Local Government Association of the Northern Territory

29 November 2010

Climate Change Risk Assessment and Adaptation Planning

Wagait Shire Council

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Prepared for

Local Government Association of the Northern Territory

Prepared by

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Table of Contents

List of Acronyms

AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
ABSLMP	Australian Baseline Sea Level Monitoring Project
a.s.l	Above sea level
AR4	(IPCC) Fourth Assessment Report
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCCEE	Department of Climate Change and Energy Efficiency
IPCC	Intergovernmental Panel on Climate Change
LAPP	Local Adaptation Pathway Program
LGANT	Local Government Association of the Northern Territory
NT	Northern Territory
OAGCM	Ocean-atmosphere coupled general circulation models
PWC	Power and Water Corporation
SRES	Special report on emissions scenarios
SLR	Sea Level Rise
SST	Sea surface temperature
TAR	(IPCC) Third Assessment Report
AAPA	Aboriginal Areas Protection Authority

Key Terms

Adaptation	Actions taken in response to actual or projected climate change and impacts that lead to a reduction in risks or a realisation of benefits. A distinction can be made between a planned or anticipatory approach to adaptation (i.e. risk treatments) and an approach that relies on unplanned or reactive adjustments.
Adaptive capacity	The capacity of an organisation or system to moderate the risks of climate change, or to realise benefits, through changes in its characteristics or behaviour. Adaptive capacity can be an inherent property or it could have been developed as a result of previous policy, planning or design decisions of the organisation.
Climate change	Climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (United Nations Framework Convention on Climate Change).
Climate scenario	A coherent, plausible but often simplified description of a possible future climate (simply, average weather). A climate scenario should not be viewed as a prediction of the future climate. Rather, it provides a means of understanding the potential impacts of climate change, and identifying the potential risks and opportunities created by an uncertain future climate.
Climatic vulnerability	Climatic vulnerability is defined by the International Panel on Climate Change (IPCC) as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".
Hazard	A physically defined source of potential harm, or a situation with a potential for causing harm, in terms of human injury; damage to health, property, the environment, and other things of value; or some combination of these.
Mitigation	A human intervention to actively reduce the production of greenhouse gas emissions (reducing energy consumption in transport, construction, at home, at work, etc.), or to remove the greenhouse gases from the atmosphere (sequestration).
Risk	Risk is defined in general terms as the product of the frequency (or likelihood) of a particular event and the consequence of that event, be it in terms of lives lost, financial cost and/or environmental impact.
Sensitivity	Refers to the degree to which a system is affected, either adversely or beneficially, by climate related variables including means, extremes and variability.
Vulnerability	Vulnerability is a function of risk and response capacity. It is a combination of the physical parameter of the hazards and its consequences such as personal injuries, degradation of buildings and infrastructure and functional perturbations. It may vary depending on non physical factors such as emergency preparation, education and recovery capacity.

Executive summary

This climate change risk assessment and adaptation planning report on the Wagait Shire Council area was commissioned by the Local Government Association of the Northern Territory with funding support from the Commonwealth Department of Climate Change and Energy Efficiency. This study provides an overview of climate change trends in the Wagait area, an analysis of expected climate change impacts and a number of proposed adaptation options. This project should not be considered as a one-off exercise but rather an ongoing process that needs to be revisited by the Wagait community and its Council from time to time.

The Vulnerability of the Wagait Shire

The Wagait Shire Council was previously known as the Cox Peninsula Community Government Council. The community lies 20 km south west of Darwin, across Darwin Harbour; however it is 130 km by road from Darwin and is considered a remote area.

The Wagait community is potentially exposed to extreme climatic events among which cyclones and flooding can be considered as the most threatening. All these elements make the community highly sensitive to climate change impacts.

However the Wagait community and the Wagait Shire Council have shown strong resilience in the face of previous adverse events. This resilience combined with the local knowledge held by the community can be built upon to prepare for the inevitable impacts of climate change.

Climate Change Observations & Projections

Wagait has experienced changes in the climate (such as air temperature and rainfall) over the past 30 years. These trends are likely to continue and even accelerate during the 21st Century.

Over the past 30 years the Wagait area experienced a warming of mean and maximum air temperature and a slight decrease of the minimum temperatures both during the wet and the dry seasons. The number of hot days (> 35°C) increased significantly during both seasons. Relative humidity decreased a little during the dry season but remained similar during the wet season compared to the current situation. Rainfall showed varying trends with a slightly wetter wet season and somewhat drier dry season.

The future climate change projections for the region include:

- Increased seasonal air temperature ranging from 0.7°C warmer (wet and dry season) by 2030 to between 1°C and 3.5°C warmer by 2070;
- Increased sea surface temperature by 0.7°C in 2030 which may reach 1.7°C by 2070;
- Although there is a high level of uncertainty, the projection of rainfall changes suggest that the driest seasons may become drier and the wet season may become slightly drier;
- A sea level rise of up to 1.1 m by 2100; and
- An increase in the intensity of cyclones (Category 4 and 5), but a decrease in the number of cyclones.

Key Vulnerabilities

Increased Damage to Coastal Areas

Increases in sea level, and the associated deterioration in coastal conditions from erosion of beaches are already important issues for the Wagait Shire Council. These problems could increase should climate change result in unforeseen changes in ocean circulation patterns and local currents.

Vulnerable Ecosystems & Biodiversity Loss

The Wagait area is home to valuable ecosystems and a number of species that are considered to be vulnerable to climate change. Climate change is expected to bring changes in terms of species distribution and migration, species abundance and vegetal productivity. Climate change is also likely to exacerbate impacts from introduced species (which are usually more opportunistic and tolerant than native species).

Risks to Buildings & Infrastructure

Buildings and infrastructure are identified as being sensitive to the effects of climate change. More intense tropical cyclones, more frequent and intense rainfall, changes in air temperature are likely to directly impact buildings and infrastructure (e.g. roads, electricity and water distribution) of the Wagait community and potentially increase repair and maintenance costs.

Implications for Culture and Traditions

Climate change is not likely to threaten the culture and traditions of the Wagait community; however, cultural values in Wagait can and will potentially influence local responses to climate and climate change as well as responses to mitigation and adaptation policies and strategies.

Risks to Human Health & Safety

Wagait Shire Council is located in the tropics and already experiences climatic conditions that are conducive to the transmission of tropical diseases such as malaria, dengue, food- and water-borne diseases and to the promotion of other climate-sensitive diseases such as diarrhoea, heat stress, skin diseases, acute respiratory infections and asthma. Whilst there has been no appreciable observed increase in these diseases to date, future climate projections suggest that proneness to these medical conditions in Wagait could increase. It is also likely that changes in the intensity of cyclones could have negative impacts on resident mortality and trauma rates in the short and medium term.

Cumulative Effects

The natural ecosystems are likely to be vulnerable to the harmful effects of climate change. It is also likely that changes to natural systems will have negative consequences for the Wagait community through loss of attractiveness. It is also possible that climate change will bring opportunities even if they are not identified at this point of time.

Uncertainties and Unexpected Events

It is possible that the Wagait Shire Council will also face a number of unforeseen changes in the physical climate system or ecological impacts that may not be anticipated, such as changes to individual species. Further research would improve the understanding of how to project against societal and ecosystem impacts, and provide the Wagait community with additional useful information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways. On the other hand, some changes may be positive and represent potential opportunities.

Adapting to Climate Change

A range of adaptation options has been identified. The Wagait Shire Council and the Wagait community both have a key role to play in this process.

Adapting to climate change involves preparing for, responding to and coping with climate induced changes. This is best achieved when government and community work together to improve the ability of communities to cope with or respond to the impacts of climate change. It is strongly recommended that a community-based approach be implemented to deal with climate change over the medium and long term.

A series of ten adaptation options ranging from climate change awareness programs to improvement of emergency management procedures and the incorporation of climate change considerations into procurement, have been identified. These options have been assessed using a set of criteria (e.g. cost, speed, effectiveness, etc.). This analysis provides supporting information for the Wagait Shire Council to select the most appropriate and most urgent options to be implemented.

A stronger awareness of the risks and ownership of the adaptation responses is required by the Council and community to build resilience to climate change impacts. To increase the effectiveness of raising awareness of climate change issues in these communities it is important to put a greater emphasis on “climate change champions” delivering the key messages to the community.

Priority Ranking	Prioritised Adaptation Options for Wagait Shire Council
1	*Develop and deliver a community education and awareness program to build community resilience. Option 1*
2	*Incorporate increased heat wave related illness into education provided by health services to the community. Option 2*
3	*Use procurement process to screen investment to address climate change risks to infrastructure and services. Option 3*
4	*Include climate change considerations in the upgrade, design and development of key community infrastructure. Option 4*
5	*Seek additional funding for additional upgrade of the drainage network. Option 5*
5'	*Engage in a dialogue with Power and Water Corporation to discuss potential reolocation of the electrical sub-station and upgrade of the community supply water tank. Option 6*
6	*Identify potential engineering, land use or natural system planning response to sea level rise and increased storm surge heights. Option 7*
6'	*Prepare a Council position paper on climate change to engage in a dialogue and influence other instiutions which have control over some risks and adaptation options. Option 8*

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Part 1 – Introduction

2.0 Introduction

2.1 Local Government and Climate Change

As the tier of Government most representative of, and most closely linked to Australian communities, the impacts of climate change will be most acutely felt by local governments. Australian Local Governments have been identified by the Commonwealth Government as being “at the forefront of managing the impacts of climate change” (LAPP, 2010) and as “key actors in adapting to the local impacts of climate change and the engagement of Local Government will be a critical part of any national reform agenda” (DCC, 2010). With some progression in the collective understanding and certainty of the impacts of climate change, the focus of local government action should now be on climate change adaptation.

A key responsibility for local government is the need to understand how climate change is likely to affect the operations, incomes, expenditure streams, strategic planning and assets of the council, and the community they support. Councils have finite resources, and this project will contribute to an understanding of how Wagait Shire Council can enhance resilience to the most urgent and threatening risks and impacts. The approach to adaptation should focus primarily on the high priority risks, with realistic actions building upon existing management and planning systems. Working with the community as a partner in adaptation process builds understanding of the issues and this in turn enhances community resilience.

2.2 Local Adaptation Pathway Program

The Commonwealth Government has focused its response to climate change around three pillars:

- Mitigating greenhouse gas emissions domestically;
- Helping to shape a global solution through international climate change negotiations; and
- Adapting to the unavoidable impacts of climate change.

Each of these themes has been and is increasingly informed by sound climate change science. As the risks that climate change poses have become clearer, the likely impacts more extreme, and the consequences more severe, the Commonwealth Government has developed increasingly robust programs and policies in response to this threat.

While much of the Australian community’s focus during the previous several years has been around the issue of setting targets to reduce greenhouse gas emissions, there has recently been a noticeable shift. There is increasing evidence that some impacts of climate change are unavoidable, no matter what target is set and there is an urgent need to prepare for these impacts. As a consequence, more efforts and resources have been devoted to climate change adaptation.

In recognition of this need to adapt, the Commonwealth Government has provided funding to local governments to undertake climate change risk assessments and develop action plans through the Local Adaptation Pathway Program (LAPP). Under Round 1 of the LAPP managed by the Department of Climate Change and Energy Efficiency (DCCEE), more than 60 local governments received funding for a total of 33 projects. Round 2 of the program provided a higher level of funding to reflect additional costs when working in remote and rural parts of Australia. Under Round 2 of the Local Adaptation Pathways Program, 30 councils in regional and remote areas of Australia received funding to undertake climate change risk assessment and adaptation action plans. This project has been funded as part of this Round 2.

2.3 Study Objectives

The Local Government Association of the Northern Territory (LGANT) engaged AECOM to conduct an assessment of the risks associated with the future impacts of climate change on Belyuen Shire Council, Coomalie Shire Council and Wagait Shire Council and the communities they support. This report presents the findings of this project for the Wagait Shire Council (refer hereafter as “Council”). The study focused on risks to the Shire’s assets and services. It has also considered the broader impact to the Wagait community.

This climate change risk assessment for the Council is the first step in the process of building an adaptation strategy for the Wagait community.

2.3.1 Purpose of the Study

The purpose of this study is to research, identify, evaluate, prioritise and report on the future impacts of climate change for Wagait. In this context the study seeks to:

- Evaluate key climatic vulnerabilities of the Council, in the context of other changes in the built, natural and social environments;
- Explore potential measures and options to adapt to climate change; and
- Identify the highest priority uncertainties about which we must know more to be able to respond to climate change in the future.

2.3.2 Scope of the Study

The scope of this risk assessment study includes:

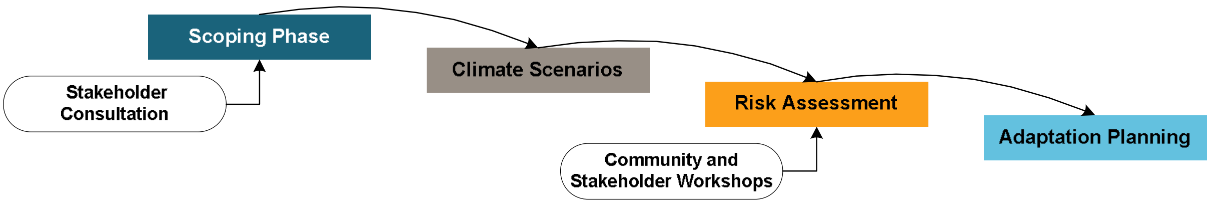
1. The collection of relevant data pertaining to physical and biological characteristics of the region, and notably an evaluation of the known impacts of: sea level rise, storm surge, cyclonic activity and sea surface temperature rise.
2. The documentation and analysis of the latest climate change projections for two future times (2030 and 2070), including projections for: air temperature, rainfall, sea level rise, storm surge, cyclonic activity and sea surface temperature.
3. The development of a risk analysis of the potential impacts to the Wagait Shire Council's core assets and services.
4. The development of a risk analysis of the potential impacts to the Wagait community.
5. The drafting of options toward an adaptation strategy.

2.4 Approach and Methodology

2.4.1 Overall Approach

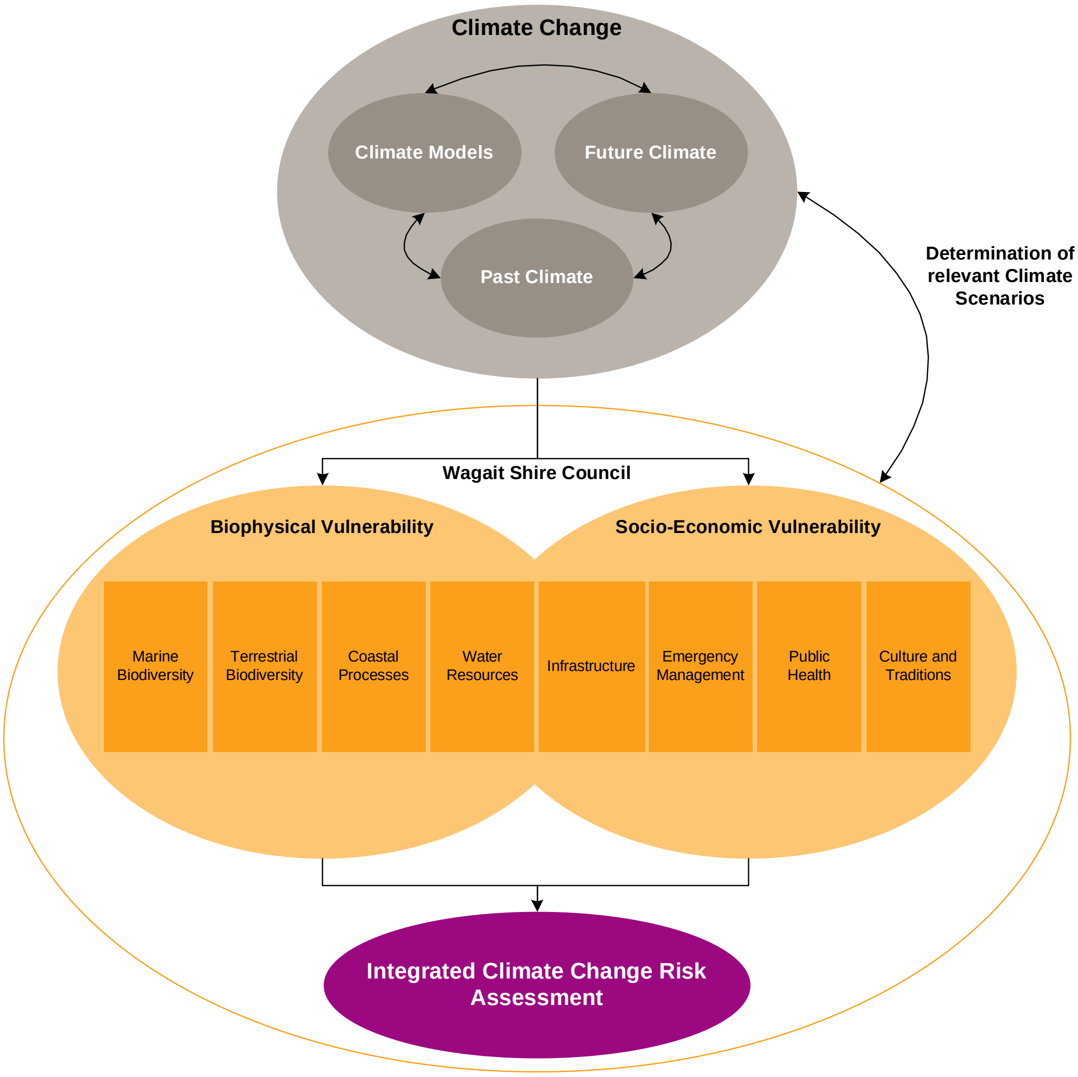
As outlined in Figure 1, the project has been developed around the following key phases: scoping phase, determination of climate trends in the studied region, climate change risk assessment (including community and stakeholders' risk workshops) and adaptation planning.

Figure 1 – Key phases of the project



The methodology adopted involved a blend of the approach recommended by the Australian Greenhouse Office 2007 report "*Climate Change and Risk Management: A Guide for Business and Government*" with a consideration of key tools proposed in the international climate change literature with respect to impact assessment. The risk assessment combined past and future climate change information at different scales (Global→Regional→Local) with assessments of climate change risks and impacts on the community, natural and built environments. Figure 2 highlights the integrated assessment approach.

Figure 2 – The integrated climate change risk assessment



2.4.2 Workshops

As part of this study a workshop was held with members of Wagait's community and Council. The elected president of the Council participated in the workshop.

The workshop was an important activity to explore key climate trends relevant for the region and to allow participants to discuss the implications of climate change and associated impacts on the community, local services, assets and natural environment. The participants suggested several adaptation responses to the risks and impacts they had identified in the workshop process. A visual tool was used to assist the participants of the workshop to initially indicate the magnitude of the risk/threat and the existing controls and influence they have over these risks/threats. More details on the workshop and the tools used are provided in Section 8.0.

2.4.3 Impacts and Vulnerability Assessment

Climate change risk is analysed as a function of the consequences associated with the risk occurring, the likelihood of the risk occurring, and the effectiveness of the control systems in place to address the risk. The risks and impacts were assigned likelihood and consequence ratings from 1 to 5 (1 being low and 5 being high) to create a combined rating out of 25. Table 1 provides a generic overview of the consequence levels. These levels represent the degree or level of consequences to which the natural system or human settlements are likely to be exposed if a given climate change impact occurs. Table 2 provides a generic overview of the likelihoods of recurrent risks and single events. No scoring was assigned to the control aspects of the risk. The workshop helped inform the ratings applied to the final risk assessment.

Table 1 – Qualitative measures of consequences

Level	Descriptor	Infrastructure	Community	Environment
1	Insignificant	No infrastructure damage.	No adverse human health effects or complaint.	No environmental damage.
2	Minor	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 5-10%.	Slightly adverse human health effects. Isolated but noticeable increased decline in social cohesion (e.g. conflict over resources).	Minor instances of environmental damage that could be reversed. I.e. negative impact on a specific species.
3	Moderate	Widespread infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Partial loss of local infrastructure. Early Renewal of Infrastructure by 10-20%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects. Minor public debate General appreciable decline in social cohesion.	Isolated but significant instances of environmental damage that might be reversed with intense efforts.
4	Major	Extensive infrastructure damage requiring extensive repair. Permanent loss of local infrastructure services, e.g. airstrip. Early renewal of Infrastructure by 20-50%.	Permanent physical injuries and fatalities may occur from an individual event. Significant public debate about climate change, constrained resources and services. Severe and widespread decline in services and quality of life within the community.	Severe loss of environmental amenities and a danger of continuing environmental damage.
5	Catastrophic	Permanent damage and/or loss of infrastructure service across state. Retreat of infrastructure. Support and translocation of residential and commercial development.	Severe adverse human health effects – leading to multiple events of total disability or fatalities. Emergency response. Public outrage.	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage.

Table 2 – Qualitative measures of likelihoods

Level	Descriptor	Recurrent risks	Single events
5	**Maybe several times every year**	Could occur several times per year	More likely than not / Probability greater than 50%
4	**Maybe once every year**	May arise about once per year	As likely as not / 50/50 chance
3	**Maybe a couple of time in a generation**	May arise once in 10 years	Less likely than not but still appreciable / Probability less than 50% but still quite high
2	**Maybe once in a generation**	May arise once in 10 years to 25 years	Unlikely but not negligible / Probability low but noticeably greater than zero
1	**Maybe once in a lifetime**	Unlikely during the next 25 years	Negligible / Probability very low, close to zero

The combination of the consequence and likelihood has been discussed during the workshop. Table 3 provides a generic overview of the risk ranking. A detailed analysis of the risks is presented in Section 8.0.

Table 3 – Risk rating matrix

		Consequences				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost certain (5)	Medium (5)	Medium (10)	High (15)	Extreme (20)	Extreme (25)
	Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
	Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	Medium (10)
	Rare (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

2.4.4 Adaptation Options

A range of adaptation options were developed to address one or several climate change risks identified during the earlier stages. Some of the adaptation responses were identified in the Council workshop.

AECOM used the analytic framework below to analyse and compare the different adaptation options that could be implemented to address key climate change risks. This framework can assist the Council in prioritising adaptation options and revising this scoring as frequently as necessary.

Table 4 – Indicative adaptation options analytic framework

	High	Medium	Low
Effectiveness	High potential to reduce risk	Moderate potential to reduce risk	Potential to reduce risk is low or uncertain
Cost	No additional budget is required / Low costs	Additional budget is required but can be covered by Council's budget / Medium costs	Additional budget is required and involves complementary external funding / High costs
Speed	Can be completed within the next 12 months	Can be completed in the medium term (1-3 years)	Long term actions (3+ years)
Technical Feasibility	Proven adaptation approach / Widespread technical skills	Limited application of adaptation approach to date / Moderately available technical skills	Adaptation approach not applied to date / Niche and rare technical skills
	High	**Medium**	**Low**

Human Capability	Capability exists within Councils	Some external expertise or support is required	Delivery is dependent on external expertise
Consistency with Council Policy	Adaptation option fits with existing Councils' planning and policy	Adaptation option could fit with existing Councils' planning and policy	Adaptation option would require new Councils' planning and policy
Community Acceptance	Potentially no conflict with communities for implementation	Possible conflict with communities for implementation	Likely conflict with communities for implementation

2.5 Limits of this Study

This study presented a number of challenges, some of which have been partially overcome, due to the unique natural environment and socio-economic characteristics of the area. However a number of limits remain and should be considered when reading this report.

2.5.1 Climate Observations and Projections

There is a limited number of functioning weather monitoring stations across the Top End and some do not continuously monitor weather variables. As a result the data set sourced from the Bureau of Meteorology presented significant gaps preventing the identification of trends for some variables or even all variables for certain locations. More details on the weather monitoring stations and gaps in the data set are provided in Appendix A.

Additionally the numerical models used to generate climate projections tend to provide climate projections in a four temperate seasons format. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has generously generated some climate variables in a two seasons (wet and dry) tropical climate format. However, some variables could not be generated in this format and have not been used as part of this study.

Finally, it should not be forgotten that climate models provide an indication of what the future climate might be like with higher concentration of greenhouse gas in the atmosphere. There are, and will always be, uncertainties associated with climate projections and emission scenarios. Therefore future climate scenarios presented in this study should be considered as possible, rather than certain futures.

2.5.2 Stakeholder Consultation and Access to the Community

A study such as this one should ideally complement the theoretical, scientific and technical understanding of the biophysical and socio-economic environment with the pool of local knowledge. However there are many barriers to an extensive and exhaustive stakeholder and community consultation in Top End communities.

2.5.3 Risk Management and Climate Change Awareness

Climate change awareness in the community was moderate. There was an interest in climate change issues with a very basic understanding of the causes and consequences of the problem and even sometimes some confusion.

Identifying the risks and potential adaptation responses to reduce these risks is only the first stage. Stronger awareness of the risks and ownership of the adaptation responses is required by the Council and community to build resilience to these climate change related impacts.

3.0 Local Government in the Northern Territory and Wagait Shire

3.1 Local Government in the Northern Territory and Related Issues

3.1.1 Local Government Reform

In October 2006, the Northern Territory (NT) Minister for Local Government announced a new direction in Government Policy with the establishment of a new framework for local government based on a system of municipal and shire councils. Local government reforms, and the introduction of a new Local Government Act, came into effect on 1 July 2008. Community government councils and associations were replaced by shires.

These reforms aim to strengthen leadership and governance in the local government sector, particularly in regional and remote areas. This includes improving the provision of services and increasing levels of indigenous employment in the local government sector.

3.1.2 Land Tenure

In 1976 the *Aboriginal Land Rights (Northern Territory) Act* was passed and recognised the rights of Aboriginals Australians to their land and set up processes to reacquire traditional lands through Land Councils, and manage land resources. The *Native Title Act 1993* was preceded by the Mabo decision delivered by the High Court of Australia in 1992. The decision stated that under Australian law Indigenous people have rights to land. This right is native title (NLC, 2010).

The administration of services on aboriginal land is divided between Land Councils and Shire Councils. Shire councils are responsible for delivering basic services and amenities to assist people in their daily living. Shire councils operating on Aboriginal land have no legal interest in the land, or control over its development, these rights belong to groups of aboriginal landowners. Land Councils make decisions about land use to protect the interests of Aboriginal land owners, as set out by section 23 of the *Aboriginal Land Rights (Northern Territory) Act 1976* (NLC, 2010).

3.1.3 Sacred Sites

Aboriginal Sacred Sites are located throughout the Northern Territory. Sacred sites are places within the landscape that have a special significance under Aboriginal tradition. The primary Commonwealth legislation that protects Indigenous heritage is the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984.* This Act aims to preserve and protect areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition (AECOM, 2009).

The Aboriginal Areas Protection Authority (AAPA) was established under this Act. AAPA holds both a register of Authority Certificates and a register of Sacred Sites. Under the *Northern Territory Aboriginal Sacred Sites Act* all sacred sites in the Territory are protected regardless of whether or not they are registered (AAPA, 2010).

3.2 Wagait

The Wagait Shire Council was previously known as the Cox Peninsula Community Government Council. Wagait Beach Township is located on the Cox Peninsula road in the Darwin Daly region, west of Darwin. The beach was named after the Wagait Tower, which was built during World War II overlooking the beach. The tower was destroyed by Cyclone Tracy.

3.2.1 Natural Environment

Wagait Shire is located within the Darwin Coastal bioregion. The Darwin coastal bioregion is generally flat, low-lying country, drained by several large rivers (DEWHA, 2008). The region contains substantial areas of mangroves, rainforest and other riparian vegetation fringing the rivers. Inland from the coast typical vegetation communities include eucalypt forest and woodlands, dominated by Darwin Stringybark (*Eucalyptus tetrodonta*) and Darwin woollybutt (*Eucalyptus miniata*), with tussock and hummock grass understorey. The most remarkable feature of this region is the extensive and diverse floodplain environments associated with the lower reaches of several large river systems (NRETAS, 2007).

Hydrology

The Darwin coastal bioregion includes several nationally important wetlands, including RAMSAR listed wetlands of Kakadu and the Coburg Peninsula. Wagait Shire is located within the nationally listed wetland (Directory of Important Wetlands in Australia) of Port Darwin, which comprises the entire Darwin Harbour. Darwin Harbour is a large embayment consisting of three main arms: East Arm, Middle Arm and West Arm. Wagait Shire is located near the West Arm region. Darwin Harbour supports a range of freshwater, marine and terrestrial environments including large areas of tidal mudflats and an extensive and diverse area of mangroves (NRETA, 2005).

Flora and Fauna

The Darwin coastal bioregion has high biodiversity values with 330 bird, 82 mammal and 135 reptile species recorded in the region, as well as 2200 plant taxa (DEWHA, 2007). The region is particularly rich in threatened species, with 33 listed species present. This includes several plant species associated with seasonally moist sand sheets east of Darwin. Threatened fauna include several marine turtles, many of which nest within the bioregion. There is some evidence of a decline in populations of some groups of mammals and birds within the bioregion (NRETAS, 2007).

Threatening Processes

Feral species known to occur within the Darwin Coastal bioregion include cane toad (*Bufo marinus*), dog (*canis* spp.), pig (*Sus scrofa*), cat (*Felis cattus*), horse (*Equus caballus*) and buffalo (*Bubalus bubalis*). Weed infestations are a major regional issue within the Darwin Coastal bioregion, particularly *Mimosa pigra.* The spread and dominance of gamba grass (*Andropogon gayanus*) and mission grass (*Pennisetum polystachion*) in the understory of eucalypt forests also pose a problem and are believed to increase the frequency of hot late dry season fires (NRETAS, 2007).

3.2.2 Socio Economic Environment

Data from the Australian Bureau of Statistics (ABS) have been used to characterise the socio-economic environment of Wagait. These data were collected during the 2006 census.

Demographics

The 2006 Census revealed that 6.8% of the population in Wagait Beach is Indigenous, compared with the national rate of 2.3%. The population is relatively old with 11.9% of the population being aged between 0-14 years and 36.5% aged 55 years and over. The median age of people in Wagait Beach was 48 years, significantly higher than the national median of 37 years (ABS, 2006).

Housing

In the 2006 Census 136 occupied private dwellings were recorded in Wagait Beach. Of these 83.1% were separate houses and16.9% were classified as other dwellings (ABS, 2006).

Economy

The 2006 Census recorded 156 people aged 15 years or over who were in the labour force. This compares with 75 people not in the labour force. Of those within the labour force 60.3% were employed full-time, 30.8% were part-time and 4.5% were unemployed.

The most commonly recorded occupation was Professional which accounted for 20.1% of workers, while Technical and Trades accounted for 19.5%, Clerical and Administrative 18.1% and Labourers 12.8%. State Government was recorded as the highest industry of employment accounting with 10.7% of employed people. School Education employed 10.1% of workers and Supermarket and Grocery Stores recorded 7.4% (ABS, 2006).

The median weekly income for people in Wagait Beach was recorded at $572, higher than the national figure of $466. The median weekly family income was $1,179, similar to the national figure of $1,171 (ABS, 2006).

The area governed by the Wagait Shire Council is approximately 562 km² and the average estimated population is 400. The Wagait Shire Council has seven elected members. There are no separate wards within the Wagait Shire. The Shire Council head office is located in Wagait Beach.

Table 5: Wagait Shire Council Overview

Shire Service Delivery Centre	Councillors
Wagait Beach	Peter Clee
	Karen Duncan
	Darryl Withnall
	Trish McIntyre
	Rocky Magnoli
	Vera Lamont
	Matt Prouse

3.2.3 Wagait Shire Council Services

Wagait Shire Core Services

Core Services are services that all Shire Councils are required to deliver to communities with the implementation of the Local Government Act (2008). Table 18 presents the core services provided by the Wagait Shire Council.

Table 6: Wagait Core Services

Core services	Comments
Local Infrastructure	
Maintenance and upgrade of parks, Reserves and Open Spaces	Council has plans to develop a memorial garden.
Maintenance and Upgrade of Buildings, Facilities and Fixed Assets	
Management of Cemeteries	There is no cemetery in Wagait.
Lighting for Public Safety, including Street Lighting	There are no street lights.
Local Road Upgrading and Construction	Council has plans to duplicate the Wagait Tower Road carriageway adjacent to the shop to provide safer movement of traffic
Local Road Maintenance	The Council is responsible for the care and maintenance of the drainage network adjacent to roads.
Fleet, Plant and Equipment Maintenance	
Natural and cultural resource management services	

Core services	Comments
Local Environment Health	
Waste Management (including litter reduction)	The Council Rubbish Tip is located on the Cox Peninsula Road on the outskirts of Wagait Beach There is no household rubbish collection and residents dispose of their own rubbish at the tip The Council is in the process arranging a recycling collection point at the Tip. Signage is being prepared to direct people where to dump various types of refuse. The Dump site will be laid out with areas for: • Recycled Aluminium cans, Glass, plastic, batteries, tyres, gas bottles • Trees and Garden waste • Household refuse • Hard waste, car bodies, fridges etc. • Oil There is no charge for depositing refuse at the Tip
Weeds Control and Fire Hazard Reduction in and around community areas	
Companion Animal Welfare and Control	The Council does not have any by laws for the control of domestic animals. Registration is not required. The Council holds a Corporate Firearms Licence that authorises Council employees to discharge firearms to destroy dangerous, feral or sick animals.
Local Civic Services	
Library and Cultural Heritage Services Civic Events	The Council offers a limited library service from the Council Office Books are provided by the Darwin Library Service The collection will be added to each year and it is Council's intention to eventually become part of a library service that will be able to offer access to a wider collection and other activities undertaken at conventional libraries The Wagait Beach Community Centre is a purpose built building that provides accommodation for a Medical Clinic, Emergency Services Communications Centre, Cyclone Shelter, Public Meetings, Training Sessions, Seniors Program, Film Nights and meeting place for any organization requiring accommodation
Local Emergency Services	A Medical Clinic is located within the Wagait Beach Community Centre. Basic and emergency care is provided by highly qualified nurses from Belyuen. Monitoring of blood pressure, diabetes, blood tests and caring for wounds are some of the more common procedures undertaken The Council has contributed approximately $80,000 to ensure that up to date equipment is available The Council is currently in the process of negotiating an extended service and possibility of attracting a doctor to provide a service on a part time basis

Wagait Shire Commercial Services

Commercial Services are services that the Council is undertaking on a full commercial basis with the intention of using profits from commercial activities to improve services to the community. Table 19 presents the commercial services provided by the Council.

Table 7: Wagait Shire Commercial Services

Commercial services	Information/Notes/issues
Housing and Infrastructure Maintenance	None
Non Council roads	None
Post office agency	None
Power, water and sewerage	None
Motor vehicle registration	None

Wagait Agency Services

Agency Services include services that the Council has agreed to deliver on behalf of other Government Agencies on a fee for service basis.

Table 8: Wagait Shire Agency Services

Agency services	Information/Notes/issues
Airstrips	None
Community safety	None
Economic development support	None
Employment and training	None
Family (including child care)	None
Aged and disabled care	A Seniors Program is conducted at the Wagait Beach Community Centre each Tuesday morning.
Outstation/homeland municipal	None
Sport and recreation	The Council employs a part time Recreation Officer for 20 hours per week Recreational activities take place at the sportsground and local beaches of an evening and on weekends. Activities include basketball, cricket, football, rugby, soccer, archery, hockey and other passive sports. In addition special events are also organised including film nights and table tennis tournaments. There is some concern in the community that there needs to be another adult at spots grounds to lend support. Adult volunteers are required. Council is seeking funding to provide a grassed oval at the sportsground
Community Media	None
Environmental Health	None
Arts and Culture	None

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Part 2 – Climate Change in Wagait

4.0 Climate Change: Context

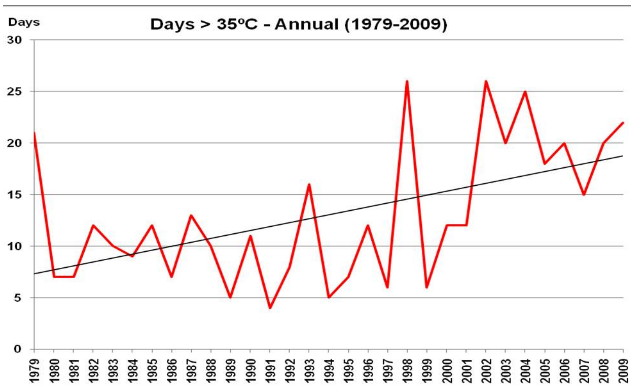
Climate change is a global phenomenon which impacts locally. The Intergovernmental Panel on Climate Change (IPCC) has evaluated evidence of climate change occurring and its consequences over the past 20 years. Worldwide industrial development since the first industrial revolution in the 18th century has caused greenhouse gases to be released into the atmosphere in great volumes. Current climate change has been caused by greenhouse gases, some of which are released by burning fossil fuels such as coal and oil, which enhance the natural greenhouse effect on the planet. Major land use changes and some natural climate variability have also contributed to the recent changes in climate conditions in Australia. Even if greenhouse gases released in the atmosphere are dramatically reduced, the warming trend will continue to rise throughout the century; this is due to the inertia of the climate system. To adapt to climate change, it is necessary to understand how our climate is changing.

4.1 Understanding Past and Future Climate Change

Climate observations are obtained through networks of meteorological monitoring stations. Precise and consistent measurements are generally only available for the second half of the 20th century.

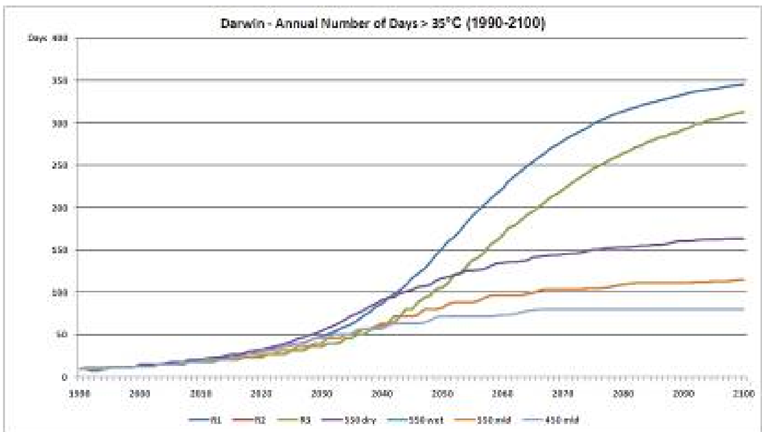
Figure 3 shows how the historical climate (annual number of days > 35°C in this instance) of the past 30 years has trended up until now.

Figure 3 – Observed trend in the annual number of days > 35°C at the Darwin airport (BoM 2010)



Climate models are used to provide an indication of the potential future climate conditions, based on a range of greenhouse gas emission scenarios. The hypotheses used to estimate how the climate system might be impacted by climate change are subject to uncertainty due to the complexity of the climate system. The climate models that simulate or replicate the past climate conditions the best for this region have been selected to inform future climate change for the region. It should be noted that even if information is uncertain it is still very valuable. Figure 4 shows how climate models information is providing a likely projection of future climate (annual number of days > 35°C until 2100).

Figure 4 – Future trends in the annual number of days > 35°C for Darwin (AECOM 2008)



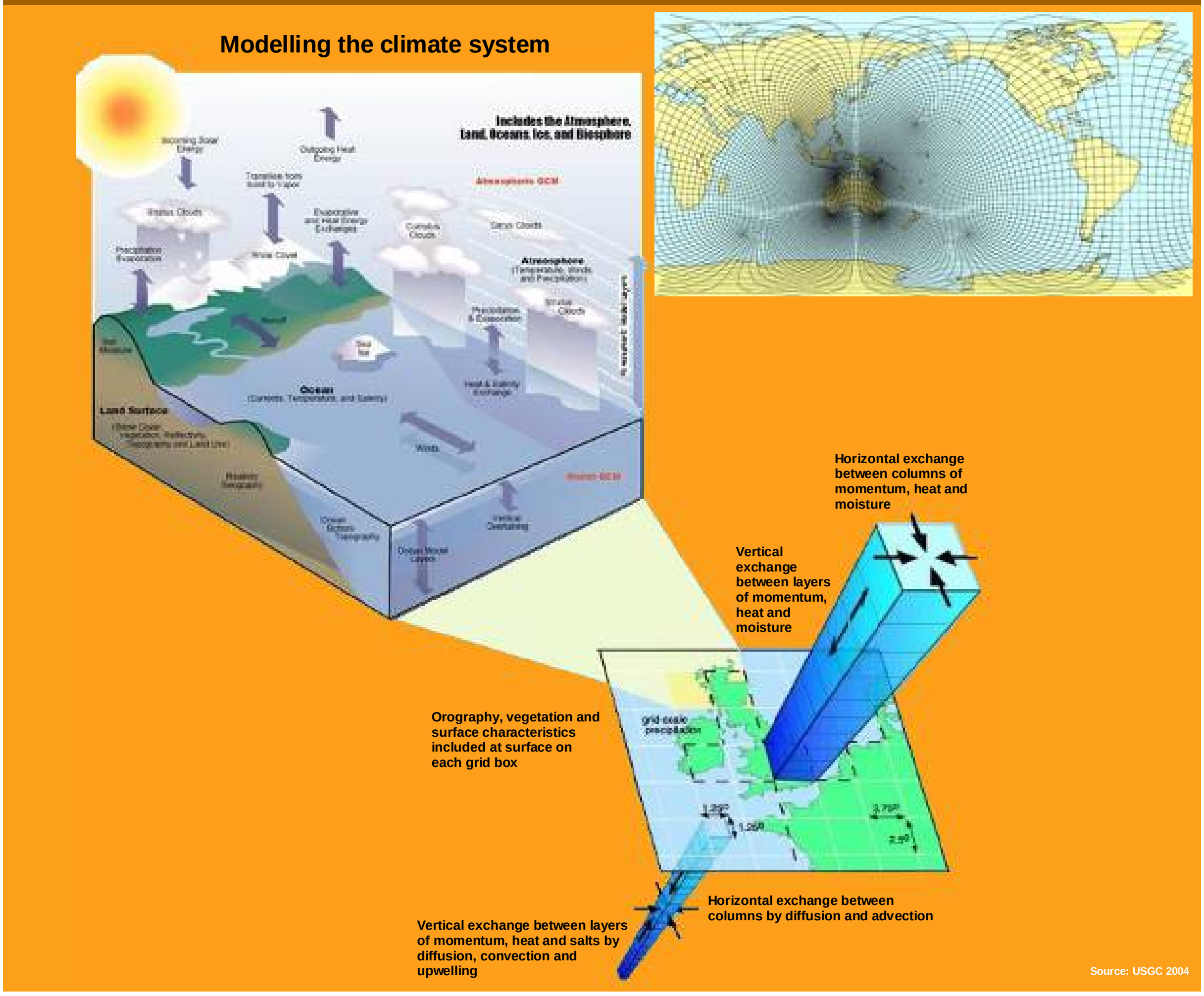
4.2 Emission Scenarios

Emission scenarios are estimations of future quantities of greenhouse gases that may be released into the atmosphere. They are based on assumptions about future demographics, the implementation and efficiency of energy policies. The IPCC developed emissions scenarios in 1990, 1992 and 2000 (released as Special Report on Emission Scenarios, SRES). The SRES are used as input data for climate models. Emissions scenarios selected for use in the climate models to provide the projections of the future climate were A1B for the year 2030; then a range for the year 2070 using B1 as a lower range and A1FI as an upper range. A range for 2070 is required because it is 60 years in the future where technology, population and energy use could be considerably different to today and therefore using a range deals with this greater uncertainty better. More detail regarding the emissions scenarios and what future they represent is provided in Appendix A.

4.3 Climate Models

The climate models are currently the best available tools to estimate what the future climate may be with increased concentration of greenhouse gases in the atmosphere. These are a simplified version of the physical and chemical processes driving our climate system through equation ensembles in a grid system covering the Earth (the grid has usually 200 km of net size). Very often, they combine the processes taking place over the continent, the ocean and the existing relation between the large land and water masses. The emission scenarios are used as inputs data for the climate models. An illustration of a climate model is provided in Box 1.

Box 1: Climate models

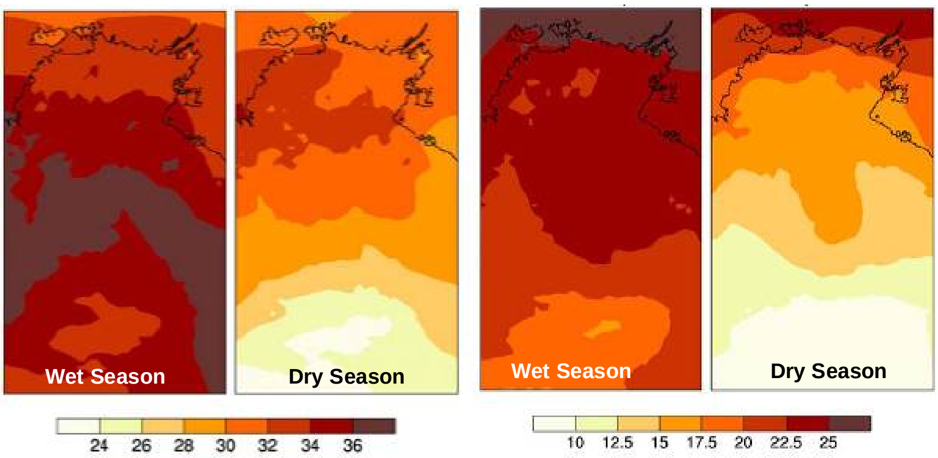


5.0 Current Climate and Climate Change

5.1 Current Climate in the Northern Territory

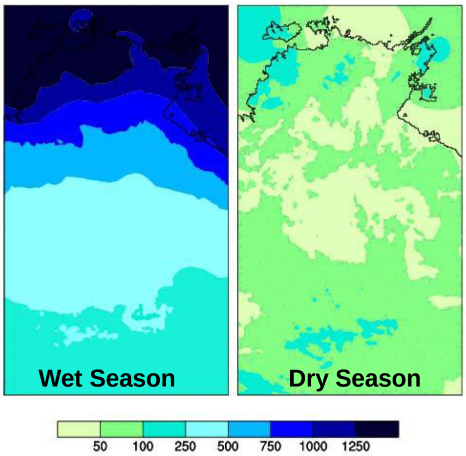
The Top End presents a tropical climate with high humidity and two distinct seasons: a wet season from November to April and a dry season from May to October. The wet season is influenced by the summer monsoon with thunderstorms and cyclones. El Niño[1] tends to limit or even suppress monsoon effect and cyclones while La Niña tends to exacerbate tropical cyclone activity and the monsoon effects. The Northern Territory experiences a warm climate with maximum temperatures higher in the south during the wet season and in the north during the dry season. Minimum temperatures are higher in the north than in the south during both seasons (see Figure 5).

Figure 5 – Maximum temperature (in °C, left) and minimum temperature (in °C, right) over the 1961-1990 period (CSIRO 2004)



From May to October, most of the Northern Territory (with the exception of the south and some areas in the far east and far west of the Top End) experiences very little rain. The wet season is much warmer and humid and this is when most precipitation occurs (see Figure 6)

Figure 6 – Rainfall (mm) averaged over the wet and dry seasons from 1961-1990 (CSIRO 2004)



[1] El Niño/La Niña-Southern Oscillation is a climate pattern occurring every 5 years on average over the tropical Pacific Ocean and influencing local climate in many regions of the World. El Niño corresponds to the warming phase and La Niña to the cooling phase of the oscillation.

Figure 7 – Current climate in the Northern Territory Top End region

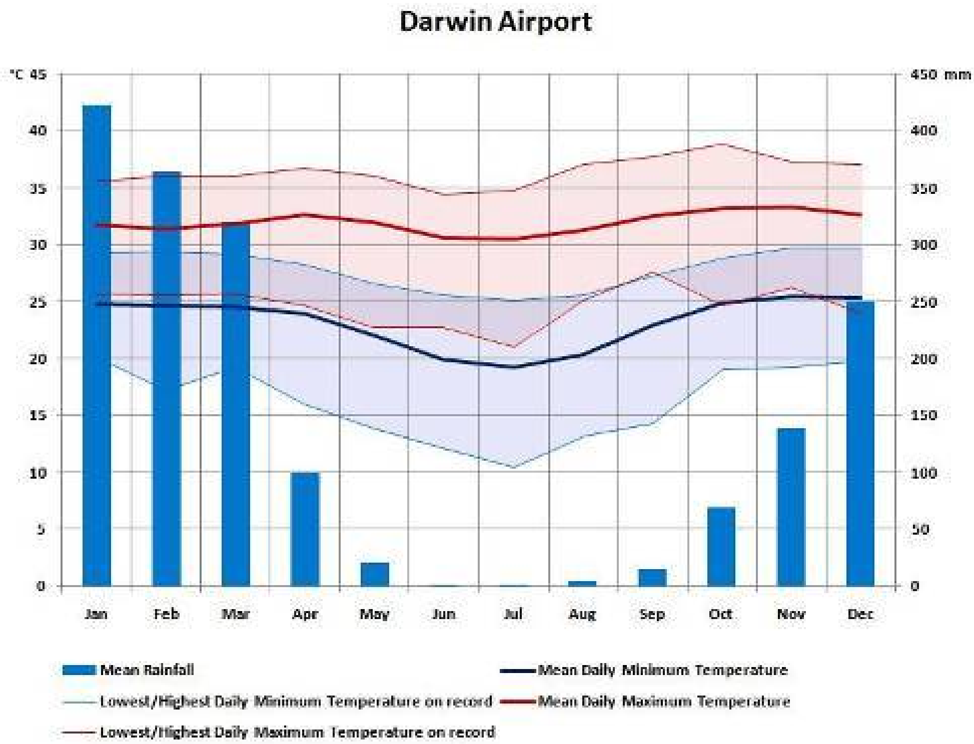
5.2 Current Climate in Wagait

There is no Bureau of Meteorology weather station within the boundaries of the Wagait Shire Council. The closest station is located at Darwin Airport. Therefore the analysis has been based on the Darwin Airport station (12°42'S, 130°89'E / 30 m a.s.l. / 1941-2010). Data from this station are considered to be representative of climatic conditions experienced in the study area. On such short distance, the only factors likely to alter climate conditions are orography (altitude and slopes) for precipitation pattern and heat island effects for air temperature. Neither the studied area nor the weather station is likely to be subject to these effects. The main features of Darwin Airport weather conditions are summarised below (see also Table 9):

- Air temperature exhibit little seasonal variations, with mean maximum temperatures ranging between 33.3°C in November and 30.5°C in July while mean minimum temperatures range between 19.2°C in July and 25.4°C in November.
- Rainfall records show the annual mean rainfall to be around 1,715 mm per year. The mean minimum monthly rainfall is recorded between June and August (1.3 to 5.2 mm) and the maximum mean monthly rainfall is recorded in March (423 mm). The highest daily rainfall monitored in the region occurred in January 1997 with 513 mm over a 24 hour period.

Table 9 – Darwin Airport key climate data (Statistic figures were rounded to the closets number, BoM 2010)

	Darwin Airport (1941-2010)
Annual mean minimum temperature	23.2°C
Annual mean maximum temperature	32°C
Mean number of days > 30°C	317 days
Mean number of days > 35°C	10 days
Mean number of days > 40°C	0 day
Mean annual rainfall	1,715 mm
Lowest mean annual rainfall (1951)	1,024 mm
Highest mean annual rainfall (1998)	2,777 mm
Highest daily rainfall (03/01/1997)	290 mm



6.0 Wagait Climate Change Snapshot

The table below provides an overview of key climate trends for the region. More information on climate change can be found in Appendix A and Appendix B.

Climate Change Variable	Observed Trend (1979-2009)	Projections 2030	Projections 2070
Mean Temperature	↗ Warming of 0.5°C	↗ Projected warming of 0.8°C ↗ Projected warming of 0.8°C	↗↗ Projected warming between 0.8°C and 3.5°C ↗↗ Projected warming between 0.8°C and 3.5°C
Min Temperature	↘ Decrease during the dry ↘ Slight decrease during the dry	↗ Projected warming of 0.8°C	↗↗ Projected warming between 0.8°C and 3.7°C
Max Temperature	↗ Slight increase during the dry ↗ Slight increase during the dry	↗ Projected warming of 0.8°C	↗↗ Projected warming between 0.8°C and 3.2°C
Days > 35°C	↗ Increase during the dry ↗ Increase during the dry	↗ Projected increase to between 20 and 50 days per year	↗↗ Projected increase to between 70 and 280 days per year
Precipitation	↘ Slight decrease during the dry ↗ Slight increase during the wet	↘↘ Decrease during the dry ↘ Slight decrease during the wet	↘↘ Decrease during the dry ↘ Slight decrease during the wet
Sea surface temperature	↗ Sea surface temp has increased in region. No local data available.	↗ The annual SST may increase by 0.7°C in 2030	↗ ↗ The annual SST may increase by 1.7°C in 2070
Sea level rise	↗ Sea level rose by 7.5 mm/year since 1993, resulting in a 12 cm rise	↗ Sea level rise should continue to rise	↗ ↗ Sea level rise should continue to rise. A worst case scenario value of + 1.1 m by 2100.
Cyclones	↘ Decrease in the overall number of cyclones	↗↗ Increase in intensity of cyclones ↘ Decrease in the overall number of cyclones	↗↗ Increase in intensity of cyclones ↘ Decrease in the overall number of cyclones
Storm surge	↗↗ As mean sea level is rising, it is expected that storm surge height also increase leading to a change in the frequency of some return period events. For instance a 1 in 100 year's storm surge could become a 1 in 10 year's storm surge.		
Ocean current	↘ Reduction in the strength of the Indonesian Throughflow Current[2]	↘ This trend should continue in the future. No quantitative projections	↘ This trend should continue in the future. No quantitative projections.
Relative humidity	↘ Slight decrease during the dry season = No changes during the wet season	↘ High uncertainties in the projections. Slight decrease during the dry and the wet season	↘ High uncertainties in the projections. Slight decrease during the dry and the wet season

↗ or ↗↗ Slight or major annual increase **↘ or ↘↘ Slight or major annual decrease**
↗ or ↗↗ Slight or major dry season increase **↘ or ↘↘ Slight or major dry season decrease**
↗ or ↗↗ Slight or major wet season increase **↘ or ↘↘ Slight or major wet season decrease**

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[2] The Indonesian Throughflow is an ocean current that transports water between the Pacific Ocean and the Indian Ocean through the Indonesian Archipelago.

6.1 Temperature, Rainfall and Humidity Changes during the Wet Season

Over the last 30 years the wet season has tended to become warmer, with more hot days (>35°C), slightly more rainfall while the relative humidity showed little change. In the future, temperature should continue to rise as will the number of hot days and possibly very hot days.

The A1FI greenhouse emissions scenario which is the worst case scenario, the temperature during the wet would increase by about 3.5°C by 2070. Most models show a rainfall decrease during the wet. The magnitude of this decrease varies between the models and the different timeframes. Most models show little change in rainfall for the near future (2030) with only a few percent decreases. The worst case emissions scenario (A1FI) for 2070 indicates a decrease of up to 25% for rainfall in the wet season which is a decrease of about 430 mm per year.

With regards to relative humidity, there has been very little change over the last 30 years and there should be a slight decrease in humidity during the wet season for the near (2030) and far (2070) future.

6.2 Temperature, Rainfall and Humidity Changes during the Dry Season

Overall the dry season over the last 30 years tended to become warmer, with more hot days (>35°C) with slightly less rainfall. In the future, temperature should continue to rise as will the number of hot days and possibly very hot days.

The A1FI greenhouse emissions scenario which is the worst case scenario, the temperature during the dry would increase by about 3.4°C by 2070. Most models show a rainfall decrease during the dry. The magnitude of this decrease varies between the models and the different timeframes. Most models show limited change in rainfall for the near future (2030) with up to 10%. The worst case emissions scenario (A1FI) for 2070 indicates a decrease of up to around 40% for rainfall in the dry season which would reduce the rainfall from 1,715 mm to around 1,030 mm.

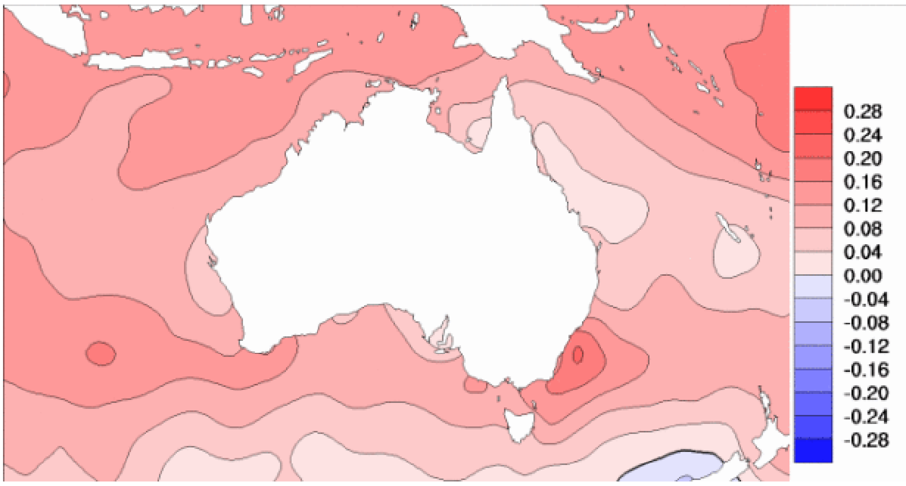
With regards to relative humidity, there has been a limited decrease over the last 30 years and there should be a slight decrease in the dry season for the near (2030) and far (2070) future.

6.3 Sea Surface Temperature

The Sea Surface Temperature (SST) is defined as the water temperature at one metre below the surface. A warmer SST can potentially increase the chance of a cyclone occurring, induce coral bleaching events and have consequences on oceanic currents or distribution of fishing resources.

Based on the BoM map (see Figure 8), SST has slightly increased over the past 40 years (between + 0.16°C and + 0.32°C). Projections for SST show a warming of approximately 0.7°C by 2030 and 1.7°C by 2070 (DCCEE 2010).

Figure 8 – Trend in annual mean of sea surface temperature 1970/2008 (°C/10 years, BoM 2009)



6.4 Sea Level Rise

Sea Level Rise Observations

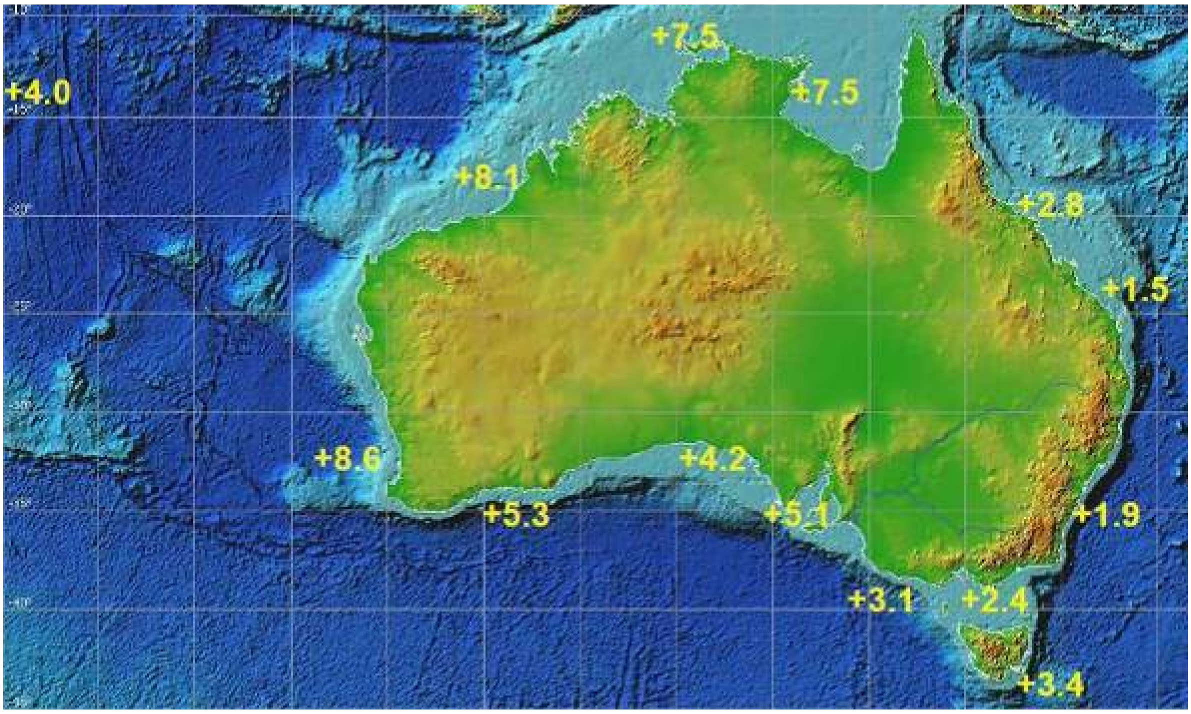
Sea Level Rise (SLR) has occurred at a global mean rate of 1.7 mm per year for the past century, and more recently over the last 20 years this has increased to rates estimated near 3.1 ± 0.7 mm per year (1993-2003) (Bindoff *et al. 2007)*. The Australian Baseline Sea Level Monitoring Project (ABSLMP) has determined that the rate of sea level rise in the Top End is significantly higher (7.5 mm per year) than the global mean (more than double).

Since 1991, the ABSLMP has been monitoring SLR rise at 14 points of the Australian coast line (12 stations in mainland Australia, one in Tasmania and one in Cocos (Keeling) Islands). There are two ABSLMP monitoring station located in the studied area, one in Darwin and one on Groote Eylandt.

Station	Latitude	Longitude	Installation Date
Groote Eylandt	13°51'36.2"S	136° 24' 56.1" E	September 1993
Darwin	12° 28' 18.4" S	130° 50' 45.1" E	May 1990

Monitoring stations have observed that sea level in Darwin has increased by 14.25 cm and since 1993; sea level in Groote Eylandt has increased by 12 cm (ABSLMP, 2009). Sea level rise trends have not been uniform across Australia as noted in Figure 9 with the largest rates of SLR have been observed along the northern and western Australian coast. The length of the date series is relatively short from a climate perspective; however it demonstrates a clear trend of SLR in the region which is consistent with satellite altimetry observation.

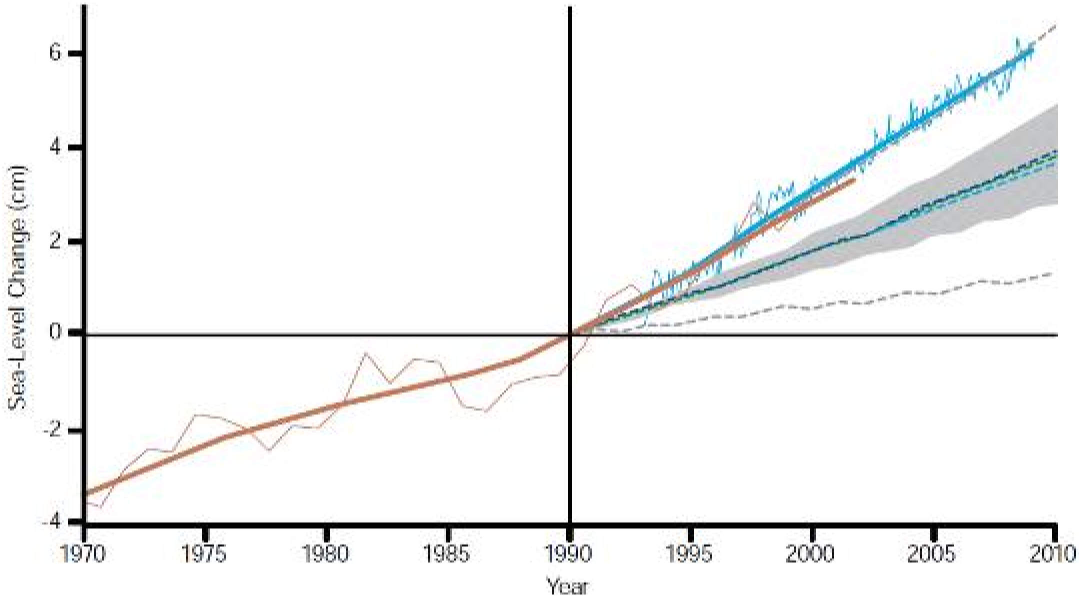
Figure 9 – Net relative sea level trend in mm/year after subtracting the effects of the vertical movement of the platform and the inverse barometric pressure (ABSLMP 2009)



SLR is particularly important for low lying areas as it enhances coastal erosion, proneness to inundation and increases storm surge/storm tide vulnerability. Sea level has been rising at close to the upper end (worst case scenario) of the IPCC projections (ACE CRC, 2008).

Figure 10 shows the global SLR changes (1970-2008) in comparison to the IPCC SLR projections. Note that the red and blue lines show observed global SLR from two different sources. The grey shaded area is showing the envelope of IPCC projections for SLR.

Figure 10 – Global sea level change from 1970 to 2008 (DCC 2009a)



Sea Level Rise Projections

The mid-range value of 1.1 m was used for this project in alignment with the DCC (2009b) report *Climate Change Risks to Australia's Coast which* stated that "A SLR value of 1.1 m by 2100 was selected for this assessment based on the plausible range of SLR values from post IPCC research" (DCC, 2009b).

An overview of recent SLR projections is provided in Table 10. These projections are the best currently available recognising that they may still evolve during the 21st century as the understanding of the processes involved in sea level rise are improved.

Table 10 – SLR projections and their various sources

Source	2100 projection
IPCC 4AR (2007)	Up to 79 cm
Copenhagen Congress (2009)	1.1-1.2 m
Rahmstorf (2007)	1.4 m
Hansen (2007)	5 m

The SLR projections presented to the March 2009 Climate Change Science Congress in Copenhagen ranged from 0.75 to 1.9 m by 2100 relative to 1990, with 1.1–1.2 m the mid-range of the projection (Rahmstorf, 2009). Rahmstorf's projection of a 1.4 m SLR by 2100 is also based on a statistical approach informed by the observed relationship between temperature and sea level (Rahmstorf et al, 2007).

Another paper by James Hansen (2007) suggests that a 5 m SLR by 2100 is plausible, based on the premise that increases in global average temperatures will become sufficient to cause ice sheets to begin disintegrating in a rapid, non-linear fashion on West Antarctica, Greenland or both, resulting in multiple positive feedbacks (Hansen, 2007).

6.5 Storm Surge and Storm Tide

The IPCC Fourth Assessment Report (2007) defines a storm surge as 'the temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions'. More specifically, the reduced atmospheric pressure resulting from a low-pressure system, as well as strong winds pushing on the ocean surface, may result in water levels rising to above mean sea level. The shape of coastal zones also influences the formation of storm surges. The most severe storm surge events typically occur when low pressure meteorological events occur in conjunction with high tides, as well as large wave swells generated by strong winds. Box 2 shows a schematic representation of a storm surge.

Box 2: Storm surge

Source: PrimNet

Storm surges are most damaging when they occur at the time of a high tide, particularly if there is a large tidal difference (big tides) like in the Top End. The most extreme storm surge events typically occur as a result of cyclones. Some low lying areas in Wagait Shire have been impacted by storm surge in the past. The town is on high ground and not likely to be directly affected.

Storm Surge and Climate Change

Climate change is expected is expected to significantly increase storm surge height by sea level rise and to a lesser extent by changes in wind speed (DCC, 2009b). Increased wind speed due to climate change may also affect storm surge heights. These changes will increase inundation risk, which is best described as the likelihood of exceeding a given level of tide, storm surge and flood height over a particular timeframe. However, this approach rests on the assumption that mean sea level will remain constant. Potential future sea level rise combined with increased wind intensity means that climate change is likely to increase the frequency of extreme sea level events.

Larger storm surges in future will inundate and flood low lying areas potentially impacting fresh water creeks in Wagait.

6.6 Cyclones

A cyclone is defined as a tropical depression of sufficient intensity to produce gale force winds, i.e. at least 63 km/h. Cyclones are called hurricanes in the North Atlantic and Typhoons in the North Pacific. This kind of event is not only dangerous because it produces destructive winds but also because it is associated with torrential rains (often leading to floods), storm surge and wild sea conditions. Generally, sea surface temperatures need to be at least 26.5°C to initiate a cyclone, although the cyclone can then move over colder waters. Cyclones are classified depending on the speed of their winds. An example of the classification is provided in Table 11.

Table 11 – Classification of the cyclones based on BoM values

10 minutes sustained winds (knots)	BoM classification of cyclones
< 28 (52 km/h) – 33 (61 km/h)	Tropical Low
34 (63 km/h) – 47 (87 km/h)	Cyclones (Cat. 1)
48 (89 km/h) – 63 (117 km/h)	Cyclones (Cat. 2)
64 (118 km/h) – 85 (158 km/h)	Severe Cyclones (Cat. 3) (e.g. Tracy)
86 (160 km/h) – 106 (196 km/h)	Severe Cyclones (Cat. 4) (e.g. Ingrid)
107 (198 km/h) – 114 (211 km/h)	Severe Cyclones (Cat. 5) (e.g. Monica)

Cyclone Projections

Most climate models indicate an increase in the intensity of cyclones (more Category 4 and Category 5 cyclones) yet also indicate that there is likely to be a decrease in the total number of cyclones for 2030 and 2070. By the second half of the 21st Century, mechanisms associated with the structure of the atmosphere may induce a decrease of the cyclonic activity in this part of the world.

6.7 Other variables

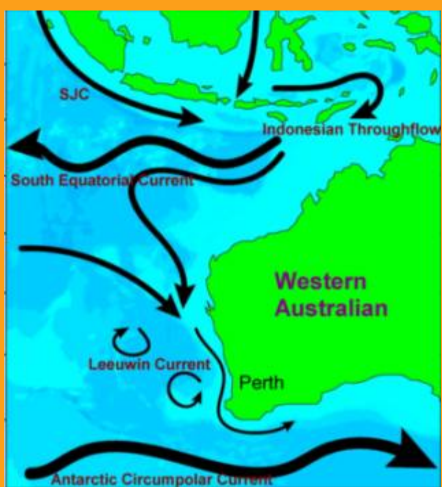
Ocean Acidification

The ocean absorbs carbon dioxide (CO_2) naturally from the atmosphere. This mechanism acts as a buffer effect for increasing atmospheric CO_2. However, the ability of the ocean to absorb CO_2 will decline over time leading to more CO_2 concentrations in the atmosphere and enhanced warming of the air temperature. A negative side effect of the CO_2 absorption is ocean acidification. One of the main concerns of ocean acidification is that it might cause some marine organisms to be unable to develop their calcium carbonate shells such as crab shells. The future pH in the ocean will be mainly driven by atmospheric CO_2 concentrations rather than the degree of warming.

Ocean Current

The main ocean current in the vicinity of the NT coast is the Indonesian Throughflow (which is the main current that flows in a westerly direction between Indonesia and the Top End). Observations over the last 50 years indicate a reduction in the strength of the Indonesian Throughflow. Results from climate models indicate that this trend should continue in the future. This will likely change the patterns of fish and seed migration along the coast which may impact the coastal ecosystems in Wagait and potentially reduce availability of ocean based food. Box 3 illustrates the Indonesian Throughflow.

Box 3: Eastern Indian ocean currents



Source: CSIRO

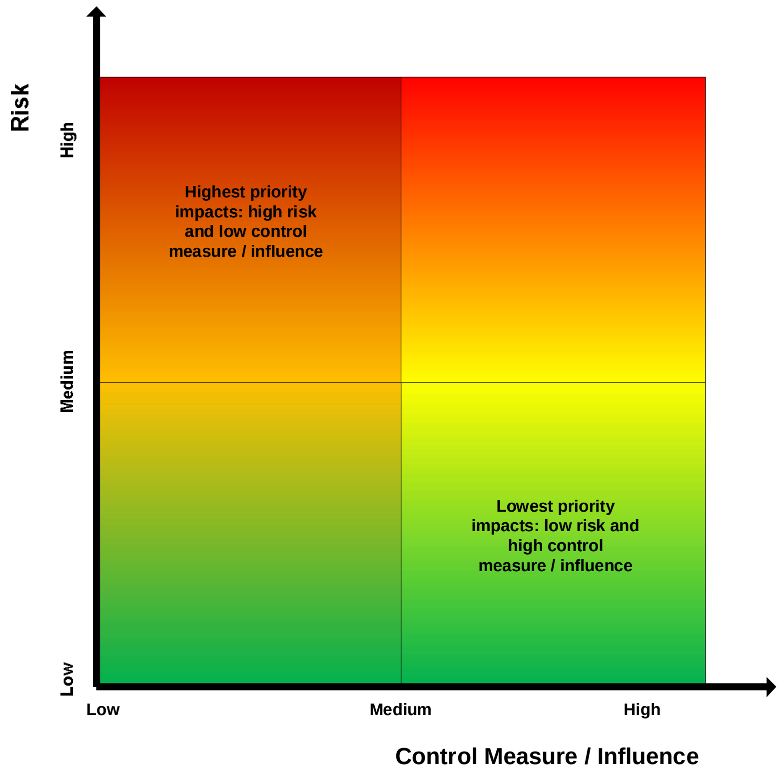
Part 3 – Climate Change Impacts and Vulnerability in Wagait

7.0 Involving Wagait Community and Shire Council: Wagait workshop

On the 11st March 2010, one workshop was held with the Wagait community. The elected president of the Council participated to the workshop. The participants were organised in three groups, one focusing on assets and infrastructure, one on emergency management and public health and the last group focusing on the natural environment and cultural issues.

The workshop provided the opportunity to discuss climate change issues with the community and Council. Key climate trends relevant for the region were presented to the workshop's attendees. Workshop's attendees were then invited to tell stories about the weather or any changes they might have observed in terms of seasons or the natural environment. The second part of the workshop focused on rating and discussing risks associated with climate change. The purpose of this phase was to understand and discuss how risks associated with climate change were perceived by the Council and the Wagait community. Perceptions and ratings were captured using a risk matrix printed on an A0 paper sheet. Figure 11 shows the matrix used at the workshops.

Figure 11 – Risk matrix used at the workshop



Each issue was first rated in terms of "risk" from low to high. This risk aspect includes both likelihood and consequence. The participants were asked to discuss how many control measures are currently in place to reduce these risks and how much influence does the community and the Council have on other organisations that are potentially able to help manage these risks. These different risks were written on post it notes and additional comments were noted on additional post it notes and stuck on the back of the relevant risk post it notes. Figure 12, Figure 13 and Figure 14 show the results of the climate change risk rating for the three different groups.

Once all the risks were identified, the participants raised and discussed several adaptation responses to the risks and impacts they had identified in the earlier phase of the workshop. The results of these different approaches and discussions were used to inform the development of the risk tables shown in Section 8.0 in combination with literature review, stakeholder discussions and AECOM experience. The workshops were also designed to raise awareness of the issues and potential responses.

Figure 12 – Emergency management and public health focus group

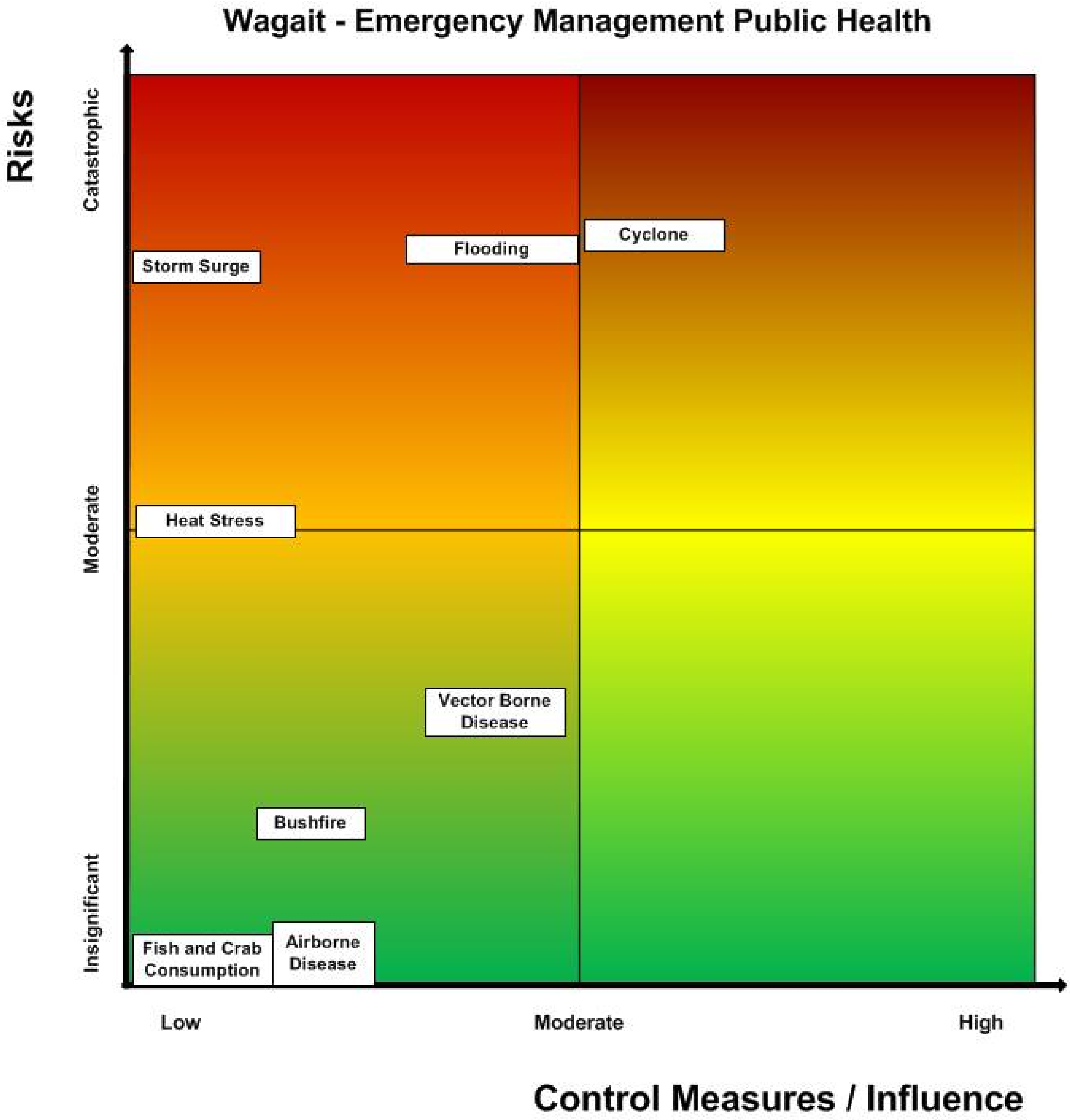


Figure 13 – Assets and infrastructure focus group

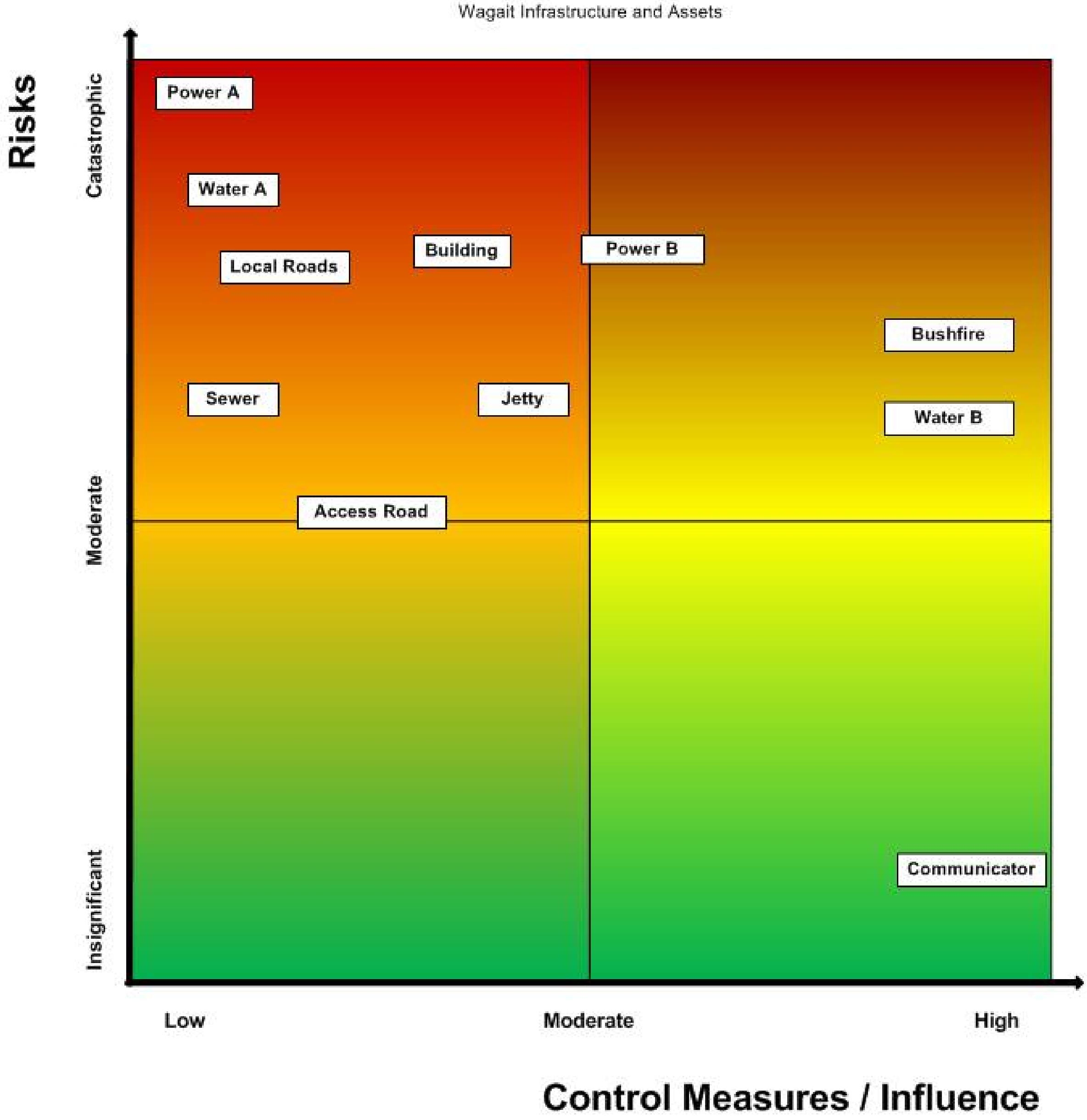
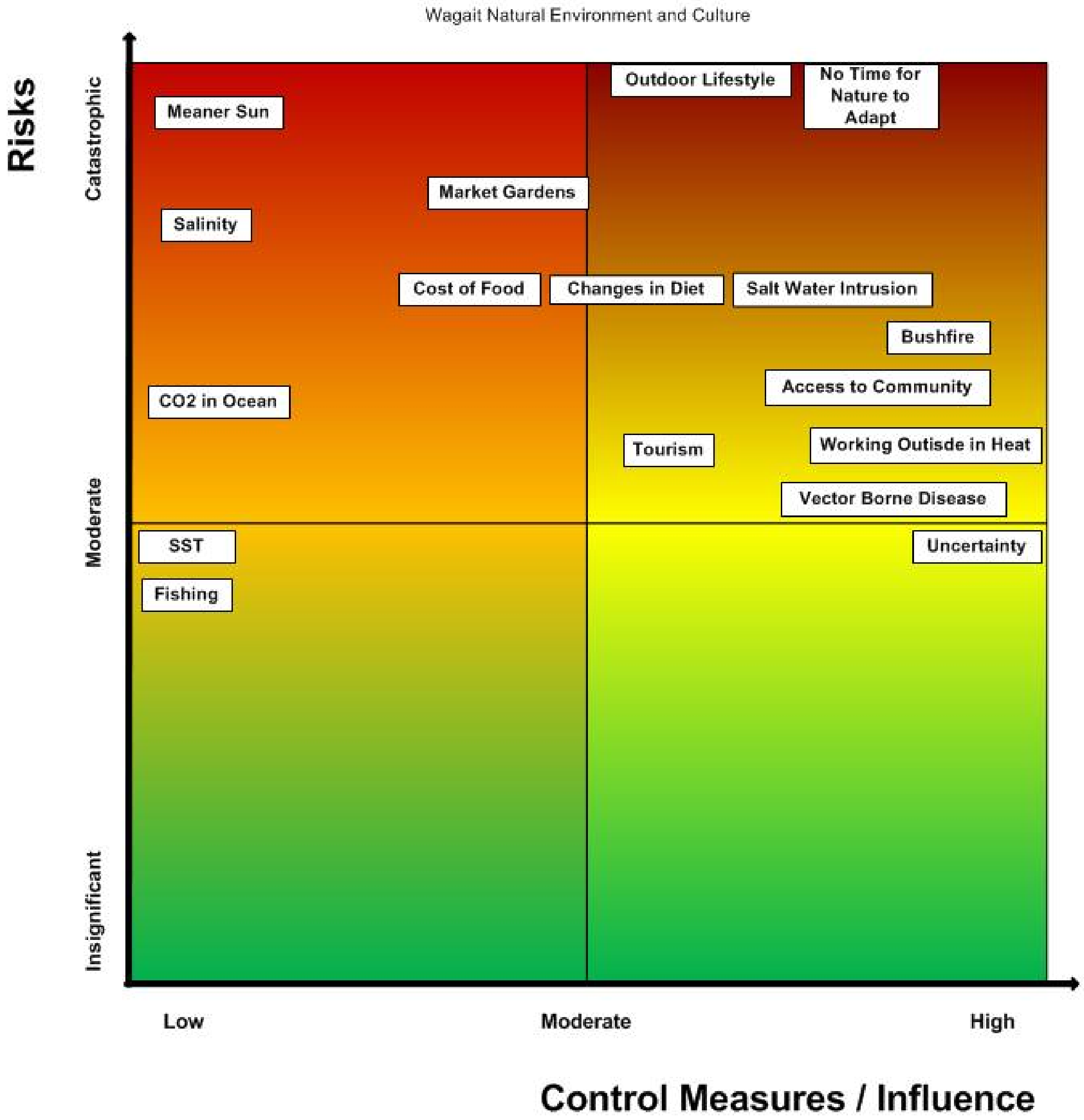


Figure 14 – Natural environment and culture group



8.0 Climate change impacts and vulnerability on Wagait Shire Council assets and services

8.1 Introduction

Climate change risk is analysed as a function of the likelihood of the risk occurring, the consequences associated with this risk occurring and the effectiveness of the control systems in place to address the risk. The risks and impacts identified for sectors and regions across the Council area is assigned likelihood and consequence ratings from 1 to 5 (1 being low and 5 being high) to create a combined rating out of 25. Table 12 provides a generic overview of the consequence levels. These levels represent the degree or level of consequences to which Wagait's infrastructure, community and environment are likely to be exposed if a given climate change impact occurs.

Table 13 provides a generic overview of the likelihoods of recurrent risks and single events.

Table 12 – Qualitative Measures of Consequences

Level	Descriptor	Infrastructure	Community	Environment
1	**Insignificant**	No infrastructure damage.	No adverse human health effects or complaint.	No environmental damage.
2	**Minor**	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 5-10%.	Slightly adverse human health effects. Isolated but noticeable increased decline in social cohesion (e.g. conflict over resources).	Minor instances of environmental damage that could be reversed. I.e. negative impact on a specific species.
3	**Moderate**	Widespread infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Partial loss of local infrastructure. Early Renewal of Infrastructure by 10-20%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects. Minor public debate General appreciable decline in social cohesion.	Isolated but significant instances of environmental damage that might be reversed with intense efforts.
4	**Major**	Extensive infrastructure damage requiring extensive repair. Permanent loss of local infrastructure services, e.g. airstrip. Early renewal of Infrastructure by 20-50%.	Permanent physical injuries and fatalities may occur from an individual event. Significant public debate about climate change, constrained resources and services. Severe and widespread decline in services and quality of life within the community.	Severe loss of environmental amenities and a danger of continuing environmental damage.
5	**Catastrophic**	Permanent damage and/or loss of infrastructure service across state. Retreat of infrastructure. Support and translocation of residential and commercial development.	Severe adverse human health effects – leading to multiple events of total disability or fatalities. Emergency response. Public outrage.	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage.

Table 13 – Qualitative Measures of Likelihoods

Level	Descriptor	Recurrent risks	Single events
5	**Maybe several times every year**	Could occur several times per year	More likely than not / Probability greater than 50%
4	**Maybe once every year**	May arise about once per year	As likely as not / 50/50 chance
3	**Maybe a couple of time in a generation**	May arise once in 10 years	Less likely than not but still appreciable / Probability less than 50% but still quite high
2	**Maybe once in a generation**	May arise once in 10 years to 25 years	Unlikely but not negligible / Probability low but noticeably greater than zero
1	**Maybe once in a lifetime**	Unlikely during the next 25 years	Negligible / Probability very low, close to zero

The combination of the consequence and likelihood analysis result in a ranking of the different vulnerabilities. Table 15 provides a generic overview of the risk ranking.

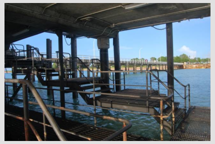
Table 14 – Vulnerability Rating Matrix

		Consequences				
		Insignificant 1	**Minor 2**	**Moderate 3**	**Major 4**	**Catastrophic 5**
Likelihood	**Almost certain (5)**	M (5)	M (10)	H (15)	E (20)	E (25)
	Likely (4)	L (4)	M (8)	H (12)	H (16)	E (20)
	Possible (3)	L (3)	M (6)	M (9)	H (12)	H (15)
	Unlikely (2)	L (2)	L (4)	M (6)	M (8)	M (10)
	Rare (1)	L (1)	L (2)	L (3)	L (4)	M (5)

The risk assessment is an important step in the process of further understanding the potential implications of changes in climate into the future. In particular it was used to guide the scoping of investigations and assessments, to guide adaptation responses, and to assist in identifying appropriate control measures and management responses. In the following tables, the risk of each identified potential impact is considered by identifying the consequences of the impact and the likelihood of it occurring. Under the risk description, an indication of potential control measures is presented in *italics*. The *control / influence measures* or comment was derived from a combination of the workshops, discussions with Council and LGANT representatives as well as from relevant literature review. Several key themes were assessed including Assets and Infrastructure; Emergency Management and Extreme Climatic Events; Public Health; Natural Environment and Culture; and Other Issues.

8.2 Assets and infrastructure

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Loss of power supply 	**Medium (9)**	**High (12)**	Loss of power supply from storms damaging transmission and distribution assets. Storm surge impacting the low lying substation located near Mandorah ferry landing. The power is supplied from Darwin via a submarine cable. *Moderate/high control/influence due to several backup generators.*	**3** **4**	Possible by 2030 due to SLR. Likely by 2070 due to more pronounced SLR and increased level of storm surge.	**3**	Moderate by 2030 and 2070 due to damage and loss of substation infrastructure at Wagait, loss of distribution lines during extreme storms. Temporary loss of power to homes, refrigeration, pumping, air conditioning and lighting.
Loss of water supply and water storage 	**Medium (6)**	**High (12)**	Loss of water distribution and storage from salt water intrusion into groundwater from sea level rise and reduction in annual rainfall and extension of the dry season reducing groundwater quality and availability. Intense cyclone could also wipe out current community supply water tanks. *Moderate control by locating new groundwater supplies.*	**3** **4**	Possible by 2030 Possible by 2070 due to increase in length of dry season.	**3**	Moderate for 2030 and 2070 due to temporary loss of water for household health functions. Loss or damages to community supply water tanks would have significant impacts on the community.
Loss of road access 	**High (12)**	**High (12)**	Loss of sealed and unsealed road access from flooding (including SLR and storm surge) leading to isolation and loss of amenity for residents. *Moderate control.*	**4**	Likely by 2030 and 2070.	**3**	Moderate by 2030 and 2070 from temporary loss of access to work, commodities, health support and schooling. Road damage recoverable by maintenance and minor repair.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damaged ferry pier 	**Medium (6)**	**Medium (9)**	Damage to ferry pier landing from increased height and intensity of storm surge reducing access to Darwin. *Moderate control/influence as temporary barge landings could be used.*	**2** **3**	Unlikely by 2030. Possible by 2070 due to significant sea level rise and increased level of storm surge.	**3**	Moderate by 2030 from temporary loss of access to work, commodities, health support and schooling. Ferry pier damage recoverable by maintenance and minor repair.
Damaged houses 	**Medium (9)**	**High (12)**	Damaged houses from increased intensity of extreme storm events impacting the housing and property. *Moderate control/influence as householders are prepared for flooding and storms during wet season.*	**3** **4**	Possible by 2030. Likely by 2070	**3**	Moderate by 2030 and 2070 from partial loss of housing requiring significant repairs. Adverse health effects and short term local disruption.
Loss of communications 	**Low (4)**	**Low (4)**	Loss of communications for an extended period of time due damaged fixed lines, mobile towers and terminals from storm events. *High control due to several households having alternative technology for communication – satellite phones.*	**2**	Unlikely by 2030 and 2070.	**2**	Minor for 2030 and 2070 from minor local communication disruption and minor restoration works.
Loss of sanitation 	**Low (2)**	**Low (2)**	Loss of sanitation from salt water intrusion into treatment ponds and into underground septic tanks caused by increased sea level rise and storm surge. *Low influence for sanitation assets.*	**1**	Rare by 2030 and 2070.	**2**	Minor for 2030 and 2070 from slight adverse health effects and impacts on amenity.

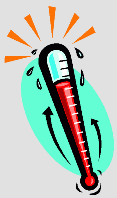
8.3 Emergency Management and Extreme Climatic Events

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damage from greater intensity cyclone 	**High (15)**	**Extreme (20)**	With climate change the intensity of cyclones is expected to increase with climate change (Note: the overall number of cyclones is projected to decrease). The last cyclone to hit Wagait was Tracy (Category 3) in 1974. *Relatively high control as there is a specific emergency management plan, a communication room and some emergency exercises (one to two per year). In case of a cyclone coming, volunteers would go around the community and check who is here. There are no clear recommendations in terms of "stay and defend" or "leave" when a cyclone is coming.*	**3** **4**	Possible by 2030. An increase in the intensity of cyclones is likely by 2070.	**5**	Catastrophic – A category 4 or 5 cyclone would result in great damage to Wagait community with widespread infrastructure damage, significant loss of environmental amenity and severe adverse human health impacts.
Damage from bushfire	**Medium (6)**	**Medium (9)**	Climate change could increase the likelihood of bushfire because of warmer and drier conditions. There have not been significant bushfires in Wagait over the past 30 years. Bushfire is not currently considered as an issue. *Moderate control as the community and Council conduct slash burning around Wagait to control fuel loads. There is a local fire fighting unit with two fire trucks and some volunteers.*	**2** **3**	Unlikely by 2030. Possible by 2070 due to increase in air temperature, possible decrease in rainfall and potential extension of the dry season.	**3**	Moderate for 2030 and 2070. Extended bushfire could damage significantly houses and infrastructure. Loss of species and simplification of habitats as a result of increasing fire frequency is well documented in many areas of the Australian continent, including the NT.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Flooding 	Medium (9)	High (12)	Potential increased in flood proneness as the drainage network is converging to one drain and flowing in the ocean. SLR would limit or even suppress the ability of this drain to evacuate water. *Moderate control. The Council is currently managing the drainage network to keep free of weeds and sediments (annual cost of around $ 20,000). However the drainage network might need to be upgraded to take into account rising sea levels.*	3 4	Possible by 2030 because of SLR and potential increase in heavy rainfall events. Likely by 2070 due to more pronounced SLR and potential increase in heavy rainfall events.	3	Moderate by 2030 and 2070 as flooding becomes more frequent and change from being just a nuisance flooding to a more damaging and long lasting flooding.
Storm surge 	High (12)	High (16)	No significant storm surge has occurred in Wagait over the past 20 years. With rising sea level, storm surge height is likely to increase. A study (ACE CRC, 2008) suggested that a sea-level rise of 0.5 m would result in a multiplying factor of 1,000 for the increase in the frequency of occurrence of high sea-level near Darwin. *No control. The Council does not have any control in terms of land use planning.*	3 4	Possible by 2030 because of SLR. Likely by 2070 due to more pronounced SLR.	4	Major as key infrastructure (ferry pier, electrical sub-station, etc.) would be damaged. Some houses could also be damaged.

8.4 Public health

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Mosquitoes and vector borne disease 	**Low (4)**	**Low (4)**	There are always lots of mosquitoes and sand flies (biting midges) around Wagait. The highest numbers of biting midges occur around the time of the full moon and to a lesser extent around the new moon, particularly from August to November Salt Marsh mosquito (*Aedes vigilax*) numbers are high from August through January, particularly following high tides greater than 7.8m.(Whelan and Kurucz 2010). Some literature (Russell 2009) indicates that higher temperature with similar or lower humidity level could decrease mosquito's population through desiccation. Potential malarial zones are expected to shift because of climate change (and shift in the zones where the vectors occur) but are unlikely to establish permanently in Australia (McMichael et al. 2003). *There is no mosquito control program at Wagait (e.g. spraying). As part of the cyclone clean-up, old tyres and drums are collected from backyards but there are too many wetlands, swamps and drains to make a significant difference.*	**2**	It is unlikely that biting insects' population will change dramatically by 2030.	**2**	Minor – Mosquitoes and biting midges mainly result in discomfort through bites. Some bites can become infected especially with young children. *Aedes vigilax* is regarded as the most important pest mosquito in the Top End because of its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in plague proportions. *Aedes aegepty* can carry disease (dengue fever) and represent a greater danger.
				2	It is unlikely that biting insects' population will change dramatically by 2070.		

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Heat related illness (including heat stress) 	High (12)	High (15)	Climate change is very likely to result in warmer air temperatures (mean and maximum temperature). It is also expected that hot spells and heat waves will become more frequent. During hot spells and heat waves morbidity increase with higher risks of heat stress, rashes and cramps and potentially fatal heat stroke. Young children and elderly are particularly at risk. People suffering medical conditions such as obesity, cardio-vascular and renal disease and alcohol dependence are also more exposed to heat related illness. Dehydration can have serious consequences on the renal system. *Low to moderate control – People in tropical areas are generally accustomed to high temperature all year round and are less sensitive than the population in southern Australia. However this can lead to a false sense of safety to extreme temperatures especially because of prevalent health conditions in the community. All the Council's buildings are equipped with air conditioning as well as many individual houses.*	4 5	Highest air temperature (minimum, mean and maximum) is likely by 2030. Highest air temperature (minimum, mean and maximum) is almost certain by 2070.	3	Moderate – Even if tropical communities are more resilient to heat stress and heat waves, it is expected that warming associated with climate change will result in temperatures exceeding historical values.
Airborne and dust related illness	Low (2)	Low (2)	All roads in Wagait are sealed; when bushfires occur the smoke is blown away by the prevailing winds. An increase in bushfire could increase the exposure of the Wagait community to bushfire smoke although it is quite unlikely.	1	Rare by 2030 and 2070.	2	Minor – Changes in dust and bushfire conditions are unlikely to be insignificant and would affect a small portion of the population.

8.5 Natural Environment and Culture

<table>
<tr><th>Risk Title</th><th>Risk Rating 2030</th><th>Risk Rating 2070</th><th>Risk Description</th><th colspan="2">Likelihood</th><th colspan="2">Consequences</th></tr>
<tr><td rowspan="2">Salt water intrusion into freshwater waterways and billabongs
</td><td rowspan="2">Medium (9)</td><td rowspan="2">High (16)</td><td rowspan="2">With climate change sea level rise and the height of storm surge is expected to increase.
There is some natural resilience in ecological systems with regard to saltwater intrusion however increasing numbers of intrusion events and/or increasing intensity of intrusion events would erode this resilience and the system would be affected
The control over saltwater intrusion would be very limited. Although there are engineering solutions available, the cost of these would be difficult to justify given the intrinsic and unquantifiable value of freshwater ecosystems to social, cultural and health outcomes in communities.</td><td>3</td><td>Possible by 2030.</td><td>3</td><td>Moderate impacts by 2030 and increasingly affected by 2070. Ecological consequences would include loss of freshwater species; e.g. in Paperbark swamps.</td></tr>
<tr><td>4</td><td>An increase in sea level and the intensity of cyclones is likely by 2070.</td><td>4</td><td>Major impacts on freshwater systems which play an important role (to date unquantified) in the social, cultural and economic life of the community. They represent a food source (e.g. turtles) as well as a key element in recreational activities.</td></tr>
<tr><td>Increased pollution from landfills</td><td>High (12)</td><td>High (12)</td><td>Increased inundation of waste management facility leading to contamination of groundwater, soil and surrounding connected landscape.
Moderate control due to ability to move waste management facility to a more appropriate location. Currently minimal management – poorly sited – often rubbish is burning or flooded.</td><td>4</td><td>Flooding is likely to increase over time by 2030 and 2070.</td><td>3</td><td>Moderate impact as population (and waste) increases and as flooding events increase. Contamination impacts to natural environment and human health are moderate.</td></tr>
</table>

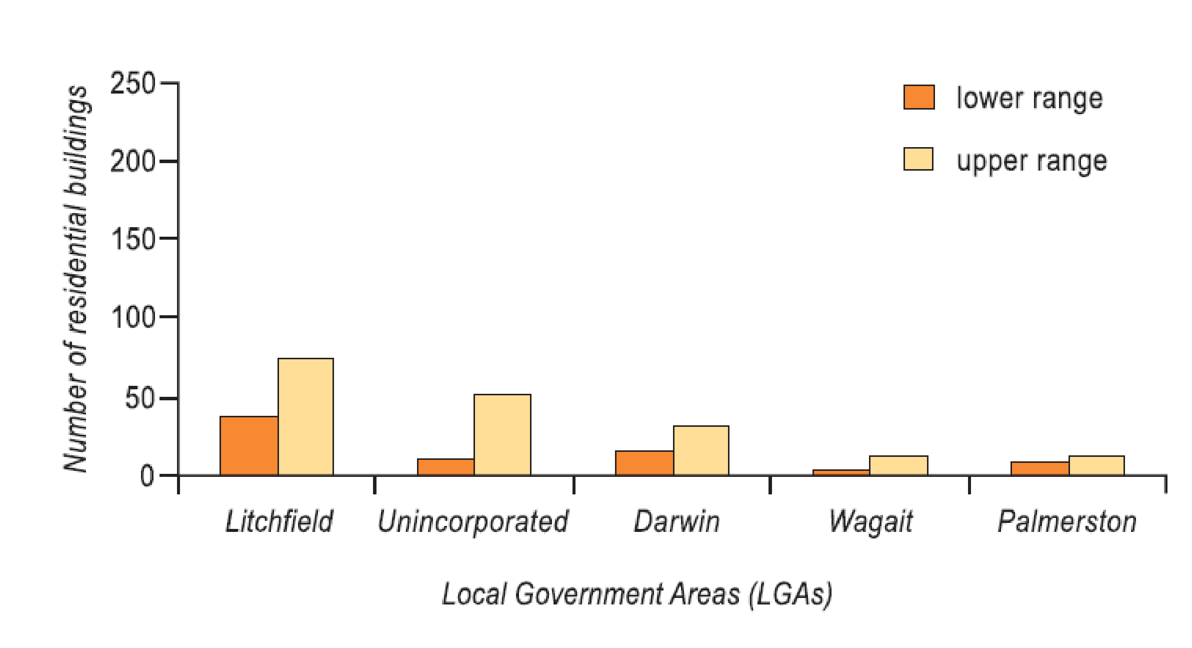
Box 4: Climate Change Risks to NT's Coast

The first pass national assessment of *Climate Change Risks to Australia's Coast* is one of the key actions identified in the *National Climate Change Adaptation Framework* endorsed by the Council of Australian Governments in 2007. This report released by DCC in 2009 examined the impacts of SLR on the Australian coastline.

Each State and Territory was considered as part of this assessment. Chapter 5.1.8 looked more specifically at the NT. Most of the NT is constituted of muddy shores (mainly muddy tidal flats and mangroves). This type of coast is very dynamic and tends to recede and over washed during extreme events.

The assessment used a worst case scenario of 1.1 m SLR. The local government area of Litchfield present the highest number of buildings potentially inundated as a result of SLR. It is expected that around 3.5% of the buildings in Wagait will be inundated with a 1.1 m SLR. Figure 15 is showing the number of residential buildings potentially inundated for the different areas considered in that study, including for the Wagait area.

Figure 15 – Estimated number of existing residential buildings in the Northern Territory at risk of inundation from a sea-level rise of 1.1 metres. The 'Unincorporated' area surrounds the LGAs of Darwin, Litchfield and Palmerston. (DCC 2009).



Source: DCC 2009b

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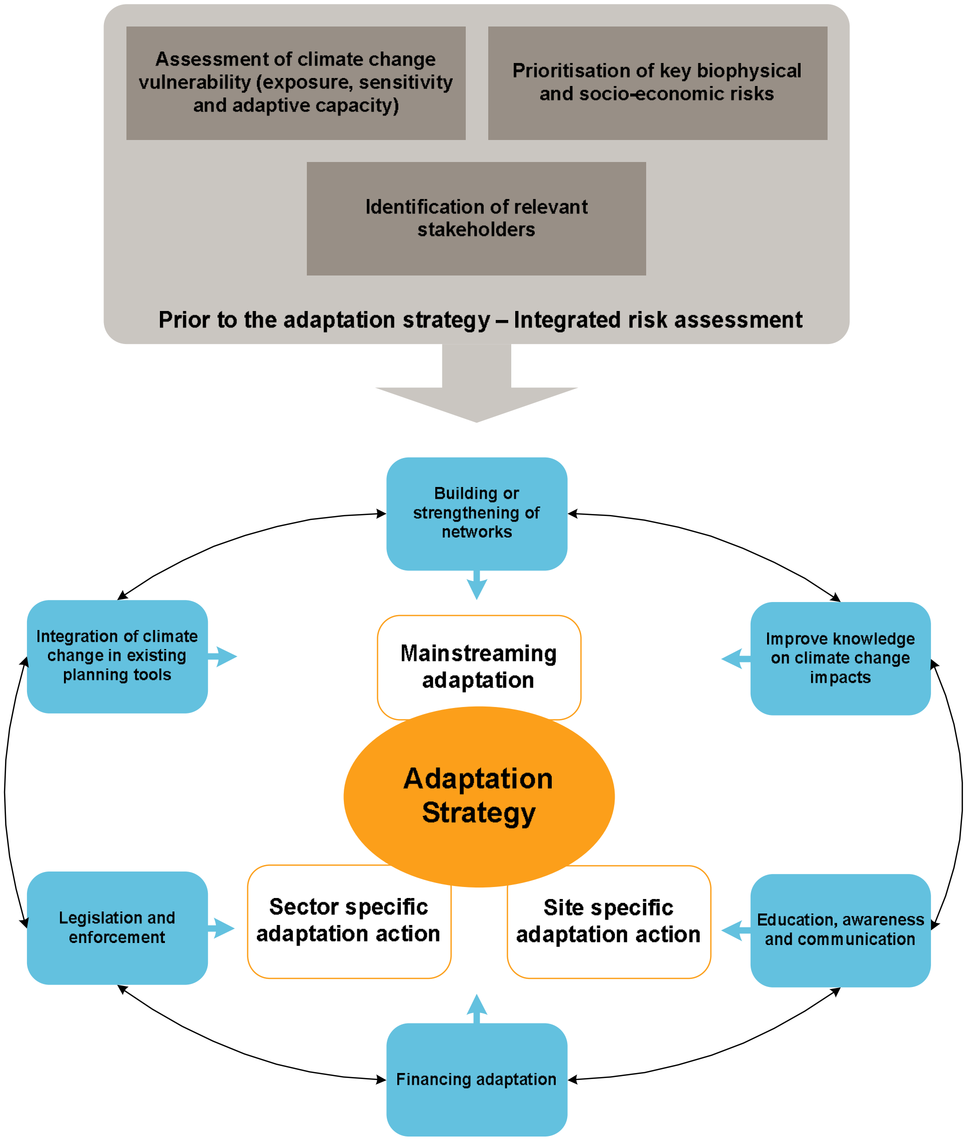
Part 4 – Towards Adaptation: Responding to Climate Change

9.0 Adaptation Strategy and Adaptation Options

9.1 Overall approach

The integrated risk assessment performed by AECOM is the first step toward an adaptation strategy. As outlined in Figure 16 the adaptation process is a cross-sectoral and multi-disciplinary approach.

Figure 16 – Strategic Planning Process for Climate Change Adaptation



This approach shows that as well as adaptation options that can be implemented for site specific or eventually sector specific issues there is a strong need for "mainstreaming" climate change adaptation. Mainstreaming adaptation means that climate change adaptation is integrated in all relevant Council policies and documents. An adaptation strategy often combines hard adaptation options (such as sea walls or infrastructure related solutions) and soft adaptation options (such as awareness program, re-vegetation actions, etc.).

The Council could consider developing an adaptation strategy to prepare for the inevitable impacts of climate change which have been discussed in Section 8.0. This strategy could explore the adaptation options shown in Section 0. One of the most important steps of this process is the community understanding, acceptance and ownership of the process. An adaptation strategy needs to be built on local knowledge and tailored to the available resources and local conditions.

9.2 Barriers to Adaptation

9.2.1 Little Climate Change Awareness within the Community

There was some awareness of climate change within the community prior to this project's workshops. While there was no questioning of the consequences of climate change there was more debate on the causes of the phenomena. This climate change risk assessment project contributed to improve the Wagait's community understanding of climate change but there is still a need for better awareness and education on climate change issues.

9.2.2 Lack of Resources

The Council has limited financial and human resources. There are few economic activities generating wealth and revenue within the Wagait area. Furthermore there are relatively limited human resources within the Wagait Shire Council. This lack of resources represents a significant constraint for any adaptation actions. Most adaptation options will rely on external and possibly once-off funding.

9.2.3 Lack of Statutory Control over Planning by the Wagait Shire Council

The Council does not have any statutory control over land use planning. Land use planning in the area is the responsibility of the NT Government (Department of Lands and Planning). This lack of control over land use planning aspects is greatly reducing the ability of the Council to develop adaptation measures.

9.3 Adaptation options

The risk assessment, community workshops, stakeholder engagement, literature review and AECOM experience informed the development of these adaptation options. Adaptation options have been developed for all Medium, High and Extreme risks identified in the previous section. The options are grouped in the following themes below:

A) Raising awareness of climate change

B) Improve awareness of heat related illness

C) Incorporate climate change into procurement

D) Improve resilience of infrastructure for the community

E) Prepare a Council position paper on climate change

Each theme explores relevant adaptive capacity and identifies one or more adaptation options. These adaptation options are prioritised in section 8.4.

Raising awareness on climate change

In order to build resilience to climate change impacts it is important that the local community is made aware of the expected impacts of climate change on their community. Building greater community appreciation of the potential climate change impacts will help mobilise community support for adaptation activities and as such create an informed and responsive local community' Public awareness and education programs involving community representatives could help convey information about the impacts of climate change and gain consensus on the adaptation options. Of special importance would be awareness efforts aimed at engaging communities in a manner that is culturally sympathetic and and which integrates cultural knowledge and traditional practices as part of the adaptation solution.

Adaptive capacity

The participants to the Wagait workshop showed a good understanding of climate change issues. The community should be relatively easy to target in terms of awareness program.

Option 1

Develop and deliver a community education and awareness program to build community resilience.

Improve awareness of heat related illness

There is a need to continue building awareness of the impacts of increased occurrence of higher temperature days on people, particularly on the elderly and young. Education on the prevention and response approaches need to be incorporated into the health services for this community (e.g., increased hydration on hot days).

Adaptive capacity

The community has well developed behavioural and cultural responses to manage heat stress. However this is sometimes seen as obstacles as tropical communities are “accustomed” to heat stress events and sometimes do not seriously consider this as a risk.

Option 2

Incorporate increased heat wave related illness into education provided by health services to the community.

Incorporate climate change into procurement

The procurement process is an important point of leverage to include climate change in relevant infrastructure, technology and services tenders and contracts. Infrastructure and technology are usually designed for long life times and will be impacted by climate changes such as flooding and sea level rise during their design life.

Adaptive capacity

There is currently very little guidance available from the Federal or Northern Territory Government on the incorporation of climate change into procurement for infrastructure and services.

Option 3

Use procurement process to screen investment to address climate change risks to infrastructure and services.

Improve resilience of infrastructure for the community

There are several infrastructure upgrades that will be required over time to respond to climate change. These include drainage infrastructure, community water supply tanks and electrical sub-station. Other assets such as roads, houses and community facilities would ideally need to be designed to cope with future climate conditions not just past conditions.

Adaptive capacity

The existing water access arrangements to groundwater are sufficient in the short to medium term, but could require new well locations in the longer term.

Option 4

Include climate change considerations in the upgrade, design and development of key community infrastructure.

Option5

Seek resources for additional upgrade of the drainage network.

Option 6

Engage in a dialogue with Power and Water Corporation (PWC) to discuss potential upgrade or relocation of the electrical sub-station and the community water supply tank.

Improve protection against storm surge and SLR

Increase in storm surge height has been highlighted as a significant risk for the Wagait. The National Coastal Vulnerability Assessment (DCC 2009) highlighted that up to 3.5% of Wagait residential buildings would be inundated with a 1.1 m SLR. The response should consider engineering solutions (defend or manage) and natural system and land use planning solutions (adapt or retreat).

Adaptive capacity

There is a very limited adaptive capacity as the Council does not have any control over land-use planning.

Option 7

Identify potential engineering solutions for the most threatened areas and integrate SLR and storm surge risks in land-use planning.

Prepare a position paper on climate change to engage with other institutions

Land-use planning is one of the most important aspects of climate change adaptation but Council does not have control over land-use planning. Additionally a number of the risks likely to be exacerbated by climate change are outside of the Council's control. Therefore the Council could prepare a position paper and use it a support material to influence other levels of government.

Adaptive capacity

There is a very limited adaptive capacity as the Council does not have any control over land-use planning.

Option 8

Prepare a Council's position paper (using this report) to engage in dialogue and influence other institutions which have control over some risks and adaptation needs.

9.4 Prioritising of Adaptation Options

AECOM used the adaptation options prioritisation framework below to analyse and compare the different adaptation options that could be implemented to address key climate change risks. Table 15 describes the indicative analytic framework for adaptation options while

Each category of adaptation prioritisation is weighted with the following scoring: High = 3 points; Medium = 2 points and Low = 1 point. The exception to this is the weighting for Effectiveness and Cost which is High = 6 points; Medium = 4 points and Low = 2 point. The results of the scoring are highlighted in Table 16.

These scores have been added up into a total score for each adaptation option. The options were then ranked in order of priority as shown in Table 17.

The highest four options related to awareness and education programs; focusing on supporting the community to explore solutions for themselves for maintaining the community and garden and dam and updating emergency management planning for extreme climatic events such as cyclones.

The next level of prioritised options focused on protecting the natural environment and reducing pollution from the landfill. The options for adapting infrastructure and seeking funding for new infrastructure for adaptation such as cyclone shelters are necessary to address the climate change risks identified for the Council but will take longer to implement.

This proposed ranking of the adpatation option should ideally be interrogated and amended by the Council in consultation with the Wagait community. The Council may for example score some other categories such as “Speed” or “Human Capability” with a higher weighting as a mean to determine the priority options that meet a particular policy and planning need.

Table 15 – Indicative adaptation options analytic framework

	High	Medium	Low
Effectiveness	High potential to reduce risk	Moderate potential to reduce risk	Potential to reduce risk is low or uncertain
Cost	No additional budget is required / Low costs	Additional budget is required but can be covered by Council's budget / Medium costs	Additional budget is required and involves complementary external funding / High costs
Speed	Can be completed within the next 12 months	Can be completed in the medium term (1-3 years)	Long term actions (3+ years)
Technical Feasibility	Proven adaptation approach / Widespread technical skills	Limited application of adaptation approach to date / Moderately available technical skills	Adaptation approach not applied to date / Niche and rare technical skills
Human Capability	Capability exists within Councils	Some external expertise or support is required	Delivery is dependent on external expertise
Consistency with Council Policy and Planning	Adaptation option fits with existing Council's planning and policy	Adaptation option could fit with existing Council's planning and policy	Adaptation option would require new Council's planning and policy
Community Acceptance	Potentially no conflict with communities for implementation	Possible conflict with communities for implementation	Likely conflict with communities for implementation

Table 16 – Prioritised adaptation options

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Effectiveness	Medium	Medium	Medium	High	High	Low	Low	Low
Cost	High[3]	Medium	High	Low	Low	High	Low	Low
Speed	High	High	Medium	Low	Low	Low	Low	Low
Technical Feasibility	High	High	Medium	High	High	Low	High	High
Human Capability	Medium	Medium	Medium	Low	Low	Medium	Low	Low
Council Acceptance	Medium	High	Medium	High	Medium	Medium	Medium	Medium
Community Acceptance	High	High	Medium	Medium	Medium	Medium	Medium	Medium
SCORE	**23**	**22**	**20**	**18**	**15**	**15**	**11**	**11**
RANK	**1**	**2**	**3**	**4**	**5**	**5'**	**6**	**6'**

[3] Please note that the scoring of High in the Cost category does not mean the cost is high but rather that it rates high as a priority because the cost is minimal.

Table 17 – Prioritised adaptation summary

Priority Ranking	Prioritised Adaptation Options for Wagait Shire Council
1	*Develop and deliver a community education and awareness program to build community resilience. Option 1*
2	*Incorporate increased heat wave related illness into education provided by health services to the community. Option 2*
3	*Use procurement process to screen investment to address climate change risks to infrastructure and services. Option 3*
4	*Include climate change considerations in the upgrade, design and development of key community infrastructure. Option 4*
5	*Seek additional funding for additional upgrade of the drainage network. Option 5*
5'	*Engage in a dialogue with Power and Water Corporation to discuss potential reolocation of the electrical sub-station and upgrade of the community supply water tank. Option 6*
6	*Identify potential engineering, land use or natural system planning response to sea level rise and increased storm surge heights. Option 7*
6'	*Prepare a Council position paper on climate change to engage in a dialogue and influence other instiutions which have control over some risks and adaptation options. Option 8*

10.0 Conclusions

Even if effective policies are put in place to reduce greenhouse gases emissions, the climate system will continue to change for decades or even centuries. The climate appears to have changed in the Wagait area over the past three decades (warmer temperature, slight rainfall decrease during the dry season and increase during the wet, etc.). It is very likely to continue to change throughout the 21st century. Among other changes, climate change will bring even hotter temperatures, more intense cyclones and sea level rise. These changes in the climate will impact the natural environment, infrastructures and the Wagait people.

This assessment has highlighted a number of risks associated with climate change to which the Wagait community and Council are exposed in the midterm (2030) and long term (2070). As the Council has limited resources it is important that the risks are identified and prioritised.

The most threatening climate change risks include: a loss of access road, damages by intense cyclones and storm surge, heat related illness, damages to houses, loss of electrical and water supply infrastructure. These risks have been rated “high” or “extreme” not only because of the climate change impacts influencing these elements but also because of the importance of the threatened assets and services to the Wagait community.

Another series of risks have been assessed as “low” including risks to some infrastructures (sanitation and communication) and risks associated with airborne and dust related illness and mosquitoes and insect borne disease. These risks could be considered as “secondary” by the Council and not treated actively for the time being.

A number of adaptation options have been identified to address these climate change risks. These adaptation options include raising awareness on climate change within the community, improving disaster preparedness and within the area, including climate change in the Council procurement and targeting heat and biting insect related illness in a health awareness campaign.

These adaptation options need to be discussed by the Council in consultation with the community to determine which actions need to be implemented in the short term. The analytical framework proposed in this report could be used as a tool to help the Council consider and rate the different adaptation options. Regardless of the adpatation options selected for implementation, it is crucial that the community is involved in the decision making process and take ownership of the solution. No adaptation strategy can be effective without the involvment of the Wagait community and the consideration of local and traditional knowledge.

This project was the first step for the Wagait community to prepare for the inevitable impacts of climate change. It has provided the opportunity for the Council and the Wagait community to discuss and interrogate the issues associated with climate change. The scoping phase visit and the workshops contributed to raising local awareness of climate change. There was a genuine interest shown by the community to discuss climate change even if some confusion remained around the causes and the impacts brought by climate change.

It is recommended that climate change risks are revisited by the community in the future. These activities could be driven by “climate change champions” within the community.

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Appendix A

Climate Change Information

Emissions Scenarios

The IPCC emission scenarios are divided into four families (A1, A2, B1 and B2). A description of each scenario is given in Table 18.

Table 18 – SRES scenarios

SRES Scenario	Description of Scenario	
A1FI	Rapid economic growth, a global population that peaks mid 21st century and rapid introduction of new technologies	Intensive reliance on fossil fuel energy resources
A1T		Intensive reliance on non-fossil fuel energy resources
A1B		Balance across all energy sources
A2	Very heterogeneous world with high population growth, slow economic development and slow technological change	
B1	Convergent world, same global population as A1 but with more rapid changes in economic structures toward a service and information economy	
B2	Intermediate population and economic growth, emphasis on development of solutions to economic, social and environmental sustainability	

The IPCC developed scenarios in 1990, 1992 and 2000 (released as Special Report on Emission Scenarios, SRES). To reflect the last (and fast) changes of societies since 2000, new emission scenarios are currently under development.

Climate Projections

Table 19 presents more detail on the climate projections provided by the CSIRO for the region encompassing Darwin and the Tiwi Islands. This table shows two selected representative climate models (INMCM3.0 and CSIRO MK3.5) for an A1B emissions scenario for the year 2030; a B1 scenario for the year 2070 and an A1FI scenario for the year 2070 also. The climate model INMCM3.0 shows outcomes that are most likely (19 models agree) or likely (5 models) to occur. CSIRO MK3.5 shows a worst case scenario (1 to 3 models have indicated this change to climate).

Table 19 – Climate projections for the Darwin/Tiwi Islands Region (CSIRO 2010)

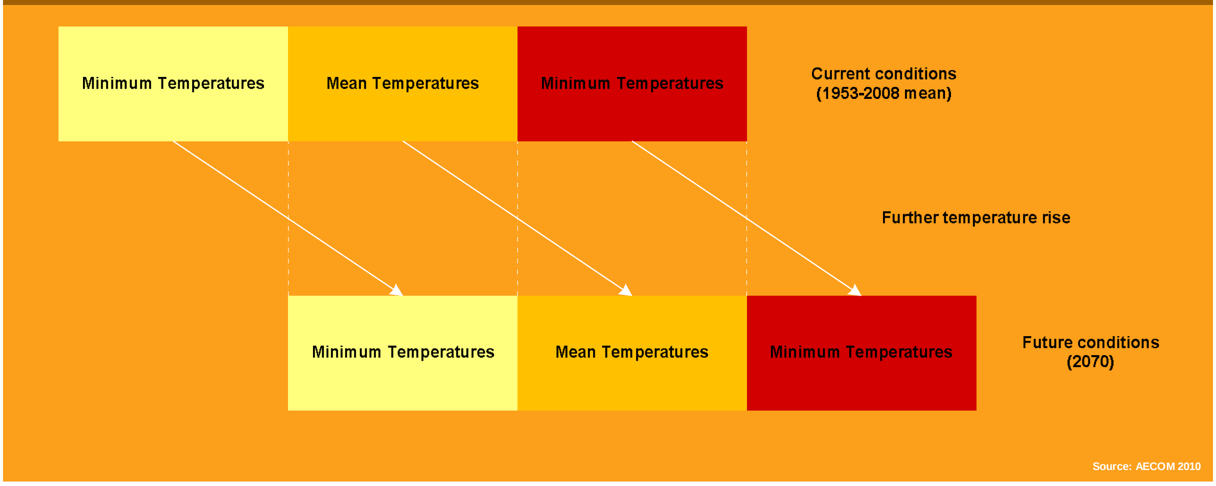
	Change in 2030 (A1B) with respect to 1990											
	Model	Mean precipitation			Mean surface temperature			Mean max surface temp	Mean min surface temp	Mean relative humidity		
Story		Ann	Wet	Dry	Ann	Wet	Dry	Ann	Ann	Ann	Wet	Dry
Most likely (19 models): Warmer - Little rainfall change	INM-CM3.0	-2.42	-1.07	-9.19	0.75	0.76	0.74	0.7	0.8	-0.67	-0.41	-0.86
Worst case (1 model): Warmer - Drier	CSIRO-Mk3.5	-6.60	-5.40	-29.80	0.94	0.95	0.93	0.96	0.91	-1.41	-1.1	-1.89

	Change in 2070 (B1) with respect to 1990											
	Model	Mean precipitation			Mean surface temperature			Mean max surface temp	Mean min surface temp	Mean relative humidity		
Story		Ann	Wet	Dry	Ann	Wet	Dry	Ann	Ann	Ann	Wet	Dry
Most likely (19 models): Warmer - Little rainfall change	INM-CM3.0	-2.60	-1.15	-9.85	0.8	0.81	0.79	0.75	0.86	-0.72	-0.43	-0.92
Worst case (1 model): Warmer - Drier	CSIRO-Mk3.5	-7.07	-5.79	-31.93	1.01	1.01	0.99	1.03	0.98	-1.51	-1.18	-2.02

	Change in 2070 (A1FI) with respect to 1990											
	Model	Mean precipitation			Mean surface temperature			Mean max surface temp	Mean min surface temp	Mean relative humidity		
Story		Ann	Wet	Dry	Ann	Wet	Dry	Ann	Ann	Ann	Wet	Dry
Likely (5 models): Much hotter - Drier	INM-CM3.0	-11.16	-4.94	-42.32	3.45	3.49	3.4	3.23	3.68	-3.08	-1.87	-3.96
Worst case (3 models): Much hotter - Much drier	CSIRO-Mk3.5	-30.38	-24.87	-137.18	4.32	4.36	4.26	4.43	4.21	-6.49	-5.08	-8.69

Temperature Shift

Box 5: Temperature shift

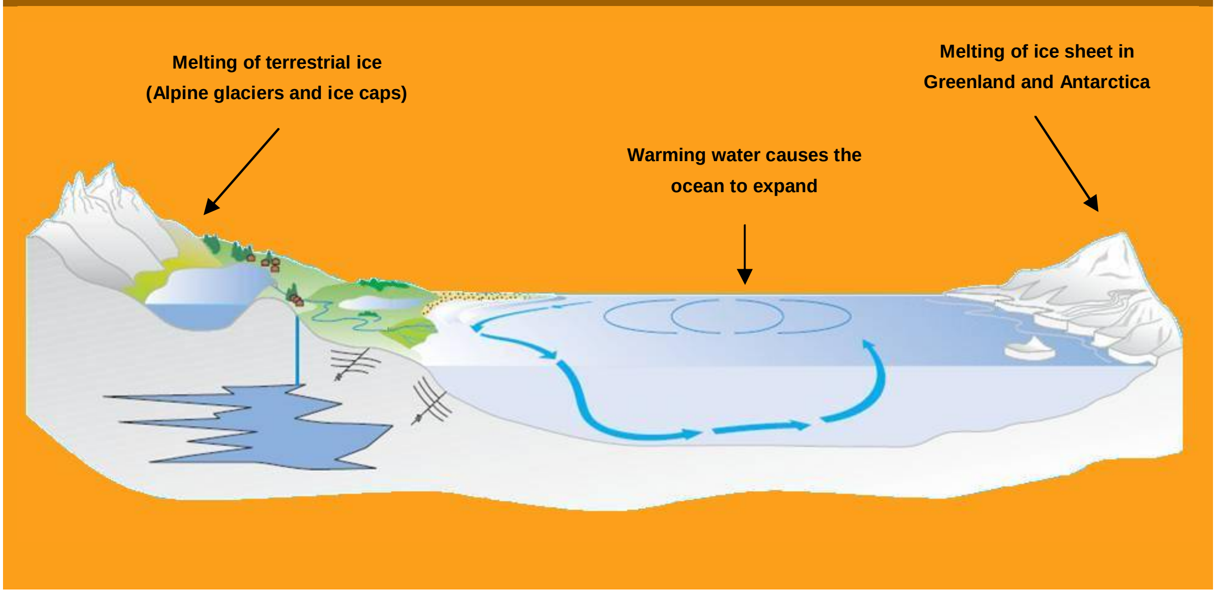


Sea Level Rise

Key Mechanisms

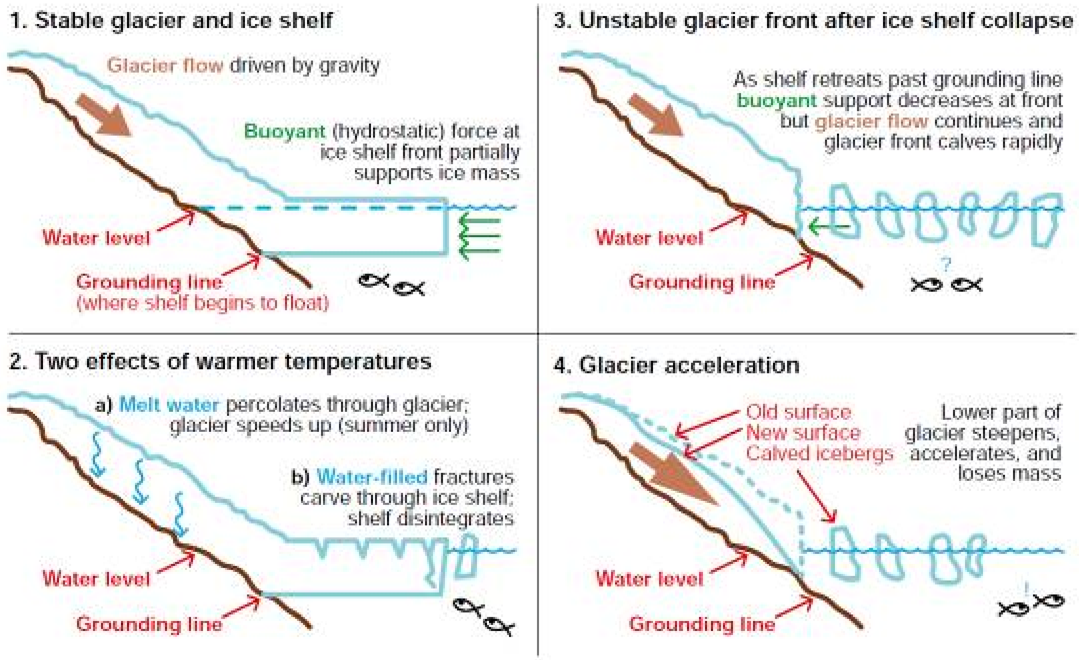
The observed sea level rise over the last 30 years is mainly the consequence of the thermal expansion of ocean water. As the water gets warmer, it expands and the global sea level rises. The melting of alpine glaciers and icesheets (in Greenland and Antarctica) are also contributing to this rise. The box below illustrates the sea level rise mechanisms.

Box 6: Sea level rise mechanisms



Glaciers and ice sheets are very dynamic environments with complex interactions and physical processes involved in their movement and melting. Researchers have recently highlighted a feedback effect where warming of the ocean and melting of ice due to warmer air temperature have the potential to accelerate the rate of melting the Greenland and Antarctica ice sheet as well as some glaciers that directly reach the sea. An overview of the process for glacier and ice shelf interactions with a warming and rising level of sea is provided in Figure 17.

Figure 17 – Glacier and ice shelf interactions and melting processes (DCCEE 2009)



Global Observations

Sea level rise has occurred at a global mean rate of 1.7 mm per year for the past century, and more recently at rates estimated near 3.1 ± 0.7 mm per year (1993-2003) (Bindoff *et al. 2007)*. Current sea level rise is considered to be at least partly due to human-induced climate change which is expected to continue to increase sea levels this century. Increasing temperatures contribute to sea level rise due to the thermal expansion of water and the addition of water to the oceans from the melting of terrestrial ice sheets. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) (2007) estimated sea level rise of 0.19-0.59 m by 2100, plus an additional 0.2 m from the potential melting of Greenland and Antarctic ice sheets.

Key developments that have occurred since the publication of the AR4 include:

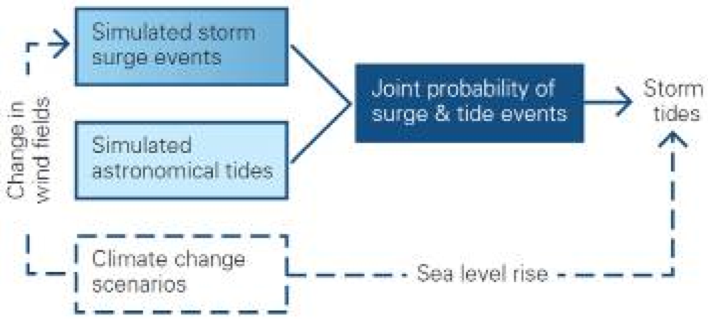
- Global emissions of carbon dioxide have accelerated rapidly since approximately 2000, consistent with the high-end emission scenarios. The Garnaut Climate Change Review suggests that global emissions will exceed the highest IPCC scenarios under a business-as-usual scenario (Commonwealth of Australia, 2008).
- Sea level has been rising at close to the upper end of the IPCC projections (Church et al. 2004, p7):
    - “Sea level observed with satellite altimeters from 1993 to 2006 and estimated from coastal sea-level measurements from 1990 to 2001 are tracking close to the upper limit of the TAR [Third Assessment Report] projections of 2001, which included an allowance for land–ice uncertainties. Recent altimeter measurements indicate sea level is continuing to rise near the upper limit of the projections.
    - Recognising the inadequacies of the current understanding of sea-level rise, simple statistical models relating observed sea levels to observed temperatures have been developed and applied with projected temperature increases to project future sea levels. These have generally resulted in higher sea level projections for 2100, of up to 1.4 m.
    - There are suggestions that the glacier and ice cap contributions into the future may have been (moderately) underestimated.”
- Concern is escalating about the potential instability of both the Greenland and the West Antarctic Ice Sheets leading to a more rapid rate of sea-level rise than current models project. It is important to note that the uncertainties related to changes in the ice sheets are essentially one-sided: the processes can only lead to a higher rate of sea-level rise than is currently estimated (Church et al. 2004).
- Recent research indicates that the climate system, in particular sea level, may be responding more quickly to increasing global temperatures than current climate models projections. In particular, the IPCC were unable to exclude larger sea level rise values and there is emerging evidence suggesting the TAR may have underestimated the future rate of sea level rise (Rahmstorf et al., 2007).

Storm surge and climate change

Storm tide height may be significantly affected by climate change, with changes expected to be predominantly driven by sea level rise and to a lesser extent by changes in wind speed (Department of Climate Change, 2009). Increased wind speed due to climate change may also affect storm surge and storm tide heights. These changes are affected to increase inundation risk, which is best described as the likelihood of exceeding a given level of tide, surge and flood height over a particular time horizon. Frequency is traditionally measured as average recurrence intervals. However, this approach rests on the assumption that mean sea level will remain constant. Potential future sea level rise combined with increased wind intensity means that climate change is likely to increase the frequency of extreme sea level events.

The modelling of storm surge and extreme sea levels is improving, although CSIRO advise that to provide coastal managers and planners with more detailed information to address climate change, much higher resolution data sets defining coastal topography, bathymetry and meteorology, and detailed sea level and coastal ocean observations will be required (McInnes, Grady, Hubbert 2009). CSIRO's modelling of extreme sea levels takes account of sea level rise, storm surge and astronomical tides, but not local considerations such wave set up, wave run up and erosion or accretion of beach sediments (DSE 2010). CSIRO's modelling approach is illustrated in Figure 18, which has been applied in Victoria's Future Coasts Program. Modelling is not yet available for the Wagait Shire Council.

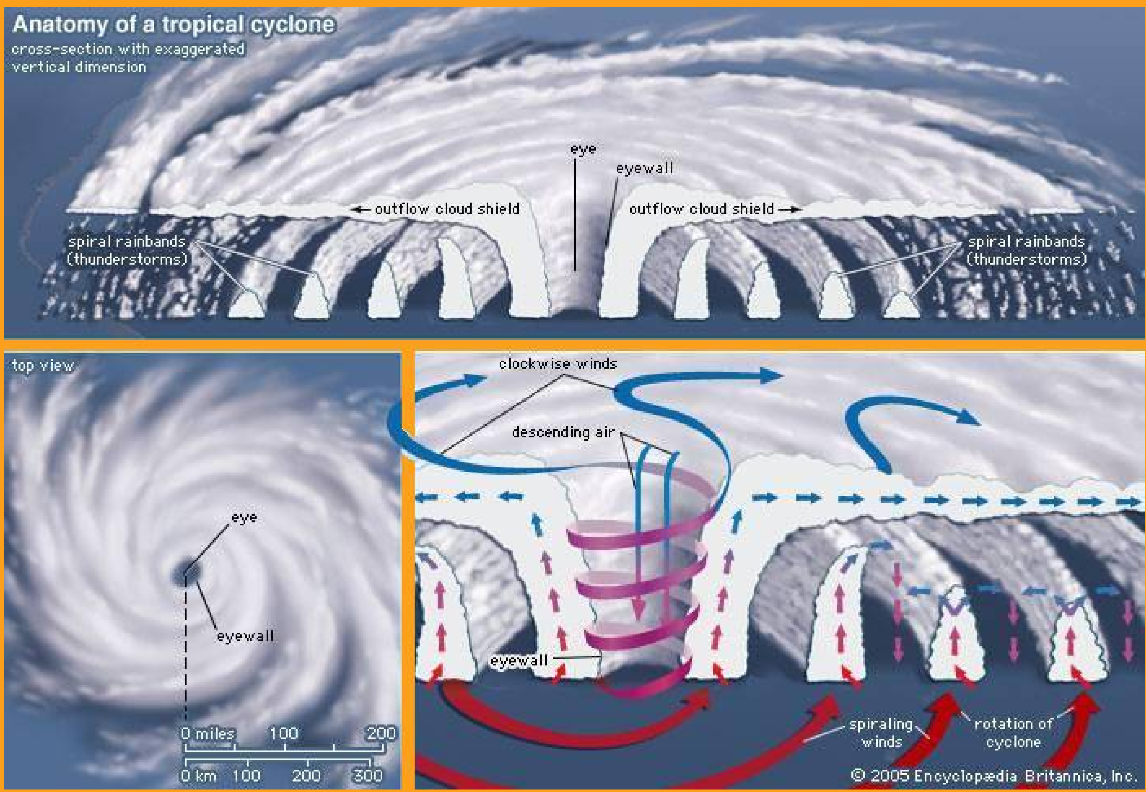
Figure 18 – An illustration of CSIRO's approach to assess potential climate change effects on extreme sea levels (DSE 2010)



Tropical cyclones

A tropical cyclone is defined as a tropical depression of sufficient intensity to produce gale force winds, i.e. at least 63 km/h. Tropical cyclones (TC) are called hurricanes in the North Atlantic and Typhoons in the North Pacific. This kind of event is not only dangerous because it produces destructive winds but also because it is associated with torrential rains (often leading to floods), storm surge and wild sea conditions. Generally, sea surface temperatures need to be at least 26.5°C to initiate a cyclone, although the cyclone can then move over colder waters.

Box 7: Tropical cyclone



Source: Encyclopaedia Britannica

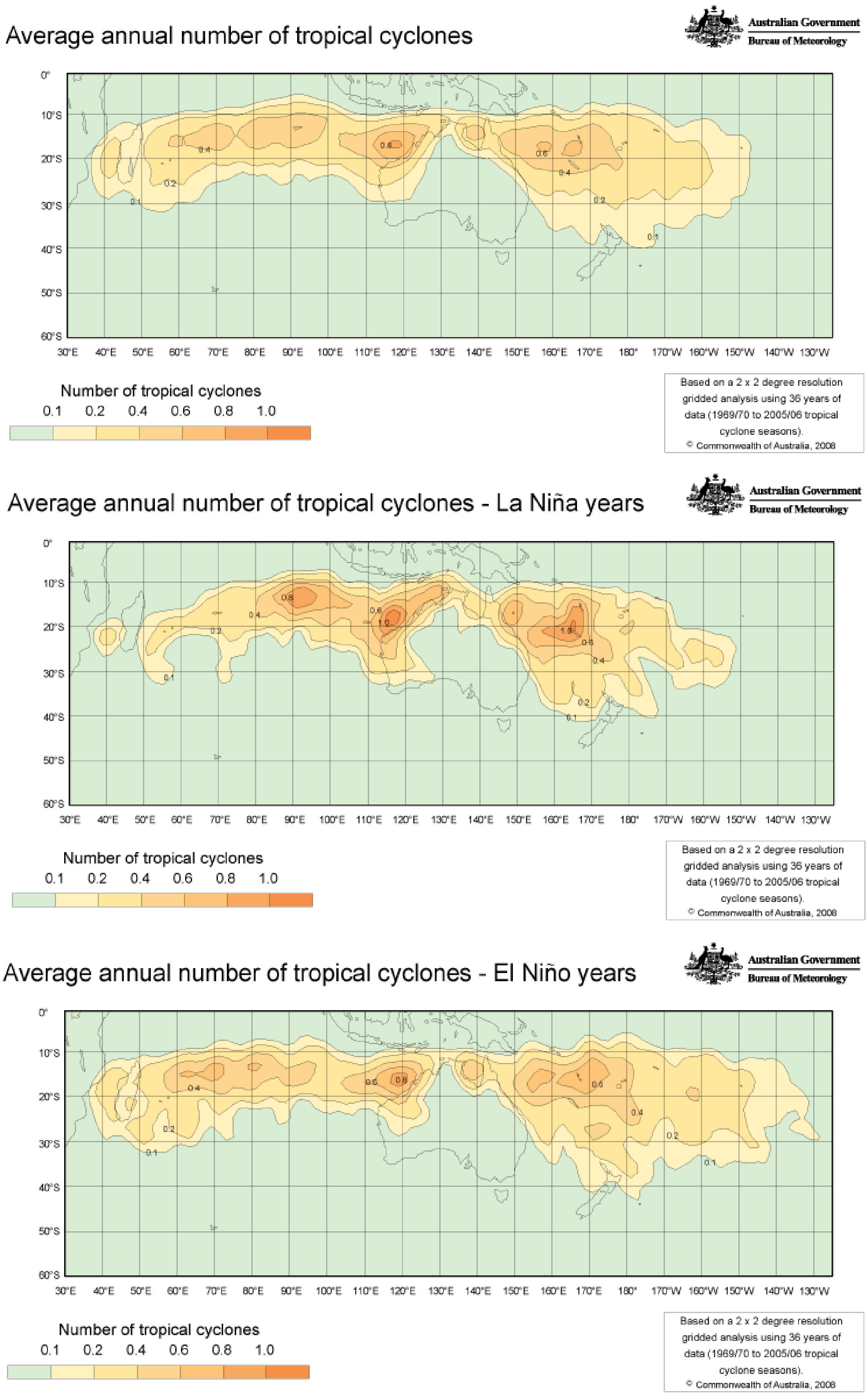
Cyclones are classified depending on the speed of their winds. An example of the classification is provided in Figure 19.

Figure 19 – Classification of the tropical cyclones based on BoM values

10 minutes sustained winds (knots)	BoM classification of tropical cyclones
< 28 (52 km/h) – 33 (61 km/h)	Tropical Low
34 (63 km/h) – 47 (87 km/h)	Tropical Cyclones (Cat. 1)
48 (89 km/h) – 63 (117 km/h)	Tropical Cyclones (Cat. 2)
64 (118 km/h) – 85 (158 km/h)	Severe Tropical Cyclones (Cat. 3)
86 (160 km/h) – 106 (196 km/h)	Severe Tropical Cyclones (Cat. 4)
107 (198 km/h) – 114 (211 km/h)	Severe Tropical Cyclones (Cat. 5)

In the eastern Indian Ocean region, the tropical cyclone activity is generally enhanced during La Niña events and lowers during El Niño events. Figure 20 shows the average annual number of tropical cyclones during normal years, La Niña years and El Niño years.

Figure 20 – Cyclone frequency for all years, La Niña and El Niño years (BoM 2010)

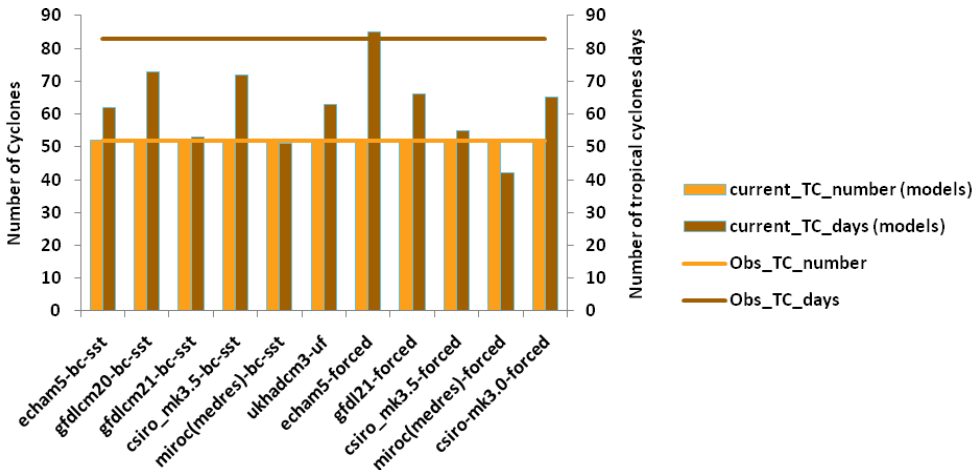


Projections

It has been assumed by scientists that in a warmer world the frequency of intense cyclones would increase. Indeed, the frequency of cyclones has increased over the North Atlantic but the trends are less clear for other cyclone regions (Indian Ocean, North and South Pacific). This is mainly because of the lack of robust data. Cyclones are a complex phenomena and their formation is the consequence of numerous factors. The sea surface temperature is important but the macro scale structure of the atmosphere also plays a significant role. Most models indicate a decrease of cyclones for 2030 and 2070. By the second half of the 21st Century, mechanisms associated with the structure of the atmosphere may induce a decrease of the cyclonic activity in this part of the world. For instance, a change in the vertical wind shear may decrease the number of cyclones formed and the life time of formed cyclones and an increase of the stability of the atmosphere would decrease the proneness to convection and to cyclone formation. CSIRO is still working to validate these assumptions and the current projections are associated with a significant degree of uncertainties.

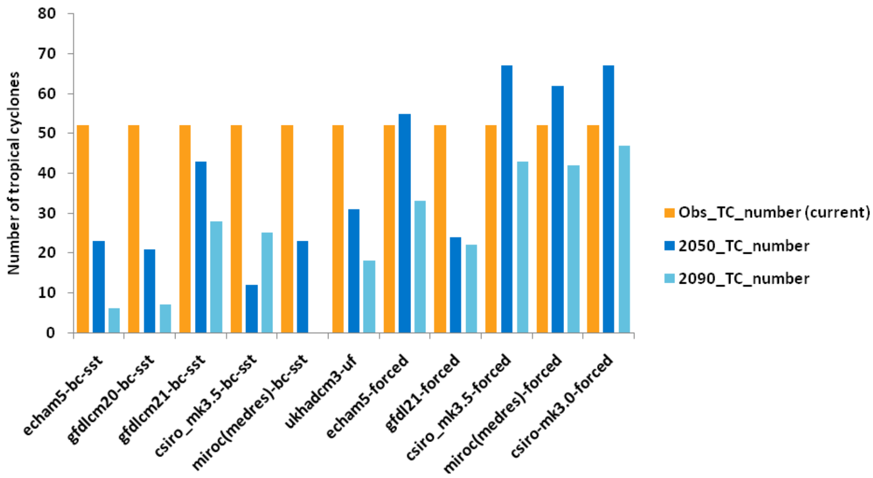
The climate models have a too large grid (200 kilometres on average) to propose an accurate evaluation of the future cyclonic activity. The projections proposed hereafter have to be considered as indicative only. They indicate direction of changes and the projected number of cyclones should not be considered as accurate forecasting of future situations. Figure 21 shows that all models have a good representation of the number of cyclone but have more difficulty representing the duration of these events.

Figure 21 – Cyclone frequency, observation vs. projections (CSIRO 2010)



As shown in Figure 22, most models indicate a decrease in the number of cyclone by 2050 and an even more significant reduction by 2090. However the proportion of intense cyclones (Category 4 and Category 5 is expected to increase).

Figure 22 – Cyclone frequency, observation vs. projections (CSIRO 2010)



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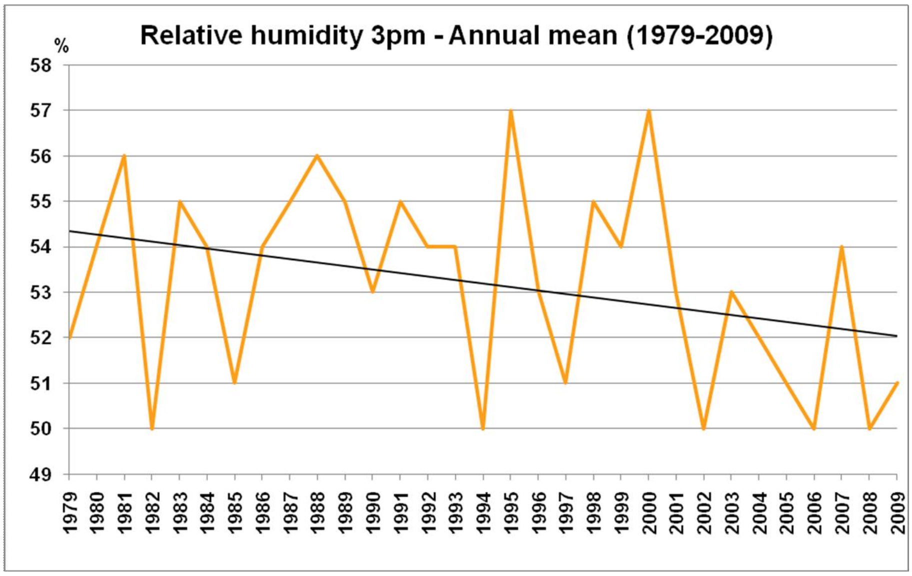
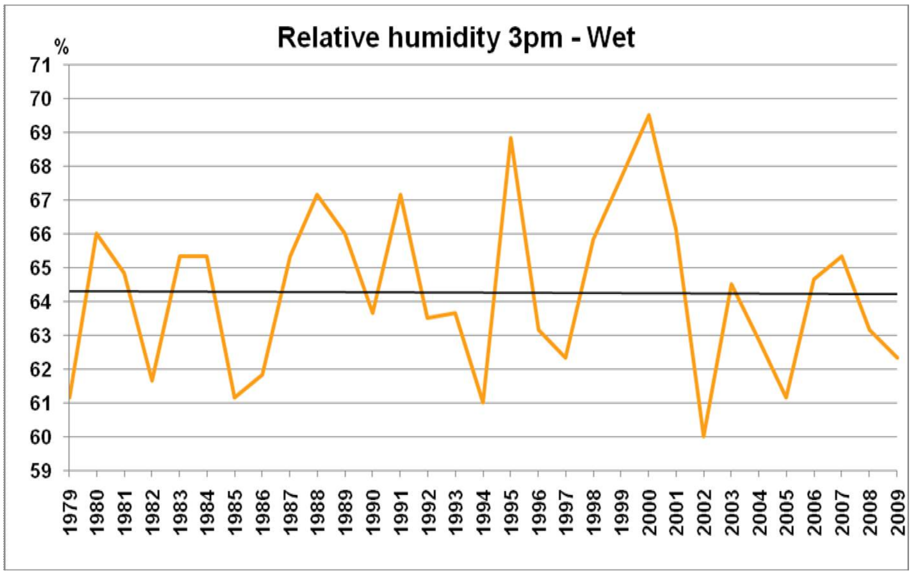
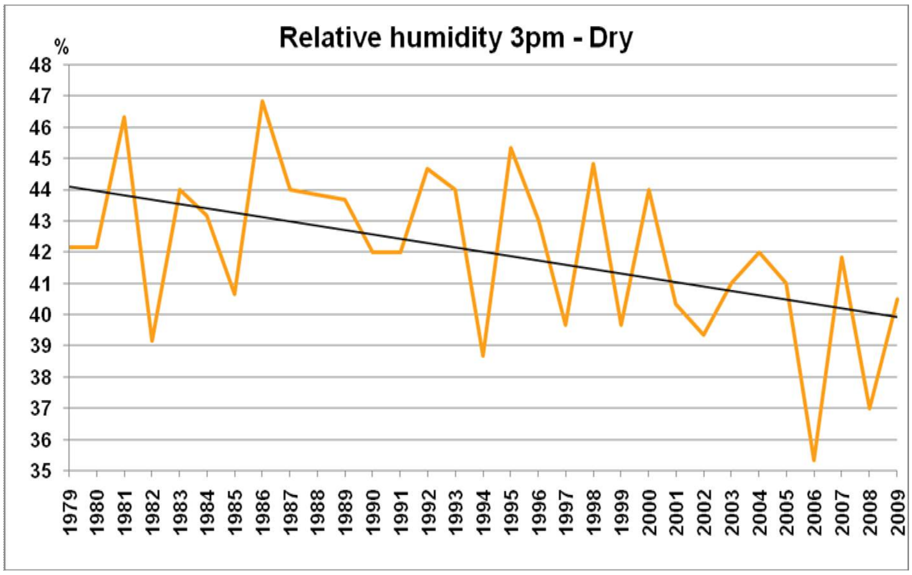
Appendix B

Climate Observations

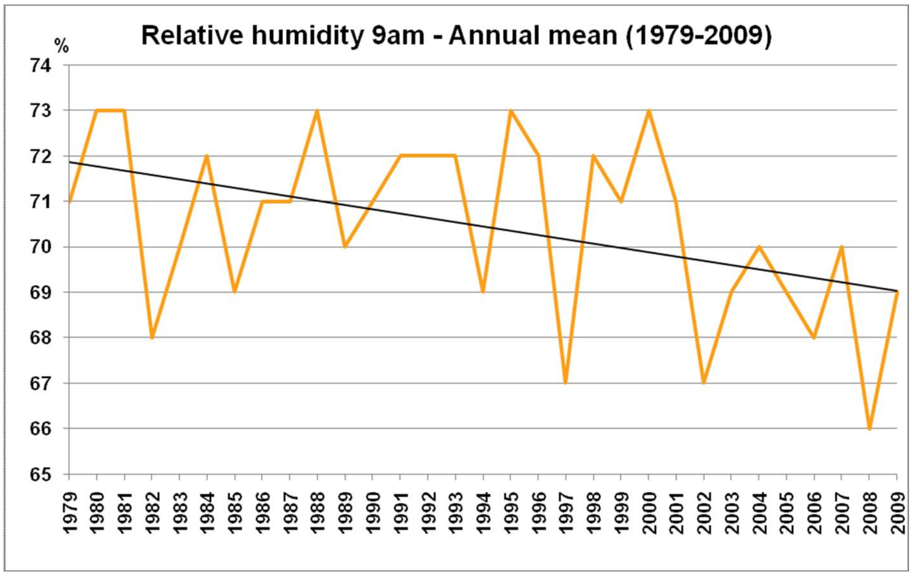
Relative Humidity 3pm

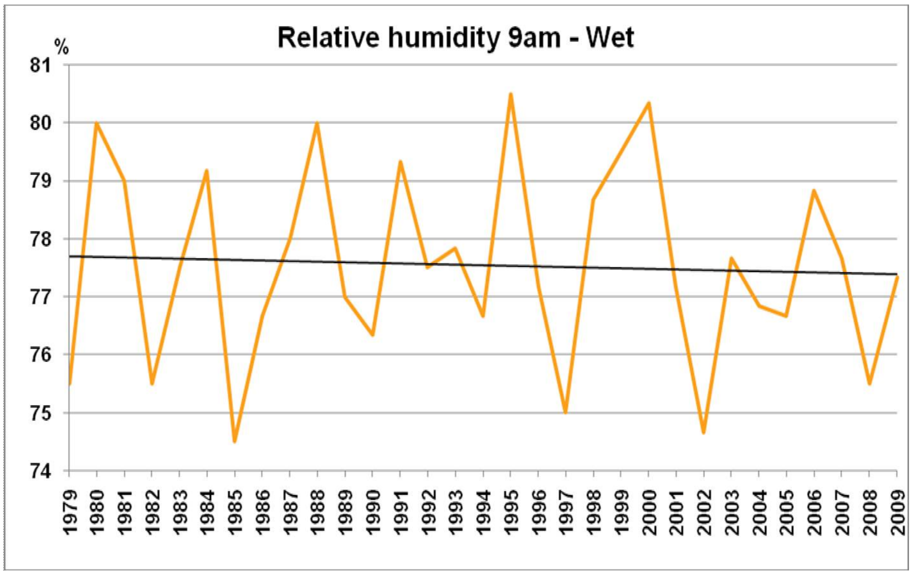


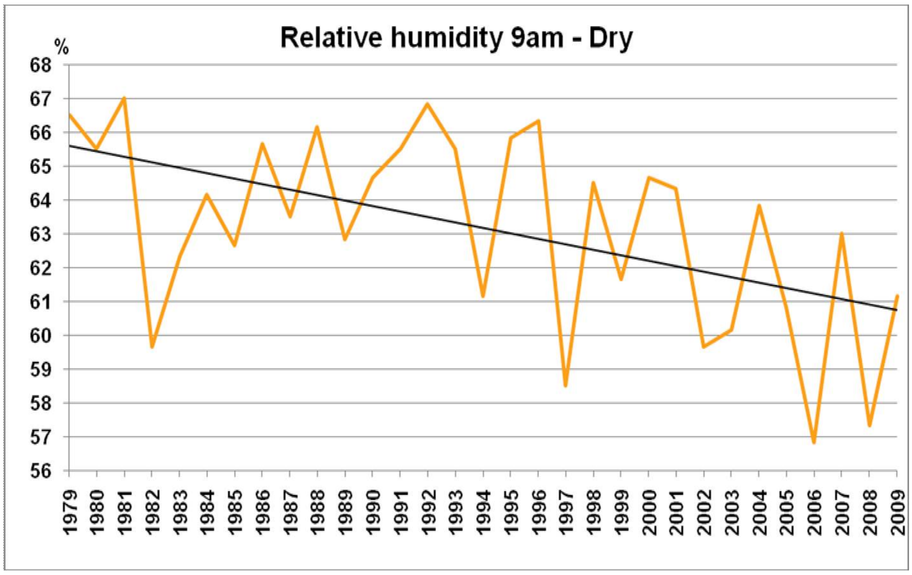




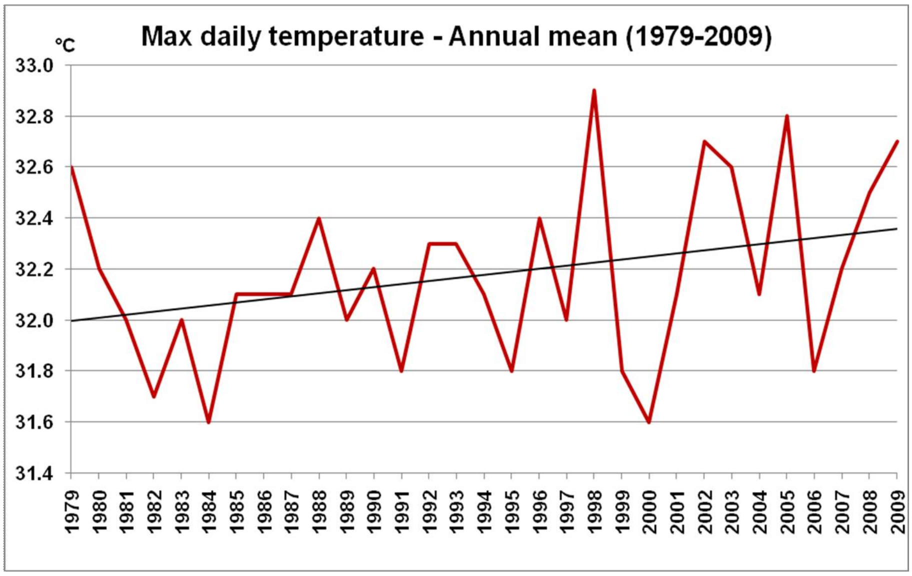
Relative Humidity 9am

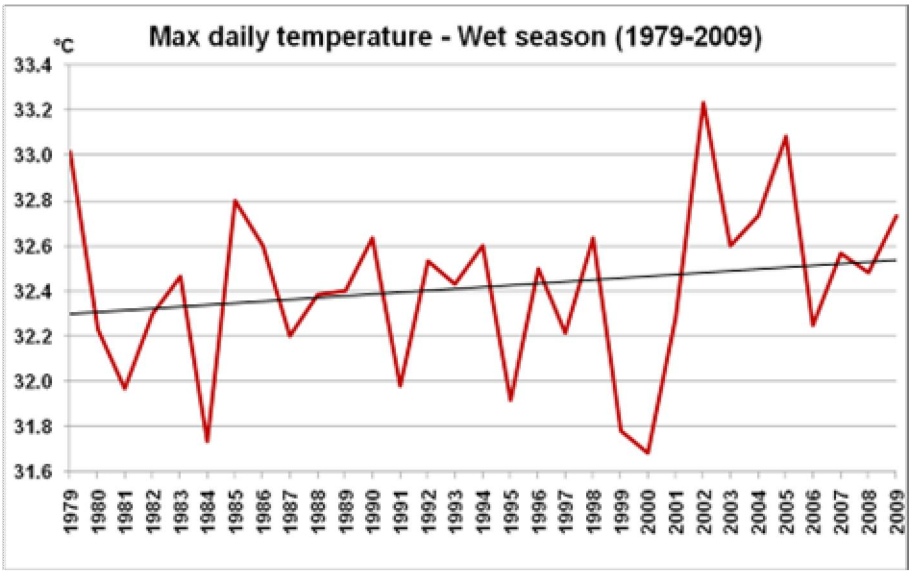


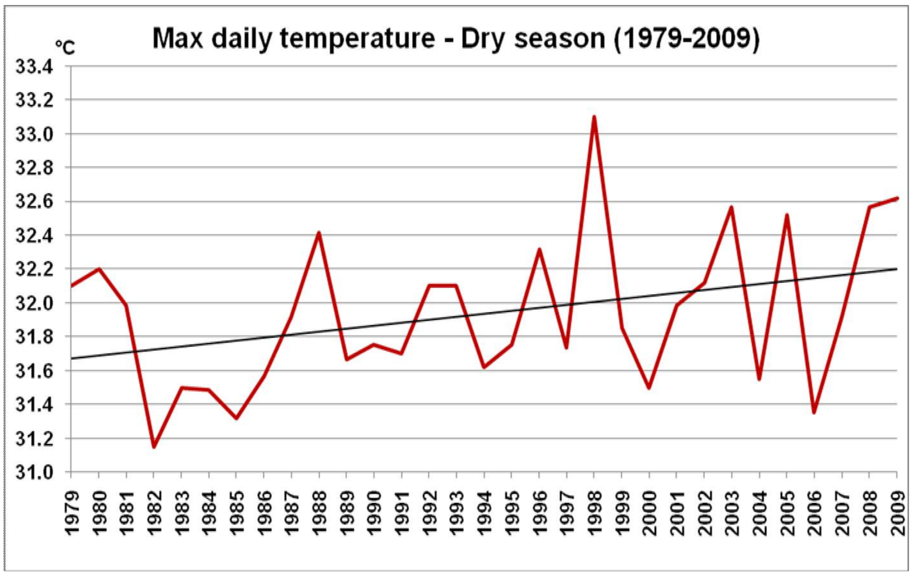




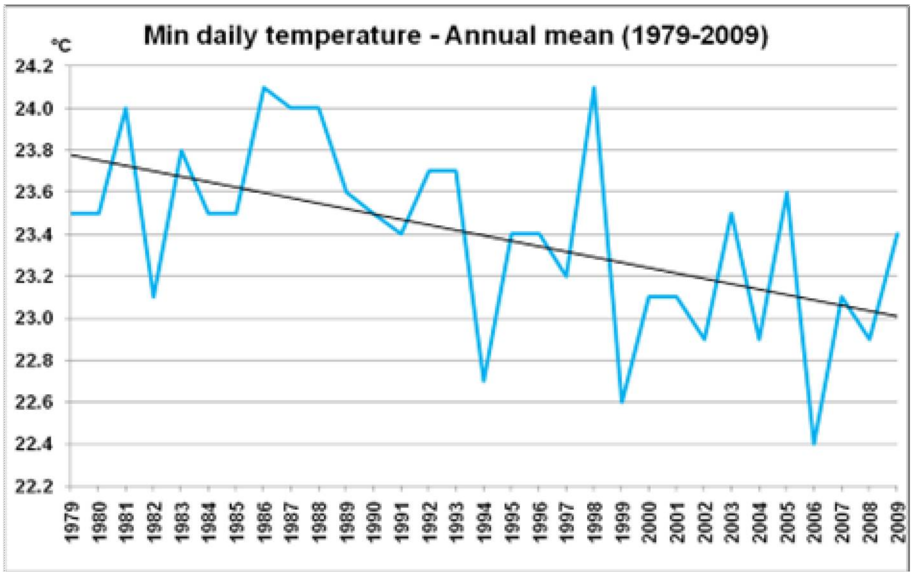
Maximum Daily Temperature

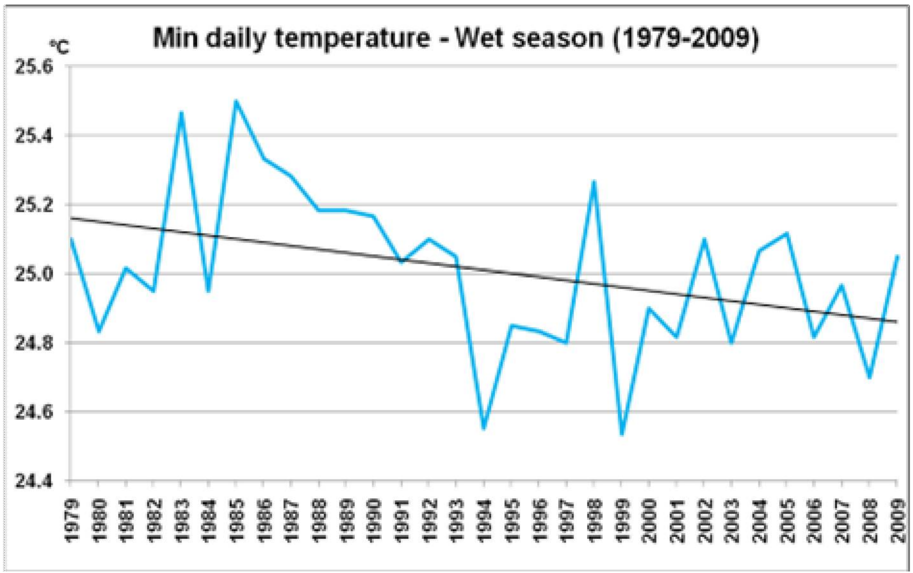


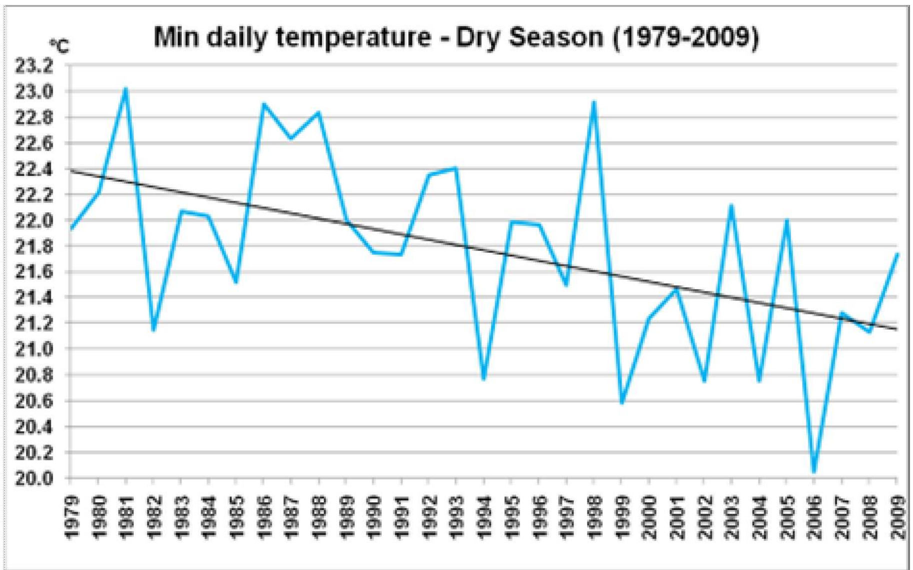




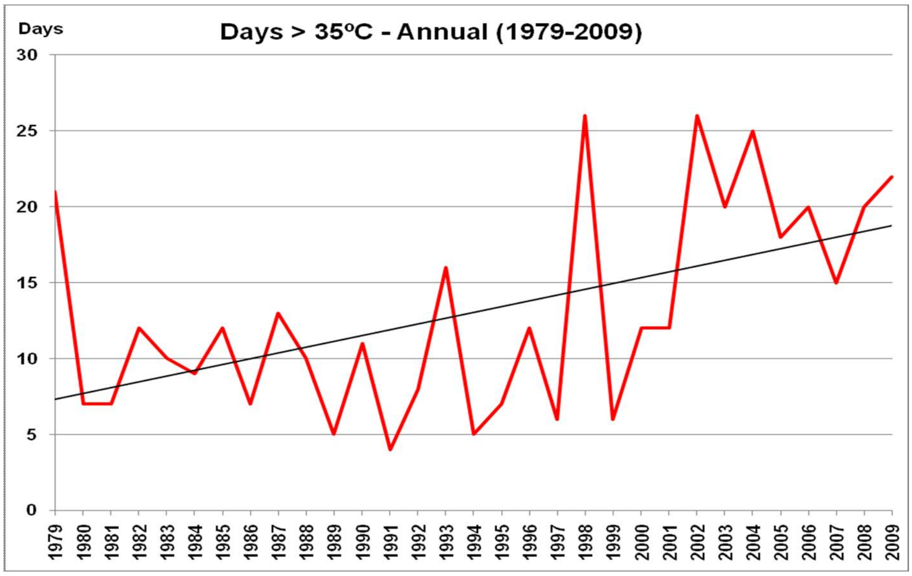
Minimum Daily Temperature

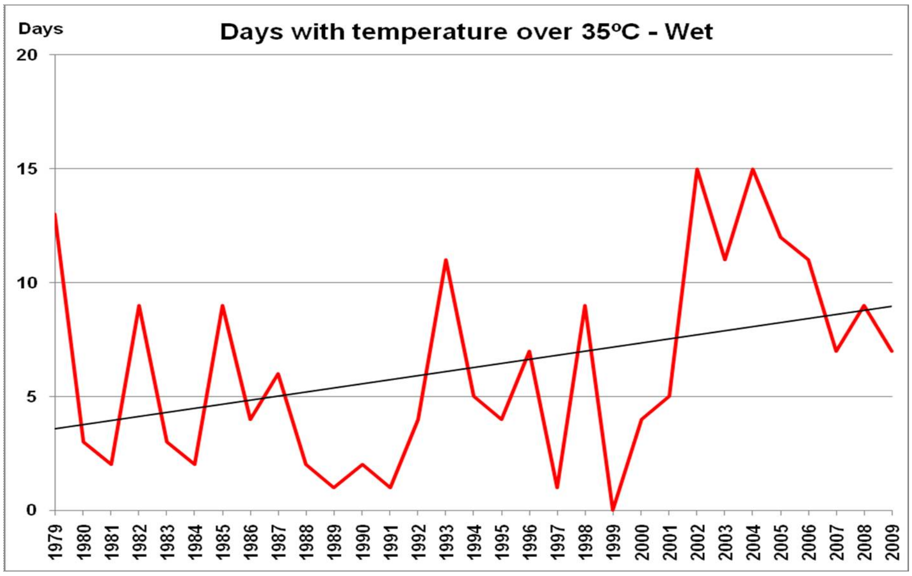


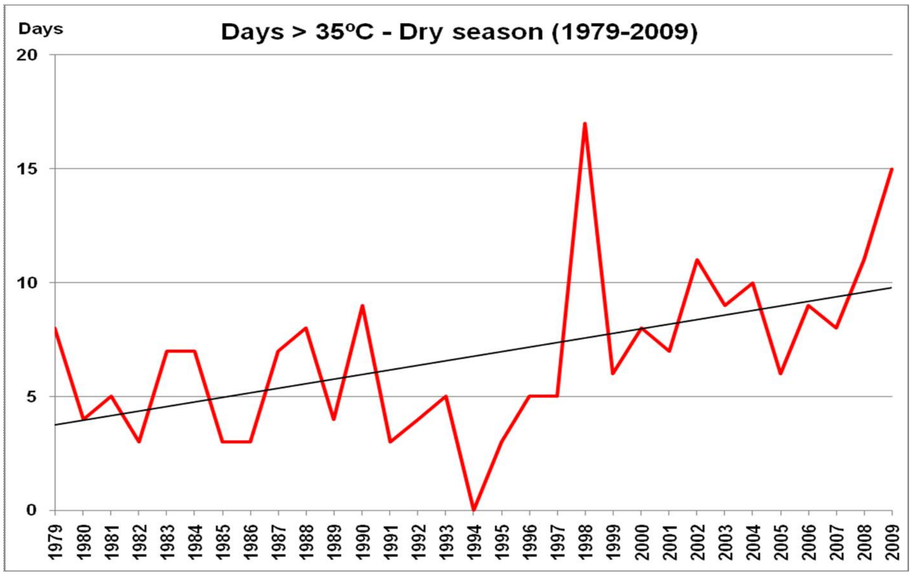




Days with temperature over 35ºc







Total Monthly Rainfall