year ARI, 50 Year ARI and extreme flood event (January 1998) have been assessed. Inundation maps have also been generated (in isolation from fresh water flooding) for the coastal communities of Pallarenda and Cungulla to assess the impact of storm surge and tidal inundation. Two events were adopted for the risk assessment, namely the 50 Year ARI static storm surge event and surge propagation modelling using the synthetic time series of water level reflecting the peak surge of Cyclone Althea coincident with a Mean High Water Spring (MHWS) tide. The maximum water level reached in this extreme event is approximately RL 4.0m AHD.

Of the above listed components of flooding and surge inundation, the impact of debris on flooding was addressed qualitatively, through development of risk statements and general mitigation strategies.

3.2.4 Flood Hazard Maps

Risks from flooding are generally associated with floodwaters that are too deep and threaten property and life, flooding that limits access or cuts major arterials and evacuation routes, and flood velocities that threaten infrastructure or cannot be safely traversed. Others risks include loss of access in an emergency medical situation, and the public health issues associated with prolonged inundation.

Hazard maps were produced for the same range of flood events detailed in Volume 2 of the Phase 2 Report, to assist the risk management process (refer to **Appendix B**). Hazard mapping has been based on the simplistic definition of hazard contained in *Floodplain Management in Australia: Best Practice Principles and Guidelines (2000), Figure J.1* from this reference shows that hazard along evacuation routes can be described by the combined assessment of depth of floodwaters (m) and velocity of flood waters (m/s). In general, fast velocities (>1.5m/s) and deep depths (>1.2m) are considered to represent extreme hazard; however, a combination of lesser values of depth and velocity can combine to also induce extreme hazard conditions. Hazards are categorised in terms of Low, Medium, High and Extreme, according to **Figure 2**.

The MIKE21 model system outputs both depth and velocity at 20 m intervals in the Study Area, and these results files (maximum maps) were used to produce the Hazard Maps, for the range of ARI events modelled. Flood hazard mapping identifies flood hazard zones and other areas that are susceptible to unacceptable levels or frequency of inundation. This process forms the basis of identifying areas at risk and quantifying the extent of flood hazards in each sub-area.

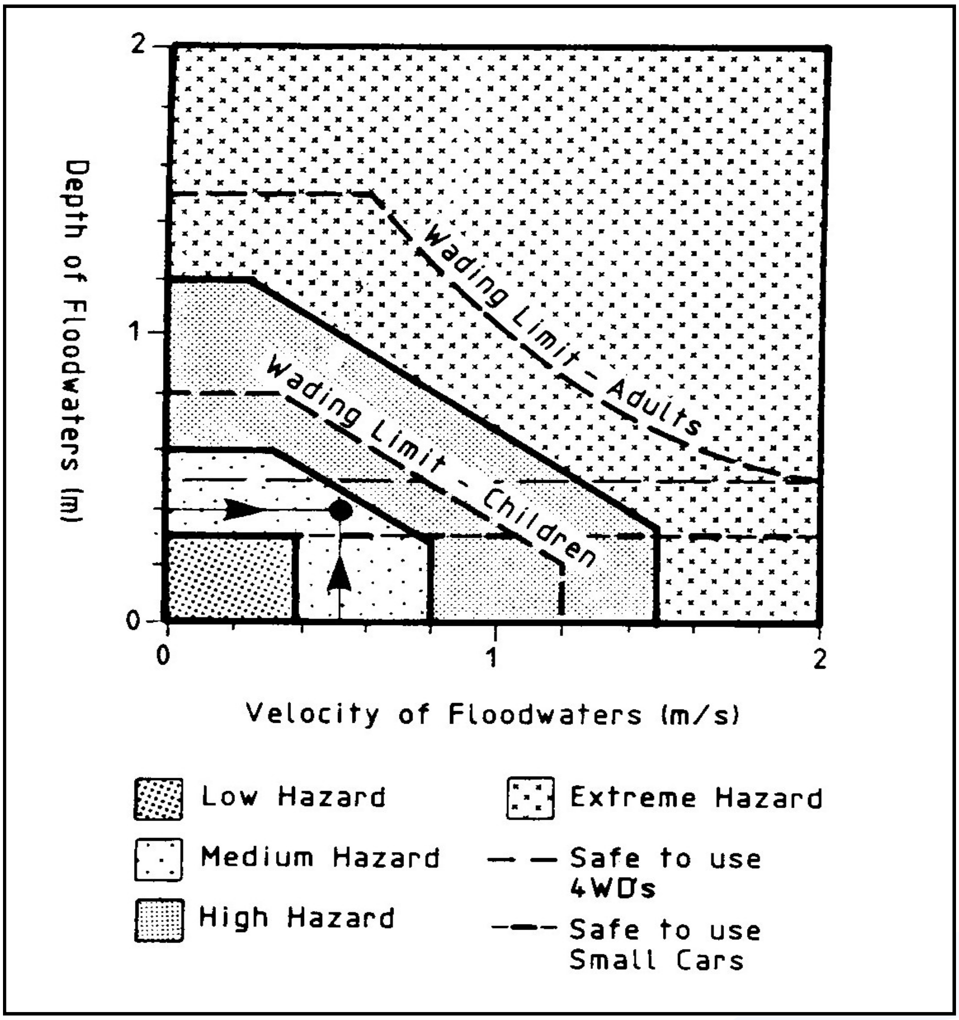
The following comments are provided regarding the Hazard Maps:

- Extreme flood hazard zones tend to exist only within the existing drainage paths, particularly for the lower ARI events. In events rarer than the 100 Year ARI event, the increase in inundation depth and runoff velocity equates to significantly greater areas of high to extreme hazard throughout the Study Area.
- The hazard map produced for Cyclone Althea (predicted peak level of RL 2.5m AHD) indicates very little environmental impact as tidal inundation is contained within existing drainage paths. The majority of reported damage from the Cyclone Althea event was not a result of storm surge, but rather the effects of cyclonic winds. However, Cyclone Althea coincident with a high tide would result in extensive environmental damage, widespread damage to home and property, as well as posing significant risks to the safety of the community. High to extreme hazard zones are evident within the South Townsville sub-catchment, as well as portions of City and Fairfield sub-catchments.

Hazard maps were used as additional input when assessing the vulnerability of the community to flooding and storm surge and tidal inundation, which is further discussed in **Section 4**.

3 Identifying Risk and Hazard

Figure 2
Estimation of Hazard along Evacuation Routes (source: ARMCANZ, 2000)



4 Community Vulnerability Assessment

4 Community Vulnerability Assessment

4.1 General

The process of identifying and describing the community and environment is necessary for the establishment of the vulnerability profile. A detailed description is presented in **Table 6** of **Appendix A**.

Zamecka and Buchanan (2000) describe vulnerability as:

> "A measure of the exposure of a persons or group to the effects of hazards and the degree to which that person or group can anticipate, cope with, resist and recover form the impacts of hazards".

Vulnerability relates to a community's susceptibility to a hazard, and its resilience in coping with the hazard. A vulnerability profile for the community is used to identify possible risks and the consequences of hazardous events. A community vulnerability profile is shown in **Table 7** of **Appendix A**, in accordance with the suggested format in Zamecha and Buchanan (2000). This is provided in addition to the following detailed analysis based on inundation mapping and the location of critical facilities.

4.2 Community Service Locations

The following sections provide some relevant information based on inspection of the detailed contour mapping and GIS layers provided by Council, to provide a more detailed assessment of the vulnerability of the community with respect to community services and major infrastructure.

The Townsville City Council's Land Information Unit provided the following community service and infrastructure layers from their GIS system:

- Police, Fire Stations and Ambulance Stations
- Hospitals, Hospices and Aged care facilities
- Water Infrastructure (pump stations and treatment plants)
- Evacuation Routes and Major Roads

The above layers were mapped (refer to **Drawings 8031202/CS1-CS10** contained in **Appendix C**) in addition to official Evacuation Centres from the Townsville Thuringowa Counter Disaster Plan. A summary of the mapping is provided below:

- Townsville has the full range of community services and infrastructure listed above, including SES and fully reticulated water and sewerage systems. A Local Government Disaster Coordination Centre (LGDCC) has been established for the purpose of the disaster response and recovery operation, and is located at the Council Citiworks building in Garbutt.
- Magnetic Island has reticulated water and some reticulated sewerage. A police station as well as a medical centre operates on the island, and a number of evacuation centres have been designated for use following a disaster.
- Cungulla has limited designated services. Reticulated water is available and septic systems operate throughout the area.
- Pallarenda has reticulated water and sewerage systems.

4 Community Vulnerability Assessment

4.3 Access Route Analysis

The low-lying coastal areas of Pallarenda and Cungulla are services by only one access road, and the Bruce Highway serves as a major arterial for traffic within and through the Study area. On Magnetic Island, the four bays are linked by one major road that traverses the length of the island. As such, understanding the susceptibility of these roads to inundation sufficient to make them untrafficable is important in assessing the risk of isolation. The following sections detail particular features of these primary access roads.

Townsville
The Bruce Highway serves as the major arterial for traffic in and out of Townsville to the north and south. The Bruce Highway to the south is a sealed road and provides for single lane traffic in two directions. The Bruce Highway to the north has in part been upgraded to provide two lanes in each direction, reverting to single lane traffic in two directions north of the Bohle River bridge.

University Road, Nathan Street, Duckworth Street and Woolcock Street provide a link between the southern and northern Bruce Highway approaches to the city, and provide for two lanes in both directions. Other alternative access routes (major roads) exist within the Study Area (varying lane capacity), including Abbot Street, Bowen Road, Ross River Road, Charters Towers Road, Dalrymple Road, Boundary Street, Cape Pallarenda Road, and a series of roads servicing the CBD that link to create a circuit around Castle Hill.

There are several low sections of the Bruce Highway, and other sections where flooding causes the highway to be overtopped. These include a section of the Bruce Highway on the southern approach road that has an average level of only RL 4.0m AHD (from the Jurekey Street intersection at the racecourse to the intersection with Stuart Drive/University Road). Abbot Street is subject to overtopping during frequent flooding events (5 year ARI), and is also at risk of inundation due to severe storm surge events. A number of low points exist along University Road, and access through the Nathan St/Charles St intersection is restricted during events less than 50 Year ARI.

Further specific details relating to the vulnerability of access routes throughout the Townsville urban area are provided below in **Table 8**. In all cases, access is considered restricted when water depths on the road approach 300 mm in depth.

4 Community Vulnerability Assessment

Table 8
Summary of Access Route Vulnerability Assessment (Townsville)

Source	Category	Description/Comments
Flooding	2 – 5yr ARI	▪ Access along Abbott Street near service station restricted in 5 year ARI event.
	10 – 20yr ARI	▪ Access along Bruce Highway at Jurekey Street intersection restricted in 10 Year ARI. ▪ Access along Townsend Street restricted (10 year ARI). ▪ Kings Road cut between Townsend St and Bayswater Rd in a 10 year ARI event. ▪ Access to Rowes Bay and Pallarenda via Heatley Parade restricted during a 1 in 10 year ARI event.
	50 – 100yr ARI	▪ Woolcock Street cut between the Lakes and Mindham Drain in 100 Year ARI event. ▪ Access to Townsville Hospital (Douglas) has flooding immunity greater than 100 Year ARI event. ▪ Access restricted along Charters Towers Road (Brodie Street end) in the 100 Year ARI Event. ▪ Bayswater Road cut at the Lakes in a 50 Year ARI event. ▪ Access along University Road restricted (near William Ross High School) in 100 Year ARI event. ▪ Hugh Street cut during 50 Year ARI event between Woolcock Street and Bayswater Road. ▪ Bruce Highway at Stuart Creek restricted in 50 Year ARI event. ▪ Bayswater Road cut at Mindham Drain in 50 Year ARI event. ▪ Ingham Road cut at the Lakes in 100 Year ARI event (overtops towards the north). ▪ Nathan Street/Charles Street intersection is restricted in the 50 Year ARI event. ▪ Bayswater Rd cut between Charters Towers Road and Kings Road between 20 Year ARI and 50 Year ARI event.
	PMF	▪ Access along Charters Towers Road (overflows near Brodie and Hughes Streets) restricted for events greater than 1 in 100 years. ▪ North Coast Railway near Barnett Street inundated in 1998 event. ▪ Access along Percy Street restricted in PMF. ▪ Dalrymple Road/Angus Avenue intersection cut off. ▪ Access along the causeway at the Woolcock Canal crossing restricted.
Storm Surge & Tidal Inundation	Cyclone Althea	▪ Boundary Street overtopped but access maintained.
	Cyclone Althea coincident with high tide	▪ Rowes Bay area bordered by Heatley Parade, Bundock Street and Howitt Street inundated, to depths up to 1.6m. ▪ Marina inundated (up to 1m), as is access and area along Sir Leslie Thiess Drive. ▪ Widespread inundation of roads throughout South Townsville, Railway Estate, Hermit Park and Oonoonba. ▪ Access restricted along Boundary Street, Railway Avenue, Abbot Street, Charters Towers Road and Woolcock Street. ▪ South Townsville Fire Station cut off and access restricted along Saunders St.

Magnetic Island

Access roads throughout Magnetic Island are sealed and support two lanes of traffic (one in each direction). Due to the small nature of the island, many of these roads exist within the low lying beach zones, and are subject to overtopping during frequent flood events. The road system is particularly susceptible to storm surge and tidal inundation and widespread inundation of all major access routes throughout Magnetic Island would occur during severe storm surge (RL 4.0m AHD).

4 Community Vulnerability Assessment

Picnic Bay is subject to tidal inundation only during extreme storm surge events; however, due to insufficient local drainage capacity, localised flooding occurs frequently. Sooning Street provides access to the new marina at Nelly Bay and is overtopped during a 50 Year ARI flood event in Gustav Creek. Access along Marine Parade, which provides the main access through Arcadia and onto Horseshoe Bay is maintained in flood events up to the PMF. Horseshoe Bay experiences widespread flooding due to relatively frequent events, isolating properties particularly along the main beach front, but also properties downstream of Apjohn Street.

Table 9 below provides further details on access road vulnerability. In all cases, access is considered restricted when water depths on the road approach 300 mm in depth.

Table 9
Summary of Access Road Vulnerability Assessment (Magnetic Island)

Source	Category	Description/Comments
Flooding	2 - 5yr	▪ Picnic Bay: Flooding along Picnic Street occurs due to the insufficient capacity of road drainage. ▪ Arcadia: Localised flooding occurs along Petersen Creek, particularly at road crossings and low-lying areas. ▪ Horseshoe Bay: 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.
	10 – 20yr	▪ Picnic Bay: Birt Street and Picnic Street crossings are overtopped due to a 10 Year ARI event in Butlers Creek. ▪ Nelly Bay: Barton Street and Elena Street road crossings are overtopped in the 10 and 20 Year ARI events respectively.
	50 - 100yr	▪ Picnic Bay: Flood waters overtop Picnic Street and inundate low-lying areas upstream and downstream, extending east to Granite Street.
	PMF	▪ Picnic Bay: Widespread flooding occurs along the two major drainage paths with significant inundation of Picnic Street. ▪ Nelly Bay: Access along Nelly Bay Road restricted for most of its length. ▪ Arcadia: Access along Marine Parade restricted.
Storm Surge & Tidal Inundation	50yr ARI + Wave Setup	▪ Picnic Bay Ring Road is overtopped. ▪ Inundation extends upstream of Sooning Street and up to Kelly Street, although contained in existing drainage paths.
	100yr ARI + Wave Setup	▪ Marine Parade overtopped. ▪ Overtopping of Horseshoe Bay Road at Horseshoe Bay lagoon and at Pacific Drive. Horseshoe Bay lagoon fills and potential for homes off Corica Street to be impacted, in addition to properties along front beach. Significant increase in flooding to west of Horseshoe Bay between Hollins Street and Pollard Street with water extending behind the sand dunes.
	Cyclone Althea (coincident with high tide)	▪ Storm surge extends to Picnic Street. ▪ Sooning Street overtopped at a number of locations. ▪ Marine Parade overtopped and drainage paths surcharged. ▪ Severe flooding of properties along front beach at Horseshoe Bay, Dent Street and Corica Street.

4 Community Vulnerability Assessment

Pallarenda and Cungulla

In areas like Pallarenda and Cungulla, the threat of inundation from extreme tides is greater than either river flooding or local runoff. The vulnerability of the community with respect to the risk of tidal inundation and possible isolation due to access restrictions is therefore relevant. Cape Pallarenda Road is the only access available to the area north of Rowes Bay. The road is located a short distance from the beach, is predominantly flat and at an approximate level of RL 5.0 m AHD. The Rowes Bay canal crossing is slightly below this level at RL 4.9 m AHD.

The bitumen road to the Australian Institute of Marine Science (AIMS) provides the single access to the turnoff to Cungulla, where an unsealed road leads to the small community established on the low lying coastal dunes that fringe the left bank at the mouth of the Haughton River. **Table 10** provides further details of the vulnerability of access roads to specific storm surge and tidal inundation events. In all cases, access is considered restricted when water depths on the road approach 300 mm in depth.

Table 10
Summary of Access Road Vulnerability Assessment (Pallarenda and Cungulla)

Source	Category	Description/Comments
Storm Surge & Tidal Inundation	50yr + Wave Setup	▪ Access to Pallarenda maintained. ▪ Local roads at Cungulla cut at a number of locations (0.5m approx).
	Cyclone Althea (coincident with high tide)	▪ Storm surge crosses road and potential to restrict access to northern suburbs of Pallarenda. ▪ Access to Rowes Bay and Pallarenda via Heatley Parade restricted near intersection with Primrose Street (depths up to 1m). ▪ Access into Cungulla restricted due to inundation of main access road (up to 1.5m).

4 Community Vulnerability Assessment

4.4 Vulnerability Assessment

By considering the inundation depicted in the flood and surge inundation mapping and the locations of critical facilities, a picture of the community vulnerability to flooding and storm surge inundation can be developed (refer to **Table 11** to **Table 13**). The vulnerability of the community with respect to access to major roads and evacuation routes during flood and storm surge events has been defined in **Table 8, Table 9** and **Table 10** above, and is to be considered in conjunction with the Community Vulnerability Assessment detailed below.

Table 11
Summary of Community Vulnerability Assessment (Townsville)

Source	Category	Description/Comments
Flooding	2 – 5yr ARI	Inundation of property in North Ward and Cranbrook (> 300mm) ss to Cleveland Bay Sewerage Treatment Plant Cut
	10 – 20yr ARI	Pump Stations: ▪ City: near Mt St John STP. ▪ Fairfield: Abbot Street. ▪ Mt Louisa: Webb Drive. ▪ City: Hugh Street/Chandler Street. Evacuation Centres: ▪ Centre at Bayswater Road inundated.
	50 – 100yr ARI	▪ Inundation of Medical Centre at Meenan Street. ▪ Inundation of Ambulance Station at Hugh Street. ▪ Aged care facility on Palmerston Street free from flooding. Pump Stations: ▪ City: Hugh Street, Douglas Street/Lancaster Street, Sussex Street, Mariners Drive. ▪ Annandale: Marabou Drive. Evacuation Centres: ▪ Fairfield: Centre at Mervyn Crossman Drive flooded. ▪ City: Access to centre at the showgrounds restricted at Kings Road and portion of area inundated. ▪ City: Access restricted to centre at Fulham Road/Swanson Street intersection. ▪ Annandale: Access restricted to Centre on Yolanda Drive / Oleander Street and portion of area inundated. ▪ Annandale: Access to centre on University Drive restricted from west however access from the east open for all events. Cleveland Bay Purification plant: ▪ Access is restricted due to flooding
	1998 – PMF	▪ Sewage pipeline that crosses the Ross River is at risk of damage. ▪ South Townsville Fire Station inundated. ▪ Ambulance Station on Hugh Street inundated. ▪ Medical Centre on Meenan Street inundated. ▪ Police Station in Sturt Street is free from inundation. ▪ Park Haven Medical Centre on Bayswater Road inundated. ▪ Access into Aged Care facility on Nathan Street restricted. ▪ Aged care facility on Palmerston Street subject to flooding. ▪ Widespread inundation of aged care facility on Acacia Street/Armit Street (up to 1.0m). ▪ Mater Hospital free from flooding ▪ Aged care facility on University Road inundated (up to 0.5m). Pump Stations (1998 Flood Event): ▪ City: North Coast Railway/Mather Street, Catalyst Ct, Woolcock

4 Community Vulnerability Assessment

Source	Category	Description/Comments
		Street/Parkes Street, Lily Street, Leeds Street/Mooney Street, Fulham Road/Biggs Street, Anne Street/Alfred Street. ▪ Fairfield: University Road, Bruce Highway (Stuart Caravan Park). ▪ South Townsville: Doorey Street. Pump Stations (PMF): ▪ City: Leyland Street, Meenan Street, Old Common Road, Fry Street, Hanran Street, Bayswater Road-Lakes, Hindley Street-Lakes, Ingham Road-Lakes, McLachlan Street, Alroy Street, Kings Road/Balls Lane, Wellington Street/Dudley Ct, Mulligan Street, Wellington Street/Tulip Street, Bomana Street/Crete Street, Inglis Smith Street, Queens Road, Charters Towers Road, Dalrymple Service Road. ▪ South Townsville: Perkins Street, Sixth Street East/Fifth Avenue, Seventh Street, Ninth Street, Railway Avenue, Flowers Street, Boundary Street-Civic Theatre. ▪ Annandale: Eucalyptus Avenue, Riverpark Drive/Kamaran Crt, Riverpark Drive/Glendale Drive. ▪ Fairfield: Mervyn Crossman Drive, Bruce Highway/Edith Street, Racecourse Road. Evacuation Centres (1998 Flood Event): ▪ Fairfield: Access to evacuation centre on Mervyn Crossman Drive restricted. ▪ Fairfield: Evacuation centre on Oonoonba Road flooded. ▪ Heatley: Evacuation centre on Dalrymple Service Road flooded. ▪ Annandale: Access to centre at army barracks off University Road restricted.
Storm Surge & Tidal Inundation	Cyclone Althea	▪ Minimal impact of storm tide on Townsville area facilities.
	Cyclone Althea coincident with high tide	▪ Access to Cleveland Bay STP restricted. ▪ South Townsville Fire Station inundated and access restricted. Pump Stations: ▪ City: Cook Street, Howitt Street/The Strand, Mariners Drive/The Strand, Hanran Street, Lily Street. ▪ South Townsville: Perkins Street, Palmer Street, Sixth Street East (end), Sixth Street East/Fifth Avenue, Seventh Street, Ninth Street, Doorey Street, Railway Avenue/Queens Road, Sussex Street/Bayswater Road.

4 Community Vulnerability Assessment

Table 12
Summary of Community Vulnerability Assessment (Magnetic Island)

Source	Category	Description/Comments
Flooding	2 - 5yr	▪ Localised flooding around existing drainage paths and culvert and road crossings. ▪ Nelly Bay: Localised flooding occurs along Gustav Creek; Inundation of some properties adjacent to drainage path between Lilac Street and Yates Street. ▪ Arcadia: Localised flooding occurs along Petersen Creek. ▪ Horseshoe Bay: Localised flooding of the urbanised area downstream of Apjohn Street. 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 – 20yr	▪ Roads overtopped at Picnic, Nelly and Horseshoe Bays. ▪ Nelly Bay: Properties built in low-lying areas downstream of Sooning Street are subject to flooding. ▪ Arcadia: Build up of floodwater upstream of Marine Parade. ▪ Horseshoe Bay: Further inundation of properties upstream of Gifford Street and adjacent to Corica Crescent.
	50 - 100yr	▪ Further inundation of property along drainage paths. ▪ Nelly Bay: Properties along Compass Crescent are subject to flooding with water backing up behind Sooning Street. ▪ Arcadia: Localised flooding around Arcadia Resort. ▪ Horseshoe Bay: Flooding of properties adjacent to Dent Street.
	PMF	▪ Emergency Service Centre at Picnic Bay free from flooding. ▪ Medical centre and pump station at Nelly Bay free from flooding. ▪ Pump stations at Horseshoe Bay inundated. ▪ Widespread flooding within each bay with significant inundation of property. ▪ Nelly Bay: Widespread flooding with inundation of properties along Murray Street from overflows from Gustav Creek; Properties downstream of Sooning Street are inundated. ▪ Arcadia: Significant number of properties inundated, and access along Marine Parade restricted. ▪ Horseshoe Bay: 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.
Storm Surge & Tidal Inundation	50yr ARI + Wave Setup	▪ Water extends up the main drainage path in Horseshoe Bay to Horseshoe Bay Road impacting upon properties at the end of Dent Street. Water also flows up the smaller drainage channel to the east of Dent Street impacting upon the low-lying property located within this area.
	100yr ARI + Wave Setup	▪ Number of properties inundated at Arcadia. ▪ Horseshoe Bay lagoon fills and potential for homes off Corica Street to be impacted, in addition to properties along front beach. Significant increase in flooding to west of Horseshoe Bay between Hollins Street and Pollard Street with water extending behind the sand dunes.

4 Community Vulnerability Assessment

Source	Category	Description/Comments
	Cyclone Althea (coincident with high tide)	▪ Storm surge extends to Picnic Street and potential inundation of surf life saving club west of the jetty at Picnic Bay. Emergency Services centre free from inundation. ▪ Significant tidal inundation of low-lying areas within Nelly Bay with number of properties affected. ▪ Property boundary for medical centre extends to within drainage path of Gustav Creek; however no apparent inundation of medical centre at Nelly Bay. ▪ Potential tidal inundation of significant number of properties within Geoffrey Bay, Arcadia. Marine Parade overtopped and drainage paths surcharged. ▪ Severe flooding of properties along front beach at Horseshoe Bay, Dent Street and Corica Street. ▪ Pump stations located on Henry Lawson St inundated.

Table 13
Summary of Community Vulnerability Assessment (Pallarenda and Cungulla)

Source	Category	Description/Comments
Storm Surge & Tidal Inundation	50yr + Wave Setup	▪ The aged care facility at Pallarenda is subject to inundation at the property boundary. ▪ Properties furthermost from the front beach at Pallarenda impacted by storm surge propagating along existing drainage path and behind development. Significant number of properties at risk of inundation. ▪ Extensive inundation of property at Cungulla, particularly at northern end. Low-lying areas subject to flooding.
	Cyclone Althea (coincident with high tide)	▪ The pump station along the Esplanade at Pallarenda is inundated. Significant flooding of property and low-lying areas throughout Pallarenda. ▪ Further inundation of the Aged Care facility at Pallarenda is evident. ▪ Entire developed area of Cungulla inundated and significant damage to property expected.

In addition to the areas identified in **Table 8** to **Table 13** at risk of inundation (and in **Tables 12** to **22** in **Appendix A**), the following critical facilities have been identified as being located within High to Extreme Hazard zones:

50 Year ARI Flood Event

- City Pump Stations: Hugh Street/Chandler Street, Fry Street, Sussex Street, Hanran Street.
- Annandale Pump Stations: Marabou Drive, Eucalyptus Avenue.
- Fairfield Pump Stations: University Road/Stuart Drive, Abbot Street.
- Fairfield: Various locations along University Road, Stuart Drive, Abbot Street and the Bruce Highway.

January 1998 Flood Event

- City Pump Stations: Catalyst Court, Mt St John, Sussex Street, North Coast Railway/Mather Street, Douglas Street/Lancaster Street, Hugh Street/Chandler Street, Fry Street, Ingham Road, Lakes, Hanran Street, Woolcock Street/Parkes Street, Alroy Street, Fulham Road.
- Annandale Pump Stations: Marabou Drive, Eucalyptus Avenue, Riverpark Drive/Kamaran Crt.

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- Fairfield Pump Stations: University Road/Stuart Drive, Abbot Street, Edith Street, Racecourse Road.
- City: Access roads around the aged care facility on Acacia Street/Armit Street, Woolcock Street, Charters Towers Road, Queen Street, Percy Street.
- Annandale: Various locations along University Road.
- Fairfield: Various locations along University Road, Stuart Drive, Abbot Street and the Bruce Highway.

Extreme Surge Event (Cyclone Althea coincident with High Tide)

- City Pump Stations: Howitt Street/Cook Street, The Strand/Howitt Street, The Strand/Mariners Drive, Hanran Street, Woolcock Street/Parkes Street, Lily Street.
- South Townsville Pump Stations: Flowers Street, Ninth Street, Doorey Street, Seventh Street, Sixth Street East/Fifth Avenue, Palmer Street, Perkins Street.
- South Townsville Emergency Services: Fire Station on Dean Street.
- Fairfield Pump Stations: Abbot Street.
- City: Charters Towers Road, Woolcock Street.
- South Townsville: Railway Avenue, Queens Road, Boundary Street, Saunders Street.
- Fairfield: Abbot Street.

5 Flood Damages

5 Flood Damages

5.1 General

There are many factors that can influence the value of flood damage to a property. These include the type of property (eg residential, commercial), type and value of structure and contents of the property, duration of flooding, velocity of floodwaters, and warning time to residents. Damages may also be classified as financial or economic, actual or potential, tangible or intangible, direct or indirect. The huge number of variables and range of conditions means that flood damage estimation is potentially complex and also very approximate, perhaps only giving an indication of the order of magnitude of costs. As an example, DNR&M Guidelines on the Assessment of Flood Damages estimate that actual damages sustained by a flood aware and experienced community can be up to half of that for an inexperienced community.

However, a flood damage assessment has been made using various methods based on recorded flood damage data for the Townsville region. The following sections detail the available damages data and adopted methodology.

5.2 Literature Review

A literature review was undertaken to determine historical flood damages data that could be reliably applied to the Townsville region. Summaries of key documents are provided below.

Guidance on the Assessment of Flood Damages (DNR&M, March 2002)
This document provides guidance on assessing tangible flood damages for applications under the Regional Flood Mitigation Program. The stage-damage curve method for assessing potential damages is described, and stage-damage curves originally developed for the computer model ANUFLOOD have been recommended to be used for estimating flood damages for both residential and commercial buildings. This data as reproduced in the bulletin, is presented in **Table 14** and **Table 15** below.

In **Table 15**, the range of values shown pertains to the five ‘value classes’ of commercial properties, which relate to the varying levels of damages sustained by different types of business. For example, florists and sports pavilions are very low or Class 1, bottle shops are medium or Class 3, while pharmaceuticals and electronics properties are very high or Class 5.

An assessment may also be made of the likelihood of structural damage to the property through consideration of flood depth-velocity combinations. In summary, velocities greater than 2 m/s or depths greater than 2 m are considered conditions for structural damage; otherwise, for velocity and depth less than these values, structural damage is possible where velocity (m/s) x depth (m) > 1.

The document specifies that for residential properties that are raised, an additional allowance may be made of $1225 for damage to items stored underneath such as mowers and washing machines.

5 Flood Damages

Table 14
Stage-Damage Relationships for Residential Properties

Depth over floor level (m)	Damage ($)		
	Small house	Medium house	Large house
0	905	2557	5873
0.1	1881	5115	11743
0.6	7370	13979	25351
1.5	17379	18585	32276
1.8	17643	18868	32768

Table 15
Stage-Damage Relationships for Commercial Properties

Depth over floor level (m)	Small properties* ($/m^2)	Medium properties** ($/m^2)	Large properties ($/m^2)
0	0	0	0
0.25	15 - 235	17 - 267	7 - 122
0.75	37 - 587	40 - 646	39 - 619
1.25	55 - 881	61 - 983	81 - 1297
1.75	61 - 979	68 - 1089	132 - 2129
2	65 - 1038	72 - 1159	159 - 2545

* Small properties have been specified as being <186 m^2. For the purposes of comparison, an average floor area of 150 m^2 has been assumed.
** Medium properties have been specified as being 186 m^2 – 650 m^2. For the purposes of comparison, an average floor area of 418 m^2 has been assumed.

Following the estimate of potential direct damage to properties through the above estimation methods, indirect residential damages are calculated as 15% of direct residential damages, while indirect commercial damages are estimated at 55% of direct commercial damages. The total damage cost is the sum of direct and indirect damages.

The estimation method given in 'Guidance on the Assessment of Tangible Flood Damages' draws heavily on the estimates from the ANUFLOOD model, predominantly from data published in '*ANUFLOOD: A Field Guide' (Smith and Greenaway, 1992)*.

Townsville Thuringowa Floods 1998 – Post Disaster Household Survey (D. King, Centre for Disaster Studies, James Cook University)
The aim of post disaster studies is to gather an immediate picture of the extent of the impact in order to discern any patterns or lessons that may be applied to future events, both in terms of emergency service response and Council planning and mitigation efforts.

The Centre for Disaster Studies carried out a post disaster survey in an attempt to gauge the overall impact of the event on the Townsville / Thuringowa residential community. The immediate aftermath of the flood saw media images of flooded streets and the devastation caused to Black River settlement and houses adjacent to Bluewater Creek. Flood damaged houses in the main urban areas of Townsville and Thuringowa did not receive this level of attention, even though it was these areas where most of the inundation impact was felt.

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Within three days of the flood event, a telephone survey of households was undertaken, with completion of all interviews by 14 days after the event. From Telstra's white pages, a random sample of 5000 telephone numbers and addresses was compiled. About 2000 households were contacted; a few refused to co-operate, but most negative contacts were answering machines. Whilst over 90% of the residential population is on the phone and listed in the White Pages, there was inevitably some bias in the adopted methodology, via unlisted numbers and lower socio-economic element of the community with no phone coverage.

In aiming for 1000 households, a total of 1014 household surveys were completed, representing just over 2% of the 49,693 dwellings recorded in the 1996 census of Townsville and Thuringowa. Because the list was completely random, some smaller suburbs are represented by very few cases. Many respondents in the survey were worried about the use of the word flood, and generally the discussions with residents focussed on inundation. A summary of the survey results is presented below:

- 15% of dwellings were inundated. Whilst the report did not want to put an absolute figure on the number of affected properties, it noted that 15% of the dwellings of Townsville and Thuringowa is 7454 houses. For the widely reported flood of Katherine in NT, it is estimated that Katherine contained approximately 2,292 dwellings. In terms of numbers of people and buildings impacted, the overall scale of the disaster in Townsville and Thuringowa was greater, although the individual extent of the damage may have been less.
- 67% of roads were inundated during the storm.
- 48% of households lost power for an average 11.4 hours.
- 17% of households lost water supply for an average of 14.7 hours.
- 32% of inundation victims experienced significant or great loss and damage to belongings.
- Distinct pattern of lesser impact in urban Thuringowa than in Townsville.
- Significant inundation damage occurred to low dwellings and to rooms built in under high set houses.
- 11% needed assistance to evacuate.
- 19% of households had at least one member unable to get home on Saturday night because of the floods.
- 53% never heard a severe weather warning.
- Fewer renters than homeowners had flood insurance - most had no flood insurance.

Townsville Thuringowa Floods 1998 – Business and Infrastructure Post Disaster Survey Summary Report (D. King and B. Girling-King, Centre for Disaster Studies, James Cook University)

Concurrently with the residential survey discussed above, the Centre for Disaster Studies carried out a post disaster survey of business and infrastructure, using a similar methodology. Key findings of the survey are summarised below:

- 6 out of 8 ambulance, police or fire stations canvassed were inaccessible during some period of the event, mostly during the crisis period on Saturday night.

5 Flood Damages

- In general, emergency services were inhibited in their response capacity during the floods, with operations disrupted by inundation both inside and outside the buildings. Emergency services staff were in many cases prevented from either reaching or leaving the premises.
- There was some loss of emergency services equipment and plant, and restoration of normal operations was delayed.
- The report lists those schools and other buildings that were designated evacuation centres prior to the event; however, it is quite clear that many of them would have had difficulties in fulfilling their role as gathering or evacuation centres.
- Government, Council, Transport and Medical service providers were also surveyed, and the responses clearly show that there was significant disruption to critical services provided and the capacity of these organisations to respond effectively.
- Several spillage incidents of fuel and toxic substances (including the overspill from the tailings ponds at Yabulu) were recorded.
- The survey identified that shopping centres could be safe evacuation centres if security issues are sorted out. There was significant inundation of Stockland's storage areas and great loss of stock.
- Based on the responses from commercial and industrial operations, normal business resumed very quickly, but not without damage and disruption. Car dealers experienced significant losses (majority insured) and many small businesses and corner stores suffered inundation and damage to stock and premises. However, despite these problems and over 100 mm of further rain, with extensive surface inundation on the following Monday, the city had largely gone back to business. The following statistics apply:
  - 50% were inaccessible during part or all of the inundation period
  - operations were disrupted for 52%
  - water came inside buildings for 50%, although much of this was roof, guttering and window leaks
  - 43% were disrupted by dependency on other services, and 50% had staff unable to reach their place of work
  - Not only were staff unable to reach work, but neither were customers or users (in many places customers were unable to leave)
  - damage of some kind affected 65% of respondents and 52% of places/services were delayed in returning to normal operations.

Given the extent of these problems, the speed of the recovery and return to normality for the community was quite remarkable. Thus although the survey indicates a significant impact on infrastructure, services and business, the city was able to function remarkably well. A final observation is a comparison with work on vulnerability recently completed for Cairns. In Cairns, a 3 metre cyclone storm surge scenario (above Australian Height Datum, which is a mid tidal range) would put similar depths of water (albeit saline and therefore more damaging) into the low lying areas of the city. Our estimates there, based on census data and the Emergency Services / Cairns City Council database, suggested an impact of between 68% of service facilities to 81% of business and industry inundated, while only 20% of residential housing would experience inundation. The results of the two post disaster surveys of Townsville and Thuringowa provide strong indications of a similar level of impact.

Disaster Loss Assessment Guidelines (Department of Emergency Services, 2002)
The purpose of the guidelines is to explain and provide a step-by-step process for carrying out an economic loss assessment for both hypothetical and actual events.

It is recommended that wherever possible, potential losses should be used rather than actual losses. Estimation techniques commonly predict potential losses – all of the losses that potentially may occur. Loss assessments carried out after an event usually record the actual losses that occurred. Actual losses have already taken into account the measures that people have taken to reduce the damage, such as moving property to higher ground. It is noted that it is difficult to estimate what the differences are between actual and potential losses, particularly since preparedness and other community response factors will come into play.

Three methods are discussed for estimating potential losses, which are:

1 the rapid assessment or averaging approach, which is based on pre-existing average data on losses, such as average loss per flooded property,
2 the synthetic approach, which is based on pre-existing databases covering a range of building types and contents, and includes the use of synthetic stage-damage curves, and
3 the recent survey or historical approach, which is based on surveys of a recent event to establish actual loss.

The information in **Table 16** relates to extracts from the report relating to the Rapid Appraisal Method.

Table 16
Summary of Rapid Appraisal Method

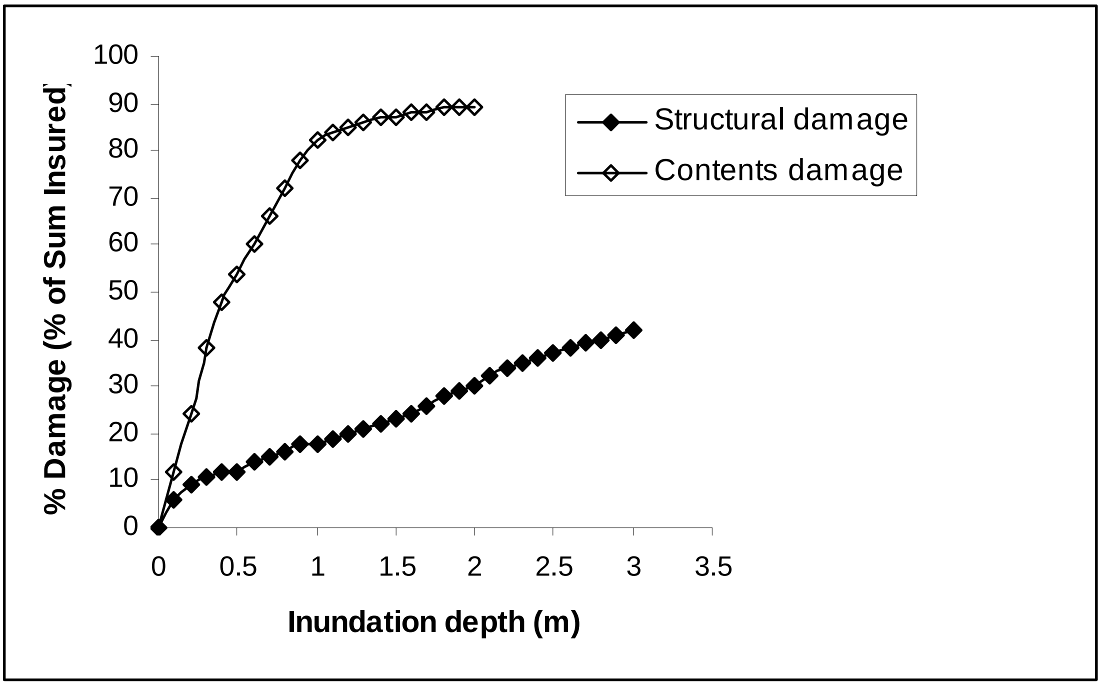
Loss Sector	Averaging Method	
Residential buildings – structures and contents	$20,500 per flood damaged residential building	
Commercial & industrial buildings < 1000 m^2 – structures and contents	$20,500 per flood damaged commercial building	
Commercial & industrial buildings > 1000 m^2 - structures and contents (1999 $ values)	Low value (eg, offices, sporting pavilions, churches)	$45/m^2
	Medium value (eg libraries, clothing businesses, caravan parks)	$80/m^2
	High value (eg electronic, printing)	$200/ m^2
Public buildings – structures and contents	$20,500 per flood damaged public building, excluding > 1000 m^2	

Source: Rapid Appraisal Method (RAM) (Read, Sturgess and Associates, 2000)

The report also cites another study (Risk Frontiers, NHRC) relating to the relationship between integrated contents and structure loss curves (figure in report reproduced as **Figure 3** below).

5 Flood Damages

Figure 3
Relationship between Structural and Contents Damage



Note: Both curves are potential loss curves.

Potential losses represent the maximum value of loss that might be expected to occur. Reasons for estimating potential damage as opposed to actual damage include:

- it is difficult to predict how much warning a community will receive and the impact that warning time will have on reduction of damages
- when assessing mitigation options, the actual (reduced) damages penalises people and communities who are effective at reducing loss in response to warnings
- actual damages will be less in poorer areas, which might be seen as discriminatory
- actual damages relate to a particular moment in time, where an untold number of factors may be unstable, such as population mobility, prior experience etc.

Economic and Social Costs of the North Queensland January 1998 Floods, Direct Loss Assessment Case Study (Department of Emergency Services, 2002)
This report estimates the economic and social costs of the January 1998 floods to the North Queensland region using the Disaster Loss Assessment Guidelines, and as such acts as a case study for demonstrating the use of these guidelines. The case study covers the local government areas from Townsville to Cairns, (including Cairns, Townsville and Thuringowa) but is centred on the Tully region.

The fact that the study focuses on the Tully region is seen as a shortcoming of the report. While Tully is a conveniently smaller 'parcel' on which to review the assessment techniques, the impact of the 1998 flooding on Tully is considered to be significantly different to that of Townsville, for the following reasons:

- the January 1998 event was a smaller magnitude flood event for Tully than for Townsville.
- Tully residents are much more ‘flood aware’.
- The nature of damage was significantly different – there were only a small number of residential properties flooded in Tully.

A further detraction from the study is the difficulty in separating out information specific to Townsville (as opposed to the Townsville Thuringowa region).

The total economic cost of the January 1998 floods on the study area has been estimated at $123.2 million. The economic loss has been calculated by deducting the financial benefits to the region, being predominantly insurance payouts. Direct losses (not including indirect and intangible) made up 92% of the total economic losses and were estimated to be $113.6 million (refer to **Table 17**).

Table 17
Total Direct Losses – Local Gov. Areas Townsville to Cairns

Direct Loss Category	Estimated Financial Loss ($m)	Insured Amount and Other Benefits ($m)	Estimated Economic Loss ($m)
Residential (Structures and Contents)	89.16	25.9	63.26
Commercial and Industrial Sector	39.1	29.1	10
Public Assets and Infrastructure	82.63	50.73	31.9
Agriculture	8	2.1	5.9
Vehicles and Boats	15.35	12.82	2.53
Indirect and Intangible	10.86	1.26	9.6
Total	**245.1**	**121.91**	**123.19**

The report details various methods for determining direct residential and commercial losses (refer to **Table 18** and **Table 19**), the results of which vary considerably. The best estimation of total commercial losses was $39.1 million, a figure derived largely from insurance data. Direct losses to infrastructure were very large, with damage to roads making up over half of the total infrastructure loss.

Table 18
Direct Residential Losses – Local Gov. Areas Townsville to Cairns

	Estimation Method			
	Insurance Data	**Survey**	**Estimate using best available data**	**Rapid Appraisal Method**
Flood damaged	All insured	Over floor	All over floor	Above and below floor
Average loss/building ($)	3735	24,491 (in-depth interviews)	11,961	20,500 (RAM)
Number of buildings	6955	7,454	7,454	In excess of 7,454
Total financial loss ($)	25,980,000	182,555,914	89,162,000	>152,807,000

5 Flood Damages

Table 19
Direct Commercial Losses – Local Gov. Areas Townsville to Cairns

	Estimation Method		
	Survey ($)	Insurance ($)	Rapid Appraisal Method ($)
Average loss/building or claim	15,998 (for small enterprises only)	35,661	20,500 (RAM)
Number of buildings	1,133 (est. from EMATrack)	850 (EMATrack)	1,133 (est. from EMATrack)
Total loss	18,125,734	29,099,376	23,226,500
Uninsured losses	N/a	Approx. 10 m	N/a
Total	18,125,734	Approx 39.1 m	23,226,500

The case study highlights the difficulties in making reliable estimates of flood losses, demonstrating the low estimate of residential loss from insurance data at $25.9 million through to a high figure of $152.8 million using the averaging approach based on survey records. Townsville (including Thuringowa) is reported to have received $22 million or 85% of the total residential insurance payout of $25.9 million. King (1998) is quoted within the reported as providing the estimate of 7454 houses inundated, with approximately 950 experiencing severe flooding of levels between 0.5 and 1 m. In-depth interviews revealed an average direct loss of $24491, however, this value is to be viewed in context that all interview participants were known to have had experienced significant over floor flooding.

Table 25 from the report is reproduced below as **Table 20**, summarising the methodology behind the 'best available data' estimate of direct residential losses. The estimated economic costs for each damage category were derived as follows:

- Minor damage of $5000 was the study's estimate of the cost of cleaning up floor-level flooding, including house and garden clean up and replacement of carpets.
- Moderate damage value of $20500 was based on the Rapid Appraisal Method value.
- Serious damage of $91500 is taken as half the value of the house and contents, based on US practices.
- The value of $183000 for destruction of a house is from the Bureau of Transport Economics (BTE 2001).

Table 20
Summary of Best Available Data (King 1998) – Local Gov. Areas Townsville to Cairns

Damage	**Estimated number of buildings**	**Estimated economic cost of damage/building (1998$)**	**Total cost to region ($m)**
Minor (between 0.001m and 0.2m)	4650	5000	23.2
Moderate (between 0.2m and 1m)	2200	20500	45.1
Serious (over 1m)	200	91500	18.3
Destroyed	14	183000*	2.562
Totals	**7454**		**89.162**

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There was little available information for the estimation of losses to the commercial sector. The best estimates were available through insurance claims ($29.1 million) with an additional $10 million uninsured component.

Infrastructure losses were predominantly direct losses caused by destruction of publicly owned assets. The economic losses due to destruction and damage to public assets was estimated from survey data, and the amount of Natural Disaster Relief Arrangement (NDRA) funding.

Economic Costs of Natural Disasters in Australia (Bureau of Transport Economics, Report 103)

This report includes a discussion of the principles for estimation of losses, particularly measuring economic loss as opposed to financial loss. Losses can be classified as direct and indirect, tangible and intangible, and the report estimates that total direct residential damages are typically comprised of 20% structural damage with lost contents making up the remaining 80%.

The report states that there are two types of stage-damage curves; one type is based on actual damage costs and the other is based on ‘synthetic’ costs. The synthetic stage-damage curves are mostly used for the prediction of flood costs such as in benefit-cost analyses. The development of residential synthetic stage-damage curves has the following steps:

- In the area of study, representative classes of houses are selected, usually based on size (for example, small, medium and large).
- A sample of houses is selected in each dwelling class. In each room type of the selected houses, contents are checked and value noted. Information on the height above floor level can also be noted or heights can be taken as the same in all dwellings. Preferably, a qualified quantity surveyor or valuer should undertake this step.
- Values are averaged across each sample for each class of house and the stage-damage curves constructed.

The stage-damage curves constructed by the synthetic cost method are for potential damage, not actual damage.

Public Infrastructure Damage Estimates (Townsville City Council, October 2001)

Townsville City Council provided estimates of costs associated with the flood events of March 1997 (Tropical Cyclone Justin), January 1998 (ex-Tropical Cyclone Sid) and April 2000 (Tropical Cyclone Tessi). A total of $23.27m was received as NDRA grants for all events, with a total contribution from Council of $932,000.

A number of public infrastructure losses were incurred that were ineligible for NDRA funding, including:

- Castle Hill Landslip - $700,000 (Tessi)
- Strand Remediation - $10m
- Crystal Creek Water Supply Intake - $10m (Sid)
- Water & Wastewater Infrastructure - $500,000

- Parks & Gardens Cleanup - $500,000
- Drainage Infrastructure - $1m
- Long Term Damage to Road Pavements - $10m over 10 years

5.3 Derived Stage-Damage Curves for Townsville

The available data for flood damages was reviewed for relevance to Townsville and the proposed methodologies for determining flood damage estimates. It is recognised that detailed flood damage assessments utilise flood level data, stage-damage curves and GIS databases of floor levels and building type for a specific Study Area to achieve the most accurate results. For the case of the Townsville urban area, flood level information was available (outputs from Phase 2 – Flood Study) and a detailed GIS property database existed with zoning information and property type/size.

However, no existing information was available on building floor levels, which potentially limits the accuracy of any derived flood damage estimates, and no information existed on damage curves for different property types. The following sections detail investigations undertaken to provide supplementary information in these two areas, sufficient to allow a detailed flood damage assessment.

5.3.1 Stage-Damage Curve Development

For a damages estimation on the scale of that for Townsville, a commonly accepted practice is to use a stage-damage relationship for estimating damages to residential properties (where damage is calculated based on the depth of over-floor flooding), while commercial and industrial property damage is estimated using area-damage rates.

Property zoning data supplied by TCC in GIS format was used for the development of stage-damage curves and area-damage rates. The GIS property zoning information supplied by TCC gave in excess of 20 different zoning classifications for Townsville. These were amalgamated into eight major zoning classifications: Residential 1, Residential 2 and Residential 3, Commercial (COM), Industrial (IND), Special Purpose (SP), Particular Development (PD) and Open Space (OS) (refer to **Figure 4**).

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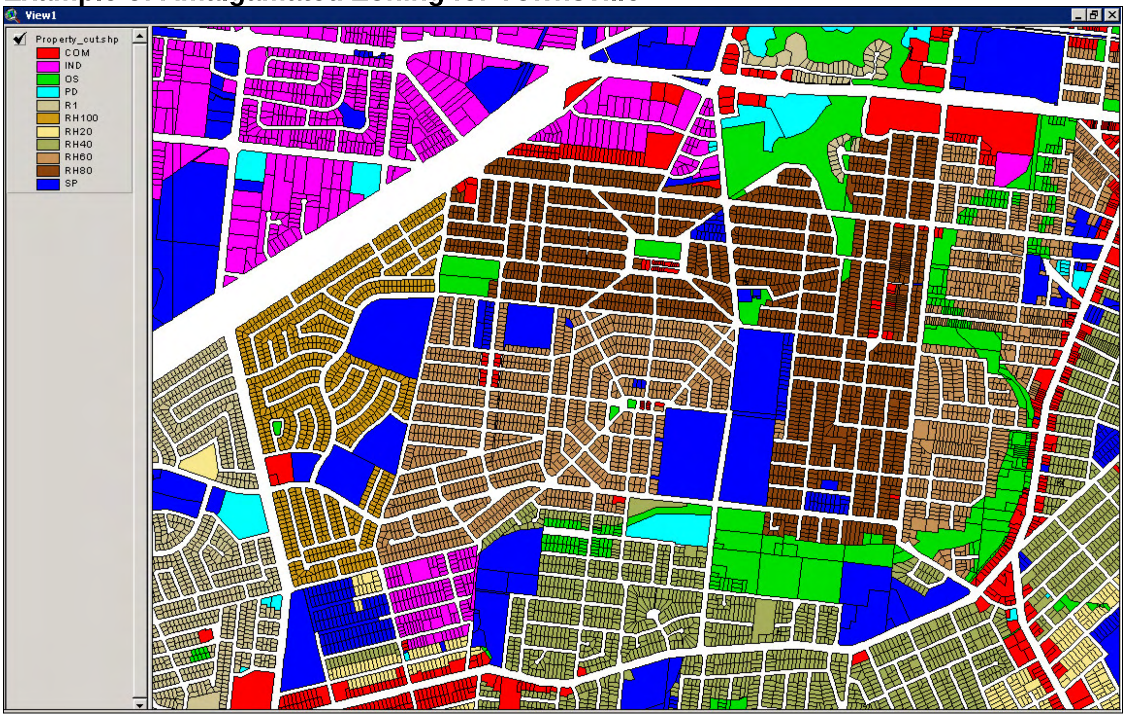
Figure 4
Example of Amalgamated Zoning for Townsville



In Townsville, properties zoned Residential 1, 2 & 3 exhibit a mix of low-set and high-set homes, varying in density between suburbs. Generally, older suburbs and those historically flood prone have a higher proportion of high-set homes. Initially, stage-damage curves were developed for a typical low-set and high-set house in Townsville, based on the available literature described in **Section 5.2** above. In both cases, depths are taken as over the ground floor level.

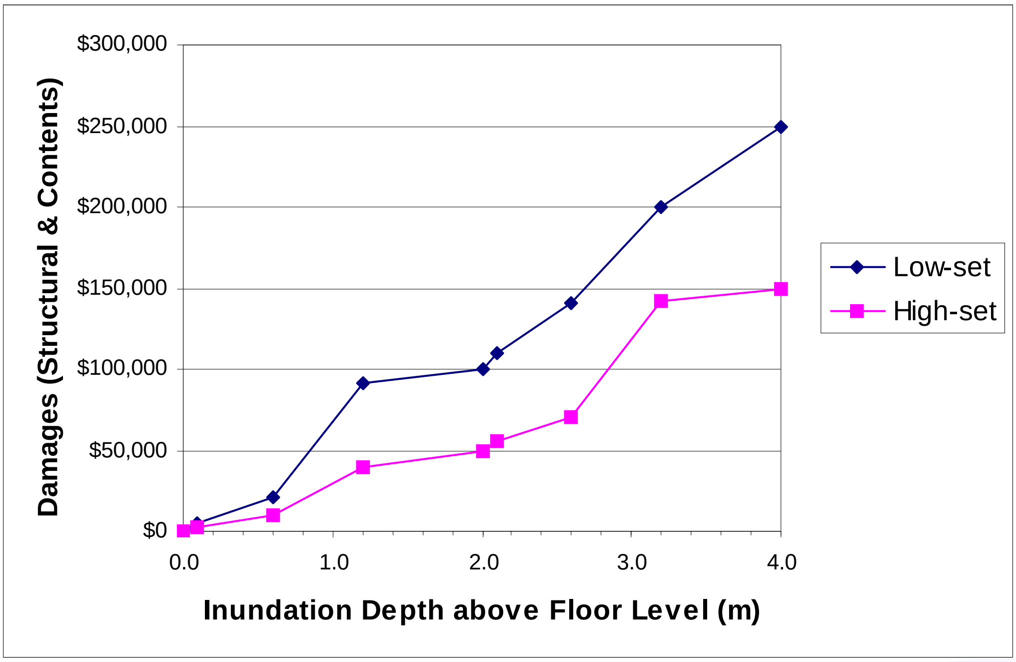
The derived curves are shown in **Figure 5**, and exhibit the following general features:

- Low set property has a greater damage at the 0.1 m over-floor level, in recognition of a reduced likelihood of a high-set property having a built in ground floor (with carpets), and the potential for residents of high-set properties to move property up to the higher level.
- Once the over-floor depth exceeds 1 m, a significant increase in damages is exhibited for both types of property. This is consistent with the best available data from the survey of residents after the January 1998 flood event (King, 1998), and reflects losses associated with permanent fixtures (kitchen and bathroom cupboards) and large furniture (fridge, washing machine, bed) that cannot be lifted out of the flood zone.
- Between 1.2 m and 2.0 m over-floor depth, the damage curve does not increase much, as the incremental damage is minimal (the damage has already been done).
- For the high-set property, it is assumed that the second (higher) level is approximately 2.0 m above the lower floor level (obviously, this height will vary

between properties). Above that level, the high-set curve exhibits a similar trend as the low-set curve at the lower level.

- Four metres over-floor is the assumed limit of the damages curve. At 3.0 m deep, a low-set property is assumed to be a total loss; however, it is noted that this will depend heavily on flow velocities experienced. For a high-set house, a four metre depth approaches the roof level, so the losses are less than for a low-set property which would have the majority of roof underwater.

Figure 5
Derived Residential Stage-Damage Curves for Townsville



For Residential 1 zoned properties a reference floor level (height above ground) was nominated for each suburb (refer to following section), and the low-set damage curve used throughout for estimation of damages. For the Residential 2 & 3 zoned properties, which comprised a mix of low and high-set houses, a uniform reference floor level (height above ground) of 300mm was selected. Based on the estimated proportion of low and high-set properties in each suburb, an additional five damage curves based on the two basic curves featured in **Figure 5**. Note that in using this approach no property damage is recorded below the reference floor level

For property types other than Residential, area based damage curves were developed (refer to **Table 21**). Values were selected on the basis of the literature review and an assessment of the average proportion of a land parcel actually occupied, since the GIS database included only the area of the total land parcel. In general, industrial properties have a higher proportion of the land under roof, and the value of losses is generally higher.

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Table 21
Damage Rates for Non-Residential Properties

Depth	Commercial* ($/m^2)	Industrial ($/m^2)	Open Space ($/m^2)	Particular Development ($/m^2)	Special Purpose ($/m^2)
0	0	0	0	0	0
0.25	51.7	103.4	0.01	0.01	0.01
0.75	125.2	250.4	0.02	0.1	0.1
1.25	190.6	381.1	0.05	0.5	0.5
1.75	211.0	421.9	0.1	1	1
2.25	224.6	449.2	0.2	2	2
2.75	237.5	475	0.5	5	5
3.25	250	500	1	10	10

* For large commercial properties associated with shopping centres (K Mart, Stockland, Hyde Park and Castletown), the curve was adjusted down by a factor of 10 to reflect actual reported losses in January 1998.

Open space losses are predominantly associated with cleanup and restoration of parks and drainage paths/structures, and this is reflected in the low damages estimates. For Particular Development and Special Purpose (encompassing sports fields, schools, Lavarack Barracks, etc.), a nominal curve was developed based on the maximum likely damage if whole of property was flooded.

5.3.2 Flood Level Survey

Flood mapping provides estimates of the depth of flooding above ground level. Based on knowledge of the Townsville area, it was reasoned that heights of floor levels above ground level typically follow trends on a suburb-by-suburb basis, and varied for different zoning. For example, in Annandale, the majority of homes are slab-on-ground construction, whereas in Vincent, a large proportion of homes are high-set.

A kerb-side survey was undertaken of selected streets in each suburb of Townsville in order to obtain representative floor heights above ground for properties. For each suburb, one or two streets were chosen that were considered representative of the overall style of properties in that particular suburb, and also contained each of the major zoning types found in that suburb. The results of the survey are shown in **Table 22** and **Table 23**.

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In **Table 22**, the adopted reference levels (height of floor above ground) and the assigned damage curve are listed for residential development in each suburb. R1 refers to the low-set curve and RH100 refers to the high-set curve. RH40 refers to an intermediate curve representing 40% high-set density (high-set density of other intermediate curves inferred from naming convention).

Table 22
Reference Levels and Stage-Damage Curves for Residential Properties

Suburb	Residential 1		Residential 2		Residential 3	
	Ref Lev (mm)	Curve	Ref Lev (mm)	Curve	Ref Lev (mm)	Curve
Aitkenvale	310	R1	300	RH40	300	RH20
Annandale	190	R1				
Belgian Gardens	400	R1	300	RH60	300	RH40
Bohle						
Castle Hill	800	R1				
City	800	R1			300	RH40
Cluden	450	R1				
Cranbrook	260	R1			300	RH20
Currajong	300	R1	300	RH80	300	RH80
Douglas	220	R1				
Garbutt					300	RH20
Gulliver			300	RH60	300	RH60
Heatley	430	R1	300	RH20	300	RH20
Hermit Park					300	RH40
Hyde Park			300	RH60	300	RH60
Idalia	200	R1	300	RH40		
Mt St John						
Mt Louisa	270	R1				
Mundingburra			300	RH40	300	RH40
Murray						
Mysterton			300	RH60		
North Ward	400	R1			300	RH40
Oonoonba			300	RH40	300	RH40
Pimlico			300	RH80	300	RH80
Railway Estate					300	RH80
Rosslea					300	RH20
Rowes Bay	400	R1	300	RH60		
South Townsville			300	RH40		
Stuart	450	R1				
Vincent			300	RH100		
West End	300	R1			300	RH60
Wulguru	460	R1				

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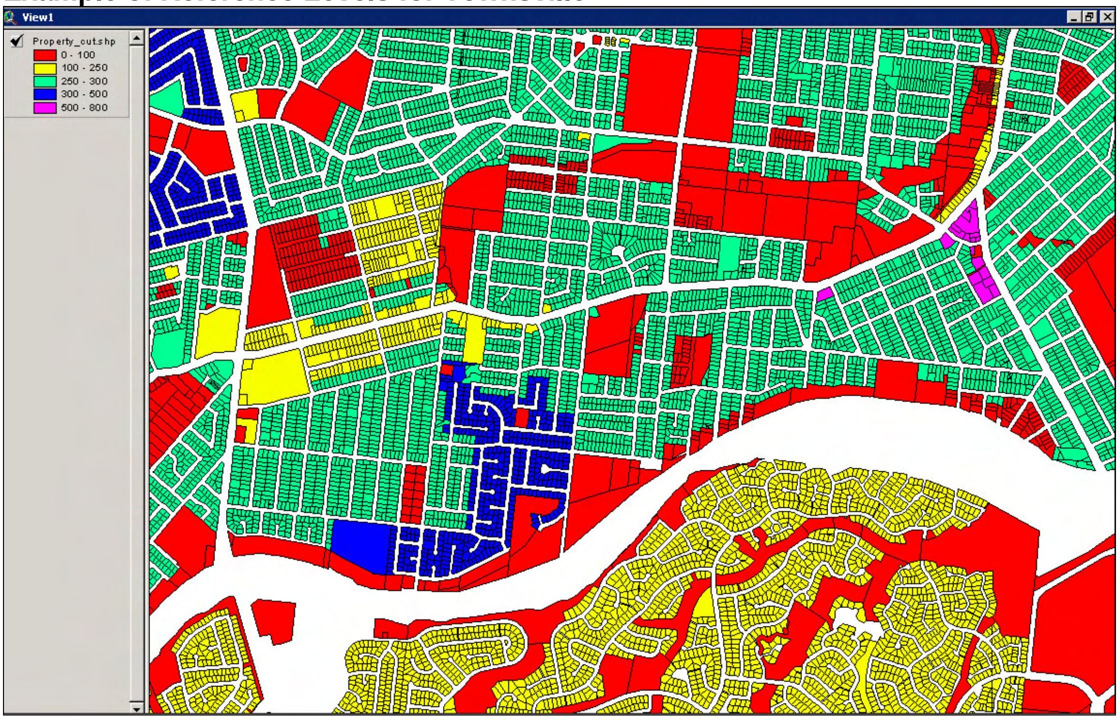
Table 23
Reference Levels and Damage Rate for Commercial and Properties

	Commercial		Industrial	
	Ref Lev (mm)	**Curve**	**Ref Lev (mm)**	**Curve**
Aitkenvale	200	COM	180	IND
Annandale	200	COM		
Belgian Gardens	400	COM		
Bohle			150	IND
Castle Hill				
City	220	COM		
Cluden				
Cranbrook	200	COM		
Currajong	200	COM	150	IND
Douglas				
Garbutt	200	COM	430	IND
Gulliver	240	COM		
Heatley	250	COM		
Hermit Park	280	COM		
Hyde Park	260	COM	300	IND
Idalia			200	IND
Mt St John			150	IND
Mt Louisa	200	COM	150	IND
Mundingburra	560	COM		
Murray				
Mysterton	150	COM		
North Ward	480	COM		
Oonoonba	200	COM		
Pimlico	300	COM*		
Railway Estate	300	COM	200	IND
Rosslea	290	COM		
Rowes Bay				
South Townsville	300	COM	200	IND
Stuart			200	IND
Vincent	200	COM		
West End	290	COM		
Wulguru	200	COM	130	IND

For Opens Space, Special Purpose and Particular Development zonings, a reference level of 0.0 m was assumed. A graphical representation of the differences in reference level (mm) across parts of Townsville are shown in **Figure 6**.

5 Flood Damages

Figure 6
Example of Reference Levels for Townsville



5.4 Flood Damage Assessment

A flood damage assessment was undertaken for Townsville, Magnetic Island and the coastal communities of Cungulla and Pallarenda, using varied methodologies. The following sections detail the assumptions made, the adopted process as applied to different areas and the results of the flood damage assessment.

5.4.1 Magnetic Island and Coastal Communities

The basis for the calculation of potential damages for Magnetic Island and coastal communities involved a simplified assessment of the numbers of properties inundated, with losses estimated at $5000 per property. The adopted 'damage per lot' value of $5000 is consistent with the best available data (King, 1998) compiled after the January 1998 flood event (for minor flooding).

This method does not allow differentiation between type of property (high or low-set, old or new, small or large, residential or commercial), and assumes an average depth of inundation across all properties shown as inundated. While the estimate of damages per house seems low, it is considered appropriate as the assessment was based on lots shown as flooded, with no consideration of the floor height above ground or the location of the residence on the property. Some property boundaries (particularly along Gustav Creek) extend into the defined creek but the actual house is located on higher ground. The methodology also cannot account for indirect losses like the landslide experienced in the January 1998 event.

5 Flood Damages

In **Table 24**, the total damages for each design flood event on Magnetic Island are calculated, together with the Annual Average Damage for each bay (in accordance with the methodology presented in the document "*Guidance on the Assessment of Flood Damages, DNR&M, 2002*").

Table 24
Estimated Damages due to Flooding – Magnetic Island

Event	No. of properties impacted by flood inundation					TOTAL ($)
	Picnic Bay	Nelly Bay	Arcadia	Horseshoe Bay	Total	
2yr ARI	2	0	13	24	39	$195,000
5yr ARI	10	12	18	28	68	$340,000
10yr ARI	17	18	23	34	92	$460,000
20yr ARI	23	23	30	36	112	$560,000
50yr ARI	27	27	34	36	124	$620,000
100yr ARI	30	37	38	36	141	$705,000
PMF	63	94	72	78	307	$1,535,000
Annual Average Damage ($)	$30,750	$30,250	$65,725	$103,300	$230,025	

Damages due to tidal (surge) inundation are presented in **Table 25** for both Magnetic Island and the coastal communities of Cungulla and Pallarenda. Similar to above, the Annual Average Damage was also calculated for each location.

Table 25
Estimated Damages due to Tidal Inundation – Magnetic Island, Pallarenda and Cungulla

Event	No. of properties impacted by tidal (surge) inundation					
	Magnetic Island				Pallarenda	Cungulla
	Picnic Bay	Nelly Bay	Arcadia	Horseshoe Bay		
50yr + Wave Setup	0	4	0	2	24	35
100yr + Wave Setup	0	4	19	4	58	47
Annual Average Damage ($)	$0	$600	$950	$400	$5,300	$5,850

The results suggest that Horseshoe Bay and Arcadia are most prone to flood damage. Damage in tidal (surge) inundation events are an order of magnitude less than that predicted for flooding. Appropriate mitigation measures for Magnetic Island, Cungulla and Pallarenda are discussed **Section 6**.

5 Flood Damages

5.4.2 Townsville

A comprehensive flood damage assessment was undertaken for the Townsville urban area using MIKE FLOOD ANALYSIS (MIKE FA), a GIS-based add-on for the MIKE suite of programs specifically developed by DHI to allow economic assessment of flood losses and mitigation options. MIKE FA works within ArcView and can read output files from both MIKE11 and MIKE21.

To reduce the memory requirements of the software, the Townsville property database was divided into three areas as depicted in **Figure 7**. Damages from each area were calculated and summed to give an overall assessment of damages across Townsville.

Figure 7
Three Damage Areas Defined for Townsville

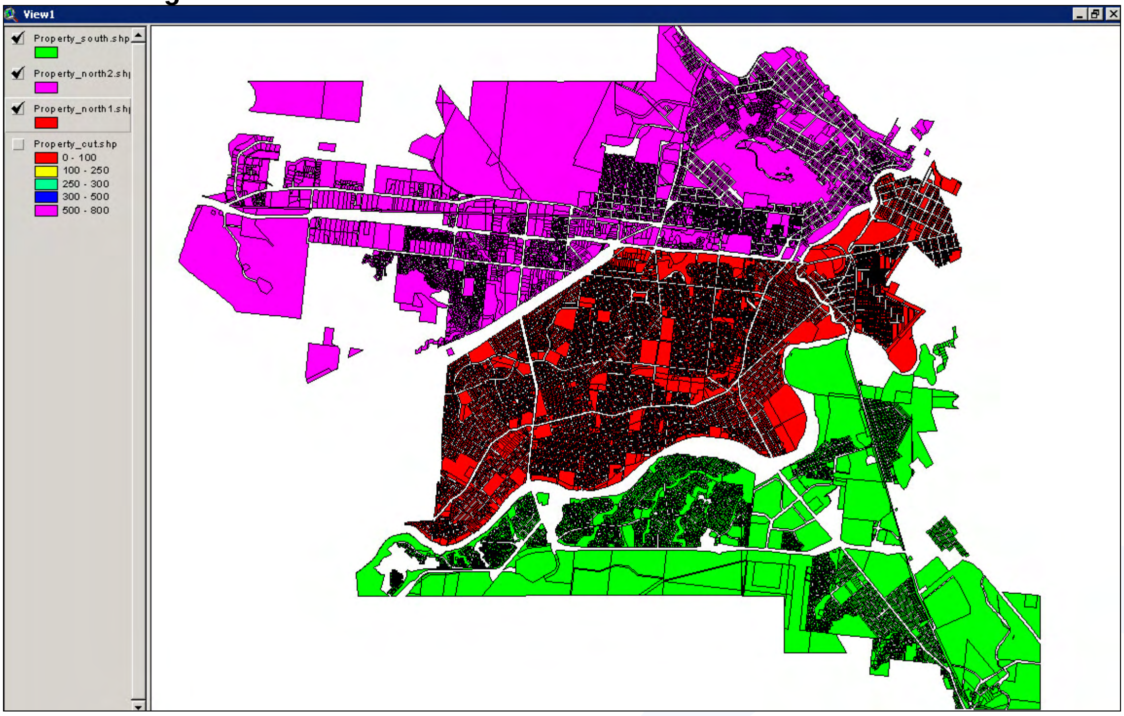


Figure 8 below provides a snapshot of the various MIKE FA windows interfaces that highlight the input requirements used in assessing flood damages. These are:

Reference levels (height of floor above ground), based on the street survey results.
Damage curves for each type of development (this has previously been discussed).
Flood information table (a database which links the property layer to the flood map, by assigning an average depth of inundation to each property).

Outputs from the damages analysis software include total direct damages and annual average damage. It is important to note that all damage estimates relate to potential damage, and are not adjusted to include the insured component.

5 Flood Damages

Figure 8
Example Software Interface

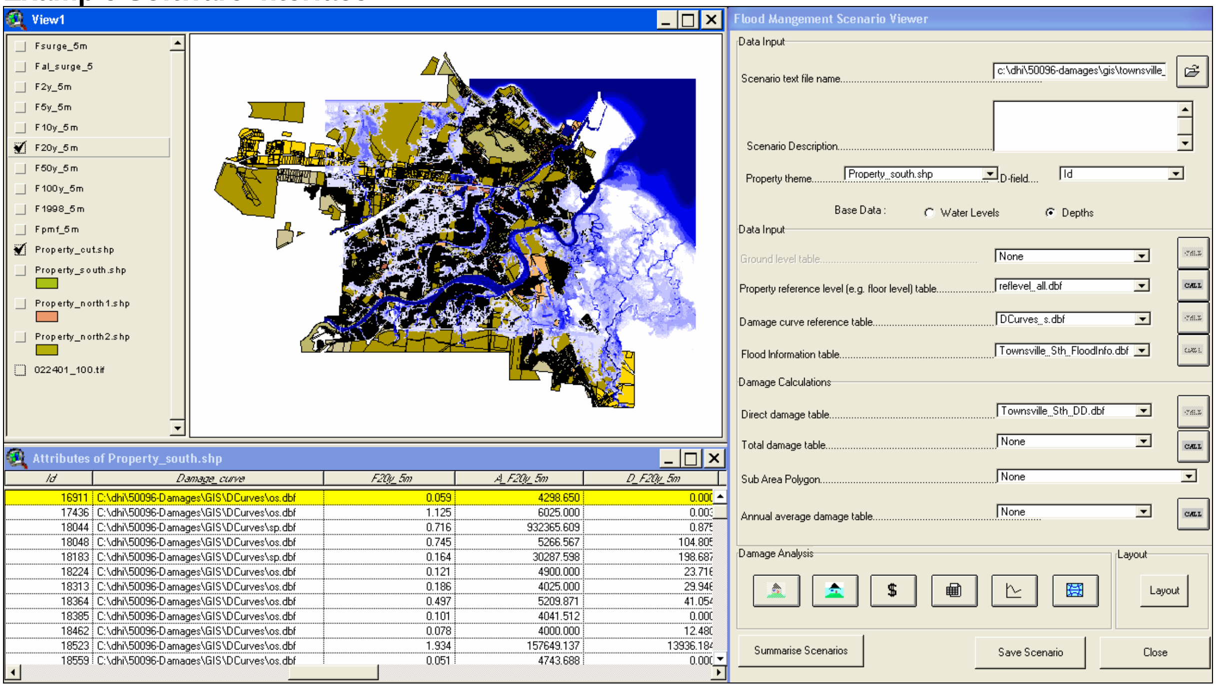


Table 26 below shows a summary of the expected number of residential and industrial buildings affected in Townsville. Also shown is the expected number of people displaced.

Table 26

	Number Affected		
Event	People	Residential Buildings	COM / IND Buildings
10yr ARI Flood	183	52	5
50yr ARI Flood	573	177	12
1998 Flood	3865	1185	310

The calculation of damages using GIS methods presents many advantages, the most obvious of which is that the damage data will be spatially represented. This means that areas that are flooded and have a high contribution to the total damage can be easily distinguished from areas with low damage impacts. A second advantage concerns the area influenced by the provision of a flood mitigation option. When comparing flood damages for pre- and post-flood mitigation option, it is often desirable to focus the flood damage on the area where the flood behaviour is influenced by the mitigation option rather than the entire study area. In a GIS based system, sub areas for damage assessment can be easily identified and delineated on screen.

The direct damages resulting from the above methodology were calibrated to damages recorded for the January 1998 flood event. As has been previously discussed, distilling Townsville damages from reported ‘regional’ damage estimates is difficult, and the calibration was somewhat subjective. To achieve a reasonable damage estimate for the January 1998 flood event, some manipulation was required of the input data sets.

The property database contains a property damage factor, used to scale the calculated damage value for each property (particularly if the damage curve for the property is based on a damage per unit area). For instance, if only 10% of a property polygon is developed with homes, and the damage curve is stated as a damage per unit of developed area, then a factor of 0.1 needs to be applied in the factor column for that property. For Townsville, manual manipulation of the damage factor was required for a number of very large industrial properties (like those at Stuart) which are undeveloped. Setting a low damage factor accounted for the lack of development on these sites.

Another area that required manipulation of the damage factor was residential properties that extend into an adjacent drainage path. In some cases, a corner of the property in the creek bed experienced very deep depths of inundation when the rest of the property is dry. This effect was causing a very distorted view of damages resulting from even minor flood events.

Once the anomalies associated with the input databases were removed, the damages for the 1998 event were calculated and checked against any available damages data specific to certain areas or properties. The resulting damages for the 1998 event are tabulated below in **Table 27**. The GIS analysis predicts a total of $34.7m in residential losses, and $19.0m in commercial/industrial losses, which are consistent with figures presented in the literature review. The prediction for open space (parks and gardens) is consistent with Council estimates, and commercial losses for the Hyde Park and Castletown shopping centres compare well with reported figures contained in recent RFMP funding applications by Council.

Table 27
GIS Damage Estimates for January 1998 Flood Event

Property Zoning	Damages (1998 Flood Event)
R1	$9.91m
RH100	$0.35m
RH80	$5.28m
RH60	$8.49m
RH40	$9.54m
RH20	$1.14m
COM	$9.63m
IND	$9.37m
OS	$0.27m
PD	$0.04m
SP	$0.51m
TOTAL	$54.53m
Total Residential	$34.72m

5 Flood Damages

On the basis of the above calibration, damage estimates were prepared for the full range of flood events (2 Year ARI up to PMF) and two storm surge events (Cyclone Althea and the extreme event of Cyclone Althea coincident with a high tide). These are presented in **Table 28**.

Table 28
GIS Damage Estimates for All Events

	Flooding							Surge	
Property Zoning	**2 Year ARI**	**5 Year ARI**	**10 Year ARI**	**20 Year ARI**	**50 Year ARI**	**100 Year ARI**	**PMF**	**Cyclone Althea**	**Cyclone Althea + MHWS**
R1	$0.55m	$1.79m	$1.81m	$2.88m	$3.86m	$4.61m	$5.57m	$0.00m	$0.00m
RH100	$0.00m	$0.03m	$0.04m	$0.11m	$0.14m	$0.16m	$1.06m	$0.00m	$0.00m
RH80	0.08	$0.15m	$0.23m	$1.18m	$1.58m	$2.05m	$5.96m	$0.81m	$19.52m
RH60	$0.14m	$0.33m	$0.47m	$3.56m	$4.05m	$4.61m	$36.03m	$0.00m	$1.01m
RH40	$0.24m	$0.38m	$1.18m	$1.62m	$2.41m	$3.34m	$90.76m	$0.18m	$14.00m
RH20	$0.00m	$0.00m	$0.01m	$0.15m	$0.23m	$0.34m	$18.06m	$0.00m	$0.00m
COM	$0.03m	$0.05m	$0.06m	$1.37m	$2.12m	$3.26m	$54.96m	$0.00m	$6.44m
IND	$0.08m	$0.09m	$0.7m	$2.62m	$2.86m	$3.19m	$74.58m	$0.00m	$1.65m
OS	$0.04m	$0.04m	$0.05m	$0.12m	$0.15m	$0.17m	$1.13m	$0.04m	$0.26m
PD	$0.01m	$0.02m	$0.03m	$0.07m	$0.08m	$0.10m	$0.54m	$0.00m	$0.00m
SP	$0.04m	$0.06m	$0.09m	$0.15m	$0.19m	$0.23m	$3.25m	$0.05m	$0.48m
TOTAL	$1.22m	$2.94m	$4.04m	$13.77	$17.59m	$21.98m	$395.72m	$1.09m	$43.38m
Total Residential	$1.02m	$2.67m	$3.75m	$9.51m	$12.26m	$15.12m	$261.26m	$1.00m	$34.54m

(for legend see section 5.3.1)

The damage estimates developed using the comprehensive GIS method show some interesting results. There is a noticeable discontinuity between the 10 and 20 Year ARI levels, which is primarily a result of the use of MIKE11 and MIKE21 flood maps with a different grid resolution. However, this is also indicative that Townsville generally has a less than 20 Year ARI channel capacity, at which the overland flow component becomes more significant and causes significant damage.

It is interesting to note the difference between damages for the PMF event and the January 1998 event (which has been estimated as having an Average Recurrence Period of approximately 500 years. In a PMF event, it is expected that damages would be in the order of $400 million, an order of magnitude higher than that experienced in January 1998.

The difference between inundation damages from Cyclone Althea and the same cyclone coincident with a high tide is also significant. While most of the damage reported for the event resulted from cyclonic winds and not storm surge, if Cyclone Althea hit today on a high tide the expected damages would rival that of January 1998, although the location of peak damage areas would be different.

The calculated Annual Average Damage estimate for Townsville is $4.5m, using the same methodology adopted for Magnetic Island and coastal communities as detailed in *Guidance on the Assessment of Flood Damages" (DNR&M, 2002)*. The following

5 Flood Damages

section details mitigation solutions targeted to address known flood problems within the Study Area, and reduce the burden to the Townsville community resulting from flood damages of this magnitude.

6 Risk Analysis, Evaluation and Treatment Options

6 Risk Analysis, Evaluation and Treatment Options

6.1 Risk Analysis

The purpose of risk analysis is to assign levels of risk, in order to assess their seriousness. Risk levels are based on the likelihood and consequence of each hazardous event. The processes involved in risk analysis include:

1. Assigning a level of likelihood of occurrence for each hazardous event.
2. Assigning a level of consequence for each event.
3. Using the assigned likelihood and consequence levels, estimate the level of risk.
4. Determining the possible consequences for each risk, based on the vulnerability of the community and environment.

The adopted scales of likelihood, consequences and risks are shown in **Table 8** to **Table 11** in **Appendix A**, addressing steps 1 – 3 above. These have been adapted from Zamecka and Buchanan (2000) and AS/NZ 4360:1999 Risk Management. For this Study, the scale of likelihood from A (Almost Certain) to E (Rare) has been linked to assigned Average Recurrence Interval of flood and storm surge inundation, from the 5 Year ARI event up to the flood extreme event experienced in 1998 and the hypothetical extreme storm surge (Cyclone Althea on a high tide).

Step 4 from above is documented in the Risk Registers (included as **Table 12** to **Table 22** in **Appendix A**). For the purposes of this study, separate registers have been set up for Townsville, Magnetic Island and Coastal Communities (Pallarenda and Cungulla), and within each further breakdown is provided between sub-areas (eg. Fairfield, City). The different locations of these communities mean that they are subject to different levels of risk and as such have been examined separately. A separate register for Other Components has been set up for the environment and major transport routes within the three areas defined above.

The risk ratings (derived from combination of likelihood and consequence) range from Low to High (no immediate action is required to address a perceived Extreme Risk).

6.2 Risk Evaluation

The purpose of evaluating the risks is to rank the risks from greatest to least so that a priority for treatment can be assigned. This involves comparing the levels of risk rating (determined in the previous section) with the initial evaluation criteria developed in **Table 7** of **Section 3.1**. Risks are generally described as acceptable, unavoidable, undesirable or unacceptable, and have been evaluated for a range of recurrence interval flood events and storm surge levels (where appropriate). The derived risk ratings (Low, Moderate and High) due to flooding and storm surge inundation are presented in **Table 23 – Table 27** of **Appendix A**.

A register of prioritised unacceptable risks are presented in **Table 28 – Table 33** of **Appendix A**. To avoid confusion between risk rating (High, Moderate and Low) and risk priority we have prioritised from 1 – 3, with 1 being the highest priority and 3 being the lowest priority.

6 Risk Analysis, Evaluation and Treatment Options

6.3 Risk Treatment Options

The final step in the risk management process involves the selection of appropriate strategies that will minimise the potential for harm to the community. The process involves the identification, evaluation and selection of treatment options to deal with unacceptable risks. Zamecka and Buchanan (2000) prescribes the use of the following framework for the selection of risk treatment options:

- Prevention/mitigation measures
- Preparedness measures
- Response measures
- Recovery measures

These elements are further described below.

Prevention/mitigation measures seek to reduce or eliminate the consequences of the event. Measures can be both structural and non-structural, including:

- Engineering works: construction of retarding basins, drainage upgrades, infrastructure improvements, road raising, channel clearing and diversions.
- Planning controls: adoption of policies restricting infill development in existing flood prone areas, thereby reducing risk escalation. Planning policies include setting development levels, freeboard requirements and even strategies to implement voluntary buy-back schemes. Developing a flood prone land code for new development (not part of this study).
- Warning systems: effective warning systems are essential in conveying information to the community, particularly in areas prone to flash flooding.
- Regulations, standards and local laws: appropriate hazard resistant building regulations, standards and codes of practice should be referred to and enforced, particularly for the design and construction of major infrastructure and components of essential services.
- Land use planning: appropriate location of service networks and facilities through coordinated planning of infrastructure.

Preparedness measures seek to reduce the harm caused by a hazard by reducing community vulnerability. Such measures include:

- Community awareness programs: improved understanding of hazards and risks by the community is an effective mitigation measure. Increased awareness helps people take steps to protect themselves and their property thus reducing their own vulnerability.
- Effective information management: collation of historical flood data and development of detailed flood mapping help to identify areas most at risk.
- Improved dissemination of flood advice: effective dissemination of warning advice is an essential component of a flood warning system. Development of responsibility protocols and procedures for issuing warnings ensures timely and targeted advice.
- Promoting community involvement: Consultation and canvassing of community opinion can maximise acceptance of mitigation schemes. Encouraging

community based flood management activities reduces the burden on Council resources, and results in community ownership of outcomes.

- Updating Counter Disaster Plan: plan should address community safety issues and allow for particular aspects of disaster management such as evacuation, establishment of assembly locations, shelter buildings and evacuation routes.
- Maintenance programs: regular maintenance programs ensure resources and equipment are operational / available when required. Minimising potential for debris and sediment build-up reduces the demands on clean up operations.

Response measures seek to reduce the harm to the community by ensuring that well trained resources are available to respond to a hazard situation. This will involve:

- activating emergency coordination centres, including designated emergency coordination centre
- conducting regular training and exercises for response and recovery teams
- utilising all available resources to ensure that reliable and timely information is provided to the public
- coordinating resources, evacuation procedures and road closures based on predicted flood levels from this study
- providing immediate relief and medical assistance
- resource logistical support as required to respond to different situations

Recovery measures seek to minimise the medium to long-term harm to a community, through:

- assistance with clean up of residential and commercial property
- provision of temporary housing and shelter, financial assistance and emergency food supplies
- counselling of emotionally affected people, particularly post-traumatic stress disorder
- public awareness programs to inform affected communities of where and when recovery assistance can be sought
- review of the Counter Disaster Plan in light of recent experiences
- restoration of lifelines and essential services, particularly to isolated communities.

The general risk treatment options available are also listed in **Table 34** of **Appendix A** and have been identified and evaluated in accordance with Zamecka and Buchanan (2000). The following sections present a qualitative assessment of the measures that are available to counter the specific impacts and hazards posed by flooding and storm surge in the Study Area.

6.3.1 Prevention / Mitigation Measures

Structural mitigation options should be evaluated through careful consideration of principal factors such as costs and benefits, risk severity and potential for its reduction.

Storm surge and flooding is generally a large-scale phenomena, and attempts to ‘hold back the flood’ through structural measures like levees are largely impractical and prohibitively expensive in an urbanised environment. Therefore, structural measures are only really an option if targeted small-scale works can be implemented to improve the immunity of communities or major access and evacuation routes to inundation. The community vulnerability analysis and flood mapping has identified areas that are inundated sooner or more regularly than is desirable.

In the assessment of whether inundation in these locations should be mitigated, consideration needs to be given to:

- the cost of the works
- alternative (cheaper) non-structural measures that could effectively achieve the same result,
- the likely level of risk reduction achievable, for both storm surge and flooding hazard,
- the likelihood that the measures will actually be required,
- social, political and environmental impacts of undertaking (or not undertaking) structural works, and
- the number of people benefiting from the works.
- the ability of the community to pay for the works.

Through many years experience designing and constructing drainage works in Townsville, Council Citiworks personnel have compiled a list of possible locations for structural mitigation works across the Study Area (refer to **Appendix D**). This list was considered along with the results of the risk registers in **Appendix A**, the community vulnerability assessment and flood inundation mapping, in development of a prioritised list of structural mitigation works. Further detail on prioritised structural works (including preliminary cost estimates) is provided in **Section 7 – Disaster Mitigation Plan**.

Town planning policies need to recognise the risks posed by flooding and storm surge and can be an effective means of limiting the impact of these hazards on new development. Town planning policies aimed at reducing flooding are less effective in areas of existing development and can only be applied to infill development or renovations. A prime example of the requirement for town planning measures is the community of Cungulla, where some properties experience inundation under extreme tides. It is considered by some that this ‘nuisance’ flooding is part of life in the community, as is tidal inundation of the access road. However, planning policies should be implemented to ensure risk escalation (from sea level rise or surge events) is minimised for infill development.

In the urban area of Townsville, the Phase 2 Report has identified areas of existing development prone to flooding and Council needs to develop planning policies to address the risks to infill development in these areas. A possible scenario would involve no new development within areas flooded in a 10-20 Year ARI event, and minimum floor levels within the area flooded in a 50 Year ARI event having suitable freeboard above the 50 Year ARI level. Whilst an approximate 50 Year ARI flood line has existed in the city for some time, this flood hazard assessment represents the first real opportunity for Council to develop planning policies based on comprehensive flood modelling results. However, correct interpretation of the flood model grid needs to be made by staff experienced in floodplain management as the model is coarse in nature.

After the extreme flood event of January 1998, Council embarked on a major upgrade of the existing network of rain and stream flow gauges across the city area, in conjunction with NQ Water and Thuringowa City Council. This Study has highlighted areas where this flood warning network needs to be upgraded (extended) including four sites in Townsville and two on Magnetic Island (pluviograph stations and/or river height stations). Both Council and the Bureau of Meteorology would access this network of recording stations during significant rainfall events, and recommendations include trigger points for notification (refer to **Section 7 – Disaster Mitigation Plan)**.

For engineering lifelines and critical facilities located on the floodplain, consideration has been given to which of these represents the greatest risk. In January 1998, the two sewerage treatment plants in the city area were not affected by flooding (apart from disruption to access); however, detailed investigations need to be undertaken into how these facilities can be protected from storm surge impacts. Saline intrusion can affect the ability of treatment plants to recover after a storm surge event.

A major outfall main to the Cleveland Bay Purification Plant crosses the Ross River near the Townsville Golf Course. The exposed nature of the pipeline represents an unacceptable risk of failure due to debris in the event of a flood. In 1977, a section of the pipeline was damaged by a flood and resulted in raw sewerage discharging to the environment for a period of 3-4 months. Other critical facilities to be affected by flooding include Ambulance Station, Fire Stations and Evacuation Centres (primarily by reduced access but also inundation in several cases).

The vulnerability assessment has identified numerous areas where major roads and evacuation routes are cut during flood events of unacceptable frequency. A series of flood maps showing the sequence of inundation of the evacuation routes needs to be prepared in the Counter Disaster Plan update. A mix of road raising and drainage upgrades are recommended to ensure that these areas are addressed, with inundation reduced to at least trafficable depths. Several of these locations are the sole access route to isolated communities, and therefore have been allocated a higher priority.

6.3.2 Preparedness Measures

Community awareness aimed at preparedness, damage reduction and response resources are critical in minimising the impact of a flood or storm surge event. Many of the issues relating to community awareness and preparedness for flood and storm surge are already reflected in the existing Counter Disaster Plan. General recommendations for review and updating of the existing Counter Disaster Plan to address specific issues arising from this investigation have been made in **Section 7 – Disaster Mitigation Plan**. However, developing these recommendations in consultation with the Counter Disaster Committee to a level where they can be incorporated into the plan or implemented is beyond the scope of the Study.

With respect to community education programs, the current study represents a very important step in educating the general community, through visual presentation of inundation patterns and consultation activities, particularly for population centres that have not recently experienced significant impacts from flood or storm surge. Residents of coastal and flood prone areas will have a better appreciation of the risks from elevated tides (storm surge) and flooding than the general populace; however, the process of community education needs to be ongoing to ensure that new residents and the transient population are also aware of the risks.

Since 1998, Council has compiled significant historical flood data, with more than 200 levels recorded for the January 1998 event. This data, together with the results of more recent flood questionnaires, survey of floor levels, recently developed inundation mapping and Council's own Geographical Information Systems (GIS) promotes a greater level of understanding of flood issues within both Council and the general community. The recent flood study in particular provides Council with the tools to undertake further assessments of mitigation works and informed decisions with respect to development applications.

Council has promoted community involvement in development of flood mitigation strategies, with access to a large group of interested community members who have volunteered to provide information and participate in mitigation workshops. The consultation phase of this investigation will result in further consolidation of the cooperative relationship between Council and the community.

Council has an ongoing maintenance program addressing drainage capacity and vegetation clearing in particular. This program needs to be expanded to include pre-wet season risk reduction strategies for loose and potentially dislodged debris. Significant flooding in Townsville is usually accompanied by cyclonic wind activity, which can result in large branches and rubbish entering the drainage channels and potentially blocking drainage culverts. Large sediment loads from developing land and exposed rock slopes can also block drainage structures, exacerbating the impact of flooding. Areas with potential for generation of such sediment loads and debris need to be identified and measures implemented to minimise the potential for drainage blockages, including upgrading to larger size culverts and systematic maintenance/controls at the source.

6.3.3 Response Measures

By far the most effective measures for minimising the risk associated with flooding and storm surge relate to effective response measures, both prior to the event occurring and during the event. Response measures generally take the form of triggers and procedures for evacuation, procedures and mechanisms for dissemination of warnings to the community, and provision of evacuation centres with structural adequacy in suitable locations outside the zone of influence of flooding and storm surge.

6 Risk Analysis, Evaluation and Treatment Options

Council has developed Storm Surge and Flood Action Plans (available from Council's Engineering Department) that detail preparedness and response measures that can be implemented on an individual basis to assist in calm and structured evacuation if the need arises.

The existing Counter Disaster Plan is comprehensive and includes general plans for Evacuation, Transport, Health, Communications, Air and Sea Search. In the event of a significant flood event or the approach of a cyclone, the document outlines responsibility, procedures, contacts and locations for convening of the Counter Disaster Committee. Some recommendations are made in **Section 7 – Disaster Mitigation Plan** regarding improving/updating the Counter Disaster Plan.

6.3.4 Recovery Measures

After a storm surge or flooding event, recovery measures are vital so that the community can start to function normally as soon as possible. If evacuation of affected areas was undertaken, assessments will be required of the damage incurred to property and the suitability of residences for occupation. It may be the case that potential public health and safety issues delay the return of a displaced population until essential services are restored.

The January 1998 flood event has allowed Council and emergency service providers an insight into the difficulties faced during and after an extreme flooding event. The flood damage assessment has shown that an extreme storm surge event would result in a similar magnitude of damage (and therefore similar issues with respect to recovery). It is interesting to note that it was surmised in the 1998 post-disaster survey (JCU, 1998) that the community returned to normal operation in a relatively short period (days to weeks) after the January 1998 flood.

In addition to the Counter Disaster Plan, Council also have a comprehensive Disaster Recovery Plan for Council Infrastructure and Heritage/Cultural facilities owned/operated by Council. The aim of the plan is to facilitate the continuity of the provision of services to the community and the restoration of Council's property. Recommendations are made in **Section 7 – Disaster Mitigation Plan** regarding improving/updating the Disaster Recovery Plan.

7 Disaster Mitigation Plan

7 Disaster Mitigation Plan

7.1 General

Tables 35 – 37 in **Appendix A** present the endorsed treatment strategy development for the Study Area, in accordance with Zamecka and Buchanan (2000). It was found that the recommended format in Zamecka and Buchanan (2000) is not conducive to easy reference as key details and initiatives are easily lost in the tables that are attached as an appendix to the main document. Details of the various treatment options are therefore provided below.

Where appropriate, schematic drawings are provided showing the location of key mitigation strategies proposed (refer to **Appendix E**). Concept level cost estimates have been prepared for most options proposed and discussion is provided on other factors that might influence the development of Benefit Cost Ratios.

The methodology adopted for the assessment of mitigation options has evolved from that proposed to suit Council's immediate priorities (in consultation with the Study Manager). Modelling of options has been undertaken for some scenarios, sufficient to determine the likely reduction in water level. Detailed flood mapping for the mitigation options has not been undertaken, and therefore the reduction in flood damages is not easily quantified. Assessment of Annual Average Damage (AAD) reduction for mitigation options recommended is beyond the scope of this Study, and would be undertaken during detailed design or planning stages and as input to external funding applications to cover the capital cost of the works.

7.2 Town Planning Controls

A planning policy for new development in flood prone areas needs to be drafted for consideration by Council, consistent with the draft city plan. It is envisaged that the policy will address the types of development restricted/allowed, and provide guidelines for development (pad and floor) levels linked to different frequency flooding events. Extracts from the planning policy adopted by Thuringowa City Council are provided below:

- *The building pad shall be constructed to a level not less than the fifty (50) year ARI flood level.*
- *The minimum floor level for all zones shall not be less than as required by the Building Code of Australia and the Sewerage & Water Supply Act, or not less than 450mm above the fifty (50) year ARI flood level, whichever is the higher level.*
- *In any area where design fifty (50) year ARI water levels have not been calculated and/or are not available, the minimum floor level is to be 450 millimetres above the ground level*
- *To account for tidal and cyclonic storm surge the minimum level for any habitable floor level within the City shall be RL 3.90 m AHD.*

It is also recommended that Council produces a flood inundation map showing the 50 Year ARI flood event in the Study Area. This would ultimately be used to establish a planning policy for infill development line for the City and Magnetic Island.

7 Disaster Mitigation Plan

As noted earlier the Study Area was mainly limited to existing properties in the Townsville floodplain and Magnetic Island and as such has limited application to areas of new development. A separate study will be needed to investigate areas of flood prone land outside the study area.

For storm surge, Council currently has mapping that shows areas potentially affected by a storm surge event equalling RL 4.0 m AHD (approximately equivalent to Cyclone Althea coincident with Mean High Water Spring tide). The BPA estimate for a 50 Year ARI storm surge level for Townsville is approximately RL 2.95 m AHD. The determination of storm surge risk based on static levels is recognised as being simplistic. A recent detailed storm surge modelling study undertaken in an adjacent Shire (Burdekin) has highlighted the incremental impact of the dynamic action of wind and waves on the maximum level and the propagation of storm surge inland.

It is understood that Council have secured funding to undertake a similar detailed surge assessment, which should address these issues. It is recommended that Council review the current 50 Year ARI storm surge estimate and use this updated value to develop a minimum floor level for all development in coastal zones potentially affected by storm surge.

Consideration should be given to risk escalation resulting from sea level rise (projected to be between 0.09 and 0.88 m by 2100, The Intergovernmental Panel on Climate Change), by incorporating a suitable freeboard above the calculated level. For flooding, this could be achieved by adopting levels for flood events coincident with Highest Astronomical Tide (HAT). This may be conservative at present but will become progressively less so over time.

7.3 Flood / Surge Warning Systems

7.3.1 Townsville

The detailed modelling investigation has identified deficiencies in the existing flood warning system for Townsville. A large proportion of the urbanised area north of the Ross River drains to the Lakes / Woolcock canal system, and parts of this catchment are notably devoid of rainfall / river height recording stations. In January 1998, the worst affected area was Pimlico and Hyde Park (the canal capacity was massively exceeded), suggesting that additional flood warning capability in this area is required.

The catchment is considered to have time of concentration of 6 hours, which puts it in the category of 'prone to flash flooding'. The Bureau of Meteorology has a policy of not issuing flood warnings in areas subject to flash flooding, due to the risk associated with not providing adequate warning time. Therefore, Council need to be pro-active and implement additional stations and trigger levels configured to provide suitable notification of Council officers.

The location (and nature) of proposed additional recording sites across Townsville are shown on **Drawing 8031202/MO1** in **Appendix E**. They include:

- Lakes 1 (D/S of Bayswater Road) – combined pluviograph / river height station measuring level in the detention basin.

- Aitkenvale Special School – pluviograph station only.
- Walkabout Palms (Gordon Creek U/S of Fairfield Development) – pluviograph station only.
- Ross River (D/S of Bowen Road Bridge) – river height station only.

For all pluviograph stations, the triggers for automatic Council notification should be the 20 Year ARI, 1-hour and 3-hour totals (90 mm and 140 mm respectively). The selection of trigger levels has been based on the existing capacity of open channels, the levels at which flooding begins to affect residences and the time of concentration of the relevant catchments. For the two river height stations, the trigger level should be RL 2.5 m AHD (above HAT) or a rate of rise of 0.5 m in 30 minutes. At the Lakes location, the adopted RL 2.5 m AHD trigger level provides some lead time with respect to overtopping of the levees, estimated to occur in a 20 Year ARI flood event.

Approximate costs for single recording stations are $5000 ($10000 for combined stations). The priority of these works is High (1).

7.3.2 Magnetic Island

The flood modelling undertaken for Magnetic Island represents the first step in quantifying the flooding risk on the island. The hydrology and hydraulic models are uncalibrated, since no reliable rainfall data was available for historical events; however, future development will require more detailed and rigorous assessment. It is therefore recommended that two rainfall stations be established on the island, one at Nelly Bay to collect representative rainfall for Picnic Bay, Nelly Bay and Arcadia, and another at Horseshoe Bay (refer to **Drawings 8031202/MO6 – MO8** in **Appendix E**).

Ideally, a rainfall recording station should be located in each bay (as significant variation in rainfall pattern can occur), and a river height station on each major creek system (particularly Gustav Creek and Butlers Creek). However, a staged approach is recommended as funding becomes available. Trigger levels for the rainfall gauges should be the same as for the Townsville area (refer above).

Approximate costs for single recording stations are $5000. The priority for implementation of the rainfall stations is Medium (2).

7.3.3 Cungulla and Pallarenda

The theoretical storm surge event of Cyclone Althea coincident with a high tide has catastrophic impacts at both Pallarenda and Cungulla. The requirement for warning devices (and priority of implementation) should be reviewed as part of the detailed storm surge investigation.

7.4 Drainage Upgrades

The following sections detail the highest priority mitigation solutions that can be achieved via drainage infrastructure upgrades, for both Townsville and Magnetic Island. In general, upgrades of drainage capacity have been targeted at containing 20 Year ARI flows or providing trafficability to roads (depths less than 300 mm). The target of containing 20 Year ARI flows stems from the desire to produce 20 Year ARI flood immunity in existing developed areas. Newer suburbs, such as Annandale, generally have higher drainage capacity and hence better flood immunities.

7.4.1 Townsville

Specific areas identified for flood mitigation works in Townsville are:

- Ross Creek: Mindham Park Drain, Lakes / Woolcock Canal, Currajong
- Gordon Creek: Fairfield, Wulguru, Murray and Stuart
- Louisa Creek: Mt Louisa, Heatley, Vincent, and Currajong
- Captains Creek (Rowes Bay Canal): West End, Garbutt and Belgian Gardens
- Ross River: Cranbrook, Aitkenvale, Rosslea, Mundingburra, South Townsville and Hermit Park
- North Ward: North Ward and Belgian Gardens

Various mitigation options for each of the areas are given below. It should be noted that preliminary cost estimates presented in this report do not include any costs associated with ongoing maintenance, land resumption, legal fees or design. The works are shown diagrammatically on **Drawings 8031202/MO2 – MO5** in **Appendix E**.

Lakes / Woolcock Canal

In the aftermath of the January 1998 flood, Council identified this area as having less than adequate capacity and requiring upgrading. Significant investigative effort has previously been undertaken to determine suitable upgrade configurations to best address the drainage deficiency, culminating in a successful application for funding under the Regional Flood Mitigation Program. In addition to those works eligible for external funding, Council has made a significant commitment to upgrading several road crossings, and are currently constructing the following mitigation works:

- New tide gates downstream of Flinders Street to control flood flows and limit tidal inundation upstream.
- New low level culverts under Flinders Street and Sturt Street.
- Widening or duplication of the canal between Parkes Street and Flinders Street.
- New low level culverts under Woolcock Street, connecting Lakes 1 and Lakes 2.

The total value of works completed or currently under construction is approximately $6.0 million, and these have been allocated a High (1) Priority. The locations of these works are shown in **Figure 9** (extract from RFMP application referred to as Stage 1 of the Townsville West Flood Mitigation Scheme).

7 Disaster Mitigation Plan

Barryman Street Pump Stations

To reduce inundation around the sump catchments of Barryman Street, Albany Road and Hindley Street, stormwater pump stations have been proposed. These areas flood as a result of local stormwater runoff, if pipe drainage systems are affected by high tailwater conditions (tide), and when the capacity of Lakes 1 detention basin is exceeded (approximately the 20 Year ARI event).

The Barryman Street pump station has been assigned a High (1) Priority and will pump water from the end of Kitchener Street to an adjacent drainage system (Mindham Park Drain). Both the Albany Road and Hindley Street pump stations, assigned a Medium (2) Priority will pump water from low areas back into Lakes 1 (over the levees).

Council have applied for approximately $2.0 million external funding through the RFMP scheme, to match an allocated Council contribution of more than $1.0 million in this years budget. The locations of these works are shown in **Figure 10** (extract from RFMP application referred to as Stage 2 of the Townsville West Flood Mitigation Scheme).

Mindham Park Drain and Additional Measures in Woolcock Canal

Drainage upgrades in an urban catchment like that of Ross Creek should start with removing constrictions downstream before progressing upstream. The proposed works above (constituting Stages 1 & 2 of the Townsville West Flood Mitigation Scheme) were modelled to determine their beneficial impact (the results are shown in **Figure 11**). Significant improvements are achievable for the 20 Year ARI flood event, justifying the considerable expense of the works to date.

However, the modelling has identified additional areas where further works are required to maximise the benefit of the downstream works. One of these areas is the reach of Woolcock Canal between Kings Road and Parkes Street, which reduces the achievable benefit of the widening downstream of Parkes Street. It is recommended that an extension of the current works include widening the Woolcock Canal in this section to a minimum width of 9m, with culverts under Kings Road to match. These works should be a High (1) Priority and are estimated to cost $1.60 million. The anticipated level reduction in the Lakes resulting from these complementary works is approximately 200 mm for the 20 Year ARI event.

In the Mindham Drain, the beneficial impact of downstream works does not extend far beyond Bayswater Road. To maximise the benefits of upgrades to the Woolcock Canal, it is recommended that works to minimise the afflux associated with successive road crossings upstream be undertaken. The modelling in Phase 2 of the Study identified that the road crossings at Bayswater Road and Gulliver Street produce the highest afflux.

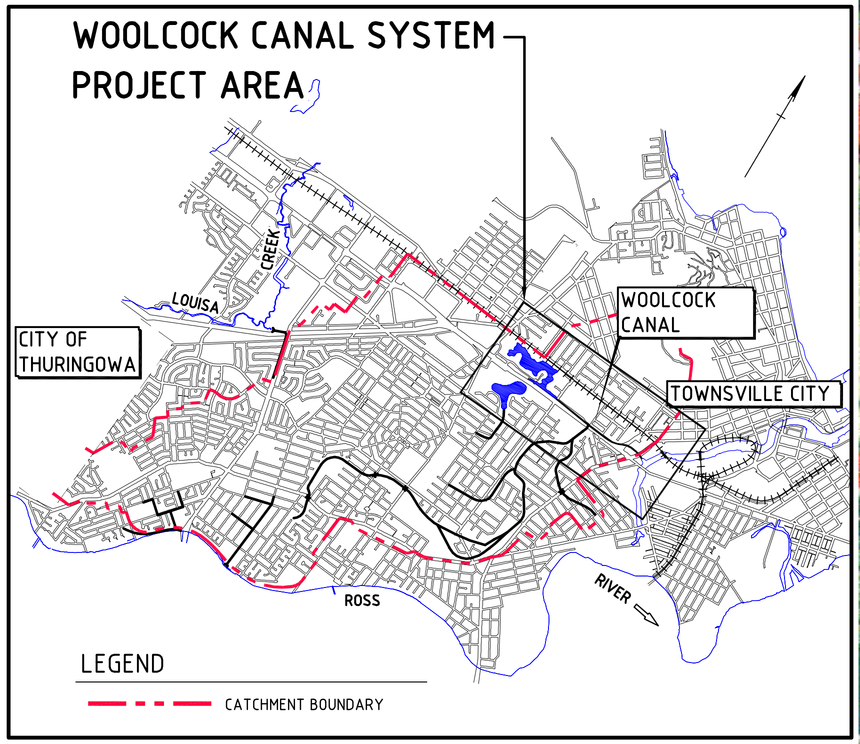
The most downstream of these, Bayswater Road, presently has 4/1680 RCP's under the road, producing an afflux of 0.9 m in the 20 Year ARI event and overtops the road. An upgrade to 6/1800×1800 RCBC's reduces the afflux to approximately 0.2 m (a reduction in upstream flood levels of 0.7 m) and provides 20 Year ARI immunity from overtopping. Allowing greater flows to pass through Bayswater Road reduces the potential for storage attenuation; however, the benefits to upstream properties outweigh any downstream impacts. The preliminary cost estimate of constructing the upgraded culverts at Bayswater Road is $0.7 million, and the works have been assigned a Medium (2) Priority. A cheaper alternative to installing new culverts may be to lower the crown of the road over the present culverts. This will provide drainage relief upstream but does decreases trafficability of the road. The crown lowering is estimated to cost $0.3 million.

At Gulliver Street an upgrade to 4/3600×1500 RCBC has been proposed, to reduce the impact of flooding on the adjacent retirement home (Villa McAuley). In January 1998, the development was severely affected by flows in excess of the channel capacity, predominantly constricted by the Existing Guliver Street culverts (9/1200 RCP's). Even in February 2002, a small event estimated to be equivalent to a 5 Year ARI, the upstream flood level almost caused overtopping of Gulliver Street.

The proposed upgraded culvert at Gulliver Street (estimated to cost $0.62 million) is effectively a doubling of the existing capacity, and has been allocated a High (1) Priority. In the January 1998 event, these works would have resulted in a reduction in upstream level of nearly 400 mm, and a significant reduction in flows passing through the adjacent development. For the 50 Year ARI event, the reduction in water level is dramatic (nearly 0.9 m).

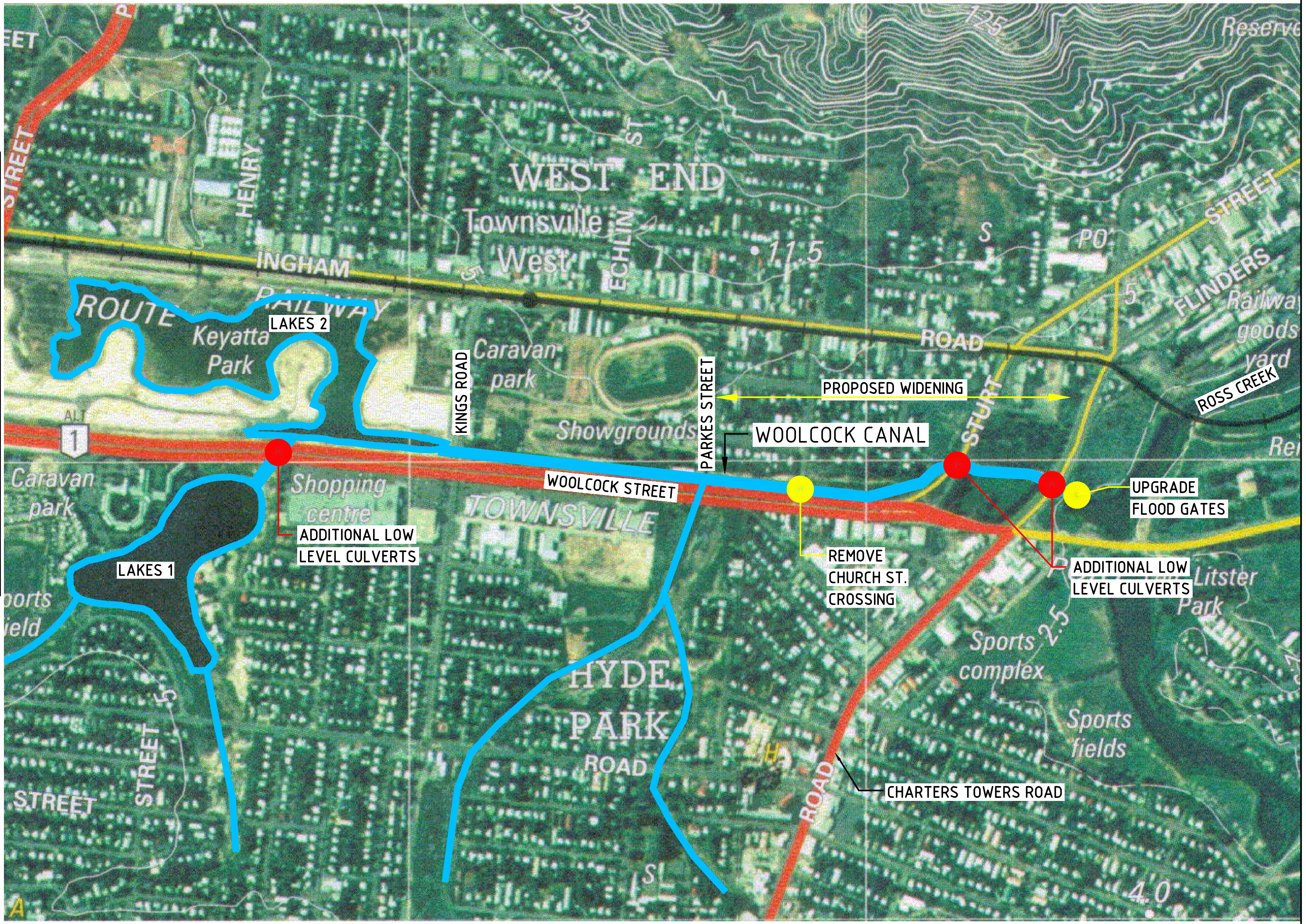
At Balls Lane, removing the existing 8/750 RCPs and replacing them with 4/1800×750 RCBC will increase the flow area and reduce afflux. These works are estimated to cost in the order of $0.19 million, although it is envisaged that they would be undertaken in conjunction with upstream works. The increased capacity at Balls Lane results in only small reductions in upstream water level (60-130 mm), so the works have been assigned a Low (3) Priority.

The Balls Lane road profile would still represent a causeway subject to relative frequent flooding, and alternative routes exist for purposes of evacuation. However, recent floods have shown that the 750 mm diameter pipes are prone to collecting debris, and the upgrade would help to significantly reduce the risk of blockage.



LOCALITY PLAN

SCALE A



PROJECT AREA

SCALE B

NOT TO BE USED FOR CONSTRUCTION

DATE	ISSUE
11.9.03	1

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Before commencing work, all controlling dimensions on the drawings must be verified on the site, particularly those relative to property alignments, other structures, and services.

Figured dimensions take preference over scaled. If in doubt, ask.

SCALES

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0 50 m 1:5000 (A1) SCALE 'B'

Original Size A1

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL AUSTRALIA QUALITY ASSURANCE SYSTEM CERTIFIED TO AS/NZS ISO 9001-1994

	PREPARED	CHECKED	PASSED
DESIGN			DATE
DRAFTING			

Maunsell

Maunsell Australia Pty Ltd

ABN 20 093 846 925

Consulting Engineers, Planners, Environmental Scientists & Project Managers

TOWNSVILLE CITY COUNCIL

TOWNSVILLE FLOOD STUDY

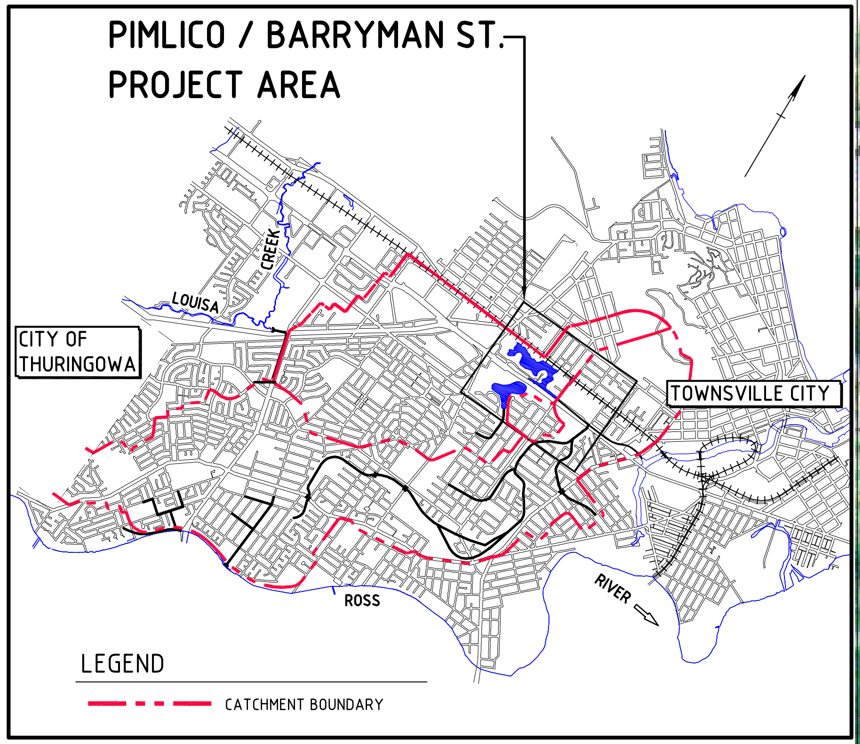
TOWNSVILLE WEST FLOOD MITIGATION PROJECT

STAGE 1 - WOOLCOCK CANAL SYSTEM

CAD Ref: 80301202_02-fig09.dwg Status:

Date: 11 Sep 03 - 11:39

FIGURE 9



LOCALITY PLAN

SCALE A

PROJECT AREA

SCALE B

NOT TO BE USED FOR CONSTRUCTION

DATE	ISSUE
11.9.03	1

No.	BY	DATE	DESCRIPTION	APPD

REVISIONS

Before commencing work, all controlling dimensions on the drawings must be verified on the site, particularly those relative to property alignments, other structures, and services.

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SCALES

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0 25 m 1:2500 (A1) SCALE `B'

Original Size A1

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DRAFTING			DATE

Maunsell

Maunsell Australia Pty Ltd

ABN 20 093 846 925

Consulting Engineers, Planners, Environmental Scientists & Project Managers

TOWNSVILLE CITY COUNCIL

TOWNSVILLE FLOOD STUDY

TOWNSVILLE WEST FLOOD MITIGATION PROJECT

STAGE 2 - PIMLICO / BARRYMAN STREET

CAD Ref: 80301202_02-fig10.dwg Status:

Date: 11 Sep 03 - 11:41

FIGURE 10

Reporting Location	Difference in Q20 water level (m)
1	0.00
2	-0.02
3	-0.03
4	-0.37
5	-0.33
6	-0.34
7	-0.34
8	-0.37
9	-0.37
10	0.00
11	0.00
12	-0.18
13	-0.15
14	-0.18
15	-0.18
16	-0.05
17	-0.05
18	-0.05
19	-0.06
20	-0.40
21	-0.42
22	-0.30
23	-0.26
24	0.03

Figure 11

Beneficial Impact of Townsville West Mitigation Works

7 Disaster Mitigation Plan

Currajong

Upstream of Lakes 1, there are two areas identified as requiring mitigation works, namely the corner of Hammett and Cambridge Streets and Hugh Street adjacent to Gill Park.

The pipe system at the northern end of Cambridge Street has limited capacity and local ground levels around Hammett Street allow excess stormwater to spill out across Warrina Park towards the east. The Cambridge Street pipes enter the Punari Street pipe system, together with flows from the southern Dalrymple Road Drain. It is proposed that the southern Dalrymple Road Drain be continued under Bayswater Road to link up with the corresponding drain on the northern side of Bayswater Road, thereby removing some of the contributing catchment putting added pressure on the Cambridge Street pipes.

The existing culvert headwall (2/675 RCPs) should be retained and the culverts extended through under Bayswater Road instead to heading towards Cambridge Street as is currently the case. The capacity of the channel downstream of the culverts to handle this additional flow needs to be verified. The preliminary estimate of the cost required to construct the culvert is $0.15 million, and the proposed works have been allocated a Medium (2) Priority.

Potentially, the pipes along Cambridge Street could also be diverted in a similar manner if the capacity of the downstream section of drain along the southern side of Woolcock Street is upgraded (widened and vegetation removed). Similarly, regrading of Hammett Street to additional side inlet pits could be achieved in conjunction with upgraded Cambridge Street culverts, to reduce the occurrence of ponded flows at the north end of Warrina Park. Both these alternatives need to be investigated further for feasibility (beyond the scope of this Study).

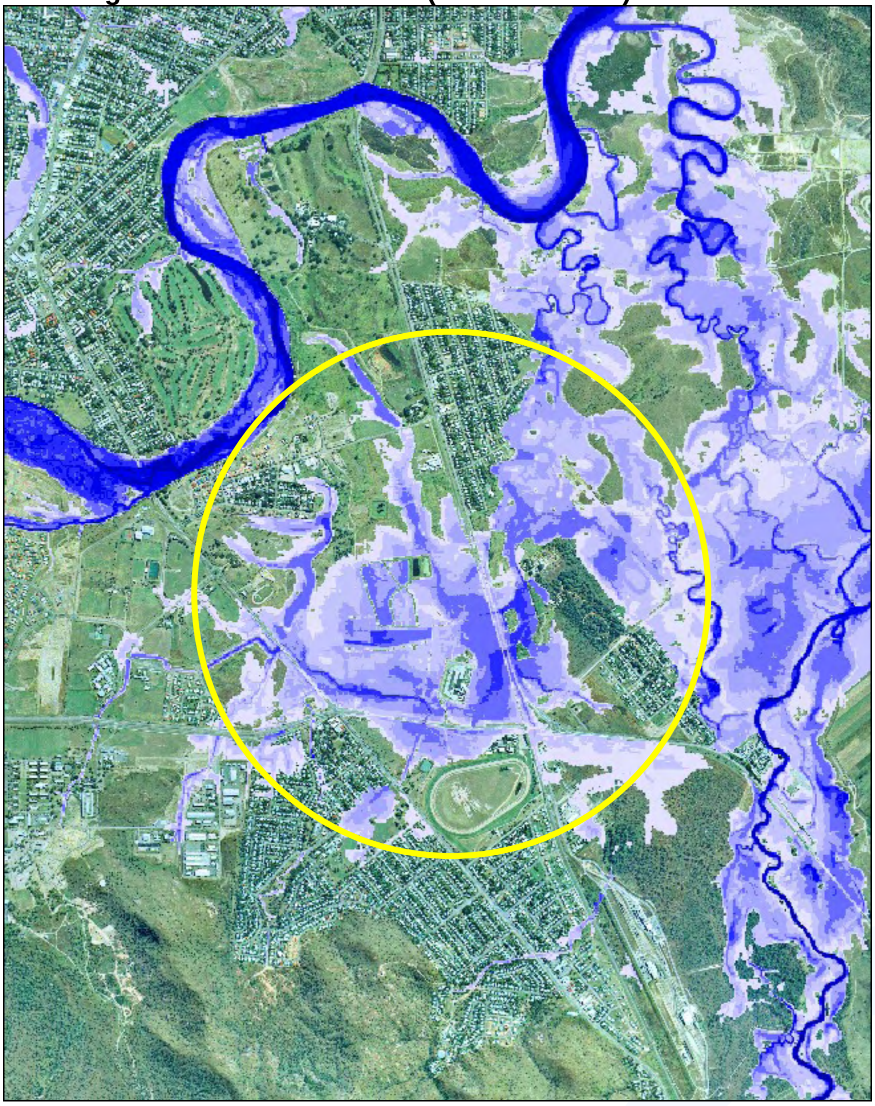
The mitigation option proposed for Hugh Street adjacent to Gill Park is to provide additional culvert capacity along Hopkins Street to link up with the open channel drain that starts east of Grosvenor Street (conveying flows to the southern arm of Lakes 1 detention basin). The existing alignment passes under private property and would be retained with a preference for new drainage infrastructure to be located within the Hopkins Street road width, designed to accommodate overland flow component in excess of the existing pipe capacity. Approximately 200 m of 2400x1200 RCBC is required, estimated to cost in the order of $0.60 million. An alternative of directing flows north along Hugh Street to the western arm of the Lakes 1 detention basin was assessed as being too expensive. The works not only benefit local residents but also improve access to the Hugh Street Ambulance Station.

Gordon Creek

Gordon Creek drains the suburbs of Wulguru, Fairfield Waters, Oonoonba, Murray, Annandale Gardens, Cluden and parts of Stuart into the Ross River. The lower section of the catchment (north of University Drive) is characterised by very flat grades and significant floodplain storage. Between Abbott Street and the Ross River, Gordon Creek is tidal and heavily vegetated with mangroves. **Figure 12** shows the inundation in the Gordon Creek area due to a 20 Year ARI flood event.

7 Disaster Mitigation Plan

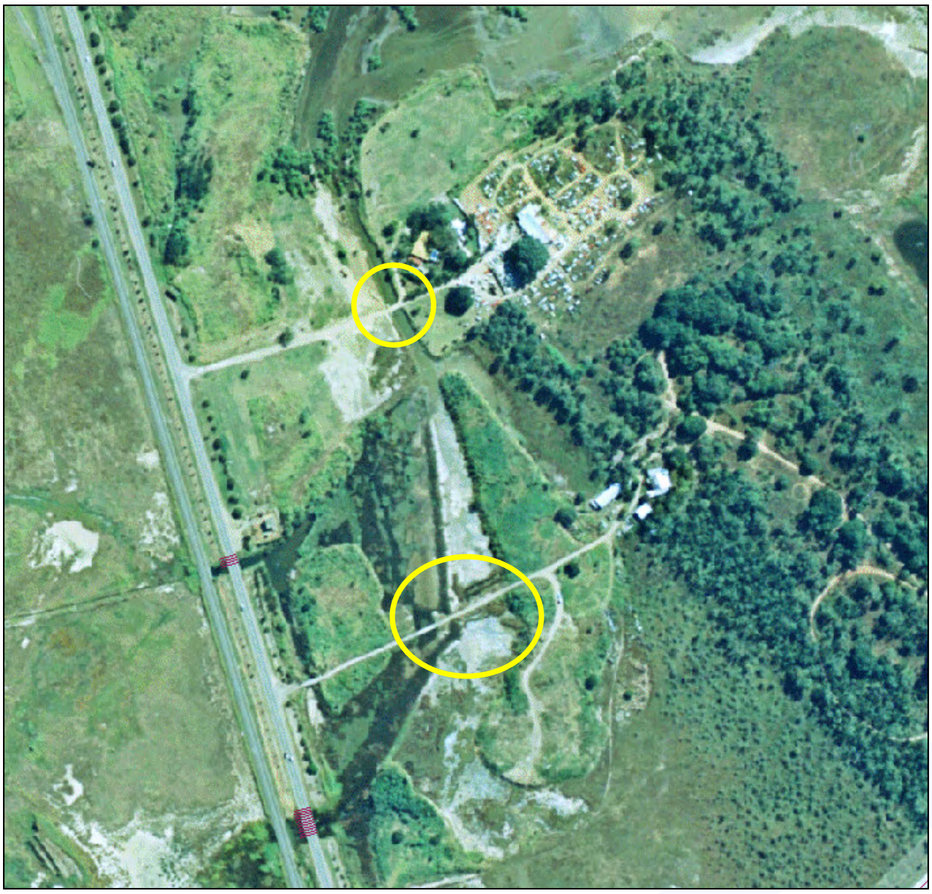
Figure 12
Flooding in Fairfield/Oonoonba (Gordon Creek)



Upstream of Abbott Street, **Figure 12** shows a large area of inundation that covers much of the land presently being redeveloped as Fairfield Waters Estate. As part of the Fairfield Waters development, it is understood that a large lake storage and formalised drainage channels will be constructed that will concentrate flows via a more direct path between Stuart Drive and Abbott Street. The improvements undertaken at Fairfield Waters will be done at the expense of the developer, and previous flood investigations have demonstrated the impact of the development and measures proposed to minimise flooding.

The modelling undertaken for this Study has shown that the 100 Year ARI peak discharge at Abbott Street is approximately 160 m^3/s. Overtopping of Abbott Street occurs in a 5 Year ARI flood event, due to flat grades and limited drainage capacity (total of 15/2100x900 RCBC's). Immediately downstream of Abbot Street, there is a noticeable constriction in Gordon Creek, as it bends towards the north and passes two access roads (this area has also been used for illegal dumping in the past). For the 20 Year ARI design flood, a head loss of more than 0.6 m occurs over this reach alone (refer to **Figure 13**). There is also concern regarding the impact of the North Coast Railway upstream of Abbott Street.

Figure 13
Gordon Creek Constriction D/S of Abbott Street



Widening of the primary drainage path in this area (and putting in larger culvert crossings of the access roads) represents the best option for reducing levels at Abbott Street, which will translate into reduced water levels at most upstream locations. The preliminary cost estimate for widening this section of Gordon Creek is $2.4 million, based on nearly 1.0 km of 50 m wide channel and two culvert crossings to suit. The area is tidal and environmental issues would arise with respect to removal of marine plants. However, it is believed the area is a already a degraded environment with little environmental significance, and works have been given a High (1) Priority.

Further downstream, Gordon Creek spreads out over the salt pan and the main drainage path becomes indistinct. There is potential for channel clearing to establish a defined flow path over a 1 km length, connecting the proposed works upstream with the defined tidal channel. This proposal is expensive (another $2.0 million) and would involve loss of mangrove habitat. A further 300 mm reduction in water level is achievable if a defined drainage path / outlet can be provided, and the works have been allocated a Medium (2) Priority.

Adjacent to Jurekey Street in Wulguru / Stuart, water concentrates before flowing northwards past the Racecourse. East of this area is Stuart Creek with a large open space between Stuart Creek and Jurekey Street. An open channel to divert flow from Jurekey Street to Stuart Creek would reduce the flood problem adjacent to Jurekey Street and the racecourse. Detailed assessment would be required to determine the affect on downstream areas of Stuart Creek and the size of the open channel required to reduce nuisance flooding at Jurekey Street. An estimate of the cost of constructing this drain is $1.7 million and the works have been allocated a Medium (2) Priority.

Presently water flowing across Stuart Drive diverges and spreads across the Fairfield Waters development area, with a large proportion (30%) heading south to flow along the northern side of Racecourse Road. An access culvert (4/1200 RCP's) to the relatively new BP Service Station constricts the flow creating an afflux of approximately 0.4 m in the 20 Year ARI flood event and overtopping. Upgrading the culvert to 7/1800×1200 RCBC's effectively reduces the afflux to nil, at a cost of $0.21 million. These works have been assigned a Low (3) Priority as the real beneficial impacts of the works proposed within the development site to the north are at this stage difficult to quantify.

Overtopping of Stuart Drive occurs relatively frequently, but the hydraulic modelling has shown that there is minimal afflux at the road crossing due to the elevated tailwater condition. If reductions in the water level between Stuart Drive and Abbott Street can be achieved, further improvement are likely achievable upstream of Stuart Drive.

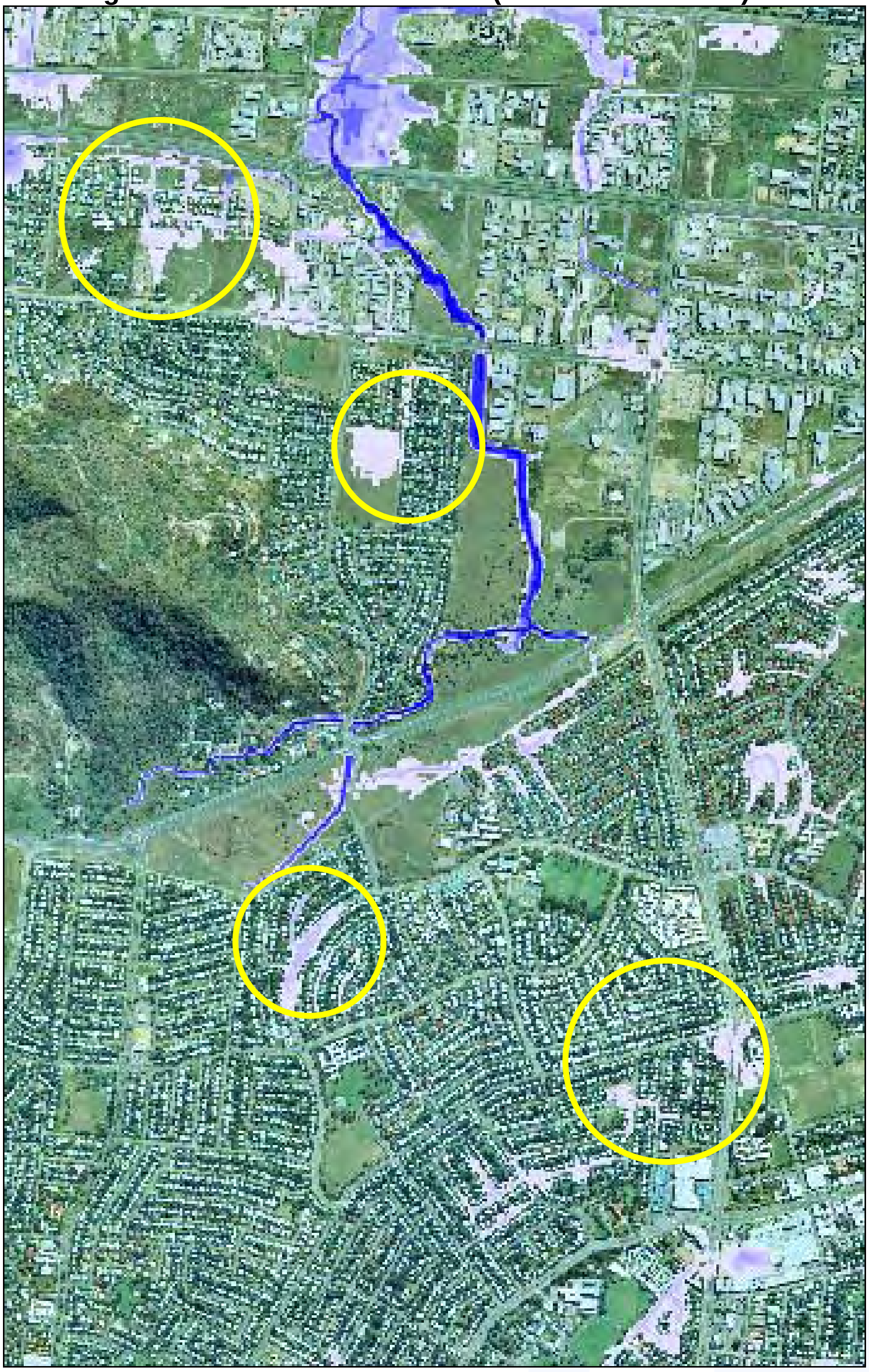
Louisa Creek

Louisa Creek drains the western suburbs of Townsville into the Town Common wetlands and ultimately to the Bohle River. **Figure 14** shows the extent of inundation modelled for the 20 Year ARI design flood. Four areas have been identified by Citiworks as requiring flood mitigation within the Louisa Creek catchment: Buchanan / Davies Streets; Brampton Avenue; Eckhoff Street and Lyndhurst Street. The recent modelling has confirmed that flood problems exist in these areas and suitable mitigation options are presented below.

The mitigation option proposed for the Buchanan Street area aims to reduce the total amount of flow in the pipe system on Davies Street downstream of Ellis Court. To remove the water that collects in the park to the west of Buchanan Street (refer to **Figure 14**), the existing pipe drainage system running east towards Davies Street needs to be upgraded (extra collection pits may also be required). The large pipe system coming down Davies Street collects a large catchment, and should be diverted directly into Louisa Creek adjacent to Ellis Court. This will indirectly increase the capacity of the pipe system between Buchanan Street and Davies Street, as well as the section further north along Davies Street. The preliminary cost estimate of this mitigation option is $0.48 million, with an assigned Priority of Medium (2).

7 Disaster Mitigation Plan

Figure 14
Flooding in Louisa Creek Catchment (Various Locations)



7 Disaster Mitigation Plan

In Brampton Avenue, inundation around the Rossvale Shopping centre needs to be mitigated (refer to **Figure 14**). The proposed mitigation option includes constructing an additional 1200 diameter stormwater pipe along Brampton Avenue, heading north to Charles Street. The new large diameter pipe would replace the small pipe along Charles Street to Nathan Street, and head north to Fulham Road (1500 mm diameter) along the western side of Nathan Street to link up with the Nathan Street box culverts, collecting minor inflows from Tyler and Aya Streets. This configuration removes the amount of water in the present stormwater system at the corner of Charles and Nathan Streets, significantly improving the immunity of this intersection. It also increases the capacity of the present system between Charles Street and Fulham Road. The preliminary cost estimate of constructing this mitigation option is $3.0 million, and the works have been assigned a High (1) Priority.

At Eckhoff Street the pipe stormwater system is presently overwhelmed (refer to **Figure 14**). The mitigation solution in this area requires doubling the capacity of the pipe system along Fulham Road and Eckhoff Street. Additional side inlet pits will also be required to remove surface water in the Eckhoff and Croft Street areas. The preliminary cost estimate for these works is $3.2 million, including pipe duplication, excavation, pavement reinstatement and additional side inlet pits. A Low (3) Priority applies to the works in this area.

In the Lyndhurst Street area, drainage through the recently developed residential estate is via pipe systems along Gracedale Street, Black Braes Court and Gainsford Place, with overland flow also down these roads and Graigea Street. Upstream of Gracedale Street, the culverts under Bayswater road are 4/1200×450 RCBC's. The pipe system under Gracedale Street is only a 1050 RCP (approximately 1/3 the capacity) and significant ponding and surcharge occurs (refer to **Figure 14**). The mitigation option proposed for the Lyndhurst Street area is to redirect flow into pipes under Barnet Street with upgraded capacity to the present situation (525 mm dia pipe).

The works will include earthworks to redirect flow from Bayswater Road towards an inlet near the corner of Barnet and Lyndhurst Streets, extending and upgrading the capacity of pipes under Barnet Street, constructing an overflow structure for water at the inlet near Barnet Street back towards Gracedale Street and upgrading the capacity of the open drain adjacent to Woolcock Street between Barnet Street and Saxby Street. The preliminary cost estimate for the works $1.15 million, with an assigned Priority of Medium (2).

7 Disaster Mitigation Plan

Captains Creek (Rowes Bay Canal)
There are five (5) areas identified by Citiworks in the Captains Creek catchment that require investigation with respect to mitigation. Captains Creek (Rowes Bay Canal) has a constriction in the lower reaches which translates into higher levels upstream. Downstream of Old Common Road, the capacity of the Creek needs to be increased (particularly downstream of Evans Street). A preliminary cost estimate was prepared based on widening the channel to provide 1.5 to 2 times the present capacity ($1.75 million). However, mangroves are present in the area and this may not be a viable option due to environmental considerations. A Medium (2) Priority applies to these outlet works.

For areas upstream (Dearness Street, Melrose Park, Meenan Street), there are limited options with respect to reducing the flood levels beyond the outlet widening proposed above. For the 20 Year ARI design flood event, the afflux at culverts under Dearness Street and at Old Common Road are practically zero, suggesting a drowned out condition. Similar to the Fairfield area, once the outlet condition is improved, further investigation into capacity of upstream systems may result in further reduction in level.

Ross River (Various Locations)
At the intersection of Campbell Street and Queens Road, there is a stormwater pump station. The present pump is capable of pumping approximately 100 l/s while the pipe outlet could easily accommodate 400 l/s. Replacing the present pump with a 400 l/s pump has been proposed as a mitigation option. The preliminary cost estimate of installing the pump is $0.15 million; however, the benefit of installing the pump needs to be investigated further (Low Priority - 3).

At the corner of Brooks Street and Tenth Avenue, there is presently a flooding problem where stormwater ponds. Even in small events (less than 5 Year ARI) water inundates the intersection. A 450 mm pipe currently drains the intersection east along Brooks Street and into the open drain at Eleventh Avenue. To mitigate this problem an upgrade of the pipe to a 1050 mm diameter has been proposed (cost estimate of $0.06 million). However, it is noted that under high tide conditions this increased capacity will most likely not achieve a significant reduction in level (Medium Priority – 2). It may be that with projected sea level rise, the only long-term solution to the problem is progressive raising and regrading of the entire length of Brooks Street to provide a free draining overland flow solution.

Around Water Street in Mundingburra, a sump exists where stormwater ponds. Presently this area is drained by under ground pipes. The proposed mitigation option is to duplicate the pipe from the sump to Ross River. A preliminary estimate of the duplication works is $0.38 million and has been assigned a Medium Priority (2).

Adjacent to the park at the intersection of O'Reilly and Brownhill Street's, there is a property that is regularly flooded. The most cost effective method of reducing this problem is for Council to purchase back this property. The cost of purchasing back this property will be subject market variation and negotiation. Because the solution to this problem affect only one property the buy back has been assigned a Low Priority (3).

North Ward

North Ward and a small area of Belgian Gardens are the only sections of Townsville that drain to the sea (Pallarenda also has pipe systems that drain to the sea). Underground stormwater pipes drain most of North Ward and Belgian Gardens, with one large concrete-lined open drain running from Rose Street between Hayes and Primrose Streets and then discharging into the sea between Ryan and Marshall Streets. Two flooding issues that require attention in North Ward and Belgian Gardens have been identified: the corner of Primrose and Marshall Streets, and the intersection of Mitchell Street and Burke Streets.

At the intersection of Marshall and Primrose Streets, surcharge of the existing pipe drainage system along Marshall Street occurs due to insufficient capacity. Two additional 1500 mm diameter pipes in addition to the existing 600 mm diameter pipe are required to convey the projected 20 Year ARI flows from the upstream catchment (if the tide is lower than MHWS). The preliminary cost estimate for these works is $0.9 million (Low Priority – 3). For the same order of costs, raising and regrading of the road and table drain along the front of the Seagulls Resort to direct flows towards the open drain could be undertaken as an alternative that would have a longer design life in the event of sea level rise.

Near the intersection of Burke and Mitchell streets there is a sump area where water ponds during storm events. There is inadequate capacity in the Kennedy Street stormwater conduit for this water to drain effectively in high intensity events. To mitigate this problem, an additional 1050 mm diameter stormwater pipe is proposed that traverses Mitchell Street towards Burke Street and then to sea via parkland near the Strand. The preliminary estimate of the cost to install the stormwater pipe is $0.50 million, and the works are considered a Medium (2) Priority.

7.4.2 Magnetic Island

On Magnetic Island, only a limited number of drainage upgrade options are recommended, with the assessment based primarily on the flood inundation mapping.

Picnic Bay

In Picnic Bay, the second largest drainage path passes through a developed area bounded by Granite Street, Hurst Street and Picnic Street. The existing drain is located predominantly on private property and is characterised by an informal channel (rock lined in places) and small culvert structures under several roads. The limited capacity of the drainage channel causes inundation of properties in relatively frequent events, particularly at the lower end.

To accommodate 20 Year ARI flows, a trapezoidal channel (mostly earth but lined in sections) is proposed together with larger culverts at each road crossing to limit the overtopping to manageable levels. The cost estimate for the works is approximately $0.1 million, with an allocated Low (3) Priority.

The 2/1200 RCP's that take flows from the above drainage channel at Picnic Street to the mangrove-lined outlet contained within the Picnic Bay Ring Road are significantly undersized. This limited capacity, issues relating to sedimentation and the complicated nature of the drainage alignment (pits and manholes to collects secondary pipe systems), causes significant inundation along Picnic Street back to Granite Street.

As a minimum, a duplication to 4/1200 RCP's is recommended, however, larger box culvert replacement is preferred (depending on a condition assessment). The estimated cost of the duplication is $0.4 million, and is considered a Medium (2) Priority.

Nelly Bay
At Nelly Bay, a drainage path starting at Sooning Street (near the shops) and crossing Warboys Street and Kelly Street has been determined as being of limited capacity. At Sooning Street, the road culvert is of minimal capacity and it appears that encroachment in the Warboys Street area has resulted in a constrained alignment. Whilst the 20 Year ARI design flow in the channel is only 2-3 m3/s, the informal drainage arrangement causes inundation to adjacent properties.

It is recommended that the channel be formalised and additional drainage capacity be provided under Sooning Street, Warboys Street and Kelly Street. The total costs estimate for the works is $0.15 million, and is considered to be a Low (3) Priority.

Horseshoe Bay
The Horseshoe Bay, the drainage patterns are dominated by the large Environmental Area (swamp). The existence of this significant area of flood storage is advantageous in the lower areas of the community. However, in the upper reaches the steeper slopes pose a problem for capturing and redirecting what is predominantly sheet flow. At Gifford Street, there are two locations where the culvert capacity causes inundation upstream and road overtopping to trafficable levels in the 20 Year ARI event. However, the sparse density of population in the area means that the risk to the community is minimal.

At the intersection of Apjohn Street and Horseshoe Bay Road, there is a set of culverts and a drain running east along Apjohn Street that have been identified as being of limited capacity. The drain is steep sided and directly abuts a property, potentially causing a public safety issue. The drain is also crossed by several small access culverts and steadily reduces in capacity before crossing in an uncontrolled manner to the south side of Apjohn Street. The reduced drain capacity also causes inundation along several streets that turn off Apjohn Street.

It is recommended that Council upgrade the culvert and realign both the culverts and drain to the south side of Apjohn Street for its entire length. The south side of the road is rural property with significant potential to accommodate a drainage easement. The estimated capital cost of the culvert upgrade and drain excavation works is $0.50 million, and has been assigned a Medium (2) Priority.

At Nelly Bay, Arcadia and Horseshoe Bay, there is potential for additional drainage upgrades to be identified and evaluated as an extension to this investigation. Unfortunately the small scale of the works required means that evaluating mitigation options in detail is beyond the current scope.

7.5 Diversion Schemes

In Townsville, the majority of stormwater north of the Ross River drains to the Lakes / Woolcock Canal system. Whilst this area is the subject of significant proposed mitigation works, there are areas in the upper catchment that are also flood prone. Catchment diversion schemes have the dual benefit of addressing flooding issues in these areas whilst providing secondary benefit to the outlet by reducing the overall catchment area contributing.

Due to the existence of Ross River Dam, the Ross River has significant capacity to convey additional diverted flows in local catchment flood events. This assessment of mitigation solutions has focused on three locations where flows can be diverted to Ross River. Schematic layouts of the proposed schemes are shown on **Drawing 8031202/MO1** in **Appendix E**). Whilst the costs of works are comparatively high, there is scope for Council to apply for funding under the Regional Flood Mitigation Program (or equivalent).

Wandella Street/Cranbrook Park (Cranbrook)
An underground stormwater diversion has been proposed to divert stormwater from Wandella Crescent to the Ross River. Currently, the higher level of Nathan Street to the east causes ponding in the area to depths of up to a metre. A large capacity pipe drainage system will be required to collect water from Wandella Crescent and Albert Street, before heading to Ross River via Cranbrook Park. The capacity of the pipe will ensure significant reductions in local flood levels of between 200 mm and 500 mm. A preliminary cost estimate of the stormwater pipe and associated road regrading works is $6.50 million, and has been allocated a High (1) Priority.

Whilst the catchment diversion reduces the total area directed to the Lakes / Woolcock Canal system, the downstream benefits are less than previous investigations have estimated due to the significant surface storage effects between Nathan Street and Mindham Park Drain. However, the expected local improvements to standing water level are still significant.

Killara Street (Cranbrook)
An upgrade has been proposed to the existing pipe system to divert flows from north and south of Ross River Road to Ross River via Killara Street, Cranbrook State School and Cranbrook Park. The existing system has a limited capacity and an upgrade to 20 Year ARI capacity would cost about $12 million. Council may be able to recover some of these costs by way of headworks charges if the existing open space aboriginal reserve is developed for residential purposes. This work has been allocated a High (1) Priority.

Anne Street (Aitkenvale)
The Anne Street diversion has been previously costed at about $7.4 million, assuming a 20 Year ARI design flow of about 24 m^3/s diverted from Patrick Street to the Ross River. The most recent study has shown that the anticipated flows potentially diverted are much smaller (approximately half) and a smaller diversion scheme could be implemented. On the basis that 2/2400x1500 RCBC's are required, a revised cost estimate of $3.4 million was determined.

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This smaller diversion provides sufficient capacity for the existing Patrick Street piped drainage and the overland flow component that currently exceeds the pipe capacity. The works are considered to have a Medium (2) Priority, which could be lowered still if the Killara Street diversion is implemented. The beneficial impact of the Anne Street diversion on the Mindham Park system would be significant due to its relatively close proximity.

O'Dowd Street (Mundingburra)
The park at the corner of Brownhill Street and O'Dowd Street is a low lying sump where water collects before discharging through pipes along O'Dowd Street. Presently the pipes are overwhelmed, with significant surcharge in the 20 Year ARI design flood event. An additional 1200 mm diameter pipe along O'Dowd Street has been proposed to increase capacity and reduce water levels in the park and surrounding low lying areas. The preliminary estimate of the construction of the additional pipe is $0.4 million, and the works have been assigned a Low (3) Priority.

Fraire Street (Hermit Park)
An expensive but high impact diversion scheme to reduce flow in the Mindham Park Drain involves diverting flows to Ross River immediately upstream of Townsend Street (this location is also where Mindham Park and Ross River are the closest to each other). The Townsend Street road crossing, whilst not overly constrictive, would help drive the flow in two large 2400x1500 RCBC's along Fraire Street and through Corcoran Park, eventually following the current alignment of a small pipe system (which would be replaced). The alignment through Corcoran Park significantly reduces construction costs, and there is potential in the future for diversion of additional areas of the Hermit Park catchment.

Assuming a tailwater condition of RL 2.15 m AHD (HAT), it is believed that 11 m^3/s is capable of being diverted, representing 30 % of the 20 Year ARI flow in Mindham Park Drain at Townsend Street and more importantly 15% of the total flow in Woolcock Canal at Church Street. A preliminary estimate of the construction cost is $3.20 million, and reductions of 0.2 m are expected at Townsend Street. Whilst the localised impact is moderate, the benefits to downstream properties are very significant.

A further diversion at Roberts Street (Hermit Park), directing flows away from Woolcock Canal to Ross Creek was assessed has having minimal benefit. However, reversing the grade of the Hermit Park Drain from Charters Towers Road back to Roberts Street and north towards Ross Creek has some merit, although further detailed feasibility investigations would be required (outside the scope of this Study).

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7.6 Major Road / Evacuation Route Upgrades

7.6.1 Townsville

In Townsville, some of the areas addressed under structural drainage upgrades indirectly improve the trafficability of Major Roads and Evacuation Routes (for example, the Nathan Street / Charles Street intersection, the Gordon Creek crossing of Abbott Street and the Charters Towers Road near the Causeway). However, there are additional locations that have been identified in the vulnerability assessment requiring either road raising or greater drainage capacity. In general, a target flood immunity of 50 Year ARI was targeted.

Bruce Highway (between Abbott Street and Stuart Drive)

This section of the Bruce Highway provides an important link between south bound and west bound traffic, as well as providing an alternative access route into the City if Abbott Street is closed. A 200 m section of road needs to be raised to at least RL 4.0 m AHD. If the existing one lane in each direction is to be retained, the estimated cost of the works is approximately $0.10 million. These works would be the responsibility of Main Roads and have been assigned a High (1) Priority.

Kings Road (between Bayswater Road and Palmerston Street)

A long section of Kings Road between Bayswater Road and Palmerston Street is inundated relatively frequently from the Mindham Park drainage system. The lowest level of the road is just RL 3.0 m AHD, and the crown level needs to be raised to RL 4.0 m AHD over a length of 500 m. The estimated cost of the works is $0.45 million, and they have been assigned a Low (3) Priority. Kings Road, whilst identified as a major road in Townsville, has alternative routes and Council has just completed pavement widening works in the area.

Boundary Street (Various Locations)

Boundary Street, the main access to route Townsville Port, has two low lying sections that are very susceptible to tidal inundation. To mitigate the problem, road raising has been proposed; 250 m between Twelfth Avenue and Fourteenth Avenue and 370 m between Perkins Street and Bell Street. Both sections need to be raised to a minimum of RL 2.6 m AHD, with an estimated total cost of $0.53 million.

Whilst king tides cause only nuisance flooding in the area (relatively infrequently for short periods), the issue of potential sea level rise raises the prospect of significant risk escalation. The works have therefore been assigned a Medium (2) Priority.

7.6.2 Magnetic Island

On Magnetic Island, it is recommended that the single road providing connectivity between the four bays be upgraded to ensure 50 Year ARI flood immunity throughout (trafficable). This road is a major lifeline for the island and all weather access is particularly important in the event of a medical emergency. Inspection of the flood mapping has highlighted one location where road upgrades are required to achieve the above criteria. It is noted that while the depth criteria (< 300 mm) is generally met, some of the crossings of larger creeks (like Gustav Creek) may experience high velocities, restricting traffic to 4WD vehicles only.

Birt Street Crossing of Butlers Creek (Picnic Bay)

The Birt Street crossing of Butlers Creek at Picnic Bay is currently not trafficable in a 50 Year ARI flood event. The depth over the road exceeds the maximum allowable depth of 300 mm, and the existing 3/1200 RCP's require to be upgraded to a total of five (5). The cost of these works is estimated to be $50,000, and has been allocated a High (1) Priority to bring the immunity of this section of the island link road up to a standard consistent with other areas.

7.6.3 Cungulla and Pallarenda

Heatley Parade (Evacuation Route from Pallarenda)

The main access road to Pallarenda has a low point near the intersection with Primrose Street (approximately RL 2.40 m AHD), and is inundated substantially for the 20 Year ARI design flood. To achieve 50 Year ARI immunity (both flooding and storm surge), the road needs to be raised to at least RL 2.7 m AHD at the crown, over approximately 100 m length, and additional cross-drainage provided (3/600 RCP's). The cost estimate for these works is approximately $0.55 million, and has been assigned a High (1) Priority.

Frank Randall Drive (Main Road at Cungulla)

The main street at Cungulla is inundated in two locations during extreme tides, effectively splitting the community and restricting access (locations are immediately north and south of the intersection with Goodsell Road). It is recommended that Frank Randall Drive be raised to a minimum level of RL 2.7 m AHD (0.5 m above HAT) at both these locations (estimated to cost $0.20 million).

It is believed that Goodsell Road is also subject to inundation in several locations between Cungulla and the AIMS road; however, ground levels along the road were not captured as part of this Study and the flood mechanisms affecting the immunity of the road were outside the scope of the present Study. The assigned priority for works at Cungulla is Medium (2).

7.7 Upgrades to the Counter Disaster Plan

The existing Townsville Thuringowa Counter Disaster Plan was reviewed, and the following general recommendations are made:

- Council and the Counter Disaster Committee should review the general content of the document in light of the outcomes of this Study.
- Council and the Counter Disaster Committee should review the list of Evacuation Centres provided in the Short Term Welfare Sub-Plan, to address:
  - the potential for some centres to have reduced access or be cut off in a flood,
  - the potential for some centres to have unacceptable risk of inundation in an extreme storm surge event, and
  - any apparent deficiencies.
- Council and the Counter Disaster Committee should update the Counter Disaster Plan to include copies of new flood inundation and community vulnerability mapping developed for this Study.
- Council and the Counter Disaster Committee should undertake to expand on the Evacuation Sub-Plan to identify where affected communities should go if evacuation is required (for example Cungulla and Pallarenda residents).
- Council and the Counter Disaster Committee should further review the Evacuation and Short Term Welfare Sub-Plans following the detailed storm surge investigation, as additional centres and procedures might need to be identified to cope with a larger displaced population (in the event of extreme Category 5 Cyclone).

Review and updating of the Counter Disaster Plan has been assigned a High (1) priority. The cost of these measures is estimated to be in the order of $5000, which relates primarily to Council time and materials.

7.8 Regular Structured Maintenance Programs

Vegetation
Council actively undertake vegetation management in open channel drainage systems across the City, predominantly on an as needs basis. Excess vegetation in channels can have a significant impact on the resulting flood level, and regular maintenance is therefore an essential component of reducing the overall risk profile. Some areas are more difficult to maintain (for example the lower reaches of Louisa Creek) due to the presence (most of the year) of standing water or favourable growing conditions.

In other areas, changes to the channel design profile can have a marked effect on the ability of vegetation to establish, including concrete lining the invert (fore example several drainage paths in Annandale). Council should undertake to identify these locations and include such preventative works in the forward works program where practical. In areas where this approach would not be suitable, a structured maintenance plan should be developed targeting the worst areas towards the end of the dry season (ideally on an annual basis).

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Debris

Council recognise the potential for debris in channels to block drainage structures and cause localised flood problems; however, a structured risk minimisation program is yet to be implemented. This program could be an extension of the ongoing parks and gardens maintenance program in the lead up to the cyclone season, and would involve identification of potential sources of debris (dead trees or overhanging branches) and strategies to encourage community involvement (eg. free dump days for green waste and community based cleanup activities).

Sediment

The impact of large sediment loads clogging drainage systems was felt in the January 1998 flood event and has proven problematic for Council in developing areas like Mount Louisa and on Magnetic Island. Council should undertake stability studies of areas like Castle Hill to identify zones/gullies most at risk of generating high sediment loads. In recent times, more stringent controls are placed on developers with respect to sediment controls, so there is potential to control the problem at the source. However, Council should also identify existing culverts with sedimentation issues (the culvert survey undertaken for this Study identified several choked culverts) and implement a systematic sediment removal program.

7.9 Relocation and Flood Proofing of Critical Facilities

Western Suburb Outfall Main to CBPP

The exposed sewerage pipeline across Ross River represents an unacceptable risk, highlighted when a section was damaged in 1977 resulting in prolonged discharge of raw sewerage to the environment. Council should undertake planning studies to assess the best way to reduce the risk (including burying the pipeline), and apply for federal funding assistance if applicable. The cost of relocating the pipeline in part is estimated to be in the order of $1 million, and has been assigned a High (1) priority.

Review of Sewerage Pump Stations

Council should undertake a review of all sewerage pump stations identified as potentially impacted by flood and storm surge inundation, with respect to susceptibility to power failure and surcharge.

Share Flood Information with Ergon

Council should disseminate relevant flood data to the local power authority (Ergon) to allow an independent risk assessment of existing power distribution facilities.

7.10 Action and Monitoring Schedule

For flood and storm surge hazard, the Hazard Project Leader is Mr Brian Milanovic (Townsville City Council). Review of the Treatment Strategy and reporting to the Counter Disaster Committee on implementation strategy development needs to be ongoing on a 6 monthly basis.

8 References

8 References

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