Proposed Development Of Foxwood Dam & Associated Infrastructure

Climate Change Study

Authority Reference No: *14/12/16/3/3/1/2/817*

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Final

Prepared for: Department of Water and Sanitation

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Title and Approval Page

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Amendments Page

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Executive Summary

The Department of Water and Sanitation proposes to develop the Foxwood Dam and associated infrastructure. The aim of the scheme is to provide additional assurance of water supply to improve resilience of domestic water supply within the region. In addition, the project is being considered for implementation as a strategic initiative to mobilize the water resources in the area as a stimulus for socio-economic development in this rural, economically depressed region.

This Climate Change Study aimed at assessing impact of the development of Foxwood Dam (and associated infrastructure) on Climate Change as well as the potential vulnerability of the Dam to Climate Change. This involved understanding Climate Change scenarios for the Eastern Cape with models suggesting that the province will experience drastic increases in the annual average temperature of 2 to 5°C (4 to 6°C) for the period 2080–2100 (Department of Environmental Affairs , 2013). In terms of Rainfall, the area is likely to exhibit a pattern of drying. However, although drying is expected overall, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario. Long term adaptation strategy models also suggest that the Eastern Cape is one of the areas which shows the highest risks in extreme runoff related events (and flooding conditions) (Department of Environmental Affairs , 2013). Based on this information, an assessment of impacts and vulnerability was undertaken and a number of mitigation responses (**human intervention to reduce the sources or enhance the sinks of greenhouse gases)** as well as adaptation measures (**adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities**) have been recommended are summarised in below:

- Mitigation:
  - Quantify natural pre-impoundment carbon fluxes. Determine de-bushing requirements and compare against monitored data from of post-impoundment greenhouse gas emissions. Employ the UNESCO Greenhouse Gases Measurement Guidelines for Freshwater Reservoirs (or other acceptable best practice) to determine the Dam’s greenhouse gas footprint as part of the Environmental Management Programme.
  - Clear vegetation within the Dam impoundment. Where possible, woody material can be provided to local communities for use as firewood.

- Detailed design and operating manual should aim to minimise water level fluctuations.
- Materials should be managed in line with the recommendations of this document including (lowest embodied Carbon content, high recycled content, local materials to be sourced if possible, correct ordering of materials, accurate ordering of materials, materials and resources are stored in a safe and dry location to minimise damage and resultant need to re-order materials). It is also recommended that a Greenhouse Gases emissions calculator be developed which will assist in the comparison of the impact of different materials.
- The operational performance of accommodation facilities on site should be considered so to maximise the efficient use of energy and water;
- Plant should be managed correctly including the use of the correct machinery, fuel efficient plant should be used and suitable training should be provided to operators to ensure that they maximise the efficiency of the plant.
- Fill material should be sourced from the closest borrow sites thereby minimising the transportation emissions
- In terms of transportation of workers and staff, collective transportation arrangements should be made to reduce individual car journeys.
- All vehicles used during the project should be properly maintained and in good working order.
- The detailed design of the infrastructure should take into account energy efficiency best practices. For example, both temporary and permanent offices can use energy efficient light bulbs.
- Possible alternative energy sources be integrated into the design of the pump station (use of solar panels in conjunction with typical sources of electricity).
- Energy controls should be put in place to minimise the use of energy. For example, the use of light controls set to timers/occupancy sensors.
- Energy management should be incorporated and energy use should be measured and reported to ensure that operational staff are aware of consumption. In addition to this, operational staff should receive training to ensure that they are aware of the importance of energy efficiency.
- Regular maintenance should take place during the operational phase to ensure efficient performance and minimise the likelihood of emissions.
- It is recommended that the potential for hydro-electricity be considered during the detailed design phase.

- Adaptation:

  - Future hydrological patterns need to take into account Climate Change scenarios.

- New mechanisms should be put in place to cope with the lower or high water levels during the detailed design stage.
- Hydrological modelling should take into account increased temperatures to ensure surface water evaporation is adequately accounted for.
- If possible, surface water evaporation should be minimised through decreasing the surface area.
- Optimum management of water resources is thus required and climate change implications should be considered in the operating manual and Resource Management Plan for the Dam.
- Water conservation and demand management strategies should be implemented and Dam managers should work with municipalities are ensuring that water losses are reduced as well as encouraging households to practice water serving technologies (e.g. dual flush toilets) and practices (e.g. use of showers instead of bath tubs) (Petermann, 2008).
- Other potential adaptation measures include increased flood storage capability and provisions for future off-stream storage (Mahahabisa, 2011).
- Where possible making buildings water-tight (e.g. temporary flood gates on doors/openings. Building designs should also enable the closure of external drains (to prevent backflow into the building) and increasing flood-resistance of buildings/assets by raising critical equipment and points of potential ingress above the maximum expected flood level. There is also potential to install physical flood barriers (for example around pump stations);
- Provision of alternative energy sources (for example solar power to ensure that pump stations have back up energy sources); and
- Raising boundary walls at intake sites (World Health Organisation, 2011).
- Long term risk management also should include inter-institutional coordination (for example with municipalities and other water users) as well as capacity building and personnel training for emergencies (World Health Organisation, 2011).
- In terms of design, it is also plan to incorporate additional measures as part of 'flood-proofing' the Dam such as planning for a supplemental spillway capacity for overflow or an emergency spillway, increasing flood storage capacity, planning for future parallel outlet tunnel as well as ensuring the diversion arrangement and Dam type selection take into account the risk of increased flooding (Babtie Group Ltd, 2002).
- There are a number of strategies available to enhance the resilience of concrete to climate change. For existing structures and infrastructure cover designs, surface coating barriers and cathodic protection can be applied. For new infrastructure, the design principles and standards will need to be amended to ensure that climate change is taken into consideration (CSIRO, 2009).

- The materials used throughout the construction of Foxwood Dam must take into account the likely increased temperatures in the area.
- Building design should also take into account potential increasing temperatures. A number of 'green building' best practices are available.
- Potential adaptation measures include the construction of berms and swales upstream to reduce siltation in areas where the erosion potential is high (Mukheibir, 2007)
- The operating manual of the Dam must take into account increased flooding potential (Babtie Group Ltd, 2002).
- Early warning systems should be developed and implemented.
- Water conservation measures should also be included in the design of the irrigation scheme.
- All downstream users must remain outside the 1:100 year floodline and floodline calculations for new downstream developments should take into account the Dam.
- The operating manual and/or Resource Management Plan for the Dam should also take into account Climate Change scenarios and should include adaptation measures for floods and droughts.
- Emergency preparedness plans should also include climate change.
- In regards to water quality, an important adaptation response is enhanced monitoring to detect deterioration water quality (turbidity/physical quality; indicator organisms (pathogen loading); algal species and counts; broad chemical screens (e.g. GC/MS scan) for emerging contaminants; limnology – risks of low draw-down, storage Dam inversion; vector-borne diseases (open Dam management); and emerging risks – suggested chemicals/pathogens, viruses, etc.) (World Health Organisation, 2011).
- In terms of flooding, where possible adaptation measures should be put in place to assist in the management of drinking-water supplies during such periods in anticipation of extreme events.
- The operating manual for the Dam should take into account the management of water level fluctuations to decrease changes in water level which are favourable to aquatic invasive plant species (Petermann, 2008).
- Furthermore, during the Resource Management Plan process, it is suggested that mechanisms to deal with and prevent aquatic invasive species be taken into account such as the implementation of wash bays at the Dam.

As the alternatives for the Foxwood Dam and associated infrastructure project occur at a localised level and the Climate Change impacts at a regional scale, there were no preferences for alternatives. However it should be noted that the mitigation and adaptation measures discussed above should be incorporated into the detailed design regardless of the alternative type.

With the successful implementation of the mitigation measures, the proposed development is not thought to pose significant long-term impacts on Climate Change. Furthermore, through the incorporation of adaptation responses into the detailed design, operating manual and RMP process, it is possible to ensure that Foxwood Dam will not be vulnerable to Climate Change. Therefore, from a Climate Change perspective, the proposed development may proceed.

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List of Abbreviations

CCAM	Conformal-cubic atmospheric model
COP	Conference of the Parties
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
ERF	Effective Radiative Forcing
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
LTAS	Long Term Adaptation Strategy
LTMS	Long Term Mitigation Strategy
LWR	Long Wave Radiation
NDP	National Development Plan
NEMA	National Environmental Management Act (No. 107 of 1998)
RMP	Resource Management Plan
SSTS	Sea Surface temperatures
SWR	Short Wave Radiation
UNFCCC	United Nations Framework Convention on Climate Convention
WMA	Water Management Area

1 PROJECT OVERVIEW

1.1 Project Background and Description

1.1.1 Overview

Adelaide (and surrounding towns) has suffered water shortages in the past and investigations into the potential development of the water resource within the Koonap River Valley have been undertaken from the 1960's. Later, during the 1990's, the development of a scheme in the area was re-considered to augment domestic supplies as well as for some development of commercial irrigation. The scheme was not developed due to farmers not accepting the resultant cost of water.

However in 2009, the Nxuba Local Municipality raised the issue of water shortages at the 2009 Eastern Cape Water Indaba. In response, the Department of Water and Sanitation (DWS) proposed a comprehensive Feasibility Study for developing a multi-purpose Dam on the Koonap River outside of Adelaide in the Eastern Cape. The proposed site is known as the Foxwood Dam site and aimed to provide additional assurance of water supply to improve resilience of domestic water supply within the region. In addition, the project is being considered for implementation as a strategic initiative to mobilize the water resources in the area as a stimulus for socio-economic development in this rural, economically depressed region. This initiative would support the objectives of the National Development Plan (NDP) and is consistent with the National Water Resource Strategy 2.

In addition, DWS has also identified a Government Irrigation Scheme on naturally occurring irrigable soils along the Koonap River downstream of the Foxwood Dam site. The scheme will use the human resource potential in the Amatole District Municipality to stimulate socio-economic development. A strategic intent of the project is to mobilize the water resources in the area for irrigation development downstream of the proposed Foxwood Dam.

The scheme involves the following the purchase of 13 000 ha of land of which 1 250 ha is irrigable land and will be run by new irrigation farmers under the guidance of current commercial farmers in the area. Overall, it is estimated that the development could generate approximately 1 934 direct sustainable jobs in the local municipality and stimulate up R 503 million of GDP contribution (Arup (Pty) Limited, 2014). This Government Irrigation Scheme is one of the key drivers of the Foxwood Dam project.

1.1.2 Project Location

The project area is situated in central part of the Eastern Cape, in the Amatole District Municipality and Nxuba Local Municipality. The town of Adelaide and the Bezuidenhoutville Township are located to the south-east of the Dam. Adelaide lies 37 km west of Fort Beaufort, on the R63 between Bedford and Fort Beaufort, and is situated in the foothills of the Winterberg Mountain range. Adelaide serves as an administrative and decision-making centre in the region. It is predominantly a farming town, in a beef, mutton, wool and citrus farming district.

From a southern direction the proposed Dam wall site is accessed via the R344 (off the R63). **Figure 1** provides the location of the proposed development.

In terms of the water resources context, the Dam would be built on the Koonap River which is a tributary of the Great Fish River, within the Fish-Tsitsikamma Water Management Area (WMA). The area of the Foxwood Dam catchment is 1 091 km^2 which is 33% of the total catchment area of the Koonap River catchment.

The Foxwood Dam catchment is rural in nature with agriculture representing a major land use. Water related infrastructure is dominated by run of river abstractions or diversions for domestic use and for the irrigation of crops.

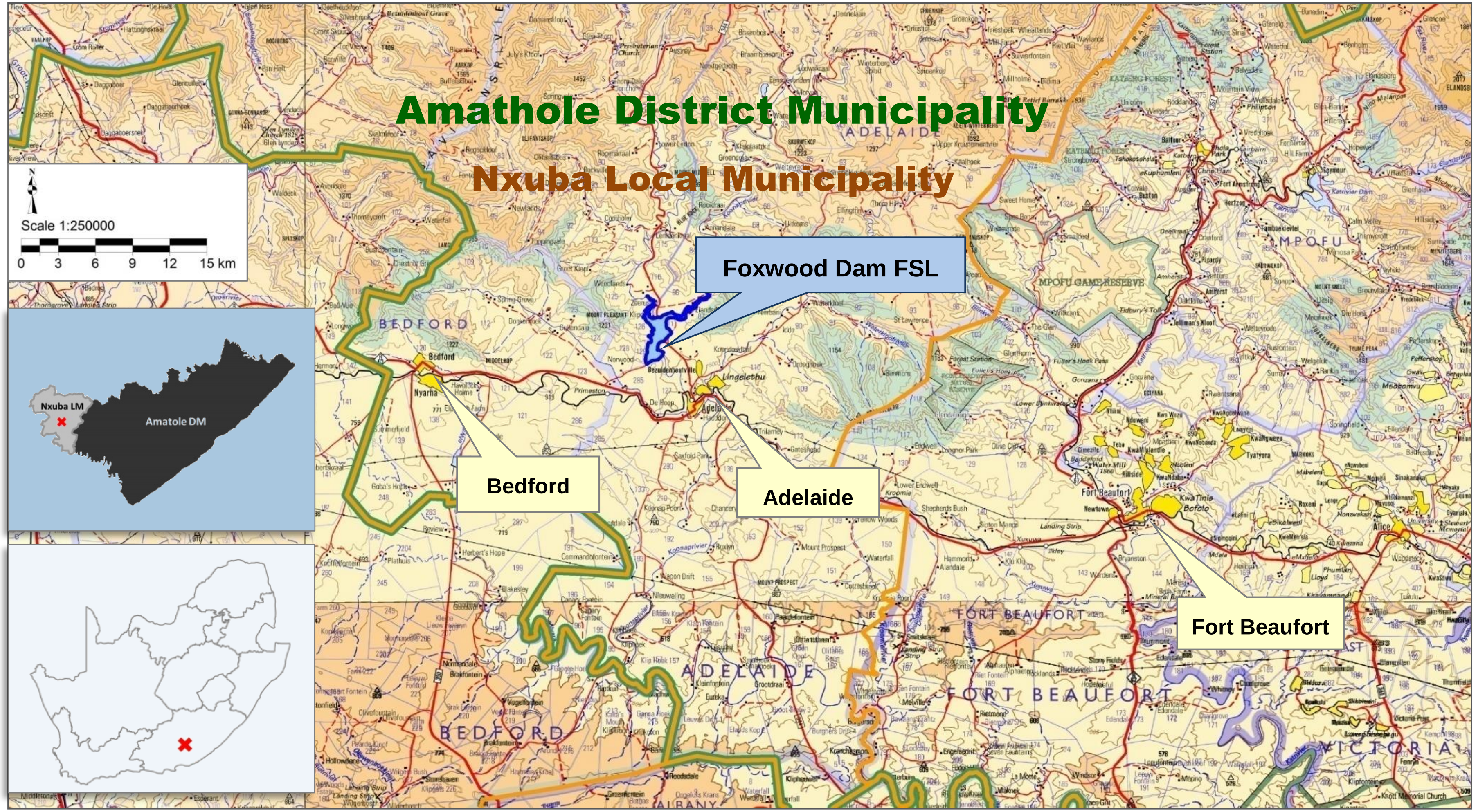

Figure 1: Regional Map

1.1.3 Project Components and Alternatives

The project consists of the components listed in the **Table 1** and mapped in **Figure 2** below.

Table 1: List of project Components and Alternatives

Project Components	Associated Infrastructure
Major storage Dam (Foxwood Dam)	1. Dam wall 2. Embankment 3. Dam outlet works (including Dam intake tower, tunnel and outlet valve house) 4. Access roads (construction and operation) 5. Quarry and earthfill borrow areas 6. Electrical supply 7. Construction camp (temporary) 8. Operator's offices and accommodation (permanent)
Bulk water supply pipeline	1. Pump station 2. Pipeline and associated structures (chambers, Cathodic Protection measures, AC mitigation measures, pipeline markers)
Gauging Weir	1. Weir and associated instrumentation 2. Access roads (construction and operation) 3. Electrical supply 4. Satellite construction camp
Relocation of Infrastructure	1. Relocate water supply canal 2. Relocate R344 3. Relocate MR00639 4. Relocate Telkom telephone line 5. Relocate Eskom power line

Alternatives are the different ways in which the project can be executed to ultimately achieve its objectives. The alternatives to the project components are listed in **Table 2**.

Table 2: Alternatives of Project Components

Component	Alternatives
Major Storage Dam	Dam type
Gauging Weir	Option 1
	Option 2
Power Line Deviation	Alignment A
	Alignment B
Laydown Area	Option 1
	Option 2

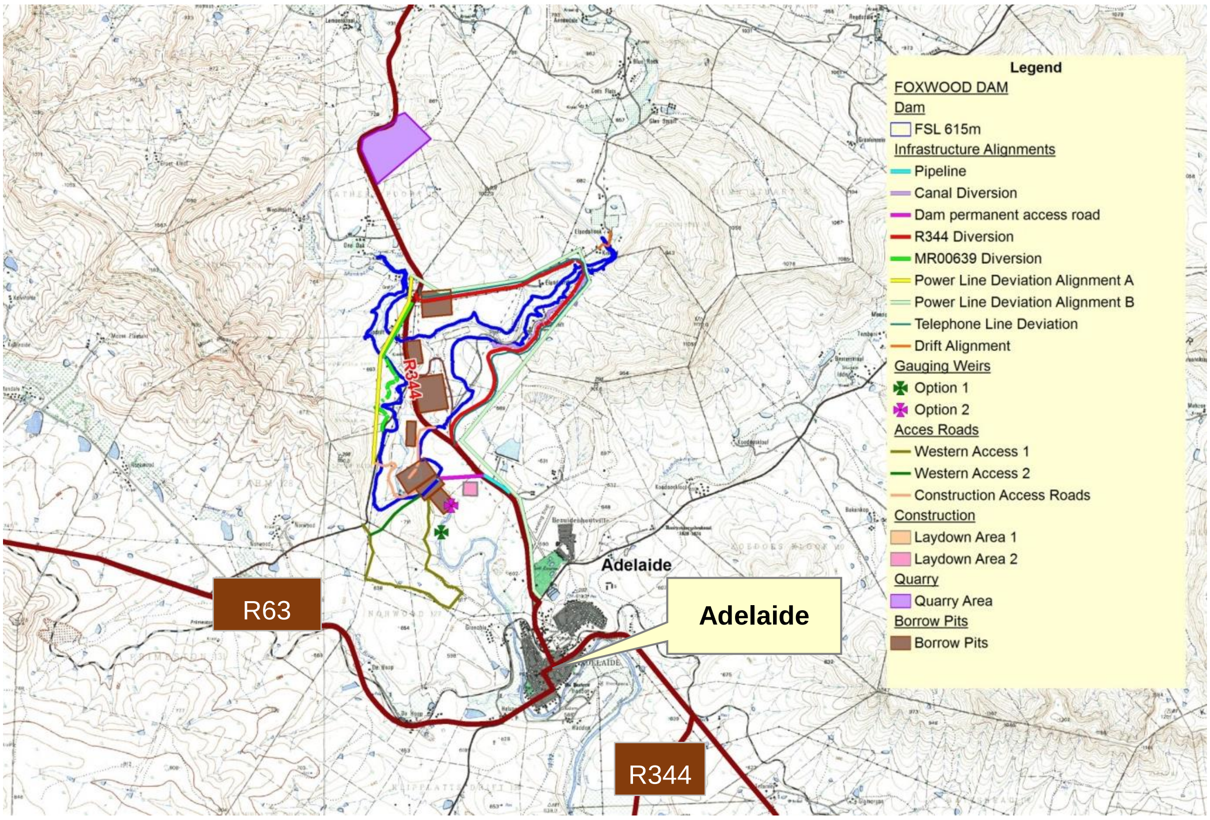

Figure 2: Project Components

1.2 Terms of Reference

The terms of the reference for the Climate Change Study include assessing impact of the development of Foxwood Dam (and associated infrastructure) on Climate Change as well as the potential vulnerability of the Dam to Climate Change and the resultant adaptation responses required.

1.3 Structure of the Report

The Climate Change Study for Foxwood Dam is structured as follows:

Table 3: Structure of the Report

Chapter Number	Chapter Name	Description
Chapter 1	Project Overview	Chapter 1 provides a brief overview of the project description, motivation and components. The terms of reference for the study and the structure of the report are also provided.
Chapter 2	Overview of Climate Change Concepts and	An overview of the Climate Change terminology is provided to provide context to the Study. In

Chapter Number	Chapter Name	Description
	Terminology	addition, a summary of the main Climate Change Concepts are also provided.
Chapter 3	Methodology	Chapter 3 provides an overview of the methodology utilised to compile the Climate Change Study.
Chapter 4	Climate Change Policy and Framework	Chapter 4 provides an overview of the legal and policy framework.
Chapter 5	Climate Change Scenarios	Chapter 5 provides an overview of climate change scenarios for the area.
Chapter 6	Identification of Activities, Aspects and Impacts	Chapter 6 explains the main activities, their interaction with the environment (aspects) and the potential impacts.
Chapter 7	Climate Change Impacts	This chapter assesses each potential impact of the Dam on climate change and proposes mitigation measures.
Chapter 8	Vulnerability to Climate Change	This chapter explains how the Dam itself may be vulnerable to climate change and proposes adaptation measures which can be incorporated into the final design.
Chapter 9	Assessment of Alternatives	Chapter 9 provides an assessment of alternatives based on the climate change impacts and vulnerability.
Chapter 10	Conclusion	Chapter 10 provides a conclusion to the study and makes a recommendation in regards to the development.
Chapter 11	References	Chapter 11 lists all references used during the study.

2 Overview of Climate Change Concepts and Terminology

2.1 A Brief Overview of Climate Change

In order to adequately respond and adapt to Climate Change, it is necessary to understand the available information regarding climatic trends. The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organization and the United Nations Environment Programme to provide governments with a clear view of the current state of knowledge about the science of climate change, potential impacts, and options for adaptation and mitigation through regular assessments of the most recent information published in the scientific, technical and socio-economic literature worldwide. There have been a number of IPCC reports through the years and the most recent work (IPCC AR5) presents the most up-to-date assessment of the current state of research regarding climate change. The information summarised below has been taken from the Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013) and aims to provide the reader with a broad overview of the science of Climate Change.

2.1.1 Climate Change Terminology

In order to provide context to the following chapters, an overview of important terminology is provided below.

Firstly, in order to understand the concept on climate and climate change, it is important to distinguish between the concepts of climate and weather: Weather describes the conditions of the atmosphere at a certain place and time with reference to temperature, pressure, humidity, wind, and other key parameters (meteorological elements). Climate, on the other hand, is usually defined as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC, 2013). The relevant quantities are most often surface variables such as temperature, precipitation and wind. Classically the period for averaging these variables is 30 years, as defined by the World Meteorological Organization (IPCC, 2013). The main difference is that while weather changes on a daily basis, climate represents the statistical distribution of weather patterns over time.

Taking the concepts of weather and Climate further, and in line with the National Climate Change Response White Paper, Climate Change refers to an *ongoing trend of changes in the earth's general weather conditions.* A more formal definition is provided by the Intergovernmental Panel on Climate Change (IPCC): *"A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer."* (IPCC, 2013).

Secondly, when dealing with Climate Change, there are two main areas to consider. These include the impacts **ON** Climate Change as well as the impacts **OF** Climate Change. The former requires management in the form of mitigation measures, whilst the latter needs to be dealt with through the use of adaptation responses.

A mitigation measure (in relation to Climate Change) is defined as a response aimed at reducing the rate at which the Climate is changing, to levels that occur naturally. This is mainly focused at reducing the atmospheric concentrations of Greenhouse Gases (GHGs). The United Nations Framework Convention on Climate Convention (UNFCCC) defines mitigation as the **human intervention to reduce the sources or enhance the sinks of greenhouse gases** (United Nations Framework Convention on Climate Change, 2011)**.**

Adaptation responses on the other hand focus on dealing with the adverse effects of climate change. The IPCC defines adaptation (in human systems), **as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities** (IPCC, 2012). There are a number of available actions that range from incremental steps to transformational changes for reducing risk from climate extremes and social, economic, and environmental sustainability can be enhanced by disaster risk management and adaptation approaches (IPCC, 2012)**.**

Another important concept is that of vulnerability. The IPCC defines **vulnerability** as the propensity or predisposition to be adversely affected. The more vulnerable a system is, the more likely Climate Change will have negative or adverse effects. Adaptation responses therefore often aim at reducing vulnerability to Climate Change.

2.1.2 What is Climate Change?

Figure 3 below provides an overview of the Earth's climate system which is primarily powered by solar radiation. Aspects such a solar shortwave radiation SWR) and longwave radiation (LWR) influence the temperature of the earth with about 20% of SWR being absorbed in the atmosphere.(IPCC, 2013). LWR is however largely absorbed by certain atmospheric constituents—water vapour, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and other GHGs ;and clouds, which themselves emit LWR into all directions. The downward directed component of this LWR adds heat to the lower layers of the atmosphere and to the Earth's surface. This is often called the greenhouse effect (IPCC, 2013).

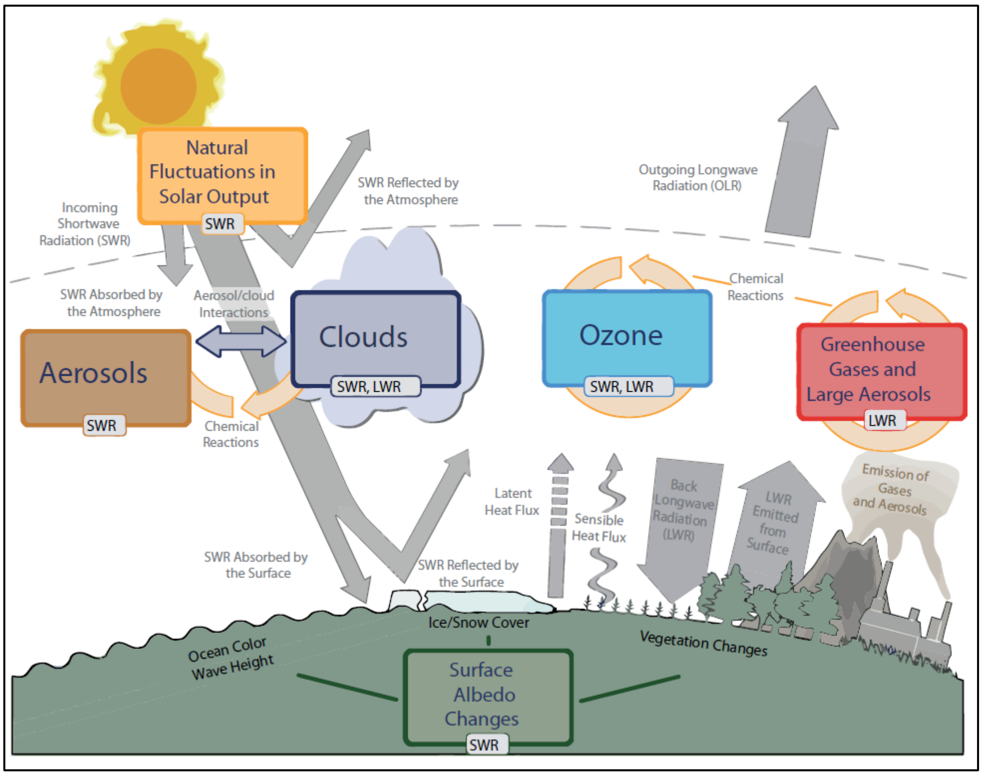

Figure 3: Main Drivers of Climate Change (IPCC, 2013)

There are also a number of global climate ‘drivers’ such as natural fluctuations in solar output (solar cycles) - which can cause changes in the energy balance (through fluctuations in the amount of incoming SWR) as well as human activity – which changes the emissions of gases and aerosols, resulting in modified O3 and aerosol amounts. O3 and aerosol particles absorb, scatter and reflect SWR, changing the energy balance. In addition, some aerosols act as cloud condensation nuclei modifying the properties of cloud droplets and possibly affecting precipitation. As the cloud interactions with SWR and LWR are large, small changes in the properties of these clouds have important implications for the radiative budget. In addition, anthropogenic changes in GHGs (e.g., CO2, CH4, N2O, O3, CFCs) and large aerosols (>2.5 μm in size) modify the amount of outgoing LWR by absorbing outgoing LWR and re-emitting less energy at a lower temperature.

In addition to changing the atmospheric concentrations of gases and aerosols, humans are affecting both the energy and water budget of the planet by changing the land surface, including redistributing the balance between latent and sensible heat fluxes (sensible heat is the energy associated with the temperature of a body whilst latent heat is the energy associated with changing the "phase" of a substance, that is, changing the state from gas to fluid or from fluid to solid, or the reverse). Land use changes change the characteristics of vegetation, including its colour, seasonal growth and carbon content. For example, clearing and burning a forest to prepare agricultural land reduces carbon storage in the vegetation, adds CO2 to the atmosphere, and changes the reflectivity of the land (surface albedo), rates of evapotranspiration and longwave emissions.

Another important concept is that of radiative forcing (RF) – where changes in the atmosphere, land, ocean, biosphere and cryosphere (both natural and anthropogenic) can perturb the earth’s radiation budget, producing a RF that affects climate. RF is a measure of the net change in the energy balance in response to an external perturbation (IPCC, 2013). However, the concept of RF cannot capture the interactions of anthropogenic aerosols and clouds and thus it is necessary to also take into account effective radiative forcing (ERF) that accounts for rapid response in the climate system. Once a forcing is applied, complex internal feedbacks determine the eventual response of the climate system, and will in general cause this response to differ from a simple linear one. There are many feedback mechanisms in the climate system that can either amplify (‘positive feedback’) or diminish (‘negative feedback’) the effects of a change in climate forcing.

In summary, GHGs are emitted from, and are reabsorbed by, a variety of natural sources, but the rate at which human economies and societies are emitting these gases far exceeds the capacity of natural ecosystems to reabsorb them. The evidence that current global warming is due to human activities associated with industrialisation and modern agriculture is overwhelming and the rate of change to the earth’s climate exceeds the ability of all types of ecosystems (marine, coastal, freshwater, and terrestrial) to adapt as well as compromising their ability to function effectively. It thus necessary to ensure that developments take into account both mitigation and adaptation responses to Climate Change.

3 METHODOLOGY

The methodology followed in the compilation of this Climate Change Study is provided in **Figure 3** and involved understanding the baseline environment as well as predicted Climate Change scenarios for the area, unpacking the activities related with the proposed development so to identify the impacts of the Dam **on** Climate Change, the impacts of the Dam **because** of Climate Change as well as the potential impacts of Climate Change on the Dam (vulnerability). The last step involves identifying mitigation and adaptation measures to minimise both the impacts and vulnerability of the Dam.

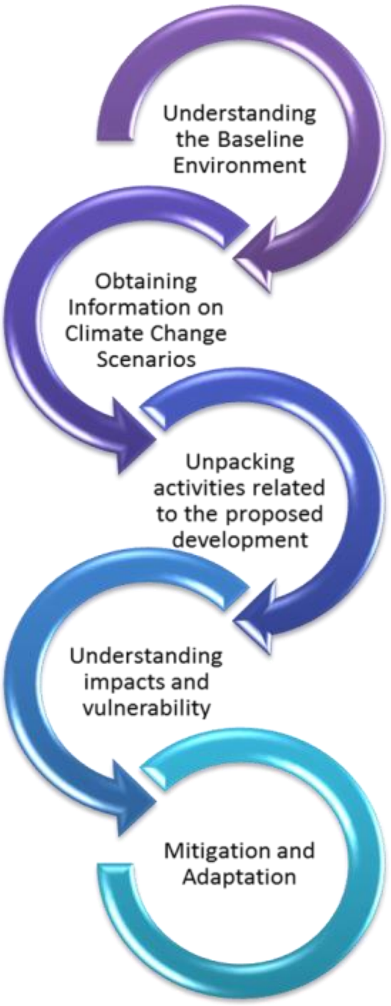

Figure 4: Methodology

It should however be noted that the scale at which Climate Change occurs is such that the impacts and mitigation measures at a localised level are not always applicable. It is for this reason that a quantitative impact assessment, whereby a significance rating is provided based on the extent, magnitude, duration and probability of the impact, is not possible. Instead, a detailed qualitative assessment has been provided. Relevant mitigation measures and adaptation responses have also been discussed.

Furthermore, it should be noted that this no downscaling of data has been done for this study. Instead, the Climate Change implications for Foxwood Dam were based entirely on existing data for the South Africa.

4 CLIMATE CHANGE POLICY AND FRAMEWORK

4.1 The United Nations Framework Convention on Climate Convention

The United Nations Framework Convention on Climate Convention (UNFCCC) is the foundation of global efforts to combat global warming. Opened for signature in 1992 at the Rio Earth Summit, its ultimate objective is the stabilization of Greenhouse Gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. This level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The Convention also sets out some guiding principles which include the precautionary principle (the lack of full scientific certainty should not be used as an excuse to postpone action when there is a threat of serious or irreversible damage) as well as the principle of the 'common but differentiated responsibilities' (which assigns the lead in combating climate change to developed countries). Other principles deal with the special needs of developing countries and the importance of promoting sustainable development.

In addition, both developed and developing countries accept a number of general commitments. All Parties will develop and submit national communications containing inventories of greenhouse gas emissions by source and greenhouse gas removals by sinks. It was also agreed that signatories would adopt national programmes for mitigating climate change and develop strategies for adapting to its impacts. They will also promote technology transfer and the sustainable management, conservation, and enhancement of greenhouse gas sinks and .Dams (such as forests and oceans). In addition, the Parties will take climate change into account in their relevant social, economic, and environmental policies; cooperate in scientific, technical, and educational matters; and promote education, public awareness, and the exchange of information related to climate change.

4.2 The Conference of the Parties (COP)

The supreme body of the Convention is the Conference of the Parties (COP). The COP comprises all the states that have ratified or acceded to the Convention (185 as of July 2001). It held its first meeting (COP-1) in Berlin in 1995 and will continue to meet on a yearly basis unless the Parties decide otherwise. The COP's role is to promote and review the implementation of the Convention. It will periodically review existing commitments in light of the Convention' s objective, new scientific findings, and the effectiveness of national climate change programmes. The COP can adopt new commitments through amendments and protocols to the Convention.

4.3 The Kyoto Protocol

The Kyoto Protocol to the UNFCC aims to strengthen the international response to climate change. Adopted by consensus at the third session of the Conference of the Parties (COP-3) in December 1997, it contains legally binding emissions targets for Annex I (industrialized) countries. By arresting and reversing the upward trend in greenhouse gas emissions that started in these countries 150 years ago, the Protocol promises to move the international community one step closer to achieving the Convention’s ultimate objective of preventing dangerous anthropogenic interference with the climate system.

4.4 The National Climate Change Response White Paper, 2011

The National Climate Change Response White Paper (2011) presents the South African Government’s vision for an effective climate change response and the long-term transition to a climate-resilient and lower-carbon economy and society. The response details South Africa’s response to climate change which has two objectives:

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa’s social, economic and environmental resilience and emergency response capacity.
- Make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

The response is guided by the principles set out in the Constitution, the Bill of Rights, the National Environmental Management Act (NEMA), the Millennium Development Goals(MDGs) and the UNFCCC. The principles include, amongst others:

- Common but differentiated responsibilities and respective capabilities – aligning our domestic measures to reduce the country’s GHG emissions and adapt to the adverse effects of climate change with our unique national circumstances, stage of development and capacity to act.
- Equity – ensuring a fair allocation of effort, cost and benefits in the context of the need to address disproportionate vulnerabilities, responsibilities, capabilities, disparities and inequalities.
- Special needs and circumstances – considering the special needs and circumstances of localities and people that are particularly vulnerable to the adverse

effects of climate change, including vulnerable groups such as women, and especially poor women; children, especially infants and child headed families; the aged; the sick; and the physically challenged.

- Uplifting the poor and vulnerable – climate change policies and measures should address the needs of the poor and vulnerable and ensure human dignity, whilst endeavouring to attain environmental, social and economic sustainability.
- Intra- and Inter-generational sustainability– managing our ecological, social and economic resources and capital responsibly for current and future generations.
- The Precautionary Principle – applying a risk-averse and cautious approach, which takes into account the limits of current knowledge about the consequences of decisions and actions.
- The Polluter Pays Principle – those responsible for harming the environment paying the costs of remedying pollution and environmental degradation and supporting any consequent adaptive response that may be required.
- Informed participation – enhancing public awareness and understanding of climate change causes and impacts to promote participation and action at all levels.
- Economic, social and ecological pillars of sustainable development – recognising that a robust and sustainable economy and a healthy society depends on the services that well-functioning ecosystems provide, and that enhancing the sustainability of the economic, social and ecological services is an integral component of an effective and efficient climate change response.

4.5 Eastern Cape Climate Change Response Strategy

The Eastern Cape Climate Change Response Strategy report was published in March 2011 and provides detailed information on the context of climate change in the Eastern Cape as well as information on technical options for climate change mitigation most appropriate province. The aim of the strategy, in keeping with the national initiative, is to facilitate planned and coordinated approaches to both climate change mitigation and adaptation.

5 CLIMATE CHANGE SCENARIOS

5.1 Summary of Findings of IPCC AR5 Report

There have been a number of IPCC reports through the years and the most recent work (IPCC AR5) presents the most up-to-date assessment of the current state of research regarding climate change. The information summarised below has been taken from the

Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013).

5.1.1 Atmosphere

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 with the globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012 (IPCC, 2013).

Changes in many extreme weather and climate events have also been observed since about 1950 and he frequency of heat waves has increased in large parts of Europe, Asia and Australia. There are also more land regions where the number of heavy precipitation events has increased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe. (IPCC, 2013).

The AR5 also notes that it is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale.

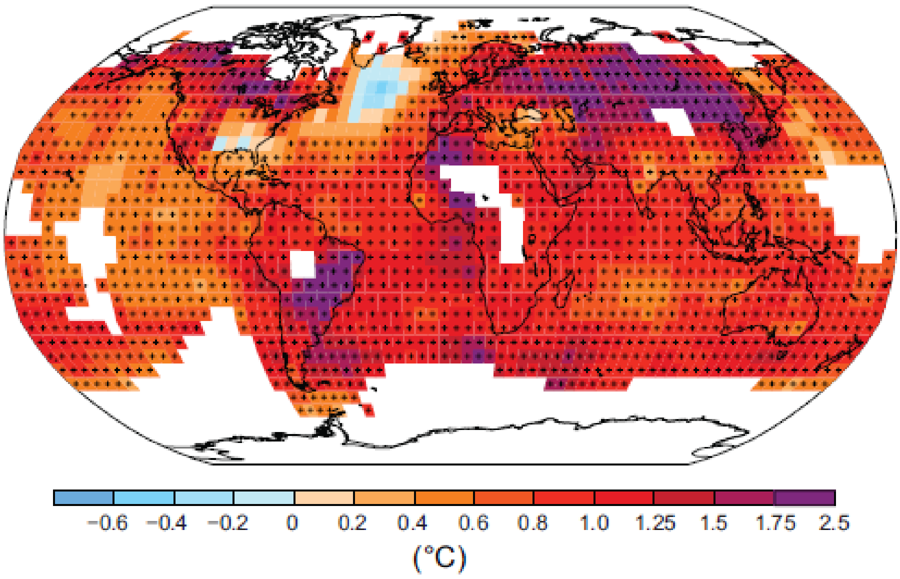

Figure 5: Observed change in surface temperature 1901–2012(IPCC, 2013)

5.1.2 Ocean

Ocean warming dominates the increase in energy stored in the climate system and accounts for more than 90% of the energy accumulated between 1971 and 2010. It is *virtually certain* that the upper ocean (0−700 m) warmed from 1971 to 2010. On a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11 [0.09 to 0.13] °C per decade over the period 1971 to 2010.

5.1.3 Cryosphere

Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent.

In addition, there is very high confidence that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century. Northern Hemisphere snow cover extent decreased 1.6 [0.8 to 2.4] % per decade for March and April, and 11.7 [8.8 to 14.6] % per decade for June, over the 1967 to 2012 period (IPCC, 2013).

5.1.4 Sea Level

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m (IPCC, 2013).

5.2 <u>The South African Context</u>

The Department of Environmental Affairs (DEA) has undertaken the Long Term Adaptation Scenarios Flagship Research Programme (LTAS) which aimed at responding to the South African National Climate Change Response White Paper by developing national and sub-national adaptation scenarios for the country under plausible future climate conditions (Department of Environmental Affairs , 2013). As part of LTAS, Climate trends and projections were done at both a national and local scale, in relation to six hydrological zones of South Africa (**Figure 6**).

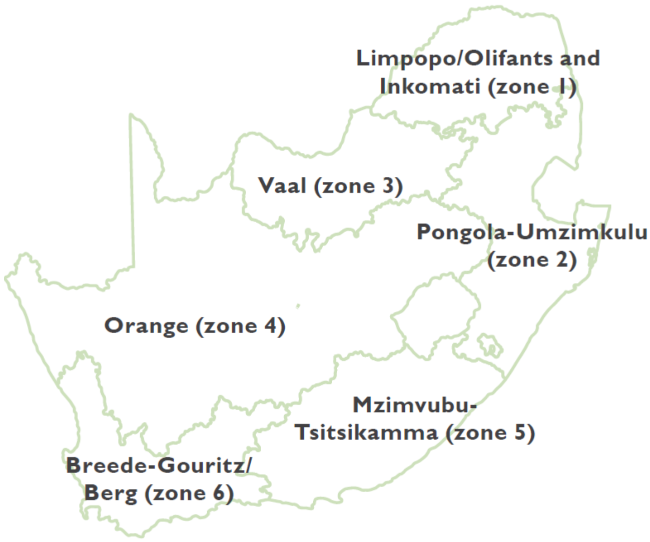

Figure 6: Boundaries of the six modelled hydrological zones (Department of Environmental Affairs , 2013)

This approach was followed due to that fact that a majority of climate change impacts across South African economic and other sectors will be mediated through primary impacts on the water sector. The six hydrological zones reflect the boundaries defined by water management areas (WMAs) in South Africa. These include:

- **Zone 1:** the Limpopo, Olifants and Inkomati WMAs in the northern interior (Limpopo/Olifants/Inkomati);
- **Zone 2**: the Pongola-Umzimkulu WMA in KwaZulu-Natal in the east (Pongola-Umzimkulu);
- **Zone 3:** the Vaal WMA in the central interior (Vaal);
- **Zone 4:** the Orange WMA in the north west (Orange);
- **Zone 5:** the Mzimvubu-Tsitsikamma WMA in the south east (Mzimvubu-Tsitsikamma); and
- **Zone 6:** Breede-Gouritz and Berg Olifants WMAs in the south west (Breede-Gouritz/Berg).

A summary of the LTAS findings is provided below to provide place the IPCC findings discussed above into the South African context.

5.2.1 Observed Climate Trends for South Africa (1960-2012)

Over the last five decades the following climate trends have been observed in South Africa.

- Mean annual temperatures have increased by at least 1.5 times the observed global average of 0.65°C reported by the Fourth Assessment Report (AR4) of the International Panel on Climate Change (IPCC) for the past five decades.
- Maximum and minimum daily temperatures have been increasing annually, and in almost all seasons. A notable exception is the central interior (zone3, Vaal), where minimum temperatures have been increasing less strongly, and some decreases have been observed.
- High and low temperatures (i.e. hot and cold extremes) have respectively increased and decreased in frequency in most seasons across the country, particularly in the western and northern interior.
- The rate of temperature change has fluctuated, with the highest rates of increase occurring from the middle 1970s to the early 1980s, and again in the late 1990s to middle 2000s.
- Rainfall has shown high inter-annual variability, with smoothed rainfall showing amplitude of about300 mm, about the same as the national average.
- Annual rainfall trends are weak overall and nonsignificant, but there is a tendency towards significant decrease in the number of rain days in almost all hydrological zones. This implies tendency towards an increase in the intensity of rainfall events and increased dry spell duration.

- There has also been a marginal reduction in rainfall for the autumn months in almost all hydrological zones.
- Extreme rainfall events show a tendency towards increasing in frequency annually, and especially in spring and summer, with a reduction in extremes in autumn.
- Overall, rainfall trends are similar in all the hydrological zones, with rainfall being above average in the 1970s, the late 1980s, and mid to late 1990s, and below average in the 1960s and in the early 2000s, reverting to the long-term mean towards 2010.

5.2.2 Projected Rainfall and Temperature Changes for South Africa (2050 and Beyond)

LTAS also incorporated climate projections which were simulated over southern Africa using both statistical and dynamic downscaling of the output of AR4 (A2 and B1 emissions scenarios) and AR5 (RCPs 8.5 and 4.5) representing unmitigated (A2 and RCP8.5) and mitigated (B1 and RCP4.5) future energy pathways. In addition, a pattern scaling method, using a two dimensional atmospheric model of the Massachusetts Institute of Technology (MIT) Integrated Global System Model was used employing 450ppm CO2 stabilisation as a mitigated scenario, contrasted with an unmitigated pathway.

The findings of the Climate Change projections for South Africa up to 2050 under unmitigated emission scenarios include:

- All modelling approaches project warming trends until the end of this century, but most approaches project the possibility of both drying and wetting trends in almost all parts of South Africa.
- Very significant warming, as high as 5–8°C, over the South African interior by the end of this century. Warming would be somewhat reduced over coastal zones.
- A general pattern of a risk of drier conditions in the west and south of the country and a risk of wetter conditions over the east of the country.
- Many of the projected changes are within the range of historical natural variability, and uncertainty in the projections is high.
- Effective global mitigation action is projected to reduce the risk of extreme warming trends, and to reduce the likelihood of extreme wetting and drying outcomes by at least mid-century.
- High resolution regional modelling suggests even larger benefits of effective global mitigation by the end of this century, when regional warming of 5–8°C could be more than halved to 2.5–3°C.
- Overall, there is far greater certainty in temperature than in rainfall projections.

It should be noted that the LTAS modelling does not provide detailed information on storm events and wind predictions.

5.2.3 Projected Climate Futures for South Africa (2015–2035, 2040–2060 and 2070–2090)

South Africa's climate future up to 2050 and beyond can be described using four fundamental climate scenarios at national scale, with different degrees of change and likelihood that capture the impacts of global mitigation and the passing of time.

1. **Warmer (<3°C above 1961–2000) and Wetter** with greater frequency of extreme rainfall events.
2. **Warmer (<3°C above 1961–2000) and Drier**, with an increase in the frequency of drought events and somewhat greater frequency of extreme rainfall events.
3. **Hotter (>3°C above 1961–2000) and Wetter** with substantially greater frequency of extreme rainfall events.
4. **Hotter (>3°C above 1961–2000) and Drier**, with a substantial increase in the frequency of drought events and greater frequency of extreme rainfall events.

Effective international mitigation responses would reduce the likelihood of scenarios 3 and 4, and increase the likelihood of scenarios 1 and 2 during this century.

In both wetter and drier futures a higher frequency of flooding and drought extremes could be expected, with the range of extremes significantly increased under unconstrained emissions scenarios. **Table 5** gives rainfall projections for these scenarios for South Africa's six hydrological zones.

Table 4: Rainfall projections for each of South Africa's six hydrological zones (Department of Environmental Affairs , 2013)

Scenario	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Warmer and Wetter	Increase in Spring and Summer	Increase in Spring	Increase in Spring and Summer	Increase in all seasons	Increase in all seasons	Decrease in Autumn, increase in winter and spring
Warmer and Drier	Decrease in Summer, Spring Autumn	Decrease in Spring and strong decrease in Summer and Autumn	Decrease in Spring and Summer and strong decrease in Autumn	Decrease in Summer, Spring Autumn	Decrease in all seasons and strong decrease in Summer and Autumn	Decrease in all seasons and strong decrease in the west.
Hotter and Wetter	Strong increase in Spring and Summer	Strong increase in Spring.	Increase in Spring and Summer	Increase in all seasons	Strong increase in all seasons	Decrease in autumn, increase in Winter and Spring.
Hotter and Drier	Strong decrease in Summer, Spring Autumn	Decrease in Spring and strong decrease in Summer and Autumn	Decrease in Spring and Summer and strong decrease in Autumn	Decrease in Summer, Spring Autumn	Decrease in all seasons and strong decrease in Summer and Autumn	Decrease in all seasons and strong decrease in the west.

5.2.4 Climate Change Impacts

Climate change impacts on South Africa are likely to be felt primarily via effects on water resources (Department of Environmental Affairs , 2013). Projected impacts are due to changes in rainfall and evaporation rate, but hydrological modelling approaches are also essential for translating these into potential water resource impacts. The findings show the following"

- Preliminary projections for national runoff range from a 20% reduction to a 60% increase by as early as mid-century based on an unmitigated emissions pathway. Across the country, this ranges from increases along the eastern seaboard and central interior to decreases in much of the Western and Northern Cape. If global emissions are constrained to stabilise at 450 ppm CO2, these changes are projected to lie between a 5% decrease and a 20% increase in annual runoff.
- Under all four future climate scenarios, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario.
- Under a **wetter future** climate scenario, significant increases in runoff would result in increased flooding, human health risks, ecosystem disturbance and aesthetic impacts.
- **Drier future** climate scenarios would result in reduced surface water availability, but would not exclude the risk of extreme flooding events.
- Areas showing highest risks in extreme runoff related events (and flooding conditions) include KwaZulu-Natal, parts of southern Mpumalanga and the **Eastern Cape**. Specific areas at risk to increased evaporation, decreased rainfall and decreased runoff include the south-west and western regions, and to some extent the central region and the extreme north-east.
- Climate-related changes in wind, upwelling, sea surface temperature, productivity, oxygen levels, storm frequency, precipitation, freshwater flow and runoff patterns, may all have impacts on estuaries, inshore and offshore ecosystems.
- Accelerated sea level rise, changes in river flows and increased frequency of high-intensity coastal storms and high water events pose a significant risk to estuarine, inshore and offshore fisheries.

5.3 Eastern Cape Baseline and Potential Climate Change Scenarios

5.3.1 Baseline Information

Information sourced from the South African Weather Services (SAWS) meteorological station located in Fort Beaufort, Eastern Cape has been used to provide an overview of the prevailing conditions.

The prevailing climate in Adelaide is known as a local steppe climate (semi-arid). The region is a convergence zone for warm, moist, subtropical air from the north, cooler, southern coastal winds and also the drier, hotter winds which originate in the arid interior of the country.

5.3.1.1 Temperature

Average daily maximum and minimum temperatures for the last fifteen years are shown in **Tables 5** and **6**, respectively. A summary follows:

Table 5: Average Daily Maximum Temperature (°C) –Fort Beaufortstation

Year	J	F	M	A	M	J	J	A	S	O	N	D
2000	27.9	28.9	26	24.1	21.1	23	22.8	25.1	24	25.5	25.5	28.9
2001	29.2	30.7	29.9	23	25.4	22.5	20.9	22.8	23.2	26.7	26.7	28.3
2002	30.3	31.1	31.3	28.4	24.3	20.6	21.2	22.2	22.5	26.3	27.7	29.4
2003	31.6	32.6	28	27	22.9	20.2	21.4	21.3	24.3	27	26.9	29.5
2004	30.3	29.8	27.5	26.4	25	22.7	20	23.6	22.5	26.8	30.4	30.3
2005	28.2	29.7	28.8	25.5	24.1	21.4	23.9	22.3	25.5	27.7	25.4	26.9
2006	30	29.9	28.8	25.6	20.9	21.7	22.1	20.6	23.4	23.3	25.7	26.3
2007	30	30.5	26.8	26.5	25.7	21.6	21.6	23.2	25.8	24.9	27.3	28.5
2008	28.5	29	27.9	24.9	25.1	21	23.2	22.6	24.6	26.5	27.4	29.2
2009	29.7	28.9	29.4	27.7	24.1	20.2	21.3	22.8	24.6	24.5	28.3	28.7
2010	29.8	30.8	30.5	26.5	25.3	20.7	22.5	25.5	26	24.5	26.6	26.9
2011	29.3	31.9	29.8	24.2	21.3	18.6	18	21	24.1	25.2	25.2	27.5
2012	32	28.1	27.6	24.1	23.2	19.5	19.4	21.2	24.1	21.9	26.9	28.7
2013	28.9	30.4	29.1	24.5	23.2	21.7	21.1	23	24.7	25.4	26.6	26.8
2014	31.3	29.4	28.8	25.5	23.6	22	22.4	22.8	26	25.3	25.8	28
2015	31.8	27.4	28.8	23.3	24.0=							

Notes:
*** indicates data is missing or is not yet available in the current month
--- indicates that data is unavailable or was not requested
= indicates that the average is unreliable due to missing daily values

Table 6: Average Daily Minimum Temperature (°C) - Fort Beaufortstation

Year	J	F	M	A	M	J	J	A	S	O	N	D
2000	16.2	17.2	16.2	12.6	7.7	6.7	6.9	8.8	8.2	11.7	14	15.1
2001	15.1	15.7	16.4	13.4	10.3	7.7	5.3	8.1	9.9	13.5	14.9	15.7
2002	16.3	16	16.1	13.9	8.9	6.4	7	9.1	11.2	11.1	11.9	17
2003	16.8	18.8	15.2	14.7	10.1	6	4.9	5.8	8.1	11.4	13.8	14.4
2004	17.1	17.5	14.6	11.8	9.5	7.1	4.6	7.6	7.7	12.3	16.1	17.6
2005	17	17.5	15.4	11.7	10.3	4.5	6.2	6	9.6	10.8	13	12.9
2006	17.8	18.4	13.7	12.8	7.9	8	6.7	7.6	10.1	12.5	13.2	14.9
2007	16.7	17.2	14.1	12.2	9.3	6.8	5.1	6.6	10.1	11.3	12.5	15.5
2008	16.8	17.6	15.1	10.6	10.4	7	6.1	6.6	6.5	10.8	13.7	15.8
2009	16.8	16.8	14.9	12.8	9.4	7	7.4	7.7	8.3	12.3	13	14.5
2010	16.8	17.8	16.1	12.9	10.7	6.5	6.6	7.4	10	11.5	14	15.3
2011	17.2	19.4	17	11.8	9.7	6.7	4.4	6	8.9	11.2	12.2	14.7
2012	18	16.6	15.5	10.7	8.3	6.4	4.4	6.7	8	11	11.9	16.5
2013	15.9	15	14.2	10.3	8	5.3	6.8	5.7	6.6	10.8	12.6	15

2014	17.2	17.3	14.2	11	9	5.9	5.8	8.8	10.2	10.3	12.6	15.3
2015	16.1	14.9	15	10.9	9.1=							

Notes:
*** *indicates data is missing or is not yet available in the current month*
--- *indicates that data is unavailable or was not requested*
= *indicates that the average is unreliable due to missing daily values*

5.3.1.2 Precipitation

The monthly daily rainfall for the last ten years is shown in **Table 7**.

Table 7: Monthly Daily Rain (mm) - Fort Beaufort station

Year	J	F	M	A	M	J	J	A	S	O	N	D
2000	133.4	33.4	123.4=	114.8	2	8.8	1.4	0.8	75.2	28	87.4	32
2001	113.2	16.4	104.4	94	4.6	3.2	9.6	21.6	43.6	31.3	29.2	45.5
2002	68	14	47.4	19	2.8	20.6	34.2	84.8	71.2	10.2	24.2	80.6
2003	7.4	86.6	50.0=	28.2	56	2.2	4.2	12.8	4.6	39	26.1	17.6
2004	45	69.4	31.2	65.4	5.4	9	6.6	8.8	85.6	9.8	18.6	114.2
2005	41.4	41.4	42	49	21.8	2	4	45	2.8	26.8	127.2	29.6
2006	14	57.6	23.8	50	33.2	6	3.8	99.6	31.2	86.4	26.6	47.8
2007	45.4	26.4	98.8	17	5.2	21.2	7.4	13.6	3.2	34.8	27.8	81.2
2008	56.2	70.6	46.8	30.2	3.8	8.2	0.4	29.6	3.8	6.8	45.2	41
2009	19	62.8	58.4	19	4.2	10.2	23.4	6	16.6	46.6	6.2	25
2010	102.4	33.8	9.4	25	2	19.4	2.2	4.2	8.4	34.2	46	44.4
2011	82.8	13.2	37.6	30	98.8	95.4	47.8	15.2	1.4	35.6	34.6	63.4
2012	78.2	81.2	80.8	14.8	8.6	24.4	25.8	13.4	11.8	74.4	7.8	77.8
2013	10.6	41.2	47.2	31.4	15.2	3.6	16.8	13.6	0.2	63.2	72.2	54.6
2014	46	70.6	18.8	88.4	5	1.6	0.2	4.8	17.6	33.8	76.6	41.2
2015	83.6	46	72.2	61	0.0=							

Notes:
*** *indicates data is missing or is not yet available in the current month*
--- *indicates that data is unavailable or was not requested*
= *indicates that the average is unreliable due to missing daily values*

5.3.1.3 Wind

The wind rose (succinct view of how wind speed and direction are typically distributed at a particular location) shown in **Figures 7** for a 10-year period (2003 – 2013) is interpreted as follows:

- Prevailing wind direction is from SE and SSE (blowing from these directions approximately 12% of the time);
- Highest percentage of winds blow with speeds of 0.5 – 2.5 m/s; and
- Winds were calm 9.8% of the time.

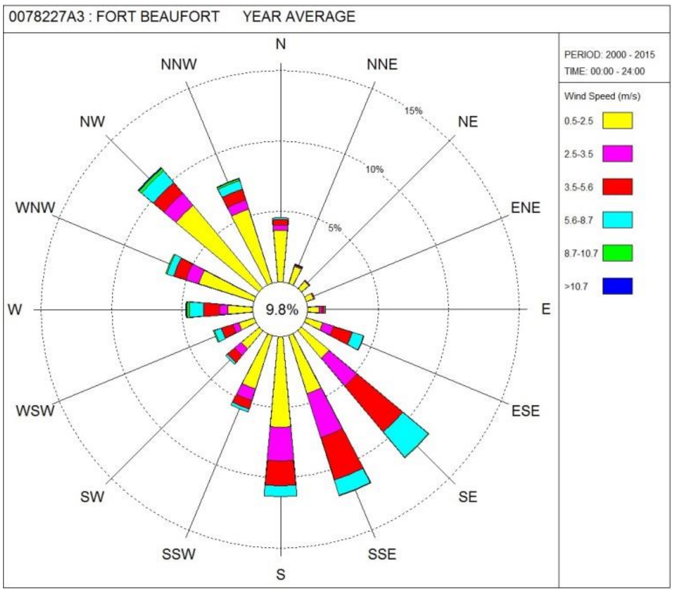

Figure 7: Wind rose for the Fort Beaufort station

5.3.2 Scenarios and Modelling

As part of the LTAS assessment, it was possible to produce dynamically downscaled models using a dynamic regional climate model known as conformal-cubic atmospheric model (CCAM) (Department of Environmental Affairs , 2013). A number of studies (detailed in the LTAS Report) have shown that CCAM may be used to obtain plausible projections of future climate change, as well as skilful forecasts at the seasonal and short-range timescales, over the southern African region. It also realistically simulates observed daily climate statistics over the region, such as the number frequency of extreme precipitation events and the tracks of cut-off lows and tropical cyclones (Department of Environmental Affairs , 2013).

A number of different climate change scenarios were developed through local and international climate modelling expertise using both statistical and dynamical downscaling methodologies based on outputs from IPCC AR4 (A2 and B1 emissions scenarios) and IPCC AR5 (RCP 8.5 and 4.5 Wm-2pathways) (as discussed in the section above). These represent an unmitigated future energy pathway (unconstrained, A2 and RCP8.5) and mitigated future energy pathway (constrained, B1 and RCP4.5, or emissions scenarios equivalent to CO2e levels stabilising between 450 and 500ppm).

The projected annual temperature and rainfall anomalies for the period 1961–2100 over Zone 5 (Eastern Cape) (aligned to the Mzimvubu-Tsitsikamma WMA), relative to the 1971–2005 baseline climatology, for the CCAM downscalings show that drastic increases in the annual average temperature of 2 to 5°C (4 to 6°C) are projected for the Eastern Cape for the period 2080–2100, relative to the baseline period, under the A2 scenario (RCP8.5) (Department of Environmental Affairs , 2013). These anomalies are well beyond the natural temperature variability of the region. The mid-future anomalies are also already beyond the range of present day climatology with the mid-future period (2040–2060) temperature anomalies of between 1 and 2°C (1 to 3.5°C) projected under the A2 scenario (RCP8.5), by the respective CCAM ensembles (Department of Environmental Affairs , 2013). Even for the near-future (2015–2035), annual temperature anomalies under the A2 and RCP8.5 scenarios are drifting slightly outside the present-day climatological regime for zone 5, reaching values of just more than 2°C (Department of Environmental Affairs , 2013).

In terms of rainfall, anomalies projected for zone 5 exhibit a pattern of drying under both the A2 scenario and RCP8.5, as reflected by the medians of the projected changes. For both the A2 and RCP8.5 scenarios the projected negative rainfall anomalies attain values that are well outside those associated with the present-day climatological regime. The pattern of drying projected for zone 5 under the more negative scenarios is significantly reduced under RCP4.5, with the simulated anomalies remaining within the realm of present-day climate (Department of Environmental Affairs , 2013). Although drying is expected overall, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario. LTAS suggested that the areas showing highest risks in extreme runoff related events (and flooding conditions) include KwaZulu-Natal, parts of southern Mpumalanga and the **Eastern Cape** (Department of Environmental Affairs , 2013).

In addition, the Eastern Cape Climate Change Response Strategy notes that the Eastern Cape is expected to experience highest temperature increases towards the northwest interior, while lowest increases are likely along the coast (**Figure 11**). The approximate location of the project site has been indicated in black in the figure below.

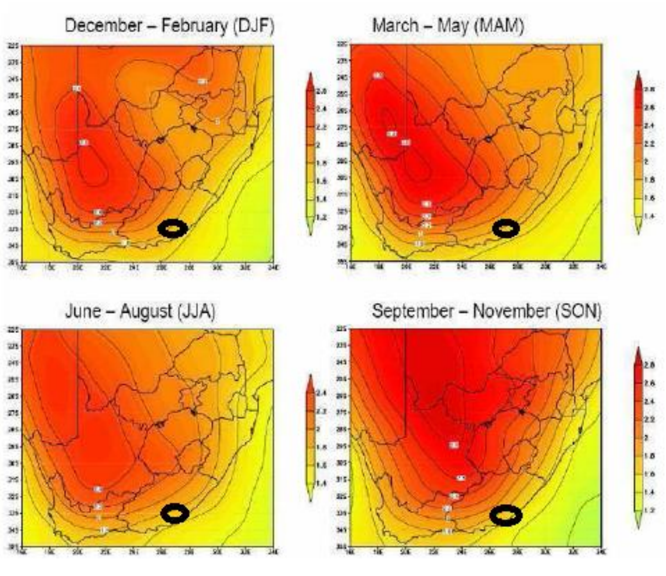

Figure 8: Projected median change in maximum surface temperature by 2050 ((Department of Economic Development and Environmental Affairs, 2011)

Associated with the higher temperature will be increases in evaporation rates and increased intensity of droughts.

In terms of precipitation, downscaling models show a wetting trend to the east and northeast of the country and a drying trend to the south and particularly the south west. **Figure 12** indicates projections for South Africa (Department of Economic Development and Environmental Affairs, 2011) and the approximate location of the site is indicated in black.

As with the national scenario, downscaling models for the Eastern Cape indicate future precipitation which is generally stable or slightly higher than present, with increasing intensity. Increased precipitation is more likely to the east of the province (Department of Economic Development and Environmental Affairs, 2011).

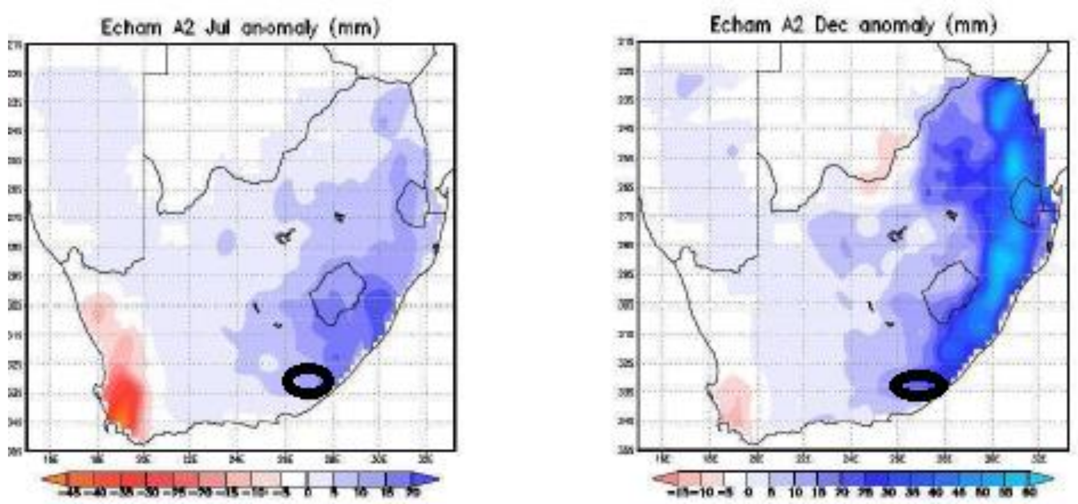

Figure 9: Project change in total annual rainfall (mm month -1) for July and December (mid-century (Department of Economic Development and Environmental Affairs, 2011))

In summary, available information suggests that the study area will become hotter and there is an increase in the frequency of droughts expected. In terms of rainfall, the Eastern Cape Climate Change Strategy notes there is likely to be more rainfall. The LTAS models suggest in general the Eastern Cape will become drier however looking at the approximate location of the study area median percentile; it appears that some increases in rainfall are expected.

6 Identification of Activities, Aspects and Impacts

In order to better understand the impacts related to the project, a summary of the activities and aspects is provided below.

6.1 Identification of Activities

The definition of Activity" is "*a distinct process or risks undertaken by an organisation for which a responsibility can be assigned activities also include facilities or pieces of infrastructure that are possessed by an organisation"*(International Organization for Standardization, 2011).

The activities identified for the project are listed in below as taken from the Scoping Report.

- Pre-Construction Phase

– Negotiations and agreements with the affected landowners, tenants, occupiers of land, stakeholders and authorities;
– Initiate legal process required for land acquisition;
– Detailed engineering design;
– Detailed geotechnical investigations, including geophysical investigations;
– Survey and mark construction servitude;
– Survey and map topography for determination of post-construction landscape, rehabilitation and shaping (where necessary);
– Possible removal of trees within construction servitude;
– Procurement process for Contractors;
– Review Contractor's method statements (as relevant);
– Selective improvements of access roads to facilitate the delivery of construction plant and materials;
– Arrangements for accommodation of construction workers (off site);
– The building of a site office and ablution facilities;
– The harvesting of timber that will be inundated (if deemed necessary);
– Confirmation of arrangements with individual landowners / tenants / occupiers of land for managing and mitigating issues such as fencing and gate dimensions for traversing servitude, traversing patterns of livestock over servitude, access to livestock drinking points, security, opening and closing of gates and access to private property;
– Confirmation of the location and condition of all buildings, assets and structures within the servitude;
– Determining and documenting the road conditions for all identified haul roads; and
– Conduct detailed hydraulic analysis to determine the optimum positioning of the scour valves.

- Construction Phase

– Site establishment;

- Relocation of structures and infrastructure;
- Prepare access roads;
- Establish construction laydown areas;
- Bulk fuel storage;
- Delivery of construction material;
- Transportation of equipment, materials and personnel;
- Storage and handling of material;
- Construction employment;
- Site clearing (as necessary);
- Excavation;
- Blasting;
- River diversion for building of Dam;
- Establishment and operation of crusher;
- Establishment and operation of batching plant;
- Establishment and operation of materials testing laboratory;
- Create haul roads;
- Create quarry and borrow areas;
- Construction of embankments, bottom outlet and spillways;
- Concrete Works;
- Steel works;
- Mechanical and Electrical Works;
- Temporary river diversion for gauging weir and pipeline crossings;
- Electrical supply;
- Construction of gauging weir;
- Construction of pipeline;;
- Cut and cover activities;
- Stockpiling (sand, crushed stone, aggregate, etc.); and
- Waste and wastewater management.

* Operation

- Maintenance of infrastructure;
- Operation of scheme;
- Bulk Water Pipeline – including create access track along pipeline servitude, conduct routine maintenance inspections of the project infrastructure, scouring of pipeline, where the water conveyed and stored within this system will be released into the receiving watercourses along the alignment from scour valves, and undertake maintenance and repair works, where necessary;
- On-going consultation with directly affected parties;

- Compliance with Operation and Maintenance Manual; and
- Implementing RMP.

6.2 Identification of Aspects

Environmental aspects are regarded as those components of an organisation's activities, products and services that are likely to interact with the environment and cause an impact.

There are two types of aspects namely;

- Direct Environmental Aspect: Activities over which a company can be expected to have an influence and control; and
- Indirect Environmental Aspect: Actual or Potential activities over which the organisation can be expected to have an influence, but no control (International Organization for Standardization, 2011).

Whilst some of the construction related environmental aspects are direct, the majority of aspects are indirect. The main aspects, as they relate, to Climate Change are listed below:

- Inadequate detailed design and planning (designs which do not take into account potential Climate Change);
- Poor management of clearing/removal of trees;
- Poor vehicle maintenance during construction phase;
- Poor management of site clearing;
- Inadequate operating conditions;
- Inadequate management of the Dam basin and the purchase boundary (1:100 year floodline);
- Inadequate consultation with downstream users; and
- Inadequate adaptation measures for operation and maintenance.

These aspects have been used in the following chapters to identify potential impacts as well as mitigation and adaptation measures.

7 CLIMATE CHANGE IMPACTS

ISO 14001-2004 defines impacts as "*any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects*". This Chapter therefore aims to identify and discuss the impacts of Foxwood Dam on Climate Change. In addition, impacts caused related to the Dam because of Climate Change are also discussed.

Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation, together with adaptation to climate change, contributes to the objective expressed in Article 2 of the UNFCCC:

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Mitigation measures aims at reducing the GHG emissions from the proposed development are also discussed below.

Mitigation measures aimed to reduce the impact of the Dam because of Climate Change are also provided.

7.1 Climate Change Impacts and Mitigation Measures

7.1.1 GHG Emissions from the Proposed Foxwood Dam

7.1.1.1 Overview

The scientific community has largely reached a consensus on the processes by which GHG emissions are formed in Dams and the different ways in which they are released into the atmosphere (Makinen & Khan, 2010). Dams generate GHG emissions through the aerobic and anaerobic decomposition of organic material including the soils and biomass initially flooded by the creation of the Dam, nutrient inflows from the upstream watershed, aquatic plants and plankton in the Dam and drawdown vegetation that grows seasonally as a result of water level fluctuations (**Figure 10**).

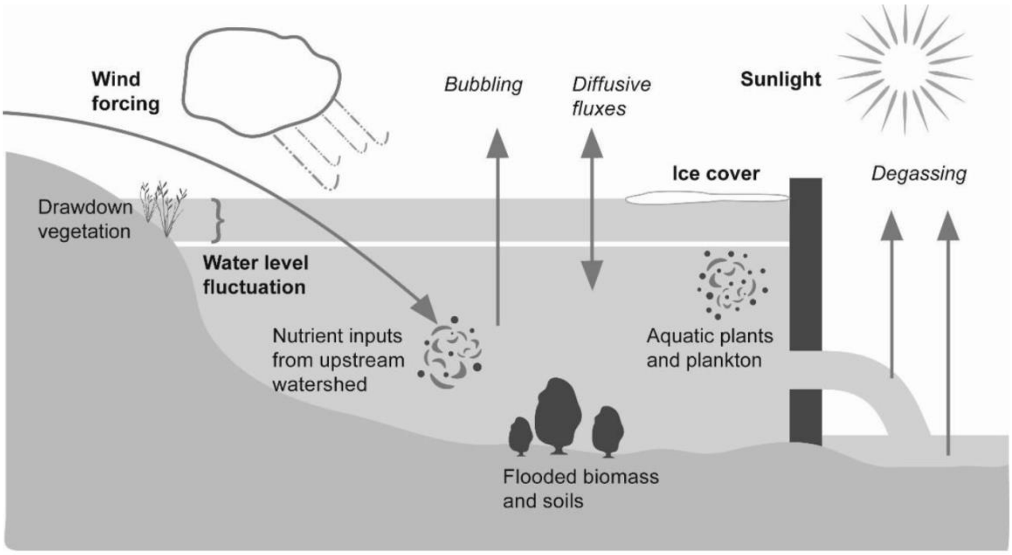

Figure 10: Sources of greenhouse gases, emission pathways and factors influencing Dam emissions (Makinen & Khan, 2010)

GHG emissions from Dams are different from the natural water bodies, such as lakes and rivers, because the impoundment of the Dam has resulted in flooding of large areas of terrestrial and natural aquatic ecosystems (Yang, Lu, Zhou, Wang, Duan, & Sun, 2014). CO2 and CH4 are the major end products of the microbial decomposition of flooded organic matter, which are transported to the atmosphere from the Dam surface by diffusion or bubbles (Yang, Lu, Zhou, Wang, Duan, & Sun, 2014). CO2 emissions from Dams are influenced by a number of factors such as latitude, Dam ages, wind speeds, pH values, precipitation, chlorophyll-a concentrations, and dissolved organic carbon in the water body, while CH4 emissions from Dams are influenced by water depths, water level fluctuations, DO concentrations, water velocities and wind speeds (Yang, Lu, Zhou, Wang, Duan, & Sun, 2014).

It is also important to note that there are two types of decomposition that can occur:

- Aerobic decomposition occurs in oxygen-rich conditions and produces CO2; and
- Anaerobic decomposition takes place in oxygen-poor (anoxic) conditions and produces primarily methane.

This distinction is significant because the conversion of carbon into methane, which has 25 times the global warming potential of carbon dioxide over a 100-year period, has a potentially magnifying effect on the overall climate impact of Dams (Makinen & Khan, 2010).

Further, in general, emissions are generally greater in lower latitudes (Yang, Lu, Zhou, Wang, Duan, & Sun, 2014). Some studies also suggest that emissions are greater and higher temperatures. Studies have also noted that in tropical regions, the lower land gradient and seasonal rainfall can expose and flood large amounts of land, producing annual decomposition within the Dam area in addition to decomposition of initially flooded material, providing long-term net emission increases (Dale, de Lucena, Marriott, Borba, Schaeffer, & Bilec, 2013).

According to Yang, Lu, Zhou, Wang, Duan and Sun (2014), CO2 and CH4 emissions from the Dam's surface are related with the amount of easily decomposable organic matter that is flooded after the filling of the Dams. For example, a large amount of organic carbon is stored in peatlands and forests; thus CO2 and CH4 emission fluxes are very high when such two land use types are flooded, such as Brazil's Balbina Reservoir. In contract, CO2 and CH4 emissions from Dams are very low if barren soils are flooded in the canyons, such as Ertan Dam

The proposed Foxwood Dam site is located in a combination of Great Fish Thicket vegetation type and Bedford Dry Grassland vegetation type (Nemai Consulting, 2015). These vegetation types are unlikely to contain similar volumes of decomposable organic matter containing organic carbon as stored in peatlands and forests. The site however is likely to contain more decomposable organic matter containing organic carbon than contained in more barren land types.

In April 2013 the World Bank published the '*Water Paper: Interim Technical Note: Greenhouse Gases from Reservoirs Caused by Biochemical Processes'* to provide guidance on how to assess GHG emissions from Dams in preparation for Dam infrastructure projects. As part of this, a number of scenarios for GHG emissions are discussed (World Bank, 2013). The most relevant scenario to Foxwood Dam is provided below (**Table 8**).

Similar to Dry Forest, Foxwood Dam occurs in an area where high temperatures occur and are expected in the future. In addition, due to the dense thicket in the basin, there is a medium density of flooded material which provides a significant but not abundant carbon stock. The high seasonal intensive rainfall gives regular annual supply of new labile organic matter through riverine transport and because of long dry seasons, the drawdown zone may be large, creating new seasonal vegetation that is flooded annually. Based on this, it can be assumed that GHGs from Dam would be in the range of 210–297 t CO2-eqv/km^2 and year (World Bank, 2013).

Table 8: Illustrated Scenarios of Global Warming Potential from Reservoirs Depending on Capacity to Supply Carbon Stock and the Conditions to Create and Release GHGs (World Bank, 2013)

Amount of carbon stock	Conditions to create and release GHGs	Typical characteristics of gross emissions	Anticipated net emissions generated by biochemical processes

• Low density of flooded material
• Low concentration of inflowing organic matter
• Relatively large drawdown zone to create new seasonal vegetation
	• High temperatures most of the year
	• Seasonally intensive rainfall, long dry season with very low inflows
	• Long retention time
	• Low concentration of inflowing nutrients
	• Example:
	  ○ Reservoirs located in mostly pristine tropical savannah or scrubland areas
		• Moderate emissions of CO2 and CH4, mainly during the first 5–10 years.
		• Generally low base level after initial years
		• Observed rates of emissions - Too little data to give representative values
		• Observed CH4/ CO2 ratio (all tropical) Median: 7.2% (1%–30%)
		• Reasons:
		  ○ Limited flooded biomass providing easily decomposed organic matter only during the first years after inundation. Even if siltation rates may be high, inflow has low content of nutrients and organic matter limiting supply of new labile carbon stock as well as preventing depletion of oxygen by nitrification.
		  ○ Because of long dry seasons, drawdown zone may be large, creating new seasonal vegetation that is flooded annually.
		  ○ High temperatures and generally long retention times create anoxic zones during dry seasons, allowing CH4 to be created. CH4 may be released and degassed through the intake canals or emitted to the atmosphere during periods when most of the water column is anoxic.
		  ○ As labile organic matter is depleted from original flooded material the decomposing rate decreases, which also decreases oxygen depletion and thus the extent of anoxic conditions.
		  ○ Low nutrient load prevents significant creation of N2O in drawdown zone.
			• Main contributions to net emissions are decomposable parts of flooded soil and vegetation in terrestrial zones plus removed sink from biomass growth.
			• Assuming flooding fully vegetated areas, the AFOLU values for biomass volume and growth for tropical scrubland and different soil types give lifespan average net emissions of 210–297 t CO2-eqv/km2 and year.
			• A hydropower Dam with power density of 1 MW/ km2 and 0.5 plant factor would (with the above emissions) give 48–68 g CO2-eqv/kWh (or 5%–7% compared to a coal plant).

7.1.1.2 Mitigation

In order to reduce the volume of material to be decomposed, clearing of vegetation within the Dam basin is suggested. The cleared woody material can be provided to local communities for use as firewood. Whilst the burning of this wood will also contribute to GHG emissions, this is not expected to be significantly different to the baseline situation as local communities throughout rural areas in South Africa rely on firewood to meet their energy requirements. It is also suggested that the net GHG exchange in the river basin caused by the creation of the Dam be calculated in line with UNESCO *GHG Measurement Guidelines for Freshwater Reservoirs (*or other acceptable best practice) to determine the Dam's greenhouse gas footprint. This should be undertaken as part of the finalisation of the Environmental Management Programme (EMPr).

Another opportunity lies in controlling water levels in a Dam and the release of water from a Dam, as water level fluctuations affect both the rate at which GHGs are released through bubbling and the size of drawdown areas (fertile ground for seasonal vegetation which, over time, becomes flooded and results in decomposition unless cleared) (Makinen & Khan, 2010).

If a Resource Management Plan (RMP) process is compiled for the Dam, it is suggested that the issues such as the amount of organic material flowing into a Dam from upstream areas be addressed. A combination of land management measures and physical capture of floating biomass may be useful to reduce GHG emissions (Makinen & Khan, 2010).

7.1.2 GHG Emissions from Materials during Construction

7.1.2.1 Overview

CO2 production in a Dam includes the carbon footprint of emissions from the use of fossil fuel, steel, and cement during the construction phase of the Dam. This is related to the size of Dam and the duration of creation (Yang, Lu, Zhou, Wang, Duan, & Sun, 2014). A GHG Emissions Study for Alpaslan II Dam and Hydro Electric Power Plant in Mus, Turkey was done in line with the European Bank for Reconstruction and Development (EBRD) Greenhouse Gas Assessment Methodology (ENCON Environmental Consultancy, 2014). The study provides an overview of the total Co2 equivalent for the various materials for the construction of the Dam and associated infrastructure. Whilst the study is specific to the Alpaslan II project, it has been used to provide a proxy of the emissions associated with the use of materials for the construction works. The Inventory of Carbon & Energy (ICE) Version 2.0 produced by the University of Bath is the principle source used for the inventory data of energy and carbon coefficients for building materials.

The study found that approximately 6 783 tCO2e would be emitted for the construction of a 50km transmission line, 286,851 tCO2e for the construction of the Dam wall and associated infrastructure and 179, 829 tCO2e for the relocation of roads.

7.1.2.2 Mitigation

During the design phase the specification of materials such as selecting materials with low embodied carbon values, high recycled content and those that can be sourced as locally as possible present a significant opportunity to minimise GHG emissions.

Detailed design and the management of the construction phase should take into account the following:

- Material selection (embodied Carbon) – materials with the lowest amount of embodied carbon should be selected where possible;
- Material selection (recycled content) – materials with a high recycled content should be used where possible and the re-use of site materials should be considered;
- Material specification (waste reduction) – ensure correct ordering of materials to avoid unnecessary surplus.
- Material specification (quantities) – ensure that materials are ordered as accurately as possible to reduce the unnecessary creation of the product (eg. Concrete);
- Resource efficient facilities – the operational performance of accommodation facilities on site should be considered so to maximise the efficient use of energy and water;
- Monitoring of Construction Emissions – it is recommended that a GHG emissions calculator be developed which will assist in the comparison of the impact of different materials.
- Protection of materials – ensure materials and resources are stored in a safe and dry location to minimise damage and resultant need to re-order materials.

7.1.3 GHG Emissions from Transportation, Equipment /Plant during Construction

7.1.3.1 Overview

The construction of the proposed Dam and associated infrastructure will require the use of a number plant, equipment and various types of vehicles for the transportation of material. All of these will result in GHG emissions during the construction phase (ENCON Environmental Consultancy, 2014). Information from the Alpaslan II project has been used to identify sources of emissions. The emissions rates used by ENCON were based on a field study undertaken by Oklahoma State University in 2010(ENCON Environmental Consultancy, 2014). The study estimated that dumper trucks, excavators, bull dozers, loaders, graders, generators, crushers, concrete plant, concrete mixer, concrete pump, roller, tower cranes, mobile cranes, sprinklers and submerged pumps would be used and would result in approximately 460 717 tCO2e.

The Foxwood Dam and associated infrastructure project will require a significant amount of material. This material will need to be transported to the site and emissions from vehicles transporting material will result in further GHG emissions. According to the Scoping Report (Nemai Consulting, 2015), a number of borrow pits are have been identified and undergoing geotechnical investigations. These sites are all located in close proximity to the Dam basin which minimises transportation and resultant GHG emissions.

In addition to fill material, other materials will be required for the construction. Transportation to the site will also result in additional emissions.

Another source of GHG emissions related to transportation is the transportation of workers to site.

7.1.3.2 Mitigation

During the construction phase there are a number of opportunities to reduce GHG emissions through the efficient use and operation of construction plant. For example, it is important that the correct machinery be used to avoid instances where machines are either over or under sized. In addition, plant which is more fuel efficient should be used. Lastly, suitable training should be provided to operators to ensure that they maximise the efficiency of the plant and idling is reduced (ENCON Environmental Consultancy, 2014).

Whilst emissions from transportation are not expected to be significant, it is possible for these to be mitigated through proper design and selection of materials and sites. Fill material should be sourced from the closest sites thereby minimising the transportation emissions). Further, materials should be sourced where possible from the local area to minimise transportation distances. In terms of transportation of workers and staff, collective transportation arrangements should be made to reduce individual car journeys (ENCON Environmental Consultancy, 2014).

7.1.4 GHG Emissions related to Energy Consumption

7.1.4.1 Overview

The proposed development has specific energy requirements for both construction and operation. Due to the fact that South Africa's main source of energy is coal based, the proposed development will indirectly influence GHG emissions from coal burning through its energy usage.

7.1.4.2 Mitigation

There are a number of possible mitigation measures available which can be used to increase energy efficiency and decrease indirect GHG emissions. Firstly, it is suggested that the detailed design of the infrastructure takes into account energy efficiency best practices. For example, both temporary and permanent offices can use energy efficient light bulbs. It is also suggested that where possible alternative energy sources be integrated into the design of the pump station (use of solar panels in conjunction with typical sources of electricity. This will be have a twofold effect as it also creates a backup energy source (see Chapter 7 for more details of this).

Other mitigation measures include the following:

- Energy controls – ensure energy controls are in place to minimise the use of energy. For example, the use of light controls set to timers/occupancy sensors;
- Energy management – ensure energy use is measured and reported to ensure that operational staff are aware of consumption. In addition to this, operational staff should receive training to ensure that they are aware of the importance of energy efficiency; and
- Maintenance – regular maintenance should take place during the operational phase to ensure efficient performance and minimise the likelihood of emissions.

7.1.5 Carbon Sink Potential

7.1.5.1 Overview

Another issue linked to the question of net emissions of Dams is the storage of organic material in Dams. Recent evidence has suggested that reduced outflow of nutrients into the ocean due to the damming of tropical rivers can decrease the effectiveness of the oceanic carbon sink function performed by plankton (Makinen & Khan, 2010). However the scientific evidence regarding this is not conclusive and some studies on Yangtze River basin instead suggest that Dams themselves can act as a new temporary carbon sink with some estimates suggesting that Dam building in the Yangtze/ Changjiang has sequestered ~4.9 ± 1.9 megatons particulate organic carbon (POC_{bio}) every year since 2003, approximately 10% of the global riverine POC burial flux to the oceans (Li, Wang, Yang, Mao, West, & Ji, 2015).

Another factor that does need to be considered is the inundation of the Dam basin results in the removal of terrestrial habitats that would normally be absorbing C02. Some studies take this further and suggest that in some areas, surrounding land can generally be considered as a net carbon sinks, and the reduction in carbon uptake is effectively a net emission (Dale, de Lucena, Marriott, Borba, Schaeffer, & Bilec, 2013). The World Commissions on Dams Report '*Dams and Development: a new framework for decision making* (World Commission on Dams, 2000) also notes that these terrestrial habitats may also be emitting GHGs. A further complication is that the land use change induced by displacement of people, resource extraction and other economic activities may also form part of the net contribution to GHG emissions associated with the construction of the Dam.

7.1.5.2 Mitigation

As there is still a lack of robust information available regarding the impact of the Dam on carbon sink potential, it is recommended that information on carbon fluxes be quantified and then compared against post impoundment GHG emissions. Should significant net emissions occur, it is suggested that additional mitigation measures be implemented including potential landscaping and rehabilitation of surrounding areas to improve the carbon sink potential of the area.

7.1.6 Potential for Hydro-Electricity

7.1.6.1 Overview

South Africa is one of the most carbon-emission intensive countries in the world, with per capita CO2 emissions higher than those of some European countries (Mukheibir, 2007) which is partly the result of its reliance on coal-based energy and the high specific energy intensity of many sectors. Due to this, the main mitigation potential for South Africa as a whole lies primarily in the energy sector and more specifically in the electricity generation sector.

Whilst Foxwood Dam will have GHG emissions, these are much lower than those of a coal plant (5%–7% compared to a coal plant for Savanna scenarios) (World Bank, 2013). There is therefore an opportunity to develop hydro-electricity at the Dam (in addition to its current purpose). The pre-feasibility studies for Foxwood Dam have suggested that there is potential for hydro-electricity although this is not currently part of the development scope. Whilst this would not be mitigating emissions from the Dam itself, it would overall be a positive impact.

7.1.6.2 Mitigation

It is recommended that the potential for hydro-electricity be considered during the detailed design phase.

7.1.7 Erosion due to Poor Rehabilitation of Borrow Areas

7.1.7.1 Overview

The proposed Foxwood Dam development includes a number of components. The impacts of these components may be amplified because of Climate Change and thus need to be assessed. One of the main impacts is poor rehabilitation of borrow areas which may result in increased erosion and resultant sedimentation during flood events.

7.1.7.2 Mitigation

All borrow areas and quarries occurring outside the Dam basin should be properly rehabilitated.

8 VULNERABILITY TO CLIMATE CHANGE

The connection between sustainable development and climate change works in two directions: firstly through mitigating greenhouse gas emissions and secondly adapting to the projected impacts due to global warming. The previous chapter dealt with the impacts (and associated mitigation measures) related to climate change impacts caused by the proposed Dam. This chapter will now focus on the vulnerability of the Dam to Climate Change and associated adaptation responses.

8.1 Vulnerability and Adaptation

The impacts of climate extremes and the potential for disasters which result from the climate extremes need to be understood in the context of Foxwood Dam and the associated infrastructure. The IPCC defines **vulnerability** as the propensity or predisposition to be adversely affected whilst **adaptation** is defined (in human systems), as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, it is the process of adjustment to actual climate and its effects; however it should be noted that human intervention may facilitate adjustment to expected climate (IPCC, 2012).

The process of adaptation is not new and throughout history, people have been adapting to changing conditions, including natural long-term changes in climate (UNDP, 2004). There are a number of available actions that range from incremental steps to transformational changes for reducing risk from climate extremes and social, economic, and environmental sustainability can be enhanced by disaster risk management and adaptation approaches(IPCC, 2012).

8.1.1 Changing/ Inaccurate Historical Datasets

Climate change is altering hydrological cycles and thus historic datasets may no longer be a reliable predictor of future hydrological patterns in a certain area (Mahahabisa, 2011). This may result in new Dams may be ill-prepared for rapid shifts in river flows and precipitation. Future hydrological patterns therefore need to take into account Climate Change scenarios and new mechanisms should be put in place to cope with the lower or high water levels (Mahahabisa, 2011).

8.1.2 Surface Water Evaporation

The Eastern Cape region is likely to experience increased temperatures (Department of Economic Development and Environmental Affairs, 2011) which may have a number of implications for Foxwood Dam. One of these relates to the potential for increased surface water evaporation. Studies have found that the greatest loss of potential water resources from Dams comes from the evaporation of water from the surface of Dams. Evaporation losses per annum have been calculated to be on average 1.1 metres of depth per square kilometre of surface area (Mukheibir, 2007). Deep dams with smaller surface areas would be less affected that those with large surface areas. Hydrological modelling should take into account increased temperatures to ensure surface water evaporation is adequately accounted for. If possible, surface water evaporation should be minimised through decreasing the surface area.

8.1.3 Reduced Run-off and Drought

The Eastern Cape Climate Change Response Strategy notes that the Eastern Cape is expected to experience highest temperature increases towards the northwest interior, while lowest increases are likely along the coast. Associated with the higher temperature will be increases in evaporation rates and increased intensity of droughts (Department of Environmental Affairs , 2013) and (Department of Economic Development and Environmental Affairs, 2011). The LTAS modelling notes that in some scenarios there may be reduced rainfall.

One of the main direct impacts of drought is that run-off is reduced and consequently the storage in dams is negatively affected (Mukheibir, 2007). During these occurrences, it is often necessary to implement water restrictions, with water to meet basic needs always receiving priority in allocations (Mukheibir, 2007). Optimum management of water resources is thus required (Nezhad, Mashal, & Hedayat, 2013). In addition, water conservation and demand management is one the critical strategies to help adapt Dam management for climate change and as part of this, there is potential for Dam managers to work with municipalities are ensuring that water losses are reduced as well as encouraging households to practice water serving technologies (e.g. dual flush toilets) and practices (e.g. use of showers instead of bath tubs) (Petermann, 2008). Other potential adaptation measures include increased flood storage capability and provisions for future off-stream storage (Mahahabisa, 2011).

Another potential impact of severe drought is reduced water levels at abstraction points which may adversely affect abstraction rates (World Health Organisation, 2011). This should be taken into account in the details design.

8.1.4 Increased Run-off and Flooding

In terms of Rainfall, some scenarios of the LTAS model for the Eastern Cape region suggests that the area will exhibit a pattern of drying (Department of Environmental Affairs , 2013). However, although drying is expected overall, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario. LTAS suggested that the areas showing highest risks in extreme runoff related events (and flooding conditions) include KwaZulu-Natal, parts of southern Mpumalanga and the Eastern Cape (Department of Environmental Affairs , 2013).

Unexpected flooding can be detrimental to large dams where the large loads of sediments carried by the rivers settle in the Dam and large logs and vegetation can cause damage or block up the system (Mukheibir, 2007). It also is a risk to downstream users should the Dam wall infrastructure not be capable of withstanding flood conditions. Flooding can also damage associated infrastructure (for example, washing away roads and flooded pump stations etc.). The risk of this damage is that it negatively impacts the ability of the Dam to provide water to local communities which can have a number of social impacts. One of the main reasons for this is that floods often damage power sources/supply.

It is also important to note that in itself, the Dam provides a level of buffering to downstream users during flood events (positive implication).

There are however, a number of adaptation responses available for management of flooding. Typical measures may include:

- Where possible making buildings water-tight (e.g. temporary flood gates on doors/openings;
- Enabling closure of external drains (to prevent backflow into the building);
- Increasing flood-resistance of buildings/assets by raising critical equipment and points of potential ingress above the maximum expected flood level;
- Installing physical flood barriers (for example around pump stations);
- Provision of alternative energy sources (for example solar power to ensure that pump stations have back up energy sources); and
- Raising boundary walls at intake sites (World Health Organisation, 2011).

Long term risk management also should include inter-institutional coordination (for example with municipalities and other water users) as well as capacity building and personnel training for emergencies (World Health Organisation, 2011).

In terms of design, it is also plan to incorporate additional measures as part of 'flood-proofing' the Dam such as planning for a supplemental spillway capacity for overflow or an emergency spillway, increasing flood storage capacity, planning for future parallel outlet tunnel as well as ensuring the diversion arrangement and Dam type selection take into account the risk of increased flooding (Babtie Group Ltd, 2002).

8.1.5 Temperature

LTAS shows that drastic increases in the annual average temperature of 2 to 5°C (4 to 6°C) are projected for the Eastern Cape for the period 2080–2100, relative to the baseline period, under the A2 scenario (RCP8.5) (Department of Environmental Affairs , 2013). These anomalies are well beyond the natural temperature variability of the region. This may have implications on the materials used in construction for example, with concrete elevated temperatures may also accelerate carbonation and also increase the rate at which chloride can penetrate the concrete. Chloride penetration into concrete exacerbates corrosion and may result structural damage (CSIRO, 2009). There are however a number of strategies available to enhance the resilience of concrete to climate change. For existing structures and infrastructure cover designs, surface coating barriers and cathodic protection can be applied.

For new infrastructure, the design principles and standards will need to be amended to ensure that climate change is taken into consideration (CSIRO, 2009).

The materials used throughout the construction of Foxwood Dam must take into account the likely increased temperatures in the area.

Building design should also take into account potential increasing temperatures. A number of ‘green building’ best practices are available including designing building geometries to limit solar gain on east and west façades, limiting the area of east- and west-facing glazing, incorporating exterior shading devices above glazing, specify glazings tuned to the orientation (glass with a low solar heat gain coefficient on east and west façades), incorporating high insulation levels to reduce conductive heat gain, provide high-albedo (reflective) roofing, and provide optimized daylighting to minimize the use of electric lighting. In addition is possible to provide landscaping to minimize cooling requirements. Trees, vines, annuals, and green roofs can all help control heat gain and minimize cooling demands on a building. Carefully designed landscaping can also help to channel cooling breezes into buildings to enhance natural ventilation.

8.1.6 Siltation

Increased temperatures, droughts (resulting in non-existent or sparse vegetation) as well as flooding can result of erosion and resultant siltation. Siltation is considered a major threat as it lessens the life span of dams and irrigation structures by reducing the depth of dams and hence the storage capacity. Potential adaptation measures include the construction of berms and swales upstream to reduce siltation in areas where the erosion potential is high (Mukheibir, 2007)

8.1.7 Dam Safety

Climate change can also impact Dam Safety especially through the increase in extreme events such as floods. It is therefore of vital importance that the detailed design of Foxwood Dam takes into account increased flooding potential (Babtie Group Ltd, 2002). Aspects that should be considered include:

- The appropriate flood category;
- The attenuation response of the Dam;
- Ultimate capacity and blockage potential of overflow;
- Nature of upstream slope;
- Presence of wave wall;
- Overall margin of freeboard; and
- Ability to resist overtopping (Babtie Group Ltd, 2002).

In addition, there are various hydrological tools available for flood or drought \hazard analysis. Hydrological analysis should be compulsory during the planning phase of water supply and sanitation utilities in changing climate conditions (World Health Organisation, 2011).

In addition, the inclusion of early warning systems is also an important adaptation strategy and to improve cooperation and avoid conflicts, an open and transparent communication mechanism between the warning manager, the disseminator, the receiver and down to the operators who should take action is required. Relevant data and information on hydrometeorological variability and trends, water quality availability and health risks should be made available to water supply and sanitation utilities operators. The main elements of the early warning chain are:

- Detecting and forecasting impending extreme events to formulate warnings on the basis of scientific knowledge and monitoring, and consideration of factors that affect disaster severity and frequency;
- Disseminating warning information, augmented by information on the possible impacts on people and infrastructure (i.e. vulnerability assessment), to the political authorities for further communication to the threatened population, including appropriate recommendations for urgent action; and
- •Responding to warnings, by the operators of the utilities, the population at risk and the local authorities, based on a proper understanding of the information, and subsequent implementation of protective measures (World Health Organisation, 2011).

8.1.8 Agricultural Vulnerability

According to the Final Scoping Report (Nemai Consulting, 2015), DWS has also identified a Government Irrigation Scheme on naturally occurring irrigable soils along the Koonap River downstream of the Foxwood Dam site. A strategic intent of the project is to mobilize the water resources in the area for irrigation development downstream of the proposed Foxwood Dam. Climate Change also has numerous implications for agriculture and this should be taken into account when the proposed irrigation scheme is developed. For example, the early warning system (detailed above) should also include communication with irrigators. There is also potential for reactive adaptation to rain shortages such as rescheduling agricultural timetables (late sowing, short cycle crops, several repeated sowings, dry sowing) as well as simultaneous practice of rain-based and irrigated farming. Other responses include changing farming practices away from crops associated with rain-based farming and increasing the use of other farming practices (common among cattle rearers) (Petermann, 2008).

Water conservation measures should also be included in the design for example, the use of efficient irrigation methods such as subsurface drip and centre pivot. Irrigation scheduling is a common practice to help ensure that irrigation is only applied when it is required (Petermann, 2008)

8.1.9 Social Impacts

Climate Change has major social implications. The negative impacts of Climate Change push those living on the margin closer to the edge and can hamper the development pathways of entire regions by impeding the fight against poverty, disease, and hunger (World Bank, 2011). Whilst the construction of Foxwood Dam does not directly hinder or impact on communities (in terms of Climate Change), the potential impacts of climate change should be taken into account when designing resettlement plans and downstream developments. This is to ensure that communities are not negatively impacted by flooding. In addition to the direct impact of flooding such as impacts to houses and loss of life. There are also indirect impacts. For example, changing water levels at the Dam can create breeding grounds for mosquitoes and potentially may increase the range of Malaria. Flash floods can also impact water and sewer infrastructure and result in increased water borne diseases.

All downstream users must remain outside the 1:100 year floodline and floodline calculations for new downstream developments should take into account the Dam.

The operating manual and/or RMP for the Dam should also take into account Climate Change scenarios and should include adaptation measures for floods and droughts. For example, communication campaigns regarding the need for houses to remain outside the floodline etc. should be implemented. Emergency preparedness plans should also include Climate Change.

As mentioned, a decrease of rainfall is expected in the Eastern Cape which may result in droughts – this may therefore result in conflict over water resources. It is therefore important that Climate Change be incorporated in the hydrological models to ensure allocation is accurate. Further, the careful management of water resources is fundamental to the supply of adequate safe drinking-water during drought conditions. Water suppliers need to identify risks to the availability and quality of resources posed by drought scenarios. In particular water suppliers need to have in place standing agreements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of dry periods can be highlighted and to identify trigger points at which prepared drought management plans can be activated (World Health Organisation, 2011).

Adaptation measures to assist in the management of drinking-water supplies during drought periods should be put in place in anticipation of future drought conditions. These measures are also likely to form part of long-term water resources planning and may also contribute to several complementary objectives of the water supplier (e.g. planning for population growth) (World Health Organisation, 2011).

Another impact of Climate Change which has social implications is that of water quality: water quality may decrease during droughts due to less dilution in source waters. Water quality and safety may also be adversely impacted by flooding events. The primary impacts are likely to be:

- General decrease in raw water quality due to greater surface runoff and pollution inputs into source waters;
- Large scale variations in surface water due to extreme flow patterns, and changes in Dam limnology;
- Increase in contamination events resulting either from inundation of contaminated land or overflowing of sewerage and drainage systems (World Health Organisation, 2011).

An important adaptation response is therefore enhanced monitoring to detect deterioration water quality (turbidity/physical quality; indicator organisms (pathogen loading); algal species and counts; broad chemical screens (e.g. GC/MS scan) for emerging contaminants; limnology – risks of low draw-down, storage Dam inversion; vector-borne diseases (open Dam management); and emerging risks – suggested chemicals/pathogens, viruses, etc.) (World Health Organisation, 2011).

In terms of flooding, the primary impacts of floods on water supply systems are too much water in the wrong place (i.e. inundation of the water supply infrastructure), or too great a volume of water of an inappropriate quality for use as a source of drinking-water (World Health Organisation, 2011). Where possible, adaptation measures should be put in place to assist in the management of drinking-water supplies during such periods in anticipation of extreme events.

As with planning for drought events, water suppliers must work with a variety of stakeholders to understand the climatic and meteorological conditions in which they are operating and also with those responsible for environmental protection, the management of water and land-use within the catchment area. Water suppliers need to identify risks to the availability and quality of water resources, and the impact of flooding on water supply assets. In addition, water suppliers need to have in place standing arrangements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of flooding can be highlighted and should identify both planning assumptions and trigger points at which prepared response plans can be activated.

As with adaptation for drought events, where possible measures to assist in ensuring the continued safety of drinking water supplies should be put in place in anticipation of future flood conditions.

Dams in South Africa are also often used recreationally. An increase in extreme events may negatively impact recreational use of the Dam. For example, increase wind and storms may make recreational use at the Dam more dangerous and result in accidents. During droughts, previously deep areas may become shallow and result in damage to recreational boats. Should a RMP be developed for the Dam, it should incorporate management of recreational use in light of Climate Change Scenarios.

Overarching adaptation responses should include the following (Department of Environmental Affairs , 2013):

- Continuous monitoring and drought/flood early warning systems;
- Improved land care, catchment management and water sensitive urban design, etc.
- Enforcement of current zoning practices to reduce the number of people in flood-risk areas;
- Routine maintenance and correct operation of existing infrastructure;
- Integrated design and planning that takes into account climate risks and change uncertainty; and
- Improved safety nets and diversification of livelihoods for particularly vulnerable groups.

8.1.10 Increased maintenance burden

Another risk related to extreme events such as flooding is the impact on infrastructure. Increased erosion may wear down infrastructure such as the Dam outlet works (including Dam intake tower, tunnel and outlet valve house), Pump station and Pipeline and associated structures (chambers, Cathodic Protection measures, AC mitigation measures, pipeline markers). Damage to this infrastructure during floods may also increase the frequency of maintenance as well as the cost of operation. Typical measures to safeguard infrastructure includes:

- Where possible making buildings/chambers/pump stations water-tight (e.g. temporary flood gates on doors/openings;
- Installing physical flood barriers (for example around pump stations); and
- Raising boundary walls at intake sites (World Health Organisation, 2011).

8.1.11 Ecological Reserve

The National Water Act of 1998 requires the implementation of 'Resource Directed Measures' (RDM) in order to make optimal use of our country's water resources while minimising ecological damage. The main focus of RDM is the determination of the 'Reserve', which is the water quality and quantity required for the protection of basic human needs and aquatic systems. Of this RDM, the 'Ecological Reserve', is the quality and quantity of water required to maintain a desired level of structure and function, or quality, of a specific aquatic system (e.g. river reach, wetland, estuary) (WRC, 2012). In order to ensure that droughts do not negatively impact the downstream environment, climate change scenarios should be integrated into the Ecological Reserve determination for Foxwood Dam.

8.1.12 Aquatic Invasive Plant Species

Another potential impact of Climate Change is increased aquatic invasive plant species. One of the main reasons for this is water level fluctuations due to drought/low rainfall conditions: For example, in Lake Kariba, a 5 to 10m change in the water levels was favourable to water hyacinth growth because shallower areas formed are not subjected to as much wind and wave action. Once the dry areas become re-flooded, there will be mass germination of seeds and the weed will undergo rapid vegetative growth (Petermann, 2008). The operating manual for the Dam should take into account the management of water level fluctuations to decrease changes in water level which are favourable to aquatic invasive plant species (Petermann, 2008). Furthermore, during the RMP process, it is suggested that mechanisms to deal with and prevent aquatic invasive species be taken into account such as the implementation of wash bays at the Dam.

8.2 Summary of Available Adaptation Responses

Table 9 provides an overview of the recommended adaptation responses available for Foxwood Dam and associated infrastructure.

Table 9: Adaptation Responses

Vulnerability/Climate Change Impact	Adaptation Response
Changing/ Inaccurate Historical Datasets	• Future hydrological patterns need to take into account Climate Change scenarios. • New mechanisms should be put in place to cope with the lower or high water levels during the detailed design stage.
Surface Water Evaporation	• Hydrological modelling should take into account increased temperatures to ensure surface water evaporation is adequately accounted for. • If possible, surface water evaporation should be minimised through decreasing the surface area.
Reduced Run-off and Drought	• Optimum management of water resources is thus required and climate change implications should be considered in the operating manual and RMP for the Dam. • Water conservation and demand management strategies should be implemented and Dam managers should work with municipalities are ensuring that water losses are reduced as well as encouraging households to practice water serving technologies (e.g. dual flush toilets) and practices (e.g. use of showers instead of bath tubs) (Petermann, 2008). • Other potential adaptation measures include increased

Vulnerability/Climate Change Impact	Adaptation Response
	flood storage capability and provisions for future off-stream storage (Mahahabisa, 2011). • Reduced water levels at abstraction points which may adversely affect abstraction rates (World Health Organisation, 2011). This should be taken into account in the details design.
Increased Run-off and Flooding	• There are however, a number of adaptation responses available for management of flooding. Typical measures may include: o Where possible making buildings water-tight (e.g. temporary flood gates on doors/openings; o Enabling closure of external drains (to prevent backflow into the building); o Increasing flood-resistance of buildings/assets by raising critical equipment and points of potential ingress above the maximum expected flood level; o Installing physical flood barriers (for example around pump stations); o Provision of alternative energy sources (for example solar power to ensure that pump stations have back up energy sources); and o Raising boundary walls at intake sites (World Health Organisation, 2011). o Long term risk management also should include inter-institutional coordination (for example with municipalities and other water users) as well as capacity building and personnel training for emergencies (World Health Organisation, 2011). o In terms of design, it is also plan to incorporate additional measures as part of 'flood-proofing' the Dam such as planning for a supplemental spillway capacity for overflow or an emergency spillway, increasing flood storage capacity, planning for future parallel outlet tunnel as well as ensuring the diversion arrangement and Dam type selection take into account the risk of increased flooding (Babtie Group Ltd, 2002).
Temperature	• There are however a number of strategies available to enhance the resilience of concrete to climate change. For existing structures and infrastructure cover designs, surface coating barriers and cathodic protection can be applied. For new infrastructure, the design principles and standards will need to be amended to ensure that climate change is taken into consideration (CSIRO, 2009). • The materials used throughout the construction of Foxwood Dam must take into account the likely increased temperatures in the area. • Building design should also take into account potential increasing temperatures. A number of 'green building' best practices are available including designing building geometries to limit solar gain on east and west façades, limiting the area of east- and west-facing glazing, incorporating exterior shading devices above glazing,

Vulnerability/Climate Change Impact	Adaptation Response
	specify glazings tuned to the orientation (glass with a low solar heat gain coefficient on east and west façades), incorporating high insulation levels to reduce conductive heat gain, provide high-albedo (reflective) roofing, and provide optimized daylighting to minimize the use of electric lighting. In addition is possible to provide landscaping to minimize cooling requirements. Trees, vines, annuals, and green roofs can all help control heat gain and minimize cooling demands on a building. Carefully designed landscaping can also help to channel cooling breezes into buildings to enhance natural ventilation.
Siltation	• Potential adaptation measures include the construction of berms and swales upstream to reduce siltation in areas where the erosion potential is high (Mukheibir, 2007)
Dam Safety	• The operating manual of the Dam must take into account increased flooding potential (Babtie Group Ltd, 2002). Aspects that should be considered include: o The appropriate flood category; o The attenuation response of the Dam; o Ultimate capacity and blockage potential of overflow; o Nature of upstream slope; o Presence of wave wall; o Overall margin of freeboard; and o Ability to resist overtopping (Babtie Group Ltd, 2002). • In addition, there are various hydrological tools available for flood or drought \hazard analysis. Hydrological analysis should be compulsory during the planning phase of water supply and sanitation utilities in changing climate conditions (World Health Organisation, 2011). • In addition, the inclusion of early warning systems is also an important adaptation strategy and to improve cooperation and avoid conflicts, an open and transparent communication mechanism between the warning manager, the disseminator, the receiver and down to the operators who should take action is required. Relevant data and information on hydrometeorological variability and trends, water quality availability and health risks should be made available to water supply and sanitation utilities operators. The main elements of the early warning chain are: o Detecting and forecasting impending extreme events to formulate warnings on the basis of scientific knowledge and monitoring, and consideration of factors that affect disaster severity and frequency; o Disseminating warning information, augmented by information on the possible impacts on people and infrastructure (i.e. vulnerability assessment), to the political authorities for further communication to the threatened population, including appropriate recommendations for urgent action; and o Responding to warnings, by the operators of the utilities, the population at risk and the local

Vulnerability/Climate Change Impact	Adaptation Response
	authorities, based on a proper understanding of the information, and subsequent implementation of protective measures (World Health Organisation, 2011).
Agricultural Vulnerability	• Early warning system (detailed above) should also include communication with irrigators. • There is also potential for reactive adaptation to rain shortages such as rescheduling agricultural timetables (late sowing, short cycle crops, several repeated sowings, dry sowing); Simultaneous practice of rain-based and irrigated farming; Changing farming practices away from crops associated with rain-based farming and increasing the use of other farming practices (common among cattle rearers) (Petermann, 2008). • Water conservation measures should also be included in the design of the irrigation scheme, for example, the use of efficient irrigation methods such as subsurface drip and centre pivot. Irrigation scheduling is a common practice to help ensure that irrigation is only applied when it is required (Petermann, 2008)
Social Impacts	• All downstream users must remain outside the 1:100 year floodline and floodline calculations for new downstream developments should take into account the Dam. • The operating manual and/or RMP for the Dam should also take into account Climate Change scenarios and should include adaptation measures for floods and droughts. For example, communication campaigns regarding the need for houses to remain outside the floodline etc. should be implemented. • Emergency preparedness plans should also include climate change. • It is important that Climate Change be incorporated in the hydrological models to ensure allocation is accurate and to minimise conflict potential. • Careful management of water resources is fundamental to the supply of adequate safe drinking-water during drought conditions. Water suppliers need to identify risks to the availability and quality of resources posed by drought scenarios. In particular water suppliers need to have in place standing agreements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of dry periods can be highlighted and to identify trigger points at which prepared drought management plans can be activated (World Health Organisation, 2011). • Adaptation measures to assist in the management of drinking-water supplies during such periods should be put in place in anticipation of future drought conditions. These measures are also likely to form part of long-term water resources planning and may also contribute to several complementary objectives of the water supplier (e.g. planning for population growth) (World Health

Vulnerability/Climate Change Impact	Adaptation Response
	Organisation, 2011). • In regards to water quality, an important adaptation response is enhanced monitoring to detect deterioration water quality (turbidity/physical quality; indicator organisms (pathogen loading); algal species and counts; broad chemical screens (e.g. GC/MS scan) for emerging contaminants; • limnology – risks of low draw-down, storage Dam inversion; vector-borne diseases (open Dam management); and emerging risks – suggested chemicals/pathogens, viruses, etc.) (World Health Organisation, 2011). • In terms of flooding, where possible adaptation measures should be put in place to assist in the management of drinking-water supplies during such periods in anticipation of extreme events. As with planning for drought events, water suppliers must work with a variety of stakeholders to understand the climatic and meteorological conditions in which they are operating and also with those responsible for environmental protection, the management of water and land-use within the catchment area. Water suppliers need to identify risks to the availability and quality of water resources, and the impact of flooding on water supply assets. In addition, water suppliers need to have in place standing arrangements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of flooding can be highlighted and should identify both planning assumptions and trigger points at which prepared response plans can be activated. • Should a RMP be developed for the Dam, it should incorporate management of recreational use in light of Climate Change Scenarios. • Overarching adaptation responses should include the following (Department of Environmental Affairs , 2013): o Continuous monitoring and drought/flood early warning systems; o Improved land care, catchment management and water sensitive urban design, etc. o Enforcement of current zoning practices to reduce the number of people in flood-risk areas; o Routine maintenance and correct operation of existing infrastructure; o Integrated design and planning that takes into account climate risks and change uncertainty; and o Improved safety nets and diversification of livelihoods for particularly vulnerable groups.
Increased maintenance burden	• Typical measures to safeguard infrastructure includes: o Where possible making buildings/chambers/pump stations water-tight (e.g. temporary flood gates on doors/openings; o Installing physical flood barriers (for example around pump stations); and o Raising boundary walls at intake sites (World Health

Vulnerability/Climate Change Impact	Adaptation Response
	Organisation, 2011).
Ecological Reserve	• In order to ensure that droughts do not negatively impact the downstream environment, Climate Change scenarios should be integrated into the Ecological reserve determination for Foxwood Dam.
Aquatic Invasive Plant Species	• The operating manual for the Dam should take into account the management of water level fluctuations to decrease changes in water level which are favourable to aquatic invasive plant species (Petermann, 2008). • Furthermore, should a RMP be developed, it is suggested that mechanisms to deal with and prevent aquatic invasive species be taken into account such as the implementation of wash bays at the Dam.

9 Assessment of Alternatives

The alternatives for the Foxwood Dam and associated infrastructure project occur at a localised level. In contrast, the nature of climate change impacts are at a large scale and as such is not possible to differentiate between the alternatives. Therefore, from a Climate Change perspective, there is **no preference** between the alternatives. However, in **all** cases, the detailed design must take into account the mitigation and adaptation measures suggested in the chapters above.

10 Conclusion

This Climate Change Study aimed at assessing impact of the development of Foxwood Dam (and associated infrastructure) on Climate Change as well as the potential vulnerability of the Dam to Climate Change. This involved understanding Climate Change scenarios for the Eastern Cape with models suggesting that the province will experience drastic increases in the annual average temperature of 2 to 5°C (4 to 6°C) for the period 2080–2100 (Department of Environmental Affairs , 2013). In terms of Rainfall, the area is likely to exhibit a pattern of drying. However, although drying is expected overall, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario. LTAS models also suggest that the Eastern Cape is one of the areas which shows the highest risks in extreme runoff related events (and flooding conditions) (Department of Environmental Affairs , 2013). Based on this information, an assessment of impacts and vulnerability was undertaken and a number of mitigation responses (**human intervention to reduce the sources or enhance**

the sinks of greenhouse gases) as well as adaptation measures (**adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities**) have been recommended are summarised in **Table 10.**

Table 10: Mitigation and Adaptation Responses

Type	Recommendation
Mitigation	• Quantify natural pre-impoundment carbon fluxes. Determine de-bushing requirements and compare against monitored data from of post-impoundment greenhouse gas emissions. Employ the UNESCO GHG Measurement Guidelines for Freshwater Reservoirs (or other acceptable best practice) to determine the Dam's greenhouse gas footprint. • Clear vegetation within the Dam impoundment. Where possible, woody material can be provided to local communities for use as firewood. • Detailed design and operating manual should aim to minimise water level fluctuations. • Materials should be managed in line with the recommendations of this document including (lowest embodied Carbon content, high recycled content, local materials to be sourced if possible, correct ordering of materials, accurate ordering of materials, materials and resources are stored in a safe and dry location to minimise damage and resultant need to re-order materials). It is also recommended that a GHG emissions calculator be developed which will assist in the comparison of the impact of different materials. • The operational performance of accommodation facilities on site should be considered so to maximise the efficient use of energy and water; • Plant should be managed correctly including the use of the correct machinery, fuel efficient plant should be used and suitable training should be provided to operators to ensure that they maximise the efficiency of the plant. • Fill material should be sourced from the closest borrow sites thereby minimising the transportation emissions • In terms of transportation of workers and staff, collective transportation arrangements should be made to reduce individual car journeys. • All vehicles used during the project should be properly maintained and in good working order. • The detailed design of the infrastructure should take into account energy efficiency best practices. For example, both temporary and permanent offices can use energy efficient light bulbs. • Possible alternative energy sources be integrated into the design of the pump station (use of solar panels in conjunction with typical sources of electricity. • Energy controls – ensure energy controls are in place to minimise the use of energy. For example, the use of light controls set to timers/occupancy sensors; • Energy management – ensure energy use is measured and reported to ensure that operational staff are aware of consumption. In addition to this, operational staff should receive training to ensure that they are aware of the importance of energy efficiency; and • Maintenance – regular maintenance should take place during the operational phase to ensure efficient performance and minimise the likelihood of emissions. • It is recommended that the potential for hydro-electricity be considered

Type	Recommendation
	during the detailed design phase.
Adaptation	• Future hydrological patterns need to take into account Climate Change scenarios. • New mechanisms should be put in place to cope with the lower or high water levels during the detailed design stage. • Hydrological modelling should take into account increased temperatures to ensure surface water evaporation is adequately accounted for. • If possible, surface water evaporation should be minimised through decreasing the surface area. • Optimum management of water resources is thus required and climate change implications should be considered in the operating manual and RMP for the Dam. • Water conservation and demand management strategies should be implemented and Dam managers should work with municipalities are ensuring that water losses are reduced as well as encouraging households to practice water serving technologies (e.g. dual flush toilets) and practices (e.g. use of showers instead of bath tubs) (Petermann, 2008). • Other potential adaptation measures include increased flood storage capability and provisions for future off-stream storage (Mahahabisa, 2011). • Where possible making buildings water-tight (e.g. temporary flood gates on doors/openings; • Enabling closure of external drains (to prevent backflow into the building); • Increasing flood-resistance of buildings/assets by raising critical equipment and points of potential ingress above the maximum expected flood level; • Installing physical flood barriers (for example around pump stations); • Provision of alternative energy sources (for example solar power to ensure that pump stations have back up energy sources); and • Raising boundary walls at intake sites (World Health Organisation, 2011). • Long term risk management also should include inter-institutional coordination (for example with municipalities and other water users) as well as capacity building and personnel training for emergencies (World Health Organisation, 2011). • In terms of design, it is also plan to incorporate additional measures as part of ‘flood-proofing’ the Dam such as planning for a supplemental spillway capacity for overflow or an emergency spillway, increasing flood storage capacity, planning for future parallel outlet tunnel as well as ensuring the diversion arrangement and Dam type selection take into account the risk of increased flooding (Babtie Group Ltd, 2002). • There are a number of strategies available to enhance the resilience of concrete to climate change. For existing structures and infrastructure cover designs, surface coating barriers and cathodic protection can be applied. For new infrastructure, the design principles and standards will need to be amended to ensure that climate change is taken into consideration (CSIRO, 2009). • The materials used throughout the construction of Foxwood Dam must take into account the likely increased temperatures in the area. • Building design should also take into account potential increasing temperatures. A number of ‘green building’ best practices are available.

Type	Recommendation
	• Potential adaptation measures include the construction of berms and swales upstream to reduce siltation in areas where the erosion potential is high (Mukheibir, 2007) • The operating manual of the Dam must take into account increased flooding potential (Babtie Group Ltd, 2002). • Early warning systems should be developed and implemented. • Water conservation measures should also be included in the design of the irrigation scheme. • All downstream users must remain outside the 1:100 year floodline and floodline calculations for new downstream developments should take into account the Dam. • The operating manual and/or RMP for the Dam should also take into account Climate Change scenarios and should include adaptation measures for floods and droughts. • Emergency preparedness plans should also include climate change. • In regards to water quality, an important adaptation response is enhanced monitoring to detect deterioration water quality (turbidity/physical quality; indicator organisms (pathogen loading); algal species and counts; broad chemical screens (e.g. GC/MS scan) for emerging contaminants; • limnology – risks of low draw-down, storage Dam inversion; vector-borne diseases (open Dam management); and emerging risks – suggested chemicals/pathogens, viruses, etc.) (World Health Organisation, 2011). • In terms of flooding, where possible adaptation measures should be put in place to assist in the management of drinking-water supplies during such periods in anticipation of extreme events. • The operating manual for the Dam should take into account the management of water level fluctuations to decrease changes in water level which are favourable to aquatic invasive plant species (Petermann, 2008). • Furthermore, during the RMP process, it is suggested that mechanisms to deal with and prevent aquatic invasive species be taken into account such as the implementation of wash bays at the Dam.

As the alternatives for the Foxwood Dam and associated infrastructure project occur at a localised level and the Climate Change impacts at a regional scale, there were no preferences for alternatives. However it should be noted that the mitigation and adaptation measures discussed above should be incorporated into the detailed design regardless of the alternative type.

With the successful implementation of the mitigation measures, the proposed development is not thought to pose significant long-term impacts on Climate Change. Furthermore, through the incorporation of adaptation responses into the detailed design, operating manual and RMP process, it is possible to ensure that Foxwood Dam will not be vulnerable to Climate Change.

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