Local Government Association of the Northern Territory

29 November 2010

Climate Change Risk Assessment and Adaptation Planning

Tiwi Islands Shire Council

Tiwi Islands Shire

LOCAL GOVERNMENT ASSOCIATION OF THE NORTHERN TERRITORY

Climate Change Risk Assessment and Adaptation Planning

Tiwi Islands Shire Council

Prepared for

Local Government Association of the Northern Territory

Prepared by

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Disclaimer

AECOM has exercised reasonable care when completing this report. However, caution must be taken when considering our conclusions because significant uncertainty remains due to the inherent complexities involved in analysing the past climate and variables typically encountered when modelling future climate change. AECOM cannot guarantee the accuracy of the climate observations and projections described in this report and cannot be responsible for any third party's reliance upon on this information.

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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
FaHCSIA	Department of Families, Housing, Community Services and Indigenous Affairs
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
TYDDU	Tiwi Youth Diversion & Development Unit

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 Tiwi Islands 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 Tiwi Islands 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 Tiwi Islands communities and its Council from time to time.

The Vulnerability of the Tiwi Islands Shire

The Tiwi Islands Shire is located about 80 km to the north of Darwin in the Arafura Sea. The Tiwi Islands include Melville Island and Bathurst Island which have a combined area of approximately 8,320 km^2 and have an estimated population of 2,525 inhabitants (ABS 2009). The 2006 Census revealed that 92.3% of the resident population of Tiwi Islands Shire is Indigenous (ABS 2006). The largest population centres are Nguiu, Pirlangimpi and Milikapiti.

The Tiwi Islands communities are exposed to extreme climatic events among which cyclones and storm surge can be considered as the most threatening. The majority of communities on the Tiwi Islands reside along the coastline and have very narrow economic basis. Considered remote, many communities can only be accessed by boat or plane. All these elements make the community highly sensitive to climate change impacts.

However, most communities on the Tiwi Islands have shown strong resilience in the face of previous adverse events. Furthermore, the simplicity and robustness of the infrastructure (e.g. concrete ramp for barge landing) make them less exposed to extreme events and less expensive to maintain and repair if they are damaged. This resilience combined with the traditional knowledge held by the community can be built upon to prepare for the inevitable impacts of climate change.

Climate Change Observations & Projections

The Tiwi Islands have 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 Tiwi Islands area experienced a warming of mean and maximum air temperature and a 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 during the dry season but remained similar during the wet season compared to the current situation. Rainfall showed varying trends with a 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;
- An increase in storm surge height; 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, storm surge height and the associated deterioration in coastal conditions represent an important issue for the Tiwi Islands Shire Council. These changes in coastal dynamics are likely to become even more noticeable by the second half of the 21st century. Coastal erosion and changes in sea level are likely to have consequences on coastal infrastructure as well as coastal ecosystems.

Vulnerable Ecosystems & Biodiversity Loss

The Tiwi Islands area contains valuable terrestrial, freshwater and marine ecosystems and a number of species that are considered to be vulnerable to climate change. Climate change is expected to bring, among other changes, variations 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 Tiwi Islands communities and potentially increase repair and maintenance costs.

Implications for Culture and Traditions

Climate change may impact the culture and traditions of the Tiwi Islands communities. Changes in seasons, migration patterns of key species and possible loss of some culturally significant sites could occur as a result of climate change. More importantly cultural values, religion and belief systems in the Tiwi Islands can and will potentially influence local community responses to climate and climate change as well as responses to mitigation and adaptation policies and strategies.

Risks to Human Health & Safety

The Tiwi Islands 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 Tiwi Islands could increase. Increase in heat related illness among the locals and the visitors has been highlighted as a key risk. 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 Tiwi Islands community, and play a major role in compounding existing socio-cultural challenges in the region, such as employment, livelihood and welfare. 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 Tiwi Islands 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 or to ocean currents. Further research would improve the understanding of how to project against societal and ecosystem impacts, and provide the Tiwi Islands communities 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 Tiwi Islands Shire Council and the Tiwi Islands 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 working 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 nine 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 Tiwi Islands 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 indigenous leaders delivering the key messages to the community. These community leaders should be resourced, trained and supported to raise awareness within their own communities and region

Priority Ranking	Prioritised Adaptation Options for Tiwi Islands Shire Council
1	*Conduct more frequent burning around the main communities to reduce the fuel loads. Option 7.*
2	*Develop and deliver a community education and awareness program to build community resilience. Option 1*
3	*Incorporate increased heat wave and mosquito related illness into education provided by health services to the community. Option 2*
4	*Use procurement process to screen investment to address climate change risks to infrastructure and services. Option 3*
4’	*Continue and expand community based biodiversity monitoring programs with a strong involvement of the Tiwi Islands Land and Sea Rangers. Option 8*
6	*Include climate change considerations in the upgrade, design and development of key community infrastructure. Option 4*
7	*Prepare a Council position paper on climate change. Option 9*
8	*Explore opportunities with Power and Water Corporation to bury transmission lines. Option 5*
9	*Improve protection against storm surge and sea level rise. Option 6*

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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 Tiwi Islands 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 Tiwi Islands Shire Council, West Arnhem Shire Council and East Arnhem Shire Council and the communities they support. This report presents the findings of this project for the Tiwi Islands 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 Tiwi Islands communities.

This climate change risk assessment for the Council is the first step in the process of building an adaptation strategy for the Tiwi Islands communities.

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 the Tiwi Islands. 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:

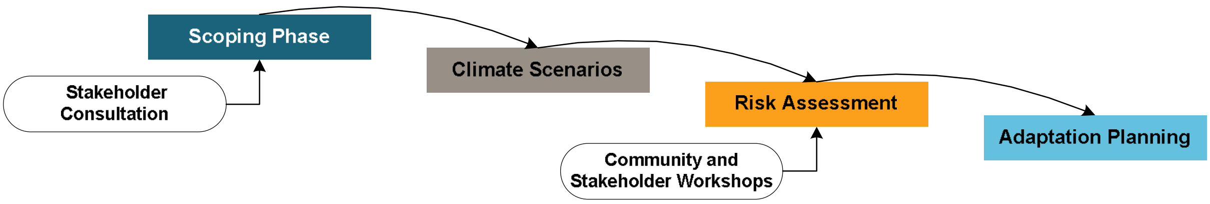
1. The collection of relevant data pertaining to physical and biological characteristics of the region, and notably an evaluation of the known impacts of: sea level rise, storm surge, cyclonic activity and sea surface temperature rise.
2. The documentation and analysis of the latest climate change projections 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 Council's core assets and services.
4. The development of a risk analysis of the potential impacts to the Tiwi Islands' communities.
5. The drafting of options toward an adaptation strategy.

2.4 Approach and Methodology

2.4.1 Overall Approach

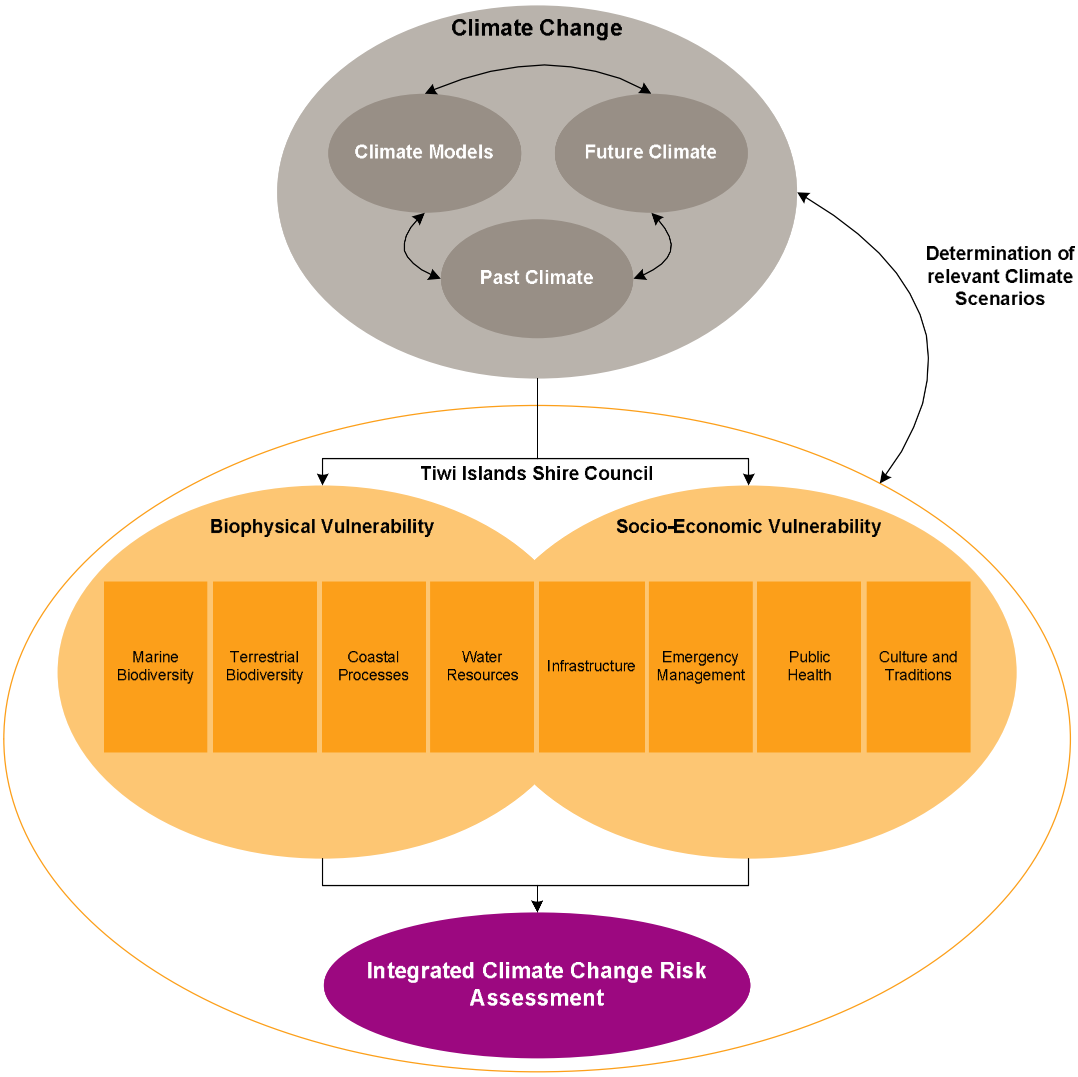
As outlined in Figure 1, the project has been developed around the following key phases: scoping phase, determination of climate trends in the studied region, climate change risk assessment (including community and stakeholders' risk workshops) and adaptation planning.

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 Workshop

As part of this study a workshop has been held on the 17/03/2010 with members of the Tiwi Islands Land and Sea Ranger Group. 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 workshops 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 of the project. 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.

It should also be noted that there has not been a strong involvement of women's group during the stakeholder consultation and the workshops. Women constitute an important part of the Tiwi Islands communities and their role in these communities is critical and complementary to the one undertaken by men. This study captures only partially issues and business associated with women.

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 the Tiwi Islands 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.

Shire councils include service centres located on a number of indigenous communities and managed by shire service managers with maintenance and essential services staff. 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 called 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 Tiwi Islands Region

The Tiwi people became isolated from mainland Australia when sea levels rose about 7,000 years ago. This isolation has enabled the Tiwi people to develop a unique culture that is different to that of mainland aborigines (TLC, 2008). A good example of this are the distinctive wooden poles used to mark gravesites. These poles are, carved and painted to represent the life of the person who dies and are quite unknown in mainland Aborignial groups.

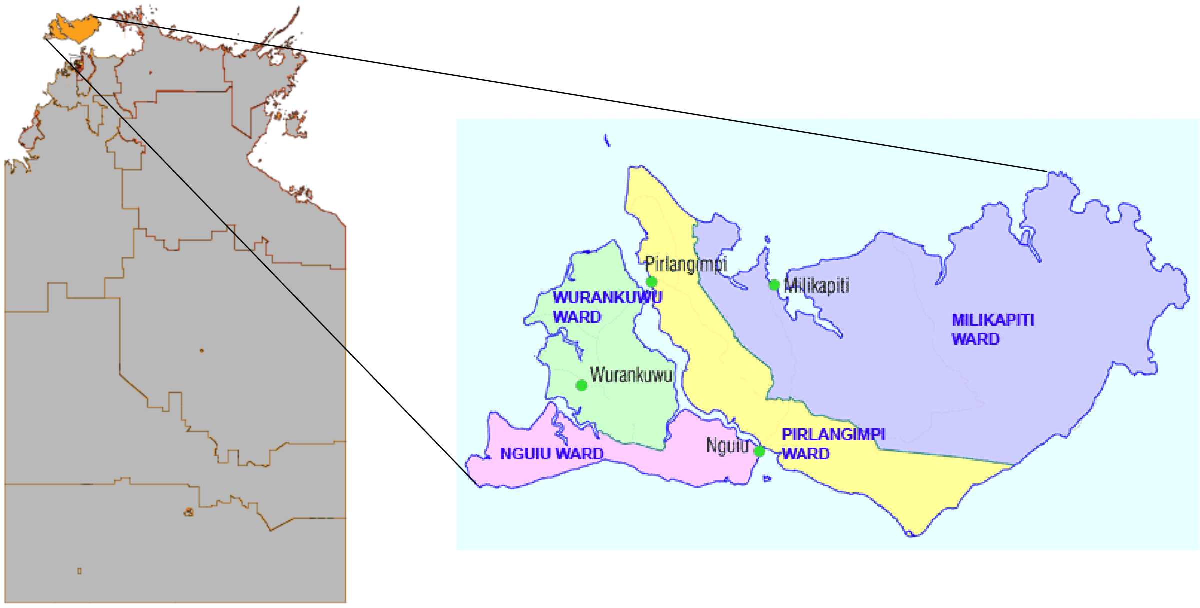
The first historical contact between Tiwi Islanders and European explorers took place when three Dutch ships, under the command of Commander Maarten van Delft landed at Shark Bay in 1705. The Dutch writings about their meetings with Tiwi Islanders are believed to be the first detailed European descriptions of Australian Aboriginal people. This gives the Tiwi people a special place in Australian history, and they proudly commemorate the meeting of Tiwi People and Dutch navigators by re-enacting the events of 1705 (Forrest, 1995).

The British Government would later attempt to settle Melville Island but they were soon driven away by the heat, disease and hostility. The Catholic Church established a mission on Bathurst Island in 1911 (Forrest, 1995).

In 1978 the ownership of Bathurst Island was formerly handed back to the Tiwi people . Administration of the Islands is divided between the local Tiwi Islands Shire Council, and the Indigenous landholder representative organisation, the Tiwi Land Council.

The Tiwi Islands Shire is located about 80 km to the north of Darwin in the Arafura Sea. The Tiwi Islands include Melville Island and Bathurst Island which have a combined area of approximately 8,320 km^2 (see Figure 3) and has an estimated population of 2,525 inhabitants (ABS 2010). The 2006 Census revealed that 92.3% of the resident population of Tiwi Islands Shire is Indigenous (ABS 2006). The largest population centres are Nguiu, Pirlangimpi and Milikapiti.

Figure 3 – Location map (AECOM 2010 and NT Government 2010)



3.2.1 Natural Environment

Tiwi Island landscapes are relatively pristine and intact. The islands are dominated by tall eucalypt forests, scattered with pockets of wet monsoon forest and dissected by mangrove-lined creeks and rivers. The eucalypt forests are considered to be the best developed in the Northern Territory and the islands contain an unusually high density and extent of rainforests that occur in association with perennial freshwater springs. Long, sandy beaches and rocky headlands line the coast (NRETAS, 2007).

Hydrology

The Tiwi Islands have 17 major catchments and two regional aquifer systems, one shallow and one deep. The highest surface flows within the catchments are during the wet season when flow is dominated by rainfall runoff. In the dry season flows are dominated by spring sources or drainage of the shallow aquifer along waterways, with smaller waterways drying up by the end of the dry season (AECOM, 2009). The Tiwi Islands supports a small number of major watercourses including Andranangoo Creek, Jessie and Johnstone River as well as a seasonal swamp at Andranangoo Creek (NRETAS, 2007).

Flora and Fauna

The Tiwi Islands supports many species that are not recorded anywhere else in Australia, partly due to their isolation and extremely high rainfall. This includes some 19 plant species and 19 animal species that are listed at the Northern Territory or National level (NRETAS, 2007). The islands support relatively abundant populations of partridge pigeon (*Geophaps smithis*) and red goshawk (*Erythrotiorchis radiates*); species that have suffered major declines in other parts of Australia. The islands support the endemic Tiwi Island Masked Owl (*Tyto novaehollandiae melvillensis*) and the coastal areas provide nesting sites for marine turtles, internationally significant seabird rookeries, and some major aggregations of migratory seabirds (NRETAS, 2007). The Mangrove palm (*Nypa fruticans)*, occurs in two locations on Melville Island, with only one other known location of this species occurring in the Northern Territory.

Threatening Processes

The isolation of the Tiwi Islands provides protection from some of the threatening processes affecting mainland ecosystems, notably cane toads (*Bufo marinus*) and some exotic plant species.

The spread of exotic grasses, such as mission grass (*Pennisetum polystachion*), may affect ecosystems and have the potential to alter fire regimes. Feral animals such as exotic ants, water buffalo, cattle, pigs and cats have impacted upon habitat and altered the conservation values of the islands. Land clearing associated with plantation forestry has altered large areas (>20,000 Ha) of land of Melville Island (NRETAS, 2007).

3.2.2 Land Tenure

The Tiwi Islands are Aboriginal freehold land owned by the Tiwi Aboriginal Land Trust, a statutory body created under the *Aboriginal Land Rights (Northern Territory) Act 1976*. A grant of land specifically to the Tiwi Land Trust was made under s 12 AAA of the Act.

On the 30/08/2007 the Tiwi Land Trust, on behalf of the traditional owners of Nguiu, and the Executive Director of Township Leasing, on behalf of the Commonwealth Government, agreed to a 99 year lease agreement over the town of Nguiu. This agreement followed a Memorandum of Understanding between the parties in May 2007. The lease is granted under s 19A of the *Aboriginal Land Rights (Northern Territory) Act 1976*. The section was part of an amendment to the Act introduced in August 2006. Under the agreement a head lease has been granted to the Executive Director of Township Leasing, a Commonwealth statutory officer, over Nguiu. Nguiu was the first community to commit to a lease agreement (ATNS, 2010).

3.2.3 Socio Economic Environment

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

Demographics

The 2006 Census revealed that 91.4% of the Tiwi Island population is indigenous, compared to the national rate of 2.3%. The population is relatively young with 29% aged between 0-14 years, and only 7.4% aged 55 years and over. The median age was recorded as 26 years, significantly lower than the national medium of 37 years (ABS, 2006).

Housing

Many existing houses on the Tiwi Islands are in various states of disrepair including some with serious structural and safety issues. A number of houses have been condemned, meaning that they have been declared unfit for human habitation by the Department of Health and Community Services. Contributing factors include age, overcrowding, deterioration of wet areas, poor workmanship or inappropriate use of materials, pest damage (e.g. Singapore ants, termites) and to a lesser extent, vandalism. Many of the houses on the Tiwi Islands also contain asbestos which is a toxic material commonly used in building product (AECOM, 2009).

In the 2006 Census there was 501 occupied private dwellings on the Tiwi Islands. Of these 98% were recorded as separate houses and 2% were other dwellings (ABS, 2006).

Economy

The Tiwi people are striving to develop an independent economy in order to improve social outcomes and greatly reduce the damaging influence of dependence on welfare. The asset base of the Tiwi economy is valued at over $500 million, with investment in areas such as education and training, road and port infrastructure, transport services, tourism, barge services, mining, community development, housing/hotel/office complex services at Nguiu, aquaculture and forestry (AECOM, 2009).

The 2006 Census recorded 811 people aged 15 years and older as being in the labour force, compared with 599 who are not in the labour force. Of those in the labour force 37.2% are in full-time employment, 45.1% are working part-time and 7.8% are unemployed. The most commonly recorded occupation was Labourer representing 26.2% of people employed while the largest employment industry is Local Government and Administration, accounting for 33.8% of employed people (ABS, 2006) Employment within the Tiwi Islands extends across such industries as agriculture, forestry, fishing, manufacturing, construction, retail trade, accommodation, cafes and restaurants, transport and storage, finance and insurance, property and business services, government administration and defence, education, health and community services, cultural and recreational services, and personal and other services (AECOM, 2009).

The median weekly income for people on the Tiwi Islands has been recorded at $ 210, a figure significantly lower than the national weekly income of $ 466. The median weekly family income has been recorded at $525, compared with $ 1,171 for all of Australia (ABS, 2006).

3.3 The Tiwi Islands Shire Council

The Council is represented by 12 councillors; five representing Nguiu, three each representing Milikapiti and Pirlangimi, and one representing Warankkuwu (see Table 5). The Council head office is located in Nguiu (TISC, 2009).

Table 5 – Tiwi Islands Shire Council Overview (TISC, 2009)

Ward	Councillors	Shire Service Delivery Centre	Population
Nguiu	Barry Puruntatameri	Nguiu	1,495
	Teresita Puruntatameri		
	Francis Xavier Kurrupuwu		
	Walter Kerinauia		
	Richard Tungutalum		
Milikapiti	Lynette De Santis	Milikapiti	449
	Raelene Mungatopi		
	David Boyd		
Pirlangimpi	Emmanuel Rioli	Pirlangimpi	434
	Henry Dunn		
	Marius Puruntatameri		
Warankuwu	Kathleen Tipungwuti	Warankuwu	85

3.3.1 Tiwi Islands Shire Council Services

Tiwi Islands 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 6 presents the core services provided by the Tiwi Islands Shire Council.

Table 6 – Tiwi Islands core services

Core services	Comments
Local Infrastructure	
Maintenance and upgrade of parks, reserves and open spaces	None.
Maintenance and upgrade of buildings, facilities and fixed assets	Council is responsible for the maintenance and upgrade of community facilities. Recent works have been undertaken on swimming pools and airports
Management of cemeteries	Council is responsible for the management of local cemeteries including: • Excavation and ground maintenance; • Internment of ashes; and • Erection of memorial.
Lighting for public safety, including street lighting	None
Local road upgrading and construction	Council has responsibility for upgrade and construction of local roads within communities Lack of sufficiently skilled staff to operate road making plant and equipment Mining and forestry organisations operating on the islands have facilitated the construction and upgrade of roads. This has greatly increased the value of council's roads
Local road maintenance	None.
Fleet, plant and equipment maintenance	None.
Natural and cultural resource management services	None
Local Environment Health	
Waste management (including litter reduction)	Rubbish tips located at all three communities (Nguiu, Milikapiti, Pirlangimpi). Each island has a single can crushing facility for the recycling of aluminium Garbage collected from communities on a daily basis.
Weeds control and fire hazard reduction in and around community areas	None.
Companion animal welfare and control	Council has facilitated a dog management program which has resulted the eradication and sterilisation of hundreds of dogs, leading to a decrease in people being bitten by dogs. Council facilitates the registration of dogs. Council also provides some feral animal control services, especially for feral pigs in Nguiu.

Core services	Comments
Local Civic Services	
Library and cultural heritage services civic events	None
Local emergency services	Police are responsible for coordinating emergency response with some help from the council. Shelter areas have been designated in case of a cyclone. Shelters include community halls and hospitals.

Tiwi Islands 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 7 presents the commercial services provided by the Tiwi Islands Shire Council.

Table 7 – Commercial Tiwi Islands Shire Services (TISC, 2009)

Commercial services	Comments
Housing and Infrastructure Maintenance	The Council is largely reliant on grants from the Department of Housing, Local Government and Regional Services. This has included a Housing Management Services Management Grant and a Housing Repairs and Maintenance Special Purpose Grant. A Housing Supervisor and a Housing Manager are responsible for housing maintenance.
Non Council roads	None.
Post office agency	None.
Power, water and sewerage	None.
Motor vehicle registration	None.

Tiwi Islands 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 presents the agency services provided by the Tiwi Islands Shire Council.

Table 8 – Agency services (TISC, 2009)

Agency services	Information/Notes/issues
Airstrips	None.
Community safety	The Council provides a night patrol service in all three communities under a Youth Diversion Program. The night patrol enforces a 9:30pm curfew on children. The NT Government has funded three safety houses; one in Nguiu, one in Milikapiti and one in Pirlangimpi.
Economic development support	Farm projects have been developed at Milikapiti, Nguiu and Pirlangimpi and employ a total of seventeen people. Workers at the farm are studying for their Horticultural Certificates I and II.
Employment and training	The Tiwi Islands Shire employs 120 full-time employees as well as another 450 people through employment programs, most of whom are Tiwi people. Tiwi Shire has amongst the highest proportion of indigenous versus non-indigenous employment along with high levels of indigenous supervisors and team leaders. The Shire Council has a number of staff engaged in training through the Tiwi Islands Training and Election Board in the areas of Carpentry, Civil (Plan), Sport and Recreation, Business and Essential Services Officer.

Agency services	Information/Notes/issues
Family (including child care)	The Tiwi Youth Diversion & Development Unit (TYDDU) runs a number of programs, often with the assistance of other service providers such as the Red Cross and Catholic Care, to bring people together and collectively perform a better service for the community. These programs include: • Attendance Program - absent students are picked up before and during school hours and returned to the classroom; • TYDDU Youth Workers assist teachers in the classroom and help deal with behavioural problems; • TYDDU Youth Workers supervise schoolchildren during recess; • Pre-Schoolers are taken home by Youth Workers after 11am; • Intervention/behaviour program – Youth Workers assist with maintaining good behaviour amongst students and assist staff/teachers with Interventions/Counselling when required; • After School Care and Vacation Care Programs which include: a Nutrition Program providing 80-110 children per day with a nutritious meal; and After School Sports, supervising children at the Pool and Recreation Hall each afternoon Monday to Friday; • Men's Meetings run in Nguiu and Milikapiti to improve the health and well-being of men in the community; • Counselling and Family Mediation/ Intervention: provided on an 'as needed' basis by TYDDU Youth Workers encouraging family members to resolve conflicts peacefully through negotiations and discussion; and • Skin Group Leaders Meetings held to empower and encourage Nguiu residents to participate in community issues.
Aged and disabled care	There are no aged care facilities or service in Milikapiti.
Outstation/homeland municipal	None.
Sport and recreation	The Council allocates sporting ovals to approved sporting organisations for seasonal and casual use. The Council provides holiday programs ran throughout the year with the help and support of the TYDDU and the Red Cross. A Sports and Recreation Program now operates on a daily basis in Nguiu as part of the TYDDU after school care program.
Community Media	None.
Environmental Health	None.
Arts and Culture	None.

Part 2 – Climate Change in the Tiwi Islands

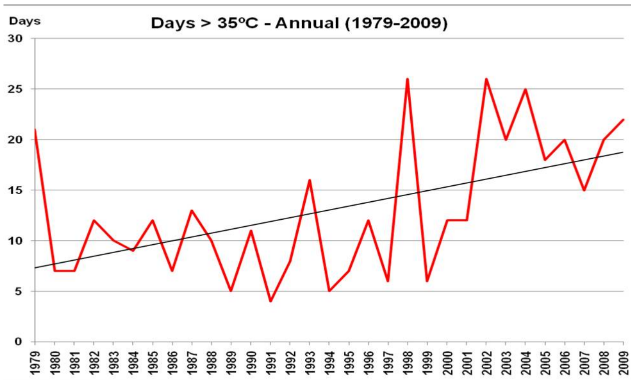
4.0 Climate Change: Context

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

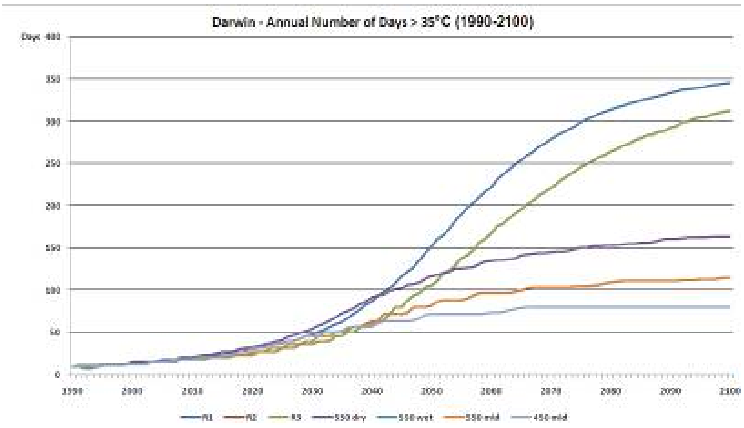
Climate observations are obtained through networks of meteorological monitoring stations. Precise and consistent measurements are generally only available for the second half of the 20th century. Figure 4 shows how the historical climate (annual number of days > 35°C in this instance) of the past 30 years has trended up until now. This graphic also highlights the significant year to year variability; some years show just a few days > 35°C while other are characterised by more than 25 days > 35°C.

Figure 4 – 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 5 shows how climate models information is providing a likely projection of future climate (annual number of days > 35°C until 2100 for Darwin).

Figure 5 – Future trends in the annual number of days > 35°C for Darwin (AECOM 2008)



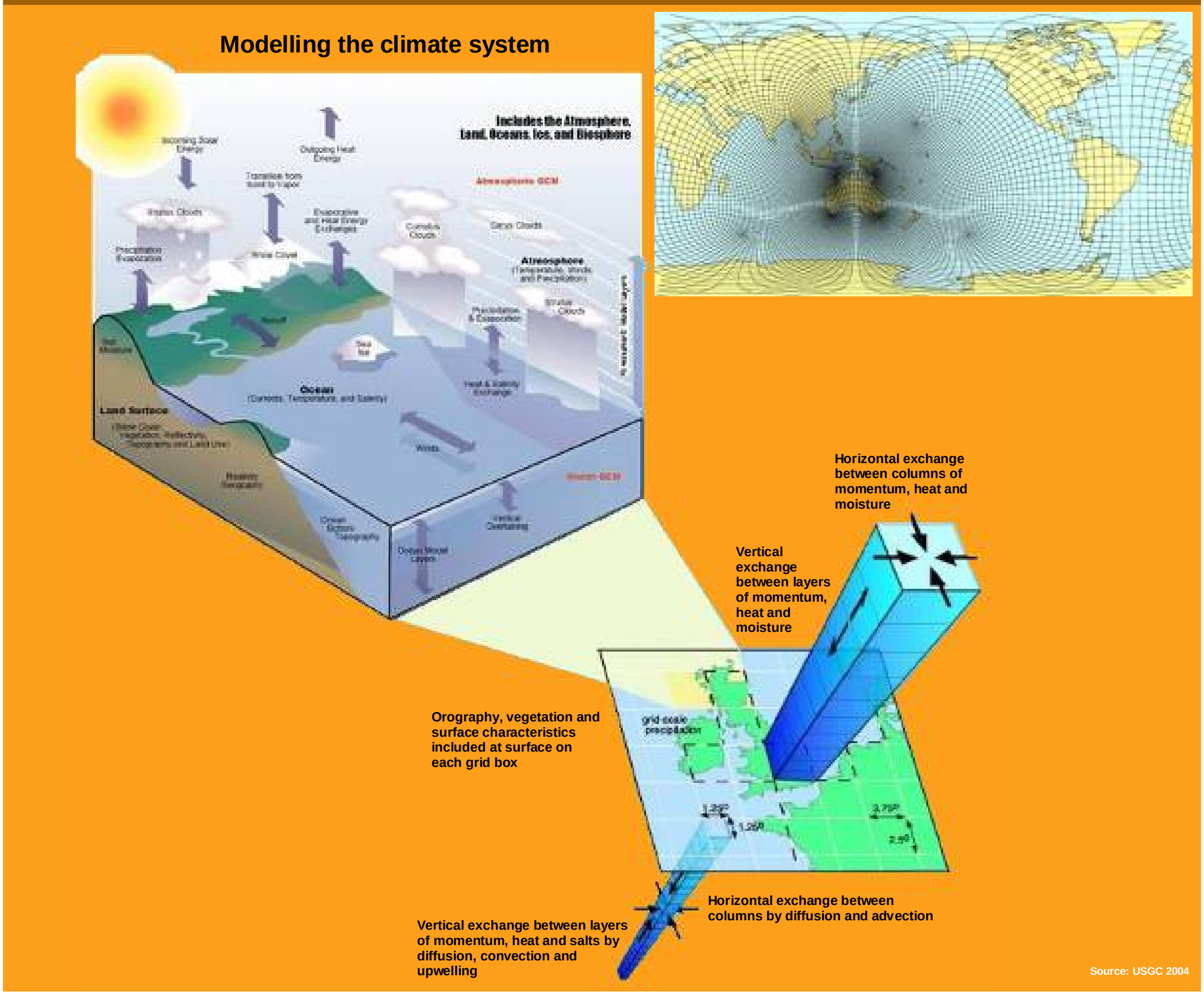
4.2 Emission Scenarios

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



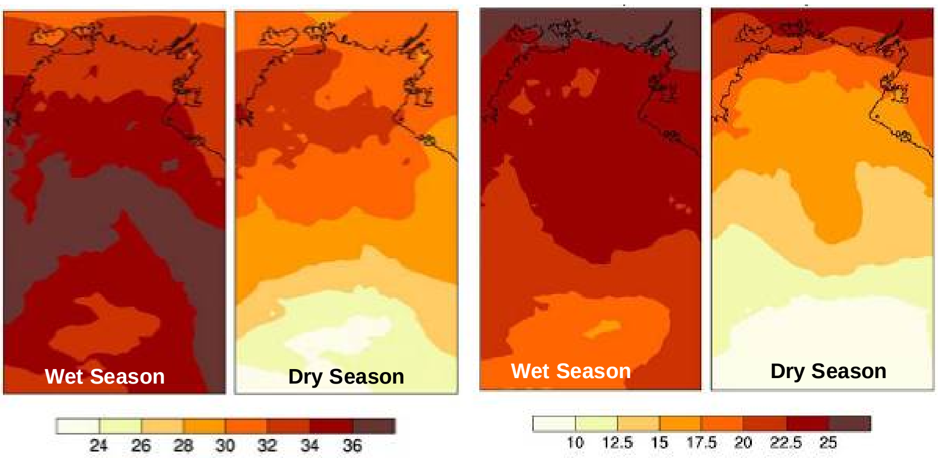
Source: USGC 2004

5.0 Current Climate and Climate Change

5.1 Current Climate in the Northern Territory

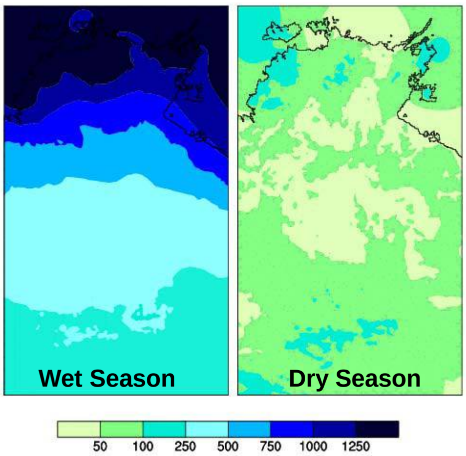
The Top End presents a tropical climate with high humidity and two distinct seasons: a wet season from November to April and a dry season from May to October. The wet season is influenced by the summer monsoon with thunderstorms and cyclones. El Niño[1] tends to limit or even suppress monsoon effect 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 6).

Figure 6 – 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 7)

Figure 7 – 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 8 – Current climate in the Northern Territory Top End region

5.2 Current Climate in the Tiwi Islands

5.2.1 Pirlangimpi

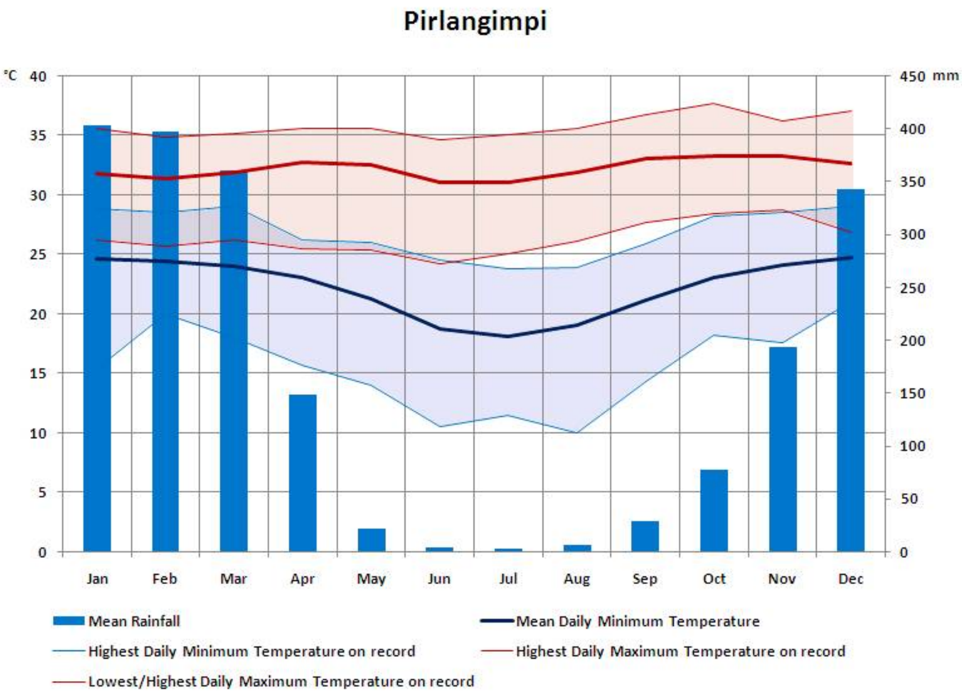
The main features of Pirlangimpi's weather conditions are summarised below (see also Figure 9):

- Air temperature exhibit little seasonal variations, with mean maximum temperatures ranging between 33.3°C in October and November and 31°C in July while mean minimum temperatures range between 18.1°C in July and 24.7°C in December.
- Rainfall records show the annual mean rainfall to be around 2,025 mm per year. The mean minimum monthly rainfall is recorded between June and August (3.1 to 6.9 mm) and the maximum mean monthly rainfall is recorded in January (around 403 mm). The highest daily rainfall monitored in the region occurred in April 1992 with 337 mm over a 24 hours period. The predominant wind directions in the morning are east and south-east while afternoon winds blow predominantly from the east, north-east, north-west and west.

The table below provides some key climate statistics from the Pirlangimpi's Bureau of Meteorology monitoring station (11°40'S, 130°42'E / 18 m a.s.l. / 1963-2009). Some statistic figures were rounded to the closets number.

Figure 9 – Pirlangimpi key climate data

	Pirlangimpi (1963-2009)
Annual mean minimum temperature	22.2°C
Annual mean maximum temperature	32.2°C
Mean number of days > 30°C	314 days
Mean number of days > 35°C	9.5 days
Mean number of days > 40°C	0 day
Mean annual rainfall	2,025 mm
Lowest mean annual rainfall (2002)	1,250 mm
Highest mean annual rainfall (1998)	2,767 mm
Highest daily rainfall (09/04/1992)	337 mm



Data: BoM 2010

5.2.2 Milikipati

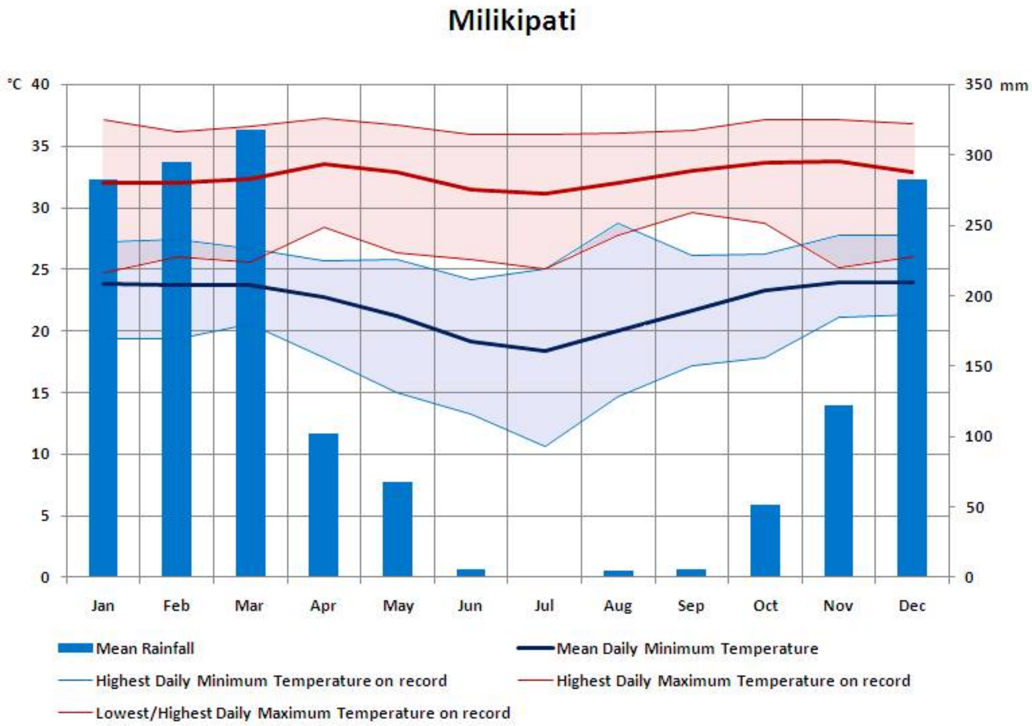
The main features of Milikipati's weather conditions are summarised below (see also Figure 10):

- Air temperature exhibit little seasonal variations, with mean maximum temperatures ranging between 33.8°C in November and 31.1°C in July while mean minimum temperatures range between 18.4°C in July and 24°C in November.
- Rainfall records show the annual mean rainfall to be around 1,550 mm per year. The mean minimum monthly rainfall is recorded between June and September (0.9 to 5.9 mm) and the maximum mean monthly rainfall is recorded in March (around 318 mm). The highest daily rainfall monitored in the region occurred in May 1977 with 205 mm over a 24 hours period. The predominant wind directions in the morning are south-east while afternoon winds blow predominantly from the north-east.

The table below provides some key climate statistics from the Milikipati's Bureau of Meteorology monitoring station (11°43'S, 130°68'E / 5 m a.s.l. / 1959-1987). Some statistic figures were rounded to the closets number.

Figure 10 – Milikipati Airport key climate data

	Milikipati (1959-1987)
Annual mean minimum temperature	22.1°C
Annual mean maximum temperature	32.6°C
Mean number of days > 30°C	307 days
Mean number of days > 35°C	25 days
Mean number of days > 40°C	0 day
Mean annual rainfall	1,550 mm
Lowest mean annual rainfall (1974)	2,600 mm
Highest mean annual rainfall (1972)	928 mm
Highest daily rainfall (02/05/1977)	205 mm



Data: BoM 2010

6.0 Tiwi Islands 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 ↘ Decrease during the wet	↗ Projected warming of 0.8°C	↗↗ Projected warming between 0.8°C and 3.7°C
Max Temperature	↗ Increase during the dry ↗ Increase during the wet	↗ 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 wet	↗ 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	↘ Decrease during the dry season ↘ Slight ddecrease 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**

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

As mentioned previously there are two weather monitoring stations operated by the BoM within the boundaries of the Tiwi Island Shire. However, only one station (Pirlangimpi) provides data for all climate variables. The other station (Milikipati) presents significant data gaps and has not been used. Additionally, climate projections have been commissioned to CSIRO by AECOM specifically for the Darwin/Tiwi Islands region.

6.1 Temperature, Rainfall and Humidity Changes during the Wet Season

The observed trends for the Tiwi Islands present similarities with the trends observed in Darwin. Both maximum and mean temperature increased over the past 30 years as well as the number of hot days (>35°C). Over the same period, minimum temperatures exhibited a slight decrease. Mean rainfall have also increased during the wet season. Relative humidity showed little changes over that period.

Mean temperature is projected to increase by 0.8°C by 2030 and between 0.8°C and 4.3°C for the wet season by 2070. Minimum and maximum temperature exhibit similar trends, with a warming between 0.7°C and 0.8°C by 2030 and between 0.8°C and 4.4°C by 2070. Most models show some changes in rainfall for the near future (2030) with only a few percent decrease for the wet season. The worst case emissions scenario (A1FI) for 2070 indicates a decrease of between 5% and 25% for the wet season. With regards to relative humidity, there should be a slight decrease in humidity during both wet season for the near (2030) and far (2070) future.

6.2 Temperature, Rainfall and Humidity Changes during the Dry Season

Similarly to the wet season, mean and maximum temperatures have increased over the past 30 years as well as the number of hot days (>35°C). Minimum temperature also showed decreasing trends. Mean rainfall decreased slightly as did the relative humidity.

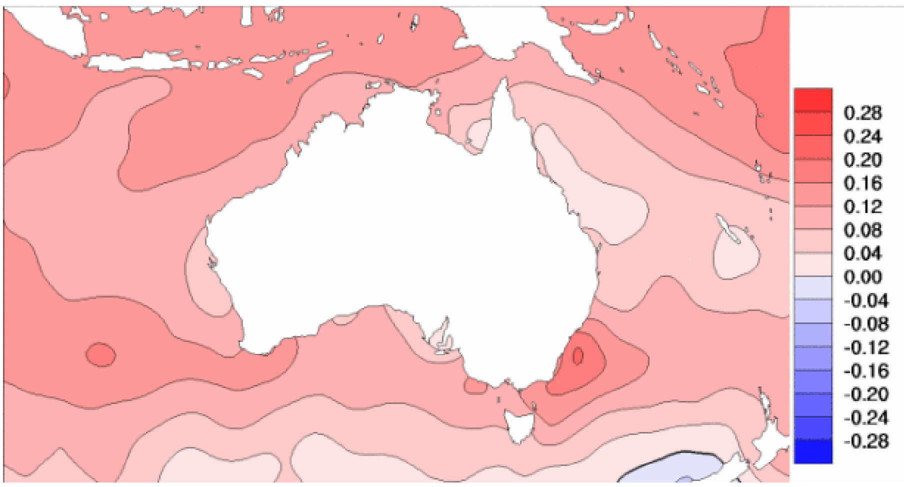
Mean temperature are projected to increase by 0.7°C by 2030 and between 0.8°C and 4.3°C for the dry season by 2070. Minimum and maximum temperature exhibit similar trends, with a warming between 0.7°C and 0.8°C by 2030 and between 0.8°C and 4.4°C by 2070. Most models show significant changes in rainfall for the near future (2030) with between 10% and 30% decrease for the dry season. The worst case emissions scenario (A1FI) for 2070 indicates a decrease of between 42% and 137% for the dry season. Relative humidity show similar trends to the wet with a slight decrease in humidity 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 11), 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 11 – Trend in annual mean of sea surface temperature 1970/2008 (°C/10 years, BoM 2009)



6.4 Sea Level Rise

Sea Level Rise Observations

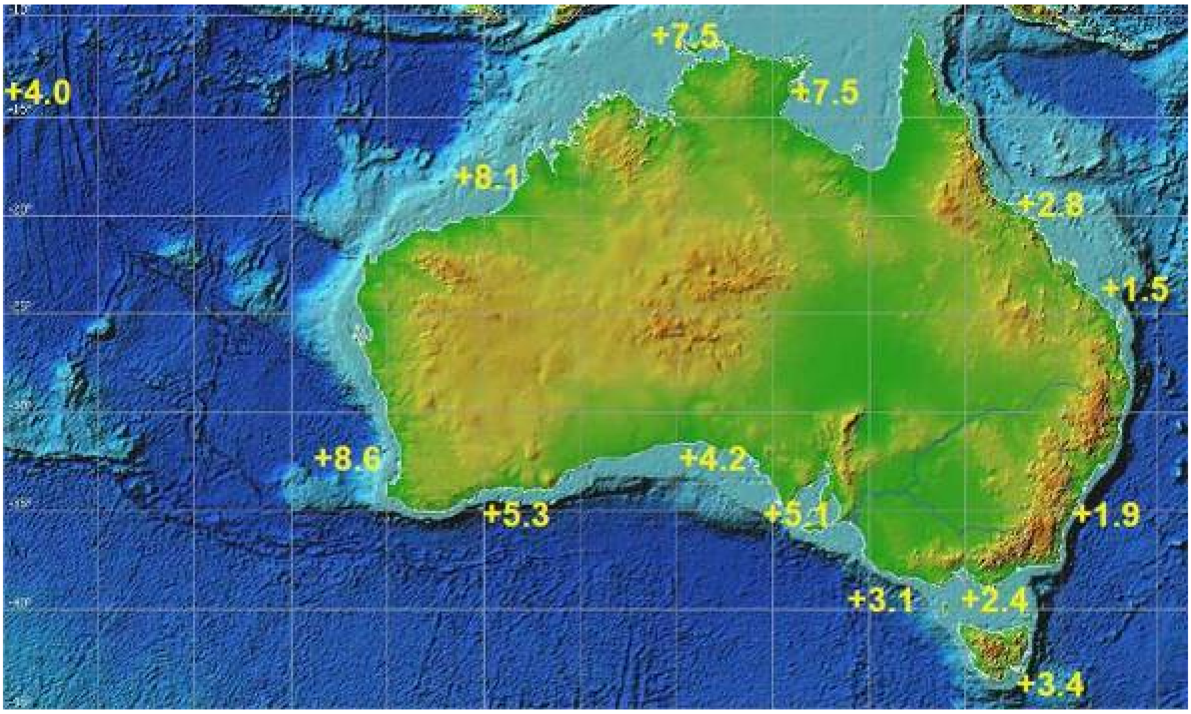
Sea Level Rise (SLR) has occurred at a global mean rate of 1.7 mm per year for the past century, and more recently over the last 20 years this has increased to rates estimated near 3.1 ± 0.7 mm per year (1993-2003) (Bindoff *et al. 2007)*. The Australian Baseline Sea Level Monitoring Project (ABSLMP) 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 12 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.

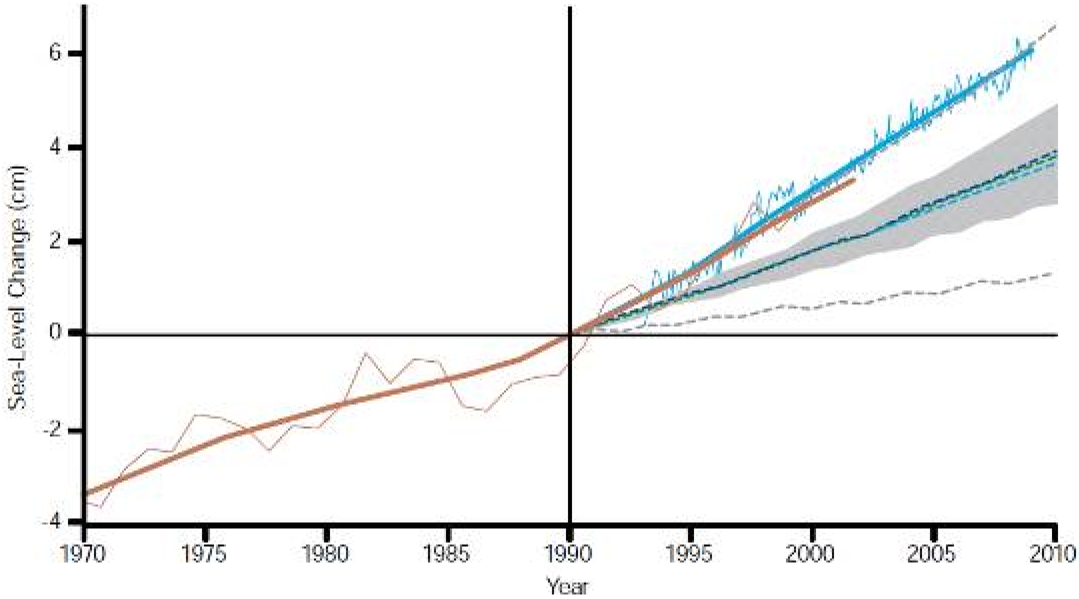
Figure 12 – Net relative sea level trend in mm/year after subtracting the effects of the vertical movement of the platform and the inverse barometric pressure (ABSLMP 2009)



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 (Church et al. 2004).

Figure 13 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 13 – 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 9. 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 9 – 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

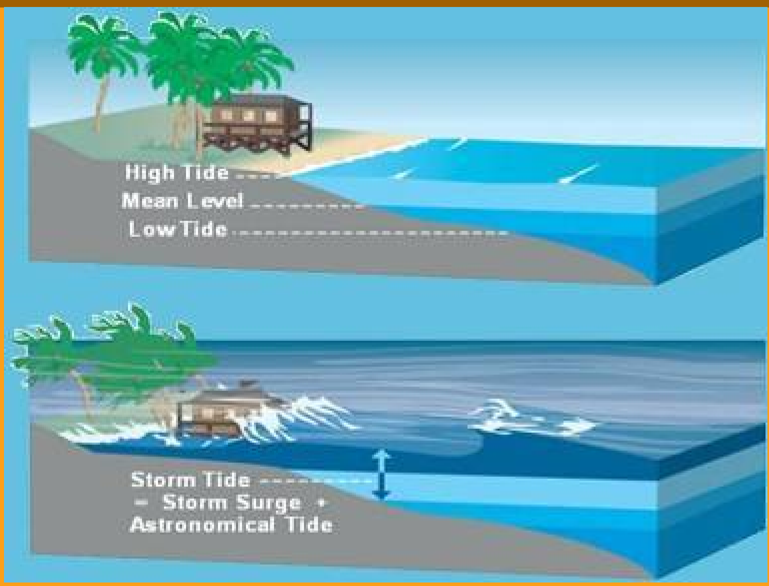
The SLR projections presented to the March 2009 Climate Change Science Congress in Copenhagen ranged from 0.75 to 1.9 m by 2100 relative to 1990, with 1.1–1.2 m the mid-range of the projection (Rahmstorf, 2009). Rahmstorf's projection of a 1.4 m SLR by 2100 is also based on a statistical approach informed 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 Tiwi Islands Shire have been impacted by storm surge in the past.

Storm Surge and Climate Change

Climate change 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 the Tiwi Islands.

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 10.

Table 10 – 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

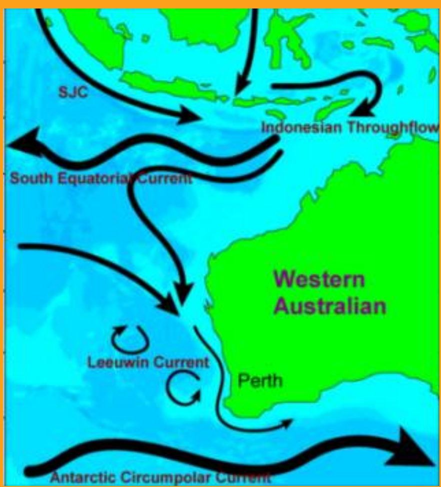
Ocean Acidification

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 the Tiwi Islands and potentially reduce availability of ocean based food. Box 3 illustrates the Indonesian Throughflow.

Box 3: Eastern Indian ocean currents



Source: CSIRO

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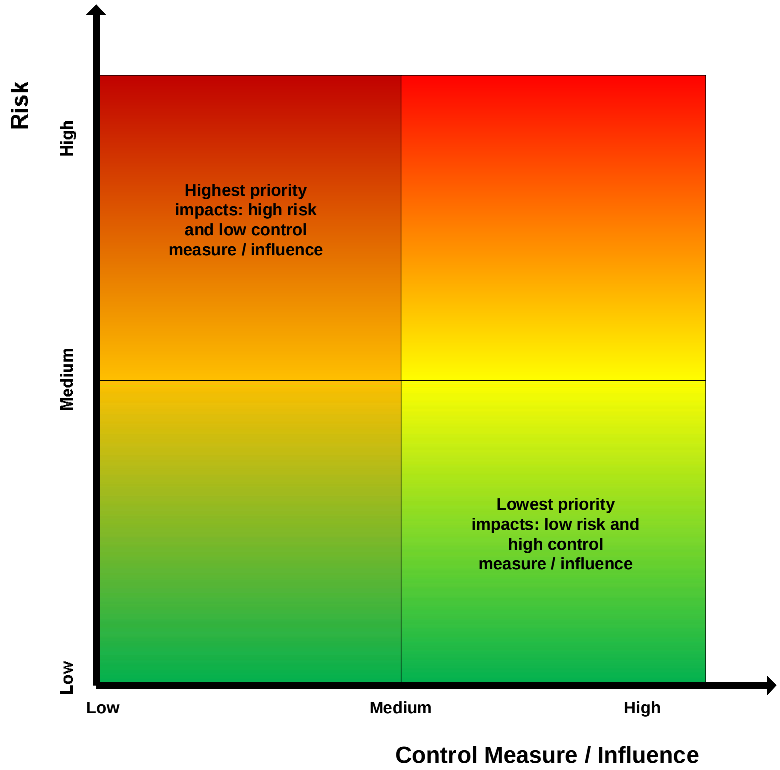
Part 3 – Climate Change Impacts and Vulnerability in the Tiwi Islands

7.0 Involving Tiwi Islands Community and Shire Council: Tiwi Islands workshop

As part of this study a workshop has been held on the 17/03/2010 with members of the Tiwi Islands Land and Sea Ranger Group at Milikipati. Key climate trends relevant for the region were presented to the workshops' attendees. Workshops' 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 members of the Tiwi Islands' community. Perceptions and ratings were captured using a risk matrix printed on an A0 paper sheet. Figure 14 shows the matrix used at the workshops.

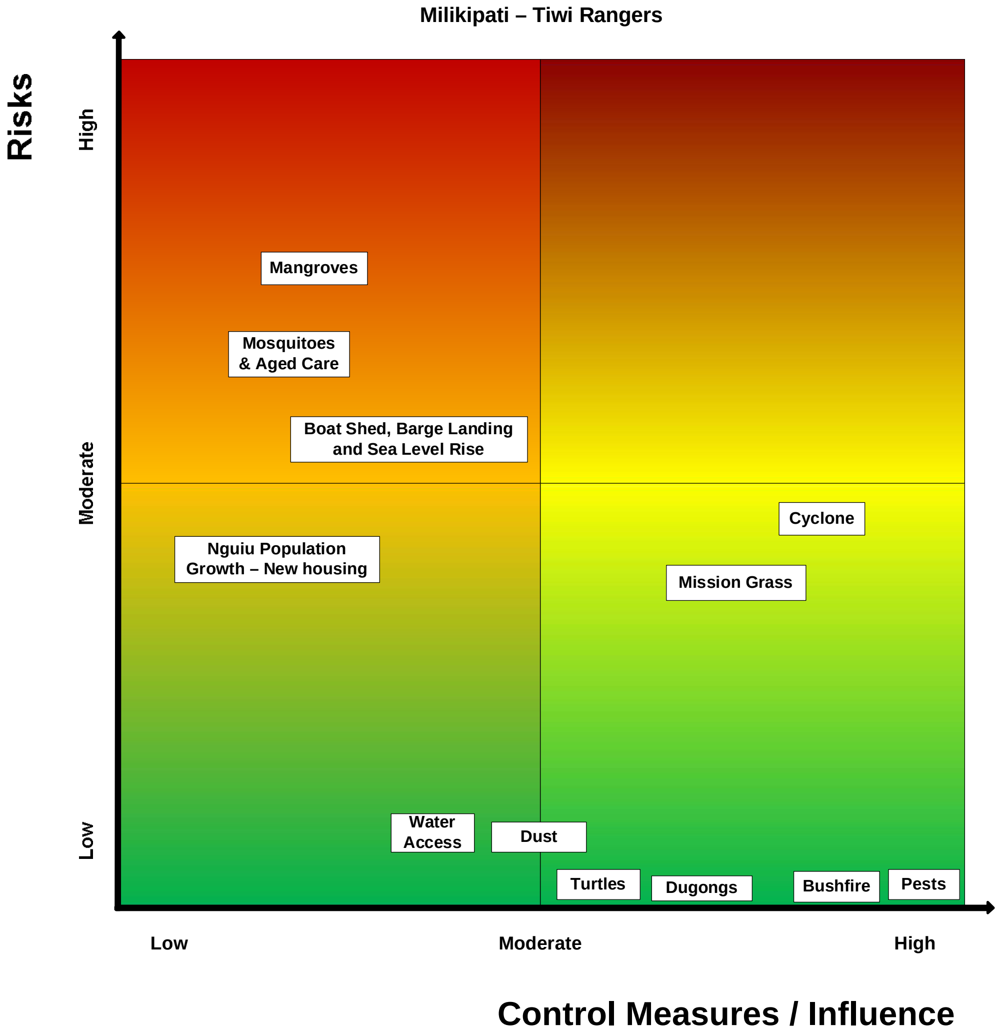
Figure 14 – Risk matrix used at the workshop



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 15 shows the results of the climate change risk rating.

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 15 – Tiwi Islands' ranger workshop



8.0 Climate Change Impacts and Vulnerability in the Tiwi Islands Shire

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 11 provides a generic overview of the consequence levels. These levels represent the degree or level of consequences to which Tiwi Islands' infrastructure, community and environment are likely to be exposed if a given climate change impact occurs.

Table 12 provides a generic overview of the likelihoods of recurrent risks and single events.

Table 11 – 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 12 – 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 14 provides a generic overview of the risk ranking.

Table 13 – 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

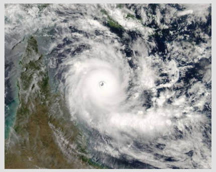
Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damage or loss of power generation facilities 	**Low (3)**	**Medium (6)**	Damage or loss of power generation (diesel) through increased number of intense cyclones, higher storm surge and more intense flooding. However most power generation facilities are located on high ground. *Moderate control from the Council as all power assets are owned and managed by Power and Water Corporation. The Council provides maintenance services.*	**1** **2**	Rare by 2030. Unlikely by 2070 due to more intense cyclone, significant sea level rise and increased height of storm surge.	**3**	Moderate by 2030 and 2070 due to damage or loss of power generation. Temporary loss of power to homes and other buildings, refrigeration, pumping, air conditioning and lighting.
Damage or loss of power transmission and distribution 	**Medium (9)**	**High (12)**	Damage or loss of power supply from storms damaging transmission and distribution assets. Currently all transmission lines are above ground and are likely to be damaged or destroyed during intense cyclones. Trees are generally cleared in the vicinity of the distribution stations. *Moderate control from the Council as all power assets are owned and managed by Power and Water Corporation. The Council provides maintenance services.*	**3** **4**	Possible by 2030. Likely by 2070 due to more intense cyclone.	**3**	Moderate by 2030 and 2070 due to damage or loss of power generation. Temporary loss of power to homes and other buildings, refrigeration, pumping, air conditioning and lighting.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Reduced or loss of water supply 	**Low (4)**	**Medium (6)**	Loss or decrease in water resources from salt water intrusion into groundwater from sea level rise and reduction in annual rainfall. Both Nguiu and Milikipati have developed bore fields for domestic supply with good water quality and good yields (3 to 8 l/s). Pirlangimpi is supplied by surface water but also has five bores with low yields (0.5 to 2 l/s) *Moderate control by locating new groundwater supplies although there is limited potential for Pirlangimpi.*	**2** **3**	Unlikely by 2030. Possible by 2070 due to significant sea level rise and increased height of storm surge.	**2**	Minor by 2030 and 2070 as saltwater intrusion in freshwater lenses might require new bores to be installed but is not likely to result in water shortage or long term disruption in water supply.
Damage or loss of water storage 	**Low (3)**	**Medium (6)**	Damage or loss of water storage and distribution facilities because of more intense cyclones. Community supply tanks are located on ground level. *Moderate control from the Council as all water assets are owned and managed by Power and Water Corporation. The Council provides maintenance services.*	**1** **2**	Rare by 2030. Unlikely by 2070 due to more intense cyclone.	**3**	Moderate by 2030 and 2070. Loss of water storage and distribution would be temporary.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Increased damage to roads 	**Medium (6)**	**Medium (9)**	Increased damages to road from changes in rainfall and increased number of intense cyclone and flooding, leading to extended isolation and loss of amenity for residents. Coastal roads are also exposed to increased coastal erosion as a result of SLR. *Moderate control by the Shire.*	**2** **3**	Unlikely by 2030. Possible by 2030 due to more intense cyclones and floods, SLR and increased storm surge height.	**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.
Damage to barge landing 	**Low (3)**	**Medium (9)**	Changes in sea level might impact the functioning of barge landings. All barge landings in the Tiwi Islands are concrete ramps (no wharf or jetties) and are therefore very resilient to cyclones and storm surge damages. *Moderate control/influence as temporary barge landings could be used.*	**1** **3**	Rare by 2030. Possible by 2070 due to significant SLR.	**3**	Moderate by 2030 from temporary loss of access. Barges deliver most goods to Tiwi Islands communities. Temporary barge landing or plane could be used for urgent goods (medications and food).
Damage to airstrip 	**Low (2)**	**Low (4)**	Damage to airstrips as a result of more intense cyclones. Nguiu and Milikipati have sealed airstrips while Pirlangimpi has an unsealed airstrip. *Moderate control as Council is currently maintaining this asset with external funding.*	**1** **2**	Rare by 2030. Unlikely by 2030.	**2**	Minor by 2030 and 2070 as most airstrips are sealed. The airstrip would be the first thing repaired after a cyclone.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damage to houses 	**Medium (9)**	**High (12)**	Damaged houses from increased number of intense cyclones. Many houses are of brick construction and a number are cyclone rated. Houses close to the shore line are at risk of SLR (e.g. lower parts of Milikipati or proposed development at Nguiu). *Low control as housing is not managed by the Council.*	**3** **4**	Possible by 2030. Likely by 2070 due to more intense cyclones and floods, SLR and increased storm surge height.	**3**	Moderate by 2030 and 2070 from partial loss of housing requiring significant repairs. Adverse health effects and short term local disruption.
Damage or loss of communication 	**Medium (6)**	**Medium (8)**	Loss of communications for an extended period of time due to damaged fixed lines and mobile towers (not all are currently cyclone rated). *Low control as assets are managed by Telstra.*	**3** **4**	Possible by 2030. Likely by 2070 due to more intense cyclones.	**2**	Minor for 2030 and 2070 from minor local communication disruption and minor restoration works.
Damage or loss of sanitation 	**Low (4)**	**Medium (6)**	Loss of sanitation due to salt water intrusion into treatment ponds caused by increased sea level rise and storm surge (all ponds are connected to the ocean). Nguiu and Pirlangimpi ponds are located on relatively high ground while Milikipati ponds are on lower ground. *Low influence for sanitation assets.*	**2** **3**	Unlikely by 2030. Possible by 2070 due to more significant SLR and storm surge height (mainly Milikipati).	**2**	Minor for 2030 and 2070 from slight adverse health effects and impacts on amenity.

8.3 Emergency Management and Extreme Climatic Events

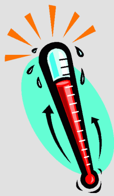
Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damage from greater intensity cyclone 	High (15)	Extreme (20)	With climate change the intensity of cyclones is expected to increase with climate change (Note: the overall number of cyclones is projected to decrease). The last cyclone to hit the Tiwi Islands was Ingrid (Category 3, 2005) with wind close to 200 km/h at Nguiu and torrential rains. There was widespread damage and even food shortage in one of the community. It is estimated to have caused around $ 5 million damages in the Tiwi Islands and Minjilang (EMA 2010). *Moderate control as there are some cyclone rated houses in the communities and there is a cyclone shelter in every community. The community and the Council generally undertake clean-up before the cyclone season, but potentially harmful debris remain around the community. There is a well defined emergency management procedure and coordination. It is acknowledged that most communities would have access to freshwater (through local creeks) and food (bush tucker) immediately after the cyclone.*	3	Possible by 2030.	5	Catastrophic – A direct hit by a category 4 or 5 cyclone would result in great damage to any Tiwi Islands community with widespread infrastructure damage, significant loss of environmental amenity and severe adverse human health impacts (possible fatalities).
				4	An increase in the intensity of cyclones is likely by 2070.		

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Damage from bushfire 	**Medium (6)**	**Medium (9)**	Climate change could increase the likelihood of bushfire because of warmer and drier conditions. *Moderate control as annual burning is conducted on most clan estates. Between 1997 and 2005, Milikipati has been exposed to the lowest frequency of fires while Nguiu and Pirlangimpi experienced higher frequency of burning around the community. Fire frequency has been considered quite low around the three communities and the resulting increase in fuel load has the potential to increase the intensity of wild fires* (AECOM 2009).	**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. Serious bushfires could significantly damage 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. Local people are used to bushfire and are likely to stay away from the danger area.
Increased damage from erosion 	**Low (4)**	**Medium (6)**	Because of significant slope gradient, most of Milikipati and some parts of Pirlangimpi are exposed to moderate to high risks of erosion (AECOM 2009). Changes in rainfall could increase the risk of erosion through more intense rainfall. *Moderate control as there are some erosion control measures in places (e.g. geotextiles on road drains, etc.).*	**2** **3**	Unlikely by 2030. Possible by 2070.	**2**	Minor by 2030 and 2070 as erosion risks are very localised. This could be considered as moderate for Milikipati as the whole area is considered as exposed to moderate to high risk of erosion.
Storm surge 	**Medium (9)**	**High (12)**	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. During the last cyclone (Ingrid in 2005) the storm surge reached the door steps of the lowest houses in the Milikipati community. *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.	**3**	Moderate as some houses would be damaged but most infrastructure is located on higher ground.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Increased risks of flooding 	**Medium (9)**	**Medium (9)**	Nguiu, Milikipati and the southern portion of Pirlangimpi are considered to be at high risk of flooding within the Tipabina, Tijpiru and Kilu-Impini river catchments respectively (AECOM 2009). Increase in heavy rainfall events could result in greater flooding risks. *No control. The Council does not have any control in terms of land use planning.*	**3**	Possible by 2030 and 2070 through increase in heavy rainfall events.	**3**	Moderate as some houses would be damaged but most infrastructure is located on higher ground.

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) in the Tiwi Islands. 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. More mosquitoes are present at the start of the wet season and especially after big tides. Russell (2009) indicates that higher temperature with similar or lower humidity level could decrease mosquito population levels through desiccation. Potential malarial zones are expected to shift because of climate change but are unlikely to establish permanently in Australia (McMichael et al. 2003). *Low control. As part of the cyclone clean-up, old tyres and drums are collected from backyards but there are too many wetlands and drains to make a significant difference. There is some prevention (e.g. window screening and not letting children play outside at dusk) but it remains sporadic but no mosquito control. New construction planned (e.g. stormwater drains and road embankments) on the islands are supposed take into account the minimisation of potential mosquito breeding.*	**2** **2**	It is unlikely that biting insects' population will change dramatically by 2030. It is unlikely that biting insects' population will change dramatically by 2070.	**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.

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Airborne and dust related illness 	Low (2)	Low (2)	Most Tiwi Islands' communities are not exposed to dust issues and bushfire smoke. Climate change is unlikely to change significantly dust and bushfire smoke conditions in the Tiwi Islands. *Moderate to high control as there are dust suppression actions during the dry (water down the main road). Most roads within Tiwi Islands' communities are sealed.*	1	Unlikely by 2030 and 2070.	2	Minor – Changes in dust and bushfire smoke conditions are unlikely to be significant and would affect a very small portion of the population.
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 the 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. Young and elderly people receive particular attention. However this can lead to a false sense of security to extreme temperatures especially because of prevalent health conditions in the community. A number of buildings are equipped with air conditioning including many individual houses.*	4	Highest air temperature (minimum, mean and maximum) is likely by 2030.	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.
				5	Highest air temperature (minimum, mean and maximum) is almost certain by 2070.		

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 levels and the height of storm surge are expected to increase. Some billabongs are located a few metres away from the shore (e.g. Pirlangimpi billabong) and are at particular risk.
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, e.g. loss of paperbark swamps.
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 largely 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 cultural activities.</td></tr>
</table>

Risk Title	Risk Rating 2030	Risk Rating 2070	Risk Description	Likelihood		Consequences	
Decreasing availability of bush tucker 	**Medium (8)**	**High (12)**	Loss of bush tucker species from the area due to changed climatic conditions impacting the ecological systems that support these species. Bush tucker species such as mussels, mud crabs form an important part of the diet of the Tiwi Islands communities. Some may disappear from habitats that are affected by saltwater intrusion, changes in fire regimes, increasing weed dominance, changes in soil moisture, etc. *Moderate control over human pressures on species.*	**2**	Unlikely due to increase in air temperature, decrease in rainfall, extension of the dry season, sea level rise and salt water intrusion.	**4**	A change in the distribution of key bush tucker species would represent a major impact.
				3	Possible due to increase in air temperature, decrease in rainfall, extension of the dry season, sea level rise and salt water intrusion.		
Coral reef bleaching and associated impacts 	**Medium (9)**	**High (16)**	Coral is made of two organisms (polyps and micro-algae) living in symbiosis. When the coral area under stress (particularly with warmer SST), the polyp expels the algae which result in coral bleaching. If the bleaching last too long, the coral dies. Coral reefs represent critical breeding and feeding grounds for many fish species. Many seafood species are fished by Tiwi Islands communities. *Moderate control over coral reefs. The current status of the reefs is unknown. Few coral bleaching events have been observed but at the same time there is very little monitoring of the reefs. There are very limited anthropogenic pressures on coral reefs in Tiwi Islands because of limited industrial activities.*	**3**	Possible by 2030.	**3**	Moderate by 2030 as coral bleaching is likely to remain localised.
				4	Likely by 2070 as SST might increase by about 1.7°C.	**4**	Major by 2070 as significant increase in SST could result in widespread coral bleaching events and possible loss of coral reefs.

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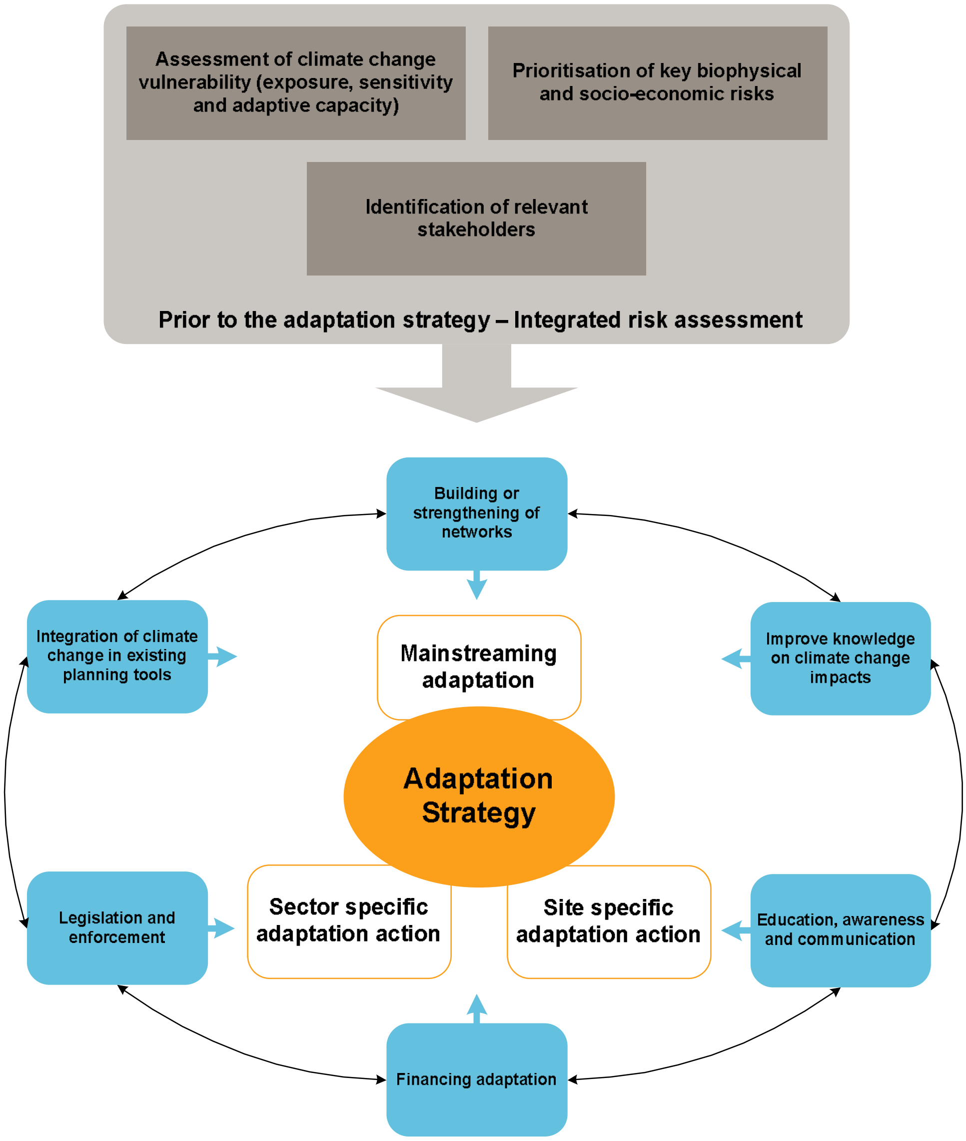
Part 4 – Towards Adaptation: Responding to Climate Change

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 Section9.0. 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 Limited Climate Change Awareness within the Community

There was some awareness and understanding of climate change within the community prior to this project's workshops. There was little questioning of the reality of climate change but there was some confusions around the consequences. In part, this climate change risk assessment project improved the Tiwi Islands communities' 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 Tiwi Islands area. Furthermore there are relatively limited human resources within the Tiwi Islands 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 Tiwi Islands 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 health related climate change impacts

C) Incorporate climate change into procurement

D) Improve resilience of infrastructure for the community

E) Encourage more frequent burning in the vicinity of the communities

F) Continue and expand community based ecosystems monitoring program

G) Prepare a Council's 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 9.4.

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 which integrates cultural knowledge and traditional practices as part of the adaptation solution.

Adaptive capacity

The existing schools and community groups represent effective mechanisms through which increased community understanding may be facilitated. It is also crucial to associate the Tiwi rangers' groups in this approach because of their connections with the communities and their knowledge of the local natural environment. The ranger groups have been delivering awareness program for the past 13 years on the islands.

Option 1
Develop and deliver a community education and awareness program to build community resilience.

Improve awareness of health related impacts of climate change (focus on heat stress)

There is a need to continue building awareness of the impacts particularly increased occurrence of higher temperature days on people targeting more specifically the elderly and the 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). While this health specific awareness campaign should focus on heat related issues other impacts (e.g. airborne related illness and vector borne diseases) could also be part of this action.

Adaptive capacity

Communities have well developed behavioural and cultural responses to manage heat stress. These include staying in shaded areas and low activity during the hottest part of the day. 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. Most communities have a clinic and the local personnel is well positioned to deliver health related advice. The challenge will be linking medical advice in a timely and relevant way to the climate impacts most likely to impact human comfort and health.

Option 2
Incorporate increased heat wave related illness into education provided by health services.

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 Commonwealth 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 might require over time to respond to climate change. These include assets such as roads, drainage, houses and community facilities which need to be designed to cope with future climate conditions not just conditions in the past.

Adaptive capacity

There is low adaptive capacity as there is little engineering capacity and financial resources within the Council to undertake these upgrades.

Option 4
Include climate change considerations in the upgrade, design and development of key community infrastructure.

Option 5
Explore options with Power and Water Corporation to bury the power transmission lines.

Improve protection against storm surge and SLR

Increase in storm surge height has been highlighted as a significant risk for the Tiwi Islands coastal areas. 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 low adaptive capacity as the Council does not have any control over land-use planning.

Option 6
Identify potential engineering solutions for the most threatened areas and integrate SLR and storm surge risks in land-use planning.

More frequent burning around the communities

It has been noted that there is currently low frequency of burning especially around Milikipati. This is likely to result in higher fuel load which would in turn increase the intensity of wild fires. More frequent burning at the beginning of the Dry season could help reducing these fuel loads.

Adaptive capacity

There is considerable local knowledge in terms of burning and it requires limited funding.

Option 7
Conduct more frequent burning around the main communities to reduce the fuel loads.

Continue and expand community base program to monitor biodiversity and ecosystems

There are currently some programs run by the Tiwi Rangers in terms of species monitoring. Some of these programs include a community awareness component with Tiwi Ranger's interventions in classrooms. These programs should be continued and could be extended to include more community and Council's involvement.

Adaptive capacity

The Tiwi Rangers have run programs for more than a decade on the islands and represent a very valuable source of knowledge and an excellent vector to reach the community.

Option 8

Continue and expand community based biodiversity monitoring programs with a strong involvement of the Tiwi Rangers.

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. This background information could for instance be used in discussion with Power and Water Corporation (PWC) when renegotiating maintenance contracts.

Adaptive capacity

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

Option 9

Prepare a Council 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 14 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 15.

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 16.

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 Tiwi Islands 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 14 – 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 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

Table 15 – Prioritised adaptation options

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9
Effectiveness	Medium	Medium	Medium	High	Low	Low	High	Medium	Low
Cost	High[3]	Medium	High	Low	High	Low	High	Medium	High
Speed	High	High	Medium	Low	Low	Low	High	Medium	Low
Technical Feasibility	High	High	Medium	High	High	High	High	High	High
Human Capability	Medium	Medium	Medium	Low	Low	Low	High	Medium	Low
Council Acceptance	Medium	High	Medium	High	Low	Medium	High	Medium	Medium
Community Acceptance	High	High	Medium	Medium	Medium	Medium	High	High	Medium
SCORE	**23**	**22**	**20**	**18**	**16**	**11**	**27**	**20**	**17**
RANK	**2**	**3**	**4**	**6**	**8**	**9**	**1**	**4'**	**7**

Table 16 – Prioritised adaptation summary

Priority Ranking	Prioritised Adaptation Options for Tiwi Islands Shire Council
1	*Conduct more frequent burning around the main communities to reduce the fuel loads. Option 7.*
2	*Develop and deliver a community education and awareness program to build community resilience. Option 1*
3	*Incorporate increased heat wave and mosquito related illness into education provided by health services to the community. Option 2*
4	*Use procurement process to screen investment to address climate change risks to infrastructure and services. Option 3*
4'	*Continue and expand community based biodiversity monitoring programs with a strong involvement of the Tiwi Rangers. Option 8*
6	*Include climate change considerations in the upgrade, design and development of key community infrastructure. Option 4*
7	*Prepare a Council's position paper on climate change. Option 9*
8	*Explore opportunities with Power and Water Coporation to bury transmission lines. Option 5*
9	*Improve protection against storm surge and sea level rise. Option 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.

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 Tiwi Islands 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. Amongst other dynamics, climate change will bring even hotter temperatures, more intense cyclones and sea level rise. These changes in the climate will impact the natural environment, infrastructure and the Tiwi Islands people.

This assessment has highlighted a number of risks associated with climate change to which the Tiwi Islands 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: damages to electricity distribution lines, damages by intense cyclones and storm surges, heat related illness, salt water intrusion in the freshwater ways and billabongs, decreasing availability of bush tucker and coral bleaching. 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 Tiwi Islands community.

Another series of risks have been assessed as “low” including risks associated with mosquitoes, insect borne and airborne illness, and damage to in the short term.

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, increase burning around the communties, including climate change in the Council procurement and targeting heat 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 Tiwi Islands community and the consideration of local and traditional knowledge.

This project was the first step for the Tiwi Islands community to prepare for the inevitable impacts of climate change. It has provided the opportunity for the Council and the Tiwi Islands 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 reassessed by the community in the future. These activities could be driven by “climate change champions” within the community. Representatives in the young, elderly, women’s and men’s groups would provide a good coverage of the Tiwi Islands community. The Tiwi Islands Shire Council also has the opportunity to work closely with the Tiwi Ranger group too expand community based biodiversity monitoring programs and activities.

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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 17.

Table 17 – SRES scenarios

<table>
<tr><th>SRES Scenario</th><th colspan="2">Description of Scenario</th></tr>
<tr><td>A1FI</td><td rowspan="3">Rapid economic growth, a global population that peaks mid 21st century and rapid introduction of new technologies</td><td>Intensive reliance on fossil fuel energy resources</td></tr>
<tr><td>A1T</td><td>Intensive reliance on non-fossil fuel energy resources</td></tr>
<tr><td>A1B</td><td>Balance across all energy sources</td></tr>
<tr><td>A2</td><td colspan="2">Very heterogeneous world with high population growth, slow economic development and slow technological change</td></tr>
<tr><td>B1</td><td colspan="2">Convergent world, same global population as A1 but with more rapid changes in economic structures toward a service and information economy</td></tr>
<tr><td>B2</td><td colspan="2">Intermediate population and economic growth, emphasis on development of solutions to economic, social and environmental sustainability</td></tr>
</table>

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 18 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 18 – Climate projections for the Darwin/Tiwi Islands Region (CSIRO 2010)

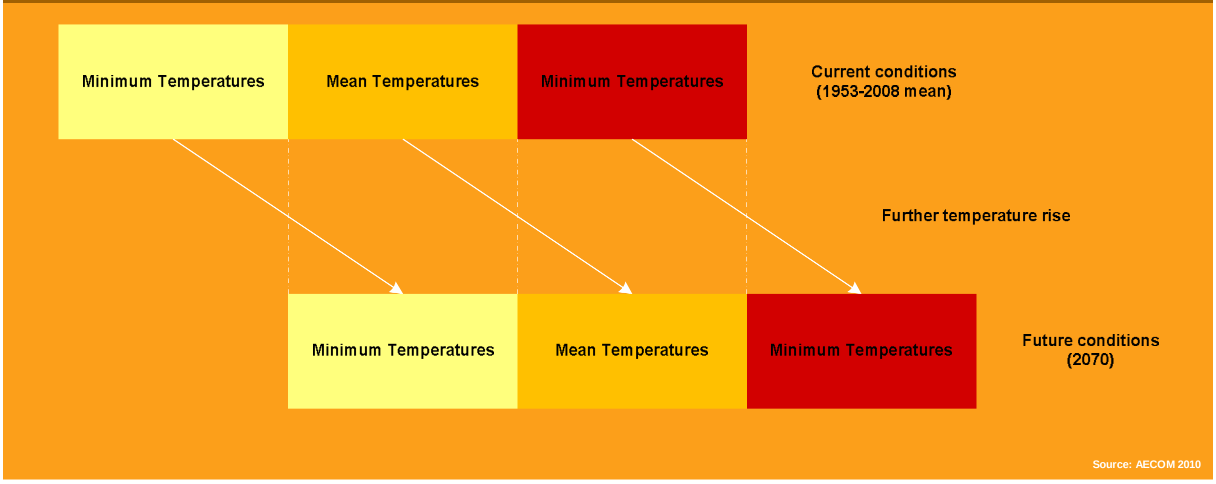
	Change in 2030 (A1B) with respect to 1990											
	Model	Mean precipitation			Mean surface temperature			Mean max surface temp	Mean min surface temp	Mean relative humidity		
Story		Ann	Wet	Dry	Ann	Wet	Dry	Ann	Ann	Ann	Wet	Dry
Most likely (19 models): Warmer - Little rainfall change	INM-CM3.0	-2.42	-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 4: Temperature shift

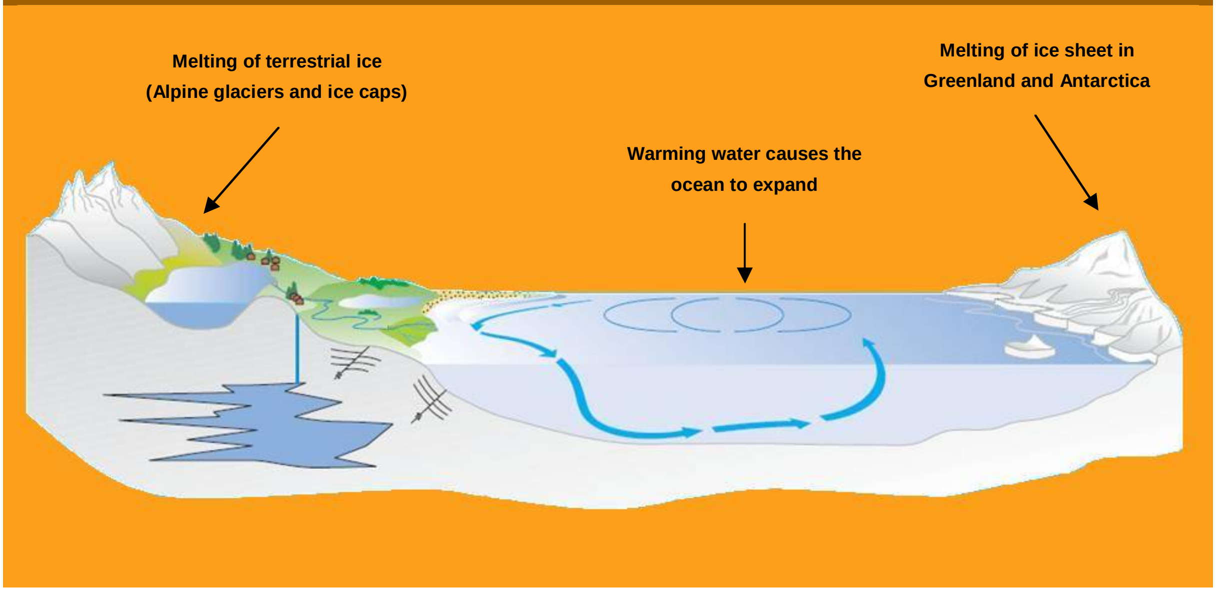


Sea Level Rise

Key Mechanisms

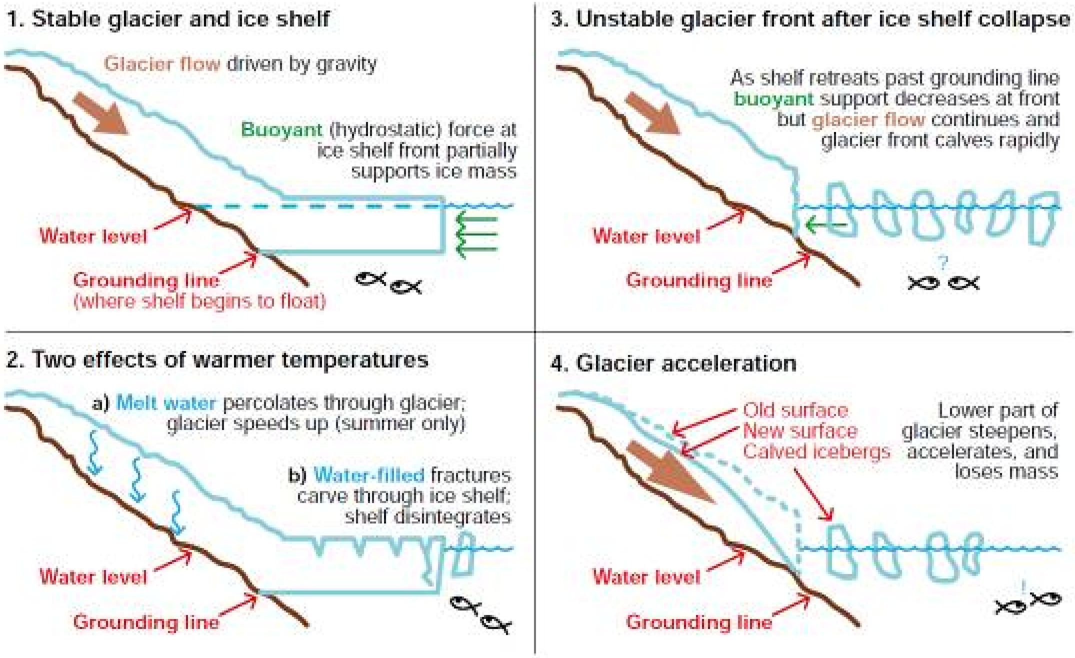
The observed sea level rise over the last 30 years is mainly the consequence of the thermal expansion of ocean water. As the water gets warmer, it expands and the global sea level rises. The melting of alpine glaciers and icesheets (in Greenland and Antarctica) are also contributing to this rise. The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

Box 5: 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:

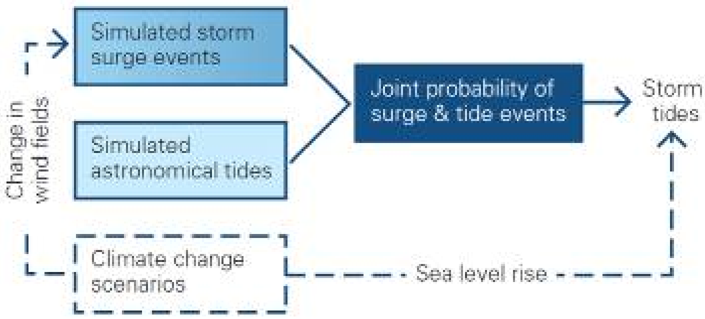
- Global emissions of carbon dioxide have accelerated rapidly since approximately 2000, consistent with the high-end emission scenarios. The Garnaut Climate Change Review suggests that global emissions will exceed the highest IPCC scenarios under a business-as-usual scenario (Commonwealth of Australia, 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 Tiwi Islands area.

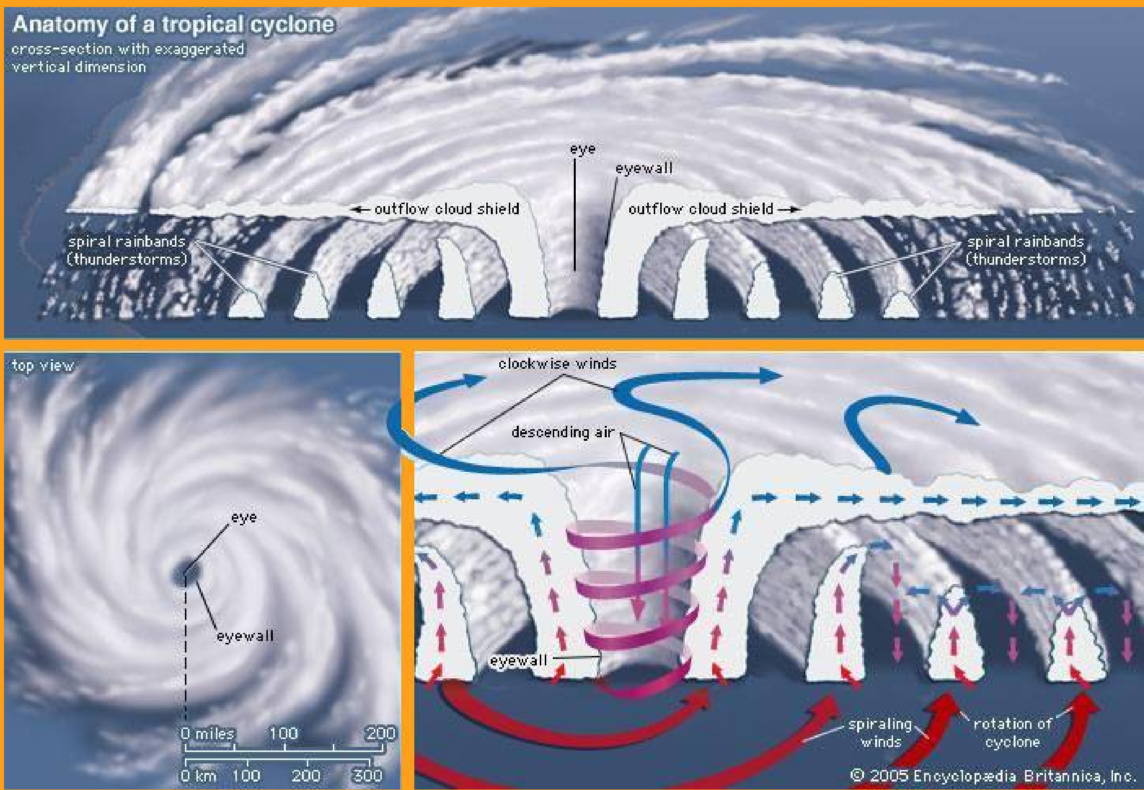
Figure 18 – An illustration of CSIRO's approach to assess potential climate change effects on extreme sea levels (DSE 2010)



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 6: Tropical cyclone



Source: Encyclopaedia Britannica

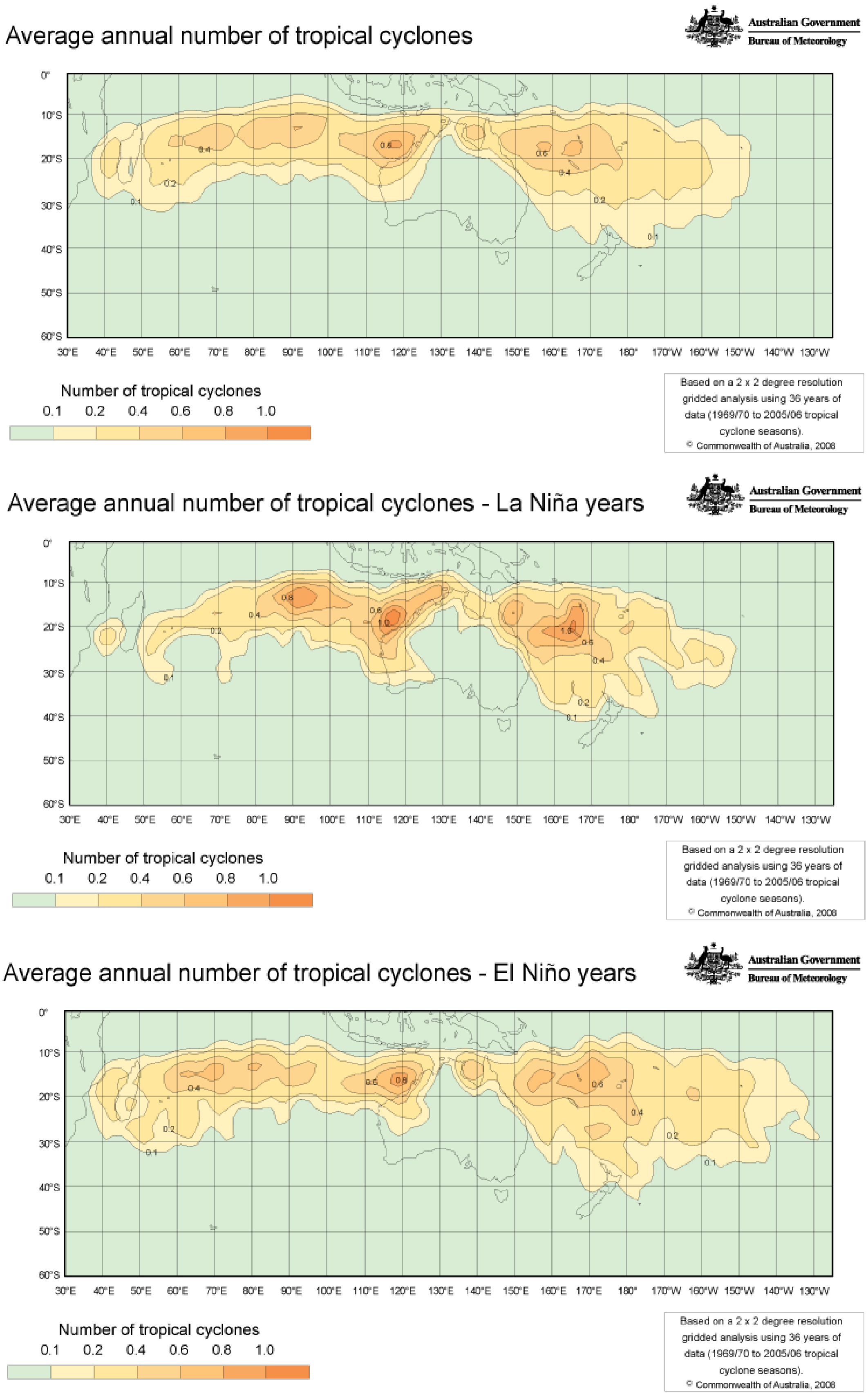
Cyclones are classified depending on the speed of their winds. An example of the classification is provided in Figure 19.

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)

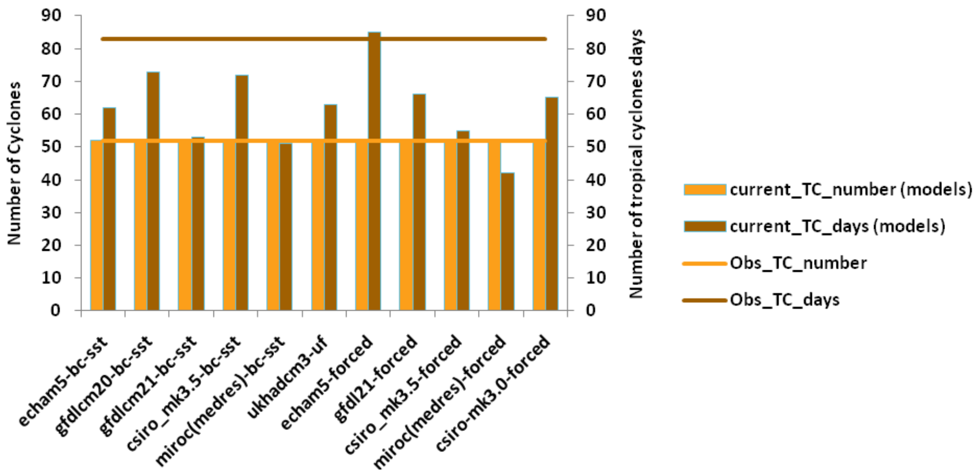


Projections

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.

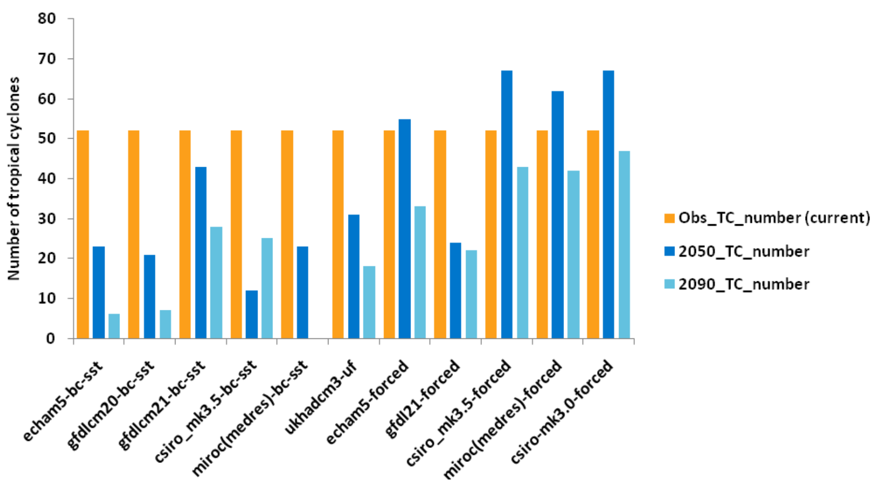
The climate models have a too large grid (200 kilometres on average) to propose an accurate evaluation of the future cyclonic activity. The projections proposed hereafter have to be considered as indicative only. They indicate direction of changes and the projected number of cyclones should not be considered 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)

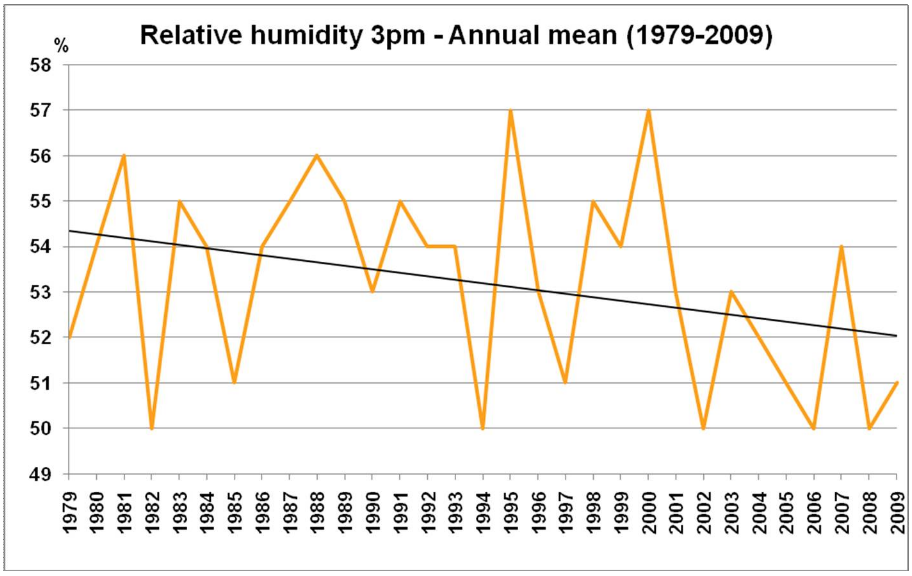


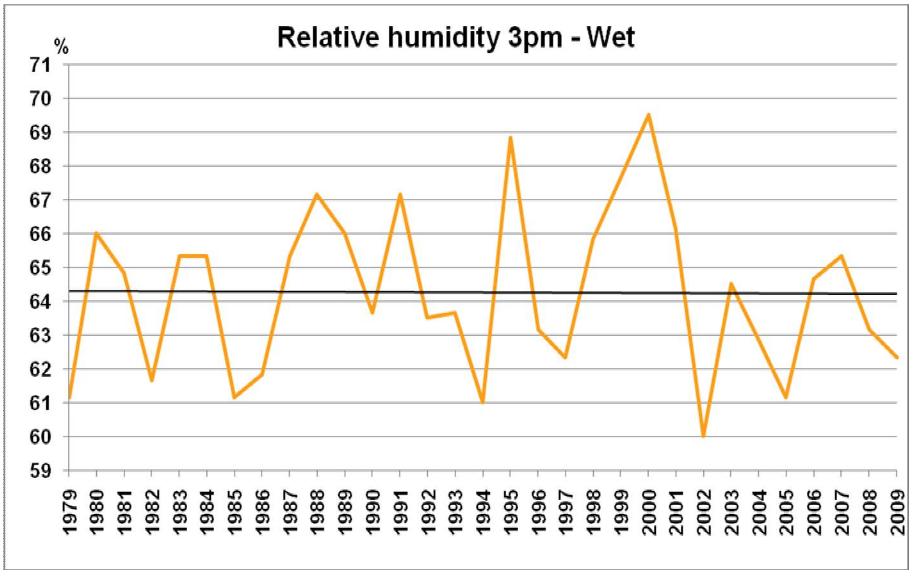
Appendix B

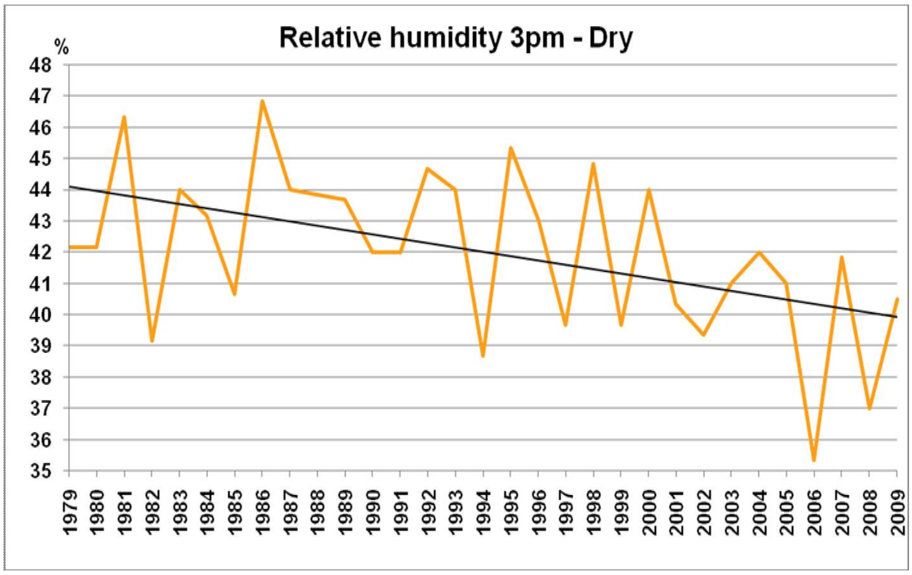
Climate Observations

PIRLANGIMPI

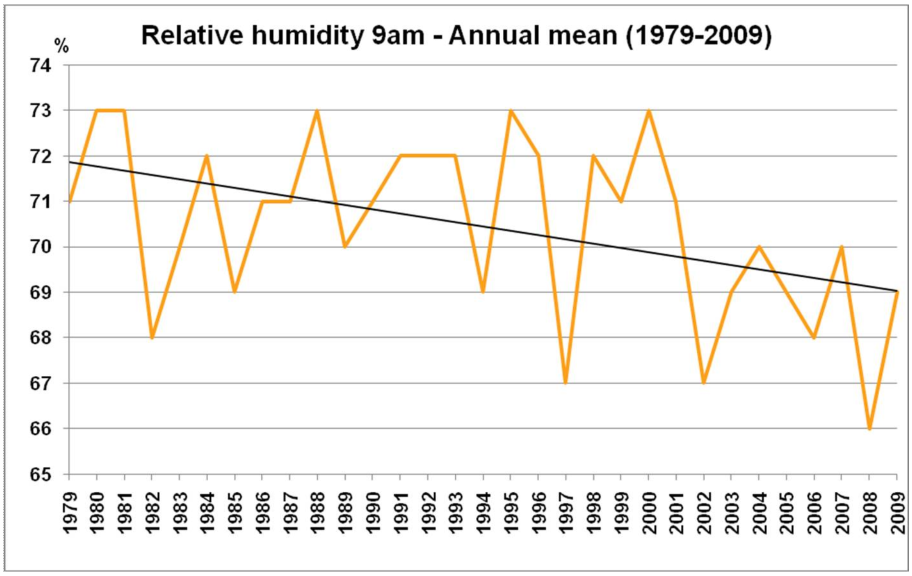
Relative Humidity 3pm

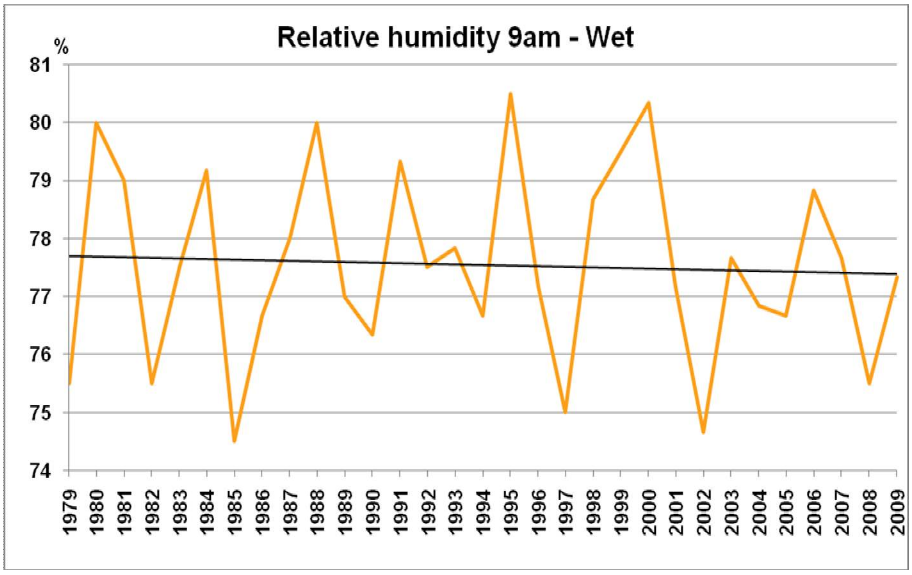


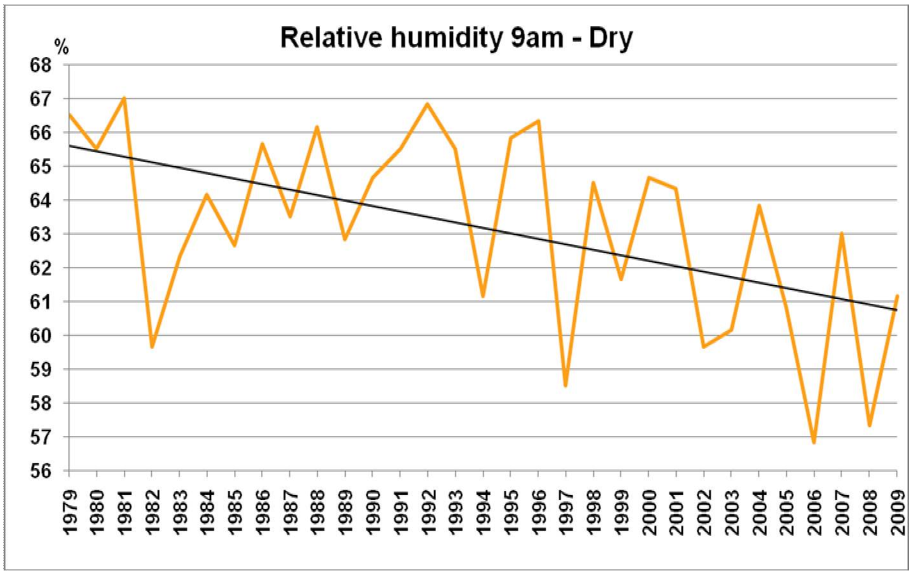




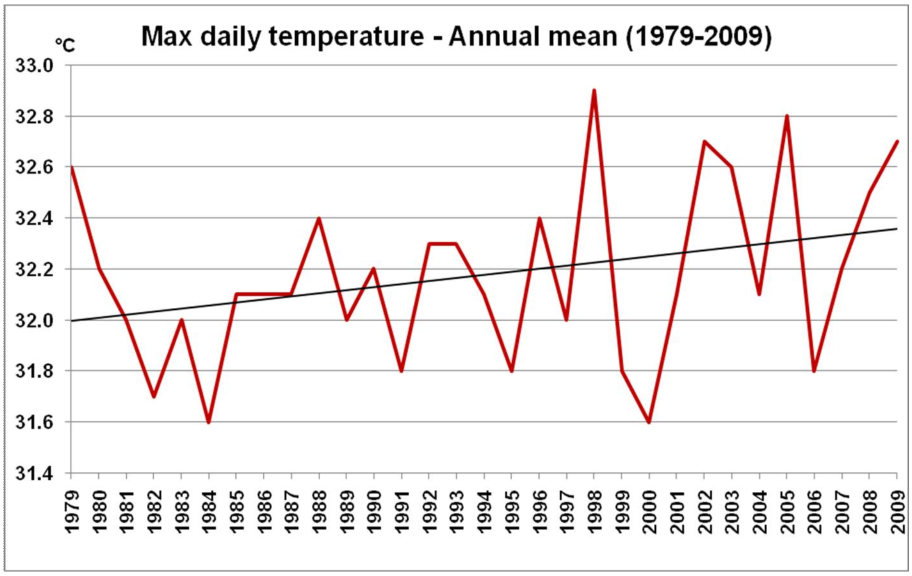
Relative Humidity 9am

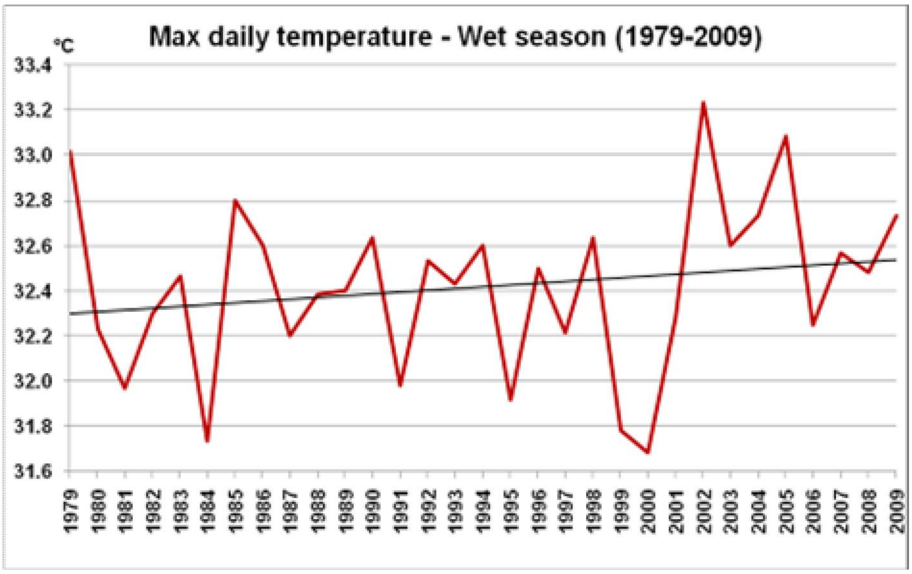


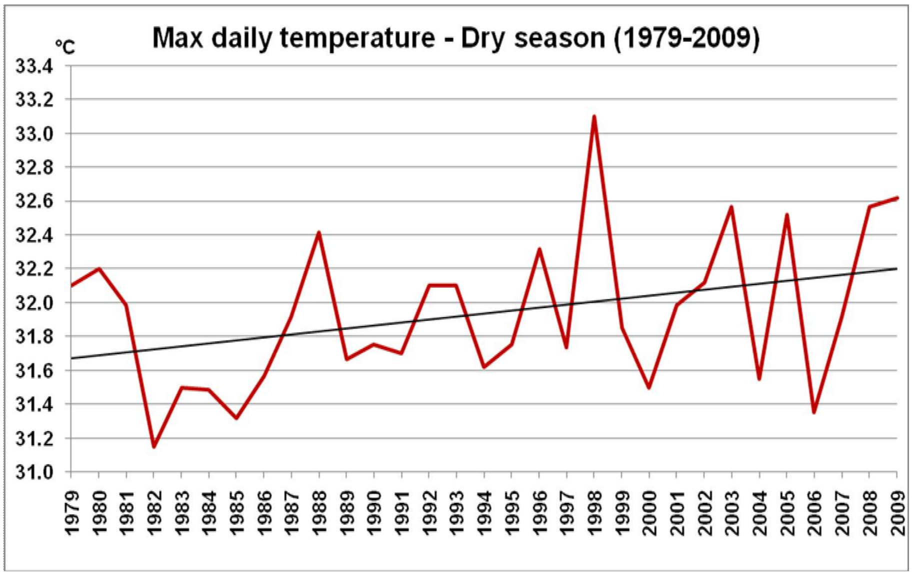




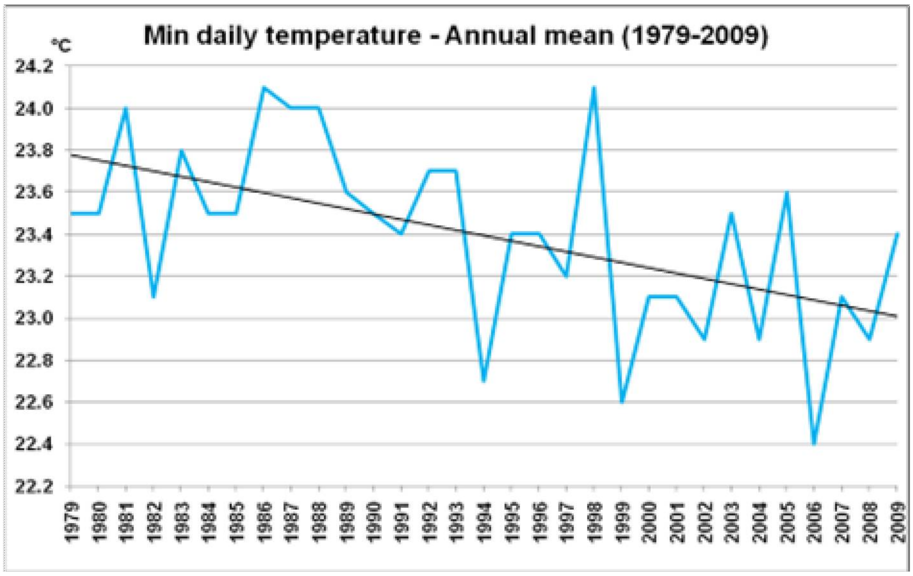
Maximum Daily Temperature

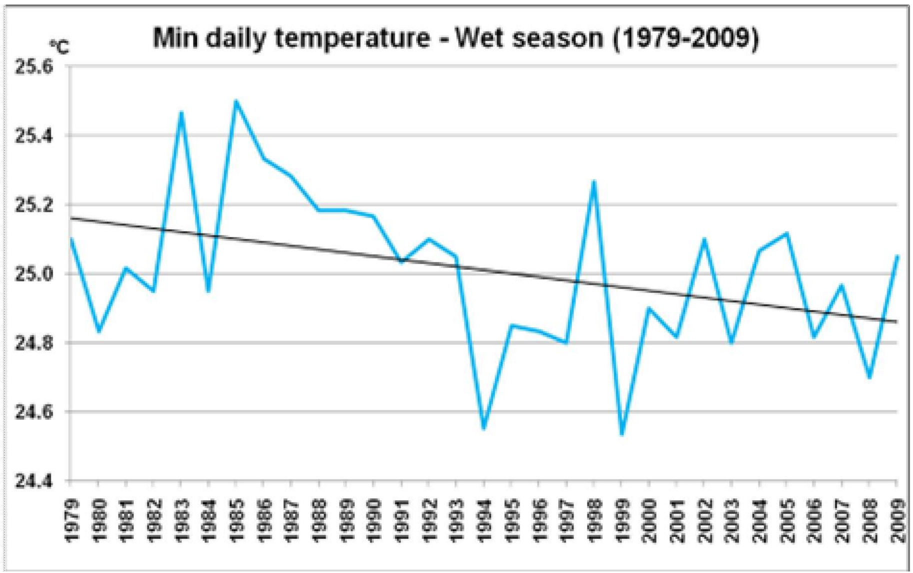


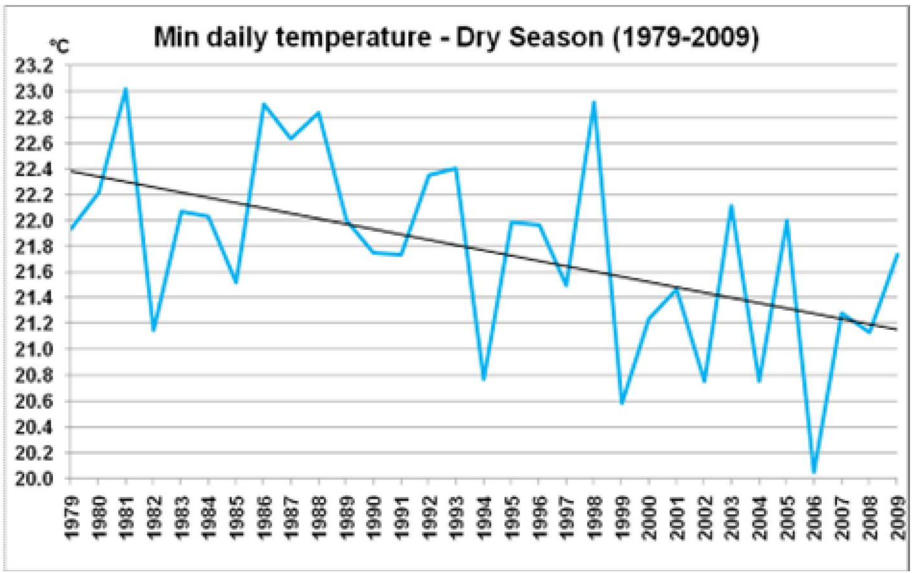




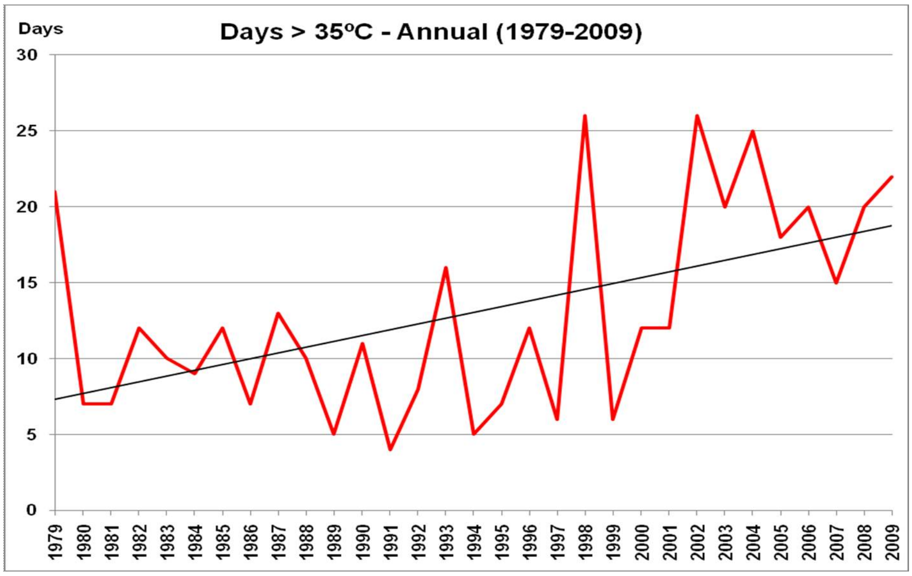
Minimum Daily Temperature

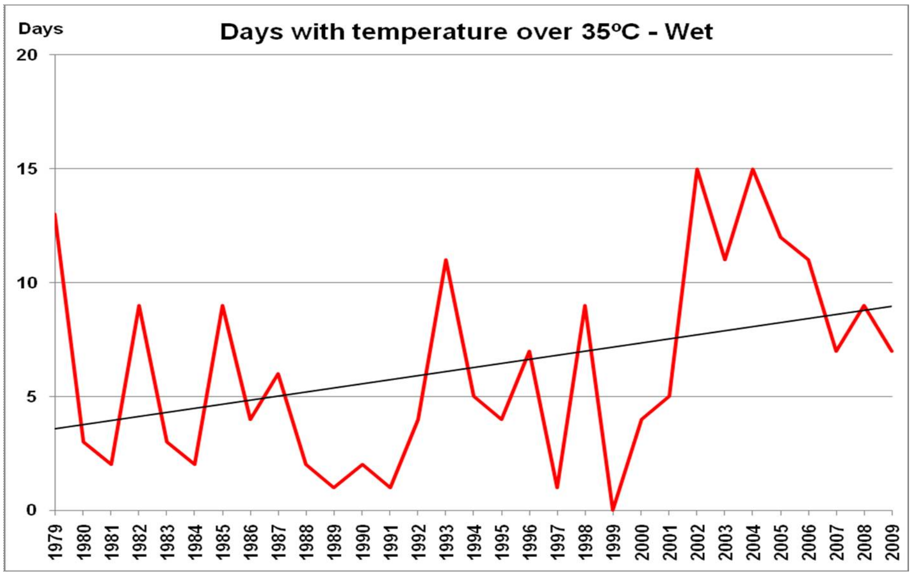


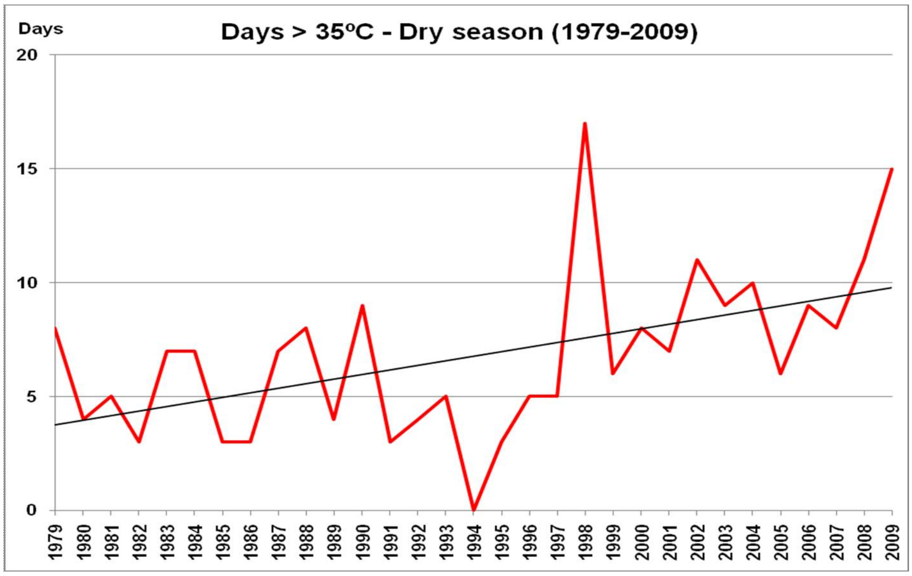




Days with temperature over 35ºc







Total Monthly Rainfall