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***Abstract:**
This project addresses knowledge, resource, capacity and networking gaps on the theme: 'Strengthening urban governments in planning adaptation.'
The main objective of this project is to develop an adaptation framework for managing the increased risk to African local government and their communities due to climate change impact. The ultimate beneficiaries of this project will be African local governments and their communities. The guiding and well-tested ICLEI principle of locally designed and owned projects for the global common good, specifically in a developing world context, will be applied throughout project design, inception and delivery.

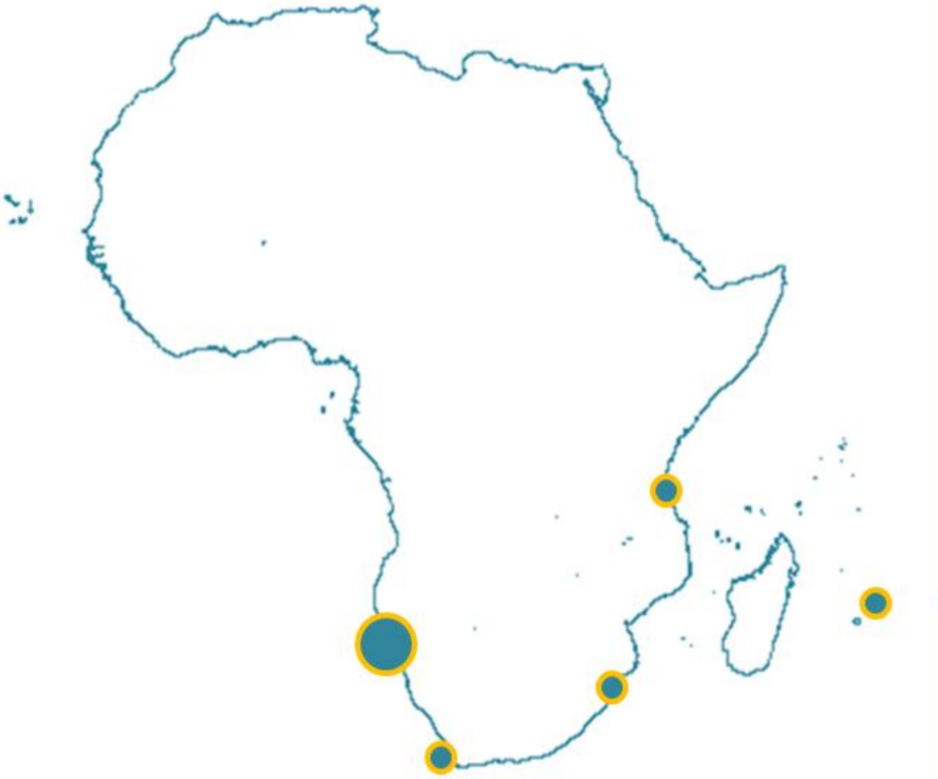
Additionally, the research will test the theory that the most vulnerable living and working in different geographical, climatic and ecosystem zones will be impacted differently and as such, will require a different set of actions to be taken. Potential commonalities will be sought towards regional participatory learning and wider applicability. The five urban centres chosen for this study, based on selection criteria, include: Cape Town, South Africa, Dar es Salaam, Tanzania; Maputo, Mozambique; Windhoek, Namibia; and Port St. Louis, Mauritius.

Through a participatory process, this project will carry out a desk-top study, long-term, multi-discipline, multi-sectoral stakeholder platforms in five Southern African cities comprising of academics, communities and the local government in order to facilitate knowledge-sharing, promote proactive climate adaptation and resource opportunities available for African cities, develop five tailor-made Adaptation Frameworks and explore regional applicability. A network of stakeholders within each urban centre will be established, feeding into a larger regional network of local authorities and partners in Sub-Saharan Africa, and globally through existing ICLEI global (e.g. the ICLEI Cities for Climate Protection programme), ICLEI Africa and UCLG-A members and networks, ensuring global best practice, roll-out, and long-term sustainability.

Key words: Adaptation, Africa, Climate Change, Local Governments, Participatory Action Research, Policy.

Sub-Saharan African Cities:
A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action

Baseline Study



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Sub-Saharan African Cities: A five-City Network to Pioneer Climate Adaptation through Participatory Research & Local Action

Walvis Bay Baseline Study

February 2011

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Contents

List of acronyms

CBD	Convention on Biological Diversity
CCAA	Climate Change Adaptation in Africa
CCD	Convention to Combat Desertification
COP	Conference of the Parties
DFID	Department for International Development
HAB	Harmful Algal Blooms
ICLEI	International Council for Local Environmental Initiative
ICZMP	Integrated Coastal Zone Management Plan
IDRC	International Development Research Council
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
LAB	Local Action for Biodiversity
MET	Ministry of Environment and Tourism
MME	Ministry of Mines and Energy
MWT	Ministry of Works and Transports
NACOMA	Namibian Coast Conservation and Management
NamWater	Namibian Water Corporation Ltd.
NCCC	Namibia Climate Change Committee
NCCP	National Climate Change Policy
NDP	National Development Plans
NSRI	National Sea Rescue Institute
SAWS	South African Weather Service
SEA	Strategic Environmental Assessment
SWAWEK	South West Africa Water and Electricity Corporation
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB LA21	Walvis Bay Local Action 21
WBM	Walvis Bay Municipality

Preface

The global climate is controlled by complex interactions between marine and terrestrial systems. These interactions generate a variety of climatic variables across different regions and exert significant controls on day-to-day developments at the global, regional and local levels. Climate change is defined by the International Panel for Climate Change (IPCC) as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (IPCC 2007). Climate change may be a result of natural internal processes, external forcing or from anthropogenic changes such as increased carbon dioxide (CO_2) emissions. However the United Nations Framework Convention on Climate Change (UNFCCC) makes a clear division between anthropogenic causes that alter the composition of the atmosphere and the natural causes attributing to climate variability. Climate change, as defined by the UNFCCC, is any 'change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is in addition to natural climate variability over comparable time periods' (IPCC 2001) and the IPCC (2007a) concurs that anthropogenic forcing is a major driver.

Climate change is expected to have severe physical, social, environmental and economic impacts on cities worldwide, both directly and indirectly. These are anticipated to be felt with greater intensity in the developing world, particularly Africa. Although there are some uncertainties surrounding the understanding of earth's complex systems, there is strong evidence in current literature and climatic measurements to demonstrate that, as a result of increasing greenhouse gas emissions, atmospheric and sea surface temperatures (SSTs) are rising.

Some of the changes likely to manifest from the projections are:

- changes in rainfall and precipitation patterns (flooding and drought),
- increases in temperature,
- increasing frequency and intensity of storm surges or extreme events,
- increasing average global sea levels due to melting glaciers and thermal expansion (permanent and non-permanent inundation) and,
- changes in wind speed.

This baseline study aims to identify and discuss the relevant literature pertaining to climate change in Africa with reference to past and projected climatic variability and how this is likely to impact upon local governments as service providers.

Local governments, as the sphere of government closest to their constituents, are required to make decisions and set directions for promoting social, cultural, environmental and economic well-being. Extreme climatic events and variability impact upon local governments and the day-to-day activities and services they provide to the communities that fall within their jurisdiction. These impacts raise challenges and come with risks and vulnerabilities that need to be strategically managed to ensure resilience. The risks associated with climate change pose a serious threat to local governments' ability as service providers to meet their own mandates. These threats may not necessarily arise as a direct result of climate change but rather indirectly as a result of a chain or cascade of events.

A changing climate will affect people's access to, and the quality of, basic goods and services such as water, shelter and food as well as other key priorities for human wellbeing such as education, employment and health. Current literature indicates that although, during extreme climatic events, the entire local human population is impacted upon, it is those who are impoverished who find it harder to recover from climate change related impacts as they have limited access and choices with regard to natural, social political, human, physical and financial capital that forms part of the holistic livelihood assets (IPCC 2007). Deprivation of these assets increases vulnerability to climate change, and climate change in return increases deprivation. Understanding the basis of livelihood assets determines the ability of people to cope with climate-induced vulnerabilities. The key goal is to reduce the vulnerability to changes and to sustain and enhance livelihoods of people, with particular attention to the poor through adaptation and coping mechanisms.

Adapting to climate change is a necessary active initiative to reduce the vulnerability of the natural and human systems. Adaptation is becoming increasingly vital as climatic changes currently experienced are reportedly increasing in magnitude and frequency. Therefore the magnitude and frequency make the reduction of vulnerability an increasingly difficult task to achieve, particularly for developing nations who, comparatively to developed nations, have limited capacity and resources to implement coping mechanisms.

1. The project in context

The official mandate of **ICLEI – Local Government for Sustainability** - **Africa**[1] – is to work with Sub-Saharan African countries towards sustainable development and this project works towards that. The project is entitled *Sub-Saharan African Cities: A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action*. ICLEI-Africa falls under the auspices of the Climate Change Adaptation Africa (CCAA) programme funded by International Development Research Council (IDRC) and Department for International Development (DFID). The "Five City Network" project aims to address the knowledge, resource, capacity and networking gaps by strengthening the ability to plan for, and adapt to, impacts associated with climate change.

Increased adaptive capacity at the local government level, by building understanding and awareness of projected threats, would enable future planning and decision-making abilities to encompass climate change. This would reduce the vulnerability of the communities, services and infrastructure that fall within their jurisdiction. The first step is to identify the impacts and risks associated with climate change variability and subsequently make informed decisions. This leads toward the identification of mechanisms that increase adaptive capacity and climate preparedness thus enabling local governments to cope with such impacts. The first phase of the project is to identify the risks and impacts at a local level, looking at various local government sectors. The Risk Assessment comprises of a number of stages namely:

- An overview of the risks and impacts associated with climate change that have already been documented (a baseline literature review – referring to this report).
- A southern African climatic variable overview of the past, present and projected changes for: sea level, temperature, wind speeds, rainfall and precipitation patterns.
- A cost-benefit analysis of present and projected risks at the local level.

Five urban centres were chosen for this project; **Cape Town** in South Africa, **Dar es Salaam** in Tanzania, **Maputo** in Mozambique, **Walvis Bay** in Namibia and **Port Louis** in Mauritius.

These cities were chosen as they are large, home to a significant number of people, are rapidly developing and are coastal economic hubs with harbours that contribute to their national GDP. Adaptation needs to be initiated quickly so that each city can contribute to the understanding of climate change, its vulnerabilities and adaptation strategies. Each city is represented in an individual

[1] ICLEI – Local Governments for Sustainability is an international association of local governments and national and regional local government organizations that have made a commitment to sustainable development. ICLEI was founded in 1990 as the International Council for Local Environmental Initiatives. The organization is now officially called 'ICLEI - Local Governments for Sustainability', encompassing a broader mandate to address sustainability issues. ICLEI – Local Governments for Sustainability – Africa (ICLEI Africa) is the regional secretariat based in Cape Town, South Africa.

case report. Port cities form a nexus between growing population and trade, and thus an excellent focus for investigating impacts and adaptation needs under changing climate.

This report focuses on **Walvis Bay, Namibia** (Figure 1). Walvis Bay was identified as the Namibian coastal municipality most vulnerable to sea level rise in a national sea level rise study undertaken in 2009 (UNFCCC-NAM). The towns of Luderitz, Oranjemund, Henties Bay and Wlotzkasbaken and Swakopmund were also examined but were found to be at less risk of wholesale inundation of infrastructure by a rising sea. At present, Walvis Bay town is protected by a sand spit called Pelican Point (Figure 1). The shelter currently provided by this barrier is threatened by increased frequency and intensity of sea storm surges and the associated erosion. This report is intended to build upon the findings of the national sea level rise report (UNFCCC-NAM 2009).

The first section of this report will provide an overview of the climatic changes in Africa, followed by a more detailed review at a regional level (Namibia) with specifics at a local level for Walvis Bay. Lastly, the infrastructure and services that fall under the municipality's jurisdiction will be provided, and the impacts and risks relating to sea level rise and climate change discussed.

Figure 1. Study focus area - Walvis Bay, Namibia[2] currently protected by Pelican Point.

[2] Source: Oxford Cartographers © & Google Earth.

2. Africa's vulnerability to climate change

Africa, covering more than one fifth of the total land area of earth, is the second largest continent and host to a billion people (United Nations 2010). It is a continent with abundant natural resources but remains the most underdeveloped continent globally. Extreme poverty, poor access to water, sanitation and health services and malnutrition from inadequate food supplies slows her progress (Sandbrook 1985). This means that the average sub-Saharan African city will bear a three-fold population-based risk of suffering adverse effects of climate change when compared to a global total (Byass 2009), a heavy burden to bear for the population group that has contributed least to the forcing of climatic change (IPCC 2007). The Stern Report (2006) concludes for Africa: 'The poorest will be hit earliest and most severely. In many developing countries, even small amounts of warming will lead to declines in agricultural production because crops are already close to critical temperature thresholds. The human consequences will be most serious and widespread in sub-Saharan Africa, where millions more will die from malnutrition, diarrhoea, malaria and dengue fever, unless effective control measures are in place' (Stern 2006).

Projections

TEMPERATURE: Africa is experiencing the physical effects of climate change and variability as experienced worldwide. Consensus in the scientific community's predictions gives us a warming of approximately 0.7°C, more so in the southern regions rather than in the central regions (IPCC 2007). Between 1961 and 2000 an increase in warm spells over southern and western parts of Africa was observed, with a decrease in the number of extremely cold days (New *et al.* 2006). According to the IPCC (2000), mean surface temperatures are projected to increase between 1.5°C and 6°C by 2100; this warming trend is anticipated to give rise to changes in precipitation which will be accompanied by sea level rises and increased frequency of extreme events in Africa, such as sea storm surges, floods, gale force winds and cyclones (Desanker 2009).

RAINFALL: Projections give a 10-20%decrease in rainfall by 2070 and a fall in river-water levels of as much as 50% by 2030, in various parts of Africa (UNECA 2010). Projections indicate that 230 million Africans will face water scarcity by 2025 as a result of decreasing water resources and as a result of increasing constraints on water resources, especially in hotter climates. Much water infrastructure will require upgrading to maintain adequate supplies for meeting current needs and increased demands in the future. This will need harmony among the wide diversity of water usage for agricultural production, fishing, navigation, industrial production, domestic consumption, and ecosystem sustainability (UNECA 2010).

FREQUENCY and INTENSITY: Increasing frequency and intensity of severe weather is expected on the African continent to be greater over the next 50 years. The IPCC (2007) states it is likely that "future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with on-going sea surface temperature increases". The scientific, peer reviewed studies used to inform the assessment, as well as studies that have since been published, indicate that climate change will affect the intensity, frequency and paths of strong storm and wave events. They also indicate a global trend towards increased intensity of hurricanes over the past few decades – most notably in the North Atlantic and Indian oceans (IPCC 2007b).

Vulnerabilities

Africa is particularly vulnerable to climate change and associated climate variability as the situation is aggravated by the interactions of 'multiple stresses'. These 'multiple stresses' include: i) endemic poverty, complex governance and institutional dimensions; ii) limited access to capital, including markets, infrastructure and technology; iii) ecosystem degradation; and iv0 complex disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity, leaving the continent vulnerable to deal with impending changes (IPCC 2007a).

Food security in many parts of Africa is likely to be severely compromised. Agricultural production, including access to food, in many African countries is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly in marginal semi-arid and arid areas, are expected to decrease. This would further affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020 (IPCC 2007), and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected (Venton 2007a).

Climate change will aggravate water stress currently faced by some countries, while some countries that currently do not experience water stress will become at risk of water stress. Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa. Even without climate change, several countries in Africa, particularly in northern Africa, will exceed the limits of their economically usable land-based water resources before 2025. About 20% of Africa's population (about 200 million people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 75-250 million and 350-600 million people by the 2020s and 2050s, respectively (IPCC 2007a).

Changes in a variety of ecosystems are already being detected, particularly in southern African ecosystems, at a faster rate than anticipated. Climate change impacts on Africa's ecosystems include according to one study, between 25 and 40% of mammal species in national parks in sub-Saharan Africa becoming endangered (IPCC 2007a). Local food supplies are projected to be negatively affected by decreasing fisheries resources in large lakes due to rising water temperatures, and also likely to be exacerbated by continued overfishing (IPCC 2007a).

Human health, already compromised, will be further negatively impacted by climate change and climate variability. It is likely that climate change will alter the ecology of some disease vectors in Africa, and consequently the spatial and temporal transmission of such diseases. Most assessments of health have concentrated on malaria but the need exists to examine the vulnerabilities and impacts of future climate change on other infectious diseases such as dengue fever, meningitis and cholera, among others (IPCC 2007a).

Climate change is a real challenge when dealing with **natural disasters**. Climate is often thought of as only the long-term averages of weather elements. However impacts on a local scale are likely to depend more upon changes in the frequency of extreme events than on changes in the average conditions. The increased frequency and/or severity of extreme events will increase human vulnerability to natural disasters such as droughts, floods, mean sea level rise and storm surges and cyclones. Semi-arid areas and coastal and deltaic regions are particularly vulnerable. Towards the end of the 21st century, projected sea level rise will affect low-lying coastal areas with large populations. The cost of adaptation in Africa could amount to at least 5-10% of GDP (IPCC 2007a).

Sea level rise and sea storm surges facing Namibia, Walvis Bay

Coastal settlements are often developed on low-lying coastal fringes, often only a few meters above mean sea level. This places the town at great risk, as a slight rise in mean sea level is likely to: i) inundate land surface and erode infrastructure; and iii) result in salt-water intrusion into underground fresh water systems. An increase in 5 cm in sea level may translate into the effect of an increase of one meter during tidal surges (MET 2009). Impacts associated with sea level rise are likely to negatively affect environmental, social and economic aspects and disrupt functionality of the services offered to the inhabitants in the jurisdiction of the coastal municipalities. Coastal regions are thus regarded as being the areas most vulnerable to climate change impacts, as a result of their geographical location, to heavy developmental pressure and population growth, of which the latter two are increasingly occurring in coastal areas. In addition, coastal areas accommodate large populations of poor communities, which are directly dependant on the ecosystem services that coastal areas provide (Fairhurst 2009).

Sea level rise thus far, has manifested not in a gradual manner but in discrete, dramatic events associated with sea storm surges, and it is the increasing intensity and frequency of these events that the coastlines are most vulnerable to (Cartwright 2009). The three main causes of global sea level rise (changes in ocean volume) are: thermal expansion of the oceans, melting of glacier and ice caps and increased land ice discharge (IPCC 2007). At the local level, the three main factors that contribute to sea level rise are: tides, weather effects (such as offshore winds are storms) and wave set up (Brundrit 2009). Tides are uniformly predictable on a daily, fortnightly, and seasonal basis and also from a year to year basis. However, surface weather patterns are not predictable. This, combined with local wave set up have a substantial role in determining the impact of these extreme events. To elaborate, storm patterns cause differences in sea level elevation with changes in pressure along the coastal areas, and are often associated with winds creating water pile-ups against the coast. Wave set up occurs in the area of the surf zone, the area along the coast where the waves break. Wave set up is created when an increase in the mean water level is caused by a wave break which then creates an increased energetic turbulent layer of water that washes up on the beach (called swash). This action intensifies erosion of the dune face and other soft materials (Brundrit 2009). Wave set up will then intensify with increased offshore winds, which will result in increased coastal erosion.

Sea level rise is projected to threaten, erode and damage low-lying coastal infrastructure and settlements along the coasts of Africa. With one quarter of Africa's population living within 100km of the coast, projections suggest that the number of people at risk from coastal flooding will increase from 1 million in 1990 to over 70 million by 2080 (DFID 2004). Satellite recordings from 1993-2003 indicate a rise in global sea level of 3.1 +/- 0.7 mm per year (Cazenave and Nerem 2004) while Rahmstorf *et al.* (2007) indicated a slightly higher rise of 3.3 +/-0.4 mm per year from 1993-2006. According to the IPCC Fourth Assessment Report (2007) the global sea level is projected to rise in the range of 0.18 - 0.59 m by 2100, depending on the emissions scenario (Figure 2).

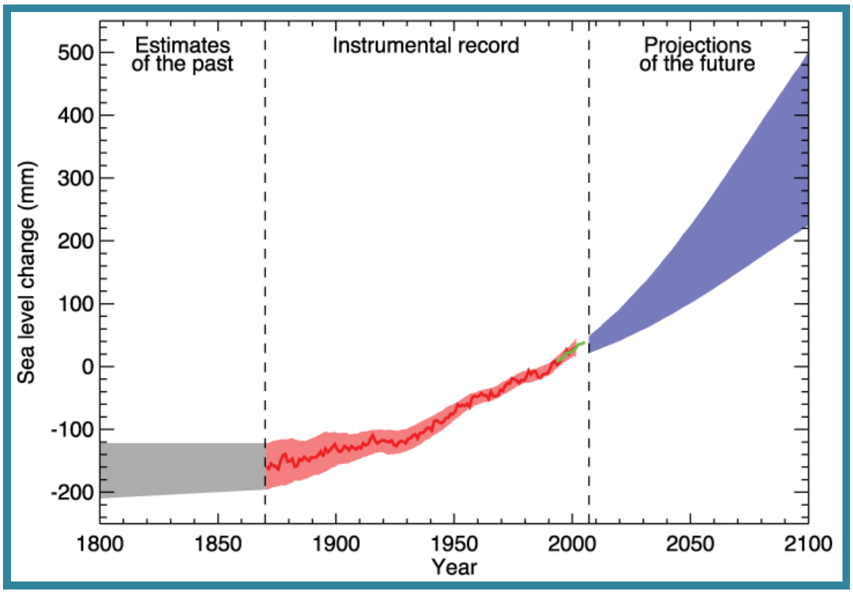

Figure 2. *Past and projected global average sea level change from 1800 to 2100*[3]*.*

[3] *IPCC (2007).*

The observed and projected rates of mean sea level rise may not be significant at present; but low-lying coastal towns are potentially under threat and require immediate adaptation planning.

Case Study: The city of Durban, South Africa, is just one location along the southern African coastline that has experienced significant impacts to the coast affecting the infrastructure, services and communities who inhabit such areas. The west coast of South Africa experienced a sea level rise of around 1.2mm per year between 1962 and 1987 (Brundrit 1995) but Durban on the east experienced a double that (2.7mm per year) between 1970 and 2003. A combination of determining factors (extreme cut off low pressure system, a sea storm and an extreme high tide) occurred during March 2007, when a storm coincided with a wave run-up. This led to devastating erosion damage along the KwaZulu-Natal coast, South Africa, with a 9m above mean spring tide recorded. Direct infrastructure damages from this storm alone were estimated to be over R400 million (Theron and Rossouw 2009) and erosion damage severely undercut beach front infrastructure making it more vulnerable to future storms (Smith et al 2007) (See Figures 3a - b). It is projected that as a result of sea level rise, the tidal levels reached during this storm along the east coast of South Africa, will effectively be reached during ordinary spring tides by 2100 (Theron and Rossouw 2009).

Figure 3. a)[4], and b)[3] Infrastructural damage along the Kwazulu Natal Coast, South Africa, 2007.

[4] © B Abrahamse (http://www.panoramio.com/photo/2346158).

As earlier stated from the IPCC (2007a), sea level rise could increase flooding, particularly on the coasts of eastern Africa, which will have implications for health, however, rise in sea level will not only impact upon health but also cause salt-water inundation, erosion and infrastructure damage which will enhance the already high socio-economic and physical vulnerability of coastal cities. Death and injury caused by extreme events will be coupled by numerous secondary cascading impacts. During and after such events the following is likely to occur: i) transport infrastructure damage or destruction; ii) energy black-outs; and iii) reduced access to food, water and sanitation which will severely impact lives. In addition, each climatic disaster that a municipality has to respond to will compromise its ability to cope with future impacts. The cost of adaptation to sea level rise could amount to at least 5-10% of gross domestic product (IPCC 2007) but this is minimal in the face of continual reconstruction and disaster management.

3. Legislation and international obligations

National context - Namibia's environmental sustainability strategies

The Constitution of Namibia highlights the need to develop and implement policies to maintain ecosystems, ecological processes and biological diversity for the benefit of present and future populations. The Constitution also states that through its various government agencies and departments it will continue to develop and adopt preventative and adaptive activities to address environmental and climate change challenges and problems (MET 2003).

Namibia presented its **Green Plan** to the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 and ratified the **Kyoto Protocol** in 1993. As a direct result of UNCED the United Nations Framework Convention on Climate Change (UNFCCC) was established; Namibia acceded to the UNFCCC in 1995 and this placed a number of legal obligations on the country. In respect of this, Namibia prepared and presented its **Initial National Communication** (INC) on the status of climate change as well as corrective actions to reduce the projected effects of climate change on Namibia in particular and globally. It included a country study and the first **Greenhouse Gases Inventory** for Namibia (1988) which was completed in 2002.

Relevant environmental policies and activities were incorporated into **Vision 2030** and **National Development Plans** (NDP) in 2004 and 2007 respectively. The goal of Vision 2030 is to transform Namibia from a developing lower-middle income country to a developed high-income country, with many long-term sustainability targets also aligned with the **Millennium Development Goals** in Namibia (LAB 2008). Vision 2030 uses the NDP as the route to achieving long term productive utilisation of the natural resources and environmental conservation of agriculture, forestry, fisheries, water, land, mining, energy, wildlife and tourism.

Namibia participated in, and contributed to, the annual **Conference of the Parties** (COP) of the UNFCCC as well as the meetings of the Subsidiary Bodies of the Convention. Namibia is one of the

G77+China nations and has developed a common negotiating position within the UNFCCC. The positions most pertinent to Namibia are technological transfer and financial resources for adaptation in vulnerable countries.

The Ministry of Environment and Tourism (MET) has been designated the lead ministry in the co-ordination of climate change activities. The **Namibia Climate Change Committee** (NCCC) was formed in 2001 as a multi-stakeholder committee to advise government on the policies and strategies it will need to adopt in preparing the country for the projected changes. The committee consists of representatives from government, NGOs and parastatals (Namibian Water Corporation Ltd and NamPower), private sector and tertiary academic institutions.

The MET, in partnership, with the United Nations Development Program (UNDP) are in the development phases of establishing a **National Climate Change Policy** (NCCP) for Namibia. The main purpose of the NCCP is to provide the legal framework and overarching national strategy for development, implementation, monitoring and evaluation of climate change mitigation and adaptation activities (UNHABITAT 2010). Namibia also sees the benefits of building links between the UNFCCC and other conventions to which it is party such as the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (CCD). These international agreements and policies all have a strong emphasis on sustainability, and sustainability leading to resilience, and thus fulfilment of goals from one convention will meet those of the others simultaneously.

Local context - Walvis Bay's environmental sustainability strategies

Since Walvis Bay's reintegration into Namibia in 1994[5] (Walvis Bay and Off-Shore Islands Act 1), the city has actively worked towards sustainable management and integration of environmental issues into decision making processes.

2001 - **Environmental Management Fund**: A grant programme that was established by the Walvis Bay Municipality (WBM) to finance activities and initiatives that facilitate sustainable management of the environment and natural resources (DLIST-BENGUELA 2010).

2001 - **Walvis Bay Local Action 21 Project (WB LA21):** Formal environmental management by the WBM started with the implementation of the Walvis Bay Local Agenda 21 Project to achieve a workable balance between protecting the environment and promoting economic and social development.

2004 - **Coastal Area Action Plan**: A management plan that consists of a set of mitigating, monitoring and institutional measures to be taken to eliminate adverse environmental impacts. The

[5] The town of Walvis Bay and the surrounding area constituted an exclave of South Africa until passing to Namibia in 1994.

action plan addresses challenges that require management to protect and restore the Walvis Bay coastal environment, including the lagoon, Pelican Point and the bay and harbour zones.

2004 - **Sea Shore By-law**: This regulates the control of use of the seashore, the sea and its environment within or adjoining the area of jurisdiction of the MWB, including the Swakop River Estuary zone.

2005 - **Walvis Bay Nature Reserve (WMNR) Management and Operational Plans:** The plans are part of the WB LA21 Project and Management requirements of the Walvis Bay Lagoon and the Kuiseb Delta zones are fully described.

2005 - **Environmental Data Sharing Policy**: This regulates the sharing of environmental data that is in the possession of the MWB with external parties.

2007 - **Walvis Bay Local Action for Biodiversity (LAB) Project**: LAB was launched by ICLEI and aims to profile and promote the importance of urban biodiversity through coordinating the sharing of experiences, successes and challenges from a diverse group of participant cities from around the world.

2008 - **The Walvis Bay Integrated Environmental Policy:** The Policy covers all the areas under the jurisdiction of the WBM and indicates clear directions for the WBM to fulfil its environmental management responsibilities (this includes the Swakop River Estuary biodiversity zone).

2008 - **Coastline Strategic Environmental Assessment (SEA):** This was commissioned by WBM for the coastline between Walvis Bay and Swakopmund to provide a balanced protection of the coastline environment. Currently the SEA report guides the Municipal Council in decision making, integrates environmental issues into urban planning and development; and promotes sustainable development and awareness.

2009 - **Climate Change Adaptation**: Walvis Bay Local Biodiversity Strategy and Action Plan is a milestone of strategic planning on the way to 2030.

1998 to current - **Dune Belt Management Plan and Regulations:** Dune Belt Management Plan and Regulations were developed specifically to promote sustainable utilisation, protection and proper management of the Dune Belt Area ecosystem. This was initiated in 1998 but failed as a result of obstruction by one stakeholder. Numerous attempts have followed but issues of land ownership and jurisdiction hampered progress to achieving holistic management of the dune belt.

The Internal Environmental Impact Assessment Guidelines: These internal guidelines were developed in accordance with Namibia’s Environmental Assessment Policy and the Environmental Management Act to guide the EIA process within the WBM.

Habitat Restoration Guidelines for the Dune Belt Area: The document contains various suggested interventions to repair damaged ecosystems. These interventions include: i) removing infrastructure; ii) cleaning up pollution; and iii) other processes of reinstating the habitats, environmental conditions, plants and animals that had been in existence before the disturbance. The guidelines are useful for the continuous restoration of environments disturbed by unsustainable human activities; however, only apply to the Dune Belt Area.

2011 - Currently under development - **Integrated Coastal Zone Management Plan (ICZMP)**: The plan will be used to integrate environmental considerations into the planning and decision making process along the coastal zone of Walvis Bay.

Uilika Nambahu, the Mayor of Walvis Bay from 2008 - 2010, pledged that the Municipal Council of Walvis Bay committed itself to achieving its sustainable development goals by continuous networking and learning from other local authorities and institutions worldwide, and in doing so developing strong capacity within Namibia (LAB 2008).

4. Namibia and its vulnerabilities

Namibia, situated on the south western coast of Africa, is large and sparsely populated. The Namibian coast is classified as desert. As a consequence it is largely underdeveloped with only three main coastal towns; Swakopmund, Walvis Bay and Luderitz. It is unlikely that new towns will develop either, as the entire coastline from the Orange River in the south to the Kunene River in the north is now formally protected as a mega-park (NACOMA 2011). Areas within the mega-park are zoned for various levels of economic and development activities but cover the entire 1,570 km of coast with an area of 10,754 million ha.

Namibia's climate is generally hot and dry and characterised by high climatic variability, evident from persistent droughts, unpredictable rainfall patterns, variability in temperatures and scarcity of water (Mfune 2005). Rainfall ranges from an average of 25 mm in the southwest to 700 mm in the northeast with a mean annual rainfall of less than 250 mm per year (Mendelsohn *et al.* 2002). Namibia experiences high solar radiation, low humidity and high temperatures. This equates to an overall loss of moisture because: 83% of the total precipitation evaporates, 14% is used by vegetation, 2% becomes runoff which may be harnessed in surface storage facilities and only 1% recharges ground water stores. Precipitation from sea fog along the cooler coastal regions exceeds that of rainfall, with as many as 146 fog days per year. On average, maximum temperatures across the country vary between 30^0C and 40^0C while minimum temperatures vary between 2^0C and 10^0C. Namibia's mean annual temperature is moderated by the cold Benguela Current and averages between 16°C to 22°C respectively from the south to the north of the country (Mendelsohn *et al.* 2002).

Projections

Climate change projections for Namibia indicate a hotter climate and more variable rainfall and an expected increased evaporation of 30% by 2020. According to the Namibia's Meteorological Services recent historical trends of climate in Namibia reveals a consistent increase in daily maximum temperatures for over 25 years (Dirkx *et al.* 2008). The effect of a changing climate is already visible along the coasts of Namibia where aggressive erosion due to sea level rise and sea storm surges can be seen.

According to the Green Paper on Coastal Policy (MET 2009) there are no local statistics available to indicate a real increase in mean sea level, but it is evident from the damage to roads and campsites along the coastline that the sea level has been gradually increasing over a number of years. Impacts associated with erosion are likely to have consequences on the local environment and economy; these will be discussed in more detail in the sectoral risk assessment (Section 5 below), where evidence of coastal erosion pertaining to sea level rise is illustrated at four locations along the Namibian coast.

Projected increases in sea surface temperatures may shift wind and pressure regimes, as well as upwelling processes and thus alter the primary production of the Atlantic Ocean (Mfune 2005).

Vulnerabilities

The Ministry of Environment and Tourism rates climate change as one of the most serious threats to Namibia's environment, human health and well-being as well as its economic development. The arid environment, recurrent drought and desertification have contributed to make Namibia one of the most vulnerable countries in Africa to the effects of climate change. Considering the natural resource based economy and limited technical and financial resources, climate change could potentially become one of the most significant and costly challenges to affect the national development process in Namibia (MET 2003).

The nation's economy is highly dependent on its natural resources including mineral deposits particularly diamonds, wildlife, fisheries and woodlands, a large area of rangeland and a small area of arable land. However food security, health and other development goals may become undermined and unachievable unless resilience against climatic change is built into development plans. The projected rise in sea level as a result of global warming is likely to submerge Namibia's ten islands and parts of Walvis Bay and also affect the entire marine and fishing industry and the coastal economy (Mfune 2005).

Projected changes in the primary production of the Atlantic Ocean will affect fisheries in Namibia (Tarr 1999). The fishing industry is central to the city's economy and has been for more than 50 years. Locally, the industry creates approximately 8,000 jobs (nearly 15% of all jobs in Walvis Bay) and generates 10% of the country's GDP. However, there is strong evidence that observed changes in marine biological systems are associated with rising water temperatures, and the related changes in salinity, oxygen levels and circulation. These changes are forcing shifts in ranges and also further changes in algal, plankton and fish abundance in high-latitude oceans (IPCC 2007). This is likely to negatively impact the health of the fisheries sector.

Other climate sensitive sectors include agriculture, water, energy, biodiversity and ecosystems, health and tourism (Mfune 2005). As Namibia becomes hotter and drier there is likely to be a shift in dominant woody vegetation. This will result in a reduction in livestock production in some areas and bush encroachment in others; which coupled with drought will lead to reduced grain/crop production and yields. Vector-borne diseases such as malaria may become more prominent in areas predicted to have higher rainfall. Respiratory and gastro-intestinal infections may also increase due to poor nutrition and shortage of clean water if conditions become drier and hotter.

4. 1. Walvis Bay and its vulnerabilities

Walvis Bay is the largest coastal town (UN Habitat 2010) and is the only deep-sea harbour in Namibia (Hughes, Brundrit and Searson 1992). The town is located between 1 and 3 m above sea level, in a small semi-sheltered bay surrounded by a soft-sand erodible coastline. The only protection from sea level rise is a 10km long sand spit called Pelican Point.

The city currently has a population of approximately 60,000 in a jurisdictional area of 24,524,778 m^2. Walvis Bay is well developed, with significant infrastructure and industrial investment and is economically highly dependent upon shipping, fishing and large salt production companies. The port (Figure 4) acts as a national and regional economic import/export access point for surrounding landlocked countries such as Botswana, Zambia and Zimbabwe. The import of liquid fossil fuel in particular is of vital importance to the city's economy.

To the south of the city lies the 12,600 ha Walvis Bay wetland and adjoining delta of the ephemeral Kuiseb River. The wetland was proclaimed a RAMSAR site in 1995 and this binds Namibia to ensuring its long term sustainability, even in the face of climate change. It is one of southern Africa's richest coastal wetlands, supporting up to 250,000 birds, many of which are migrants, in the peak summer season (UNEP 2008). These wetland ecosystems are important for both climate change adaptation and mitigation (RAMSAR 2009).

Figure 4. Walvis Bay is the largest port in south-western Africa[6].

Observed climate trends

Developments along the shoreline have already started to suffer as a result of the effects of coastal erosion, following higher tides and more frequent swells (NACOMA 2008). The sea surface temperature of the Benguela Current Ecosystem has risen by about 1^{0}C between 1920 and 1990 (Clark 2006) and sea level measurements of southern African coasts show an increase of 1.2 mm per year over the last three decades (Shannon *et al.* 2006).

Projected sea level changes

A recent national sea level rise assessment (UNFCCC-NAM 2009) for the coast of Namibia has drawn attention to the city's vulnerability to climate change (Figure 5) and was based on the following scenarios for the future:

1) The Present Day Worst Case Scenario results from the simultaneous occurrence of an extreme tide and an extreme storm, an event with a nominal return period of 100 years. The maximum levels that should be expected to be reached by the sea along the coast of Namibia are:

Mean sea level +1.5 m in sheltered environments
Mean sea level +4 m in exposed environments, and
Mean sea level +6 m in very exposed environments.

2) For 2030, when the sea level is expected to have risen by to 20 cm the projections are the same:

[6] Mentor Shipping Agency (Pty) Ltd (http://www.mentorshipping.co.za/).

Mean sea level +1.5 m in sheltered environments
Mean sea level +4 m in exposed environments, and
Mean sea level +6 m in very exposed environments

However the frequency that these levels will be reached differs from the first scenario. The frequency with which the sea levels for exposed and very exposed environments are reached will depend on the frequency of severe storms. It is possible that, with climate change, severe storms will become more frequent, and so the critical levels may well be reached more often in the future. In addition, the critical sea level of mean sea level +1.5 m in sheltered coastal environments will definitely be reached more frequently. By 2030, these levels are likely to be reached every year.

Under this scenario, if the protective Pelican Point Sandspit remains in place, the town and harbour of Walvis Bay will remain a sheltered environment. However if the Pelican Point Sandspit is breached, then Walvis Bay will be exposed to the full impact of storms from the sea. This in combination with a projected sea level rise of 20 cm will lead to enhanced coastal erosion and a likely coastal set-back estimated at almost 100 m.

3) Looking towards 2100, it is likely that a sea level rise of several metres will be evident along the coast of Namibia. The prime effect of the rapid sea level rise over the longer term future is the permanent inundation of low-lying coastal areas, rather than the intermittent effect of storm damage, leading to complete disruption of infrastructure and services along the coast. As there will be warning of such a large sea level rise and time to adapt, it is important to plan ahead, explore the possible adaptation options and to put appropriate policies and strategies in place to enable and support the required action. The implications for the onshore and offshore diamond industry, for coastal tourism, and for urban settlements such as Walvis Bay in particular should be the priority in national adaptation planning.

Vulnerabilities

Rising sea level could cause a permanent breach in the Pelican Point sand bank, exposing Walvis Bay and the harbour to higher waves and sea storm surges. This will not only make the city port vulnerable to wave action but also impact on fresh water supply as the city relies on coastal aquifers for fresh water supply, which are susceptible to saline intrusions (Hughes, Brundrit and Searson 1992). Increasing temperatures could also lead to reduced flow rates, another major constraint to urban water supply and quality in the future. Rising sea levels, coupled with increasing frequency of storm surges, may lead to deaths and injuries associated with such events and a suite of impacts in the aftermath of such an event. Impacts could be immediately felt on health and transport infrastructure.

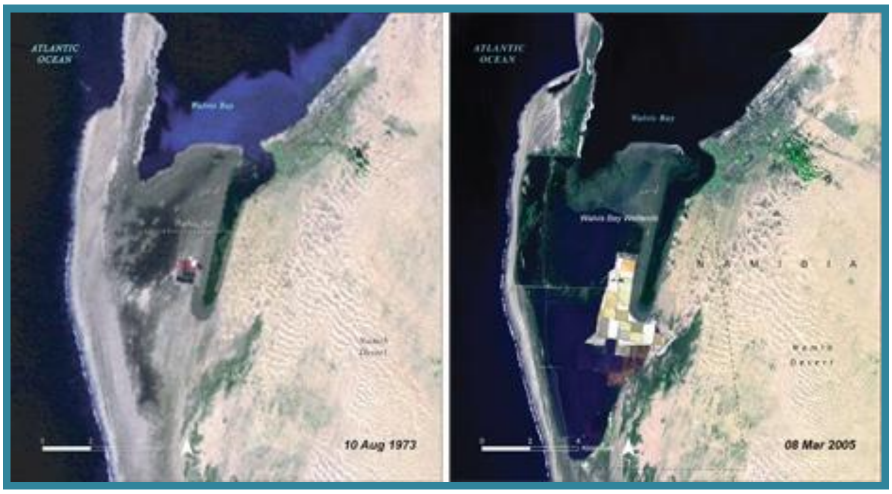

Figure 4. Images of Walvis Bay in 1973 and 2005 illustrating changes in the coastal physique associated with sea level rise and climate change[7].

4.2. The Topnaar community

This project will be engaging with the Topnaar Community. They live along the lower parts of the Kuiseb River, just south of Walvis Bay and are a community who represent the urban/rural interface and who are especially vulnerable to the negative impacts of climate change. The Topnaar or #Aonin are the original inhabitants of the area, one of 13 groups of Nama people, and the earliest written record of them in the Walvis Bay area was in 1838 by Sir James Alexander (Dentlinger 1977). They lead a predominantly subsistence existence and thus their livelihoods are extremely dependent upon their immediate environment as they herd sheep and goats, gather veld food[8] and obtain water from the Kuiseb River. In the past hunting also was an important part of their lives but the formation of the Namib-Naukluft park in the 1960's had reduced the significance and played a role in the marginalisation of the #Aonin.

The Topnaar economy is highly dependent on one plant species in particular, the !nara melon *Acanthosicyos horridus* (Figure 5 a-c) that grows in the Kuiseb riverbed and it is this plant that has allowed them to survive in marginal farming land. The !nara is a desert-adapted plant which can live up to a hundred years. The fruit consists of an outer hard husk, a fleshy layer and then seeds. The seeds are highly nutritious, containing 57% oil and 31% protein (Van Damme and Van Den Eynden 2000) and form an essential part of Topnaar diet (Berry 1991). The peels of the !nara fruit are fed to donkeys and goats, and the seeds to poultry. The fruit is also used for medicinal properties; fresh

[7] Atlas of our changing environment, UNEP (http://na.unep.net/atlas/webatlas.php?id=274).
[8] Veld food is edible wild plants of southern Africa botanically identified and described. Veld is a colloquial term for natural vegetation in Southern Africa.

fruit used for stomach ailments and oil from the seeds used to treat sunburn (Van Damme and Van Den Eynden 2000). A major source of income for the Topnaar is harvesting seeds as a cash crop – sold for use both in Namibia and South Africa. The plant is, however, locally threatened around the towns of Walvis Bay and Swakopmund (Victor 2002). Declines reported are mainly the result of decreased groundwater levels brought about by extraction of water in the towns of Walvis Bay and Swakopmund (Breuninger 1977). Less available water affects production of fruits, and limits the ability of male plants to produce flowers, thus limiting reproductive capabilities (Eppley and Wenk 2001). In addition, with the projected sea level rise, intrusion of salt water is likely to have an impact on the !nara and other plant life found along the river.

Recent changes both in socio-economic conditions of the #Aonin and declines in the !nara fruit production prompted the initiation of the NARA programme (Natural Resource management by the #Aonin), jointly coordinated by the Topnaar Community Foundation and the Desert Research Foundation of Namibia (Henschel 2004).

Figure 5. a)[9], b)[10] and c)[11] !Nara plant being harvested by the Topnaar in Walvis Bay dunes.

5. Sectoral risks and impacts of sea level rise

Sea level rise presents risks to a multitude of local government sectors and departmental functions, namely water and sanitation, health, energy, sustainable livelihoods and transport, as well as biodiversity, housing, coastal zones and spatial and town planning. For example, sea level rise may result in a number of biological changes such as a shift in species distribution, which may result in a knock on effect upon the livelihoods of local community members that may depend directly upon the availability of the species. Local authorities that are positioned in coastal areas therefore, need to analyse the associated and projected impacts and adapt and plan accordingly to strategically build resilience against such climatic variables such as sea level rise and sea storm surges. There is a need

[9] The Namibia Cardboard Box travel shop: http://www.namibian.org/travel/namibia/population/topnaar.htm.
[10] Namibia adventures: http://anneandandyinnamibia.wordpress.com/.
[11] Kalahari People Network: http://www.kalaharipeoples.net/article.php?i=187&c=6.

for adaptation strategies and increased preparedness to protect local communities, such as the Topnaars, that depend on basic municipal services and the immediate environment for their livelihoods and well-being.

A recent assessment on threats associated with climate change in Walvis Bay indicated the following vulnerabilities (UN Habitat 2010):

- Increased number of extreme weather events;
- Increasing mean sea level;
- Coastal erosion;
- Contaminated and decreased water resources;
- Loss of biodiversity, ecosystems, natural and marine resources;
- Damage to residential, key industrial and municipal infrastructure;
- Change in local temperature and precipitation; and
- Increased health problems due to heat stress.

The risks and impacts upon sectors such as water and sanitation, energy, transport and health ultimately and inherently affect livelihoods. Thus risks and impacts associated with sea level rise (both storm-driven intermittent and permanent inundation) will also embody impacts upon livelihoods.

5.1. Livelihoods

The term 'livelihoods' is defined as the way and the means of 'making a living' (Chambers and Conway, 1992; Bernstein *et al.* 1992; Carney 1998; Ellis 1998; Batterbury 2001; Francis 2002; and Radoki 2002); the capabilities, activities and assets (both material and social resources) required for a means of living (Carney, 1998) and 'refers to people and their dependence upon their surrounding resources for their well-being, such as water, shelter, land, agriculture, livestock, knowledge, money, social relationships and so on' (Chambers and Conway, 1992). These resources, either natural or derived from natural, however, cannot be disconnected from the challenges and problems of access and changing of structural systems such as political, economical, socio-cultural and especially environmental circumstances. This study investigates the likely impacts and risks upon services and the cascade of risks and impacts that may lead to livelihood alteration or deprivation.

Changes in the environment and environmental degradation associated with climate change are likely to impact on the resources that people depend on for their livelihoods and thus their survival. Urban dwellers rely more on service providers (for water and sanitation, energy and a means of transport to and from work places and markets) than directly from the natural environment. Peri-urban and rural communities also rely on some of these basic services in addition to natural resources such as grazing for livestock and soil and water for crop production. Many communities have to cope with risks and uncertainties but those living closer to the land are most affected by erratic rain, diminishing resources, grazing pressure, spreading of diseases, increase in food prices and inflation. If climate variability and extreme events occur more frequently and more intensely, these impacts are likely to disrupt day-to-day business activities and delivery of basic services, impacting people's ways of living and their ability to maintain a sustainable livelihood. These impacts and risks are likely to influence management and use of resources and the choices that people make.

The basic services provided by local governments are vulnerable to changes in climate. For the purpose of this study, the general vulnerabilities associated with sea level rise and sea storm surges upon the local government services are discussed with the aid of international case studies. The four sectors are:

- Water and sanitation;
- Transport;
- Health;
- Energy.

In Walvis Bay, the following livelihood issues have been specifically raised by various local stakeholders (UNFCCC-NAM 2009):

- A rise in mean sea level has caused sea water to intrude into underground aquifers, which affects access to fresh water;
- Flash floods have disrupted fresh water and energy supplies, causing an inability to freeze and/or store fish on ice that meets the export standards, thereby affecting fish exports. As a result, factories have to close for days in succession thus affecting the main source of income for a large proportion of Walvis Bay's human population; and
- Increased extreme heat conditions were noted to reduce productivity in the work place, causing dehydration, heat stress and food spoilage, all of which affect quality of life and economic productivity.

And for the Topnaar community in particular, the following key issues were raised (UNFCCC-NAM 2009):

- Roof damage by high-velocity winds;
- Changes in the !nara melon season due to changes in rainfall and precipitation;
- A decrease in !nara melon production due to increased salinity in aquifers causing salt crystallisation of the plant's extensive tap root;

- Flooding episodes, sand storm events and extreme temperatures delaying transportation and causing discomfort during travels to and from the Walvis Bay urban centre;
- An increased frequency in high air moisture from mist which dampens fire wood that is intended for energy supply and food preparations;
- Community members moved to higher ground as a result of flooding along the Kuiseb River during February 2008 and 2009. This has led to the community becoming increasingly dispersed;
- Flooding has affected access to water boreholes; and
- Sea water intrusion has reportedly resulted in tap water becoming more saline than borehole water taken from boreholes positioned along the river bed.

5.2. Water and sanitation

Background

The provision of fresh water supplies to the municipality and rural areas of Walvis Bay is a task undertaken by the Namibian Water Corporation Ltd (NamWater), a commercial entity solely owned by the government. The water is drawn from aquifers along the Kuiseb River and supplied to Walvis Bay, via five storage reservoirs (NamWater 2006, Figure 6).

The supply of water services in Walvis Bay has, in the past, faced a number of challenges. These include low mean annual rainfall, high evaporation rates, salt water intrusion in areas directly adjacent to the coast and fresh water flooding from extreme rainfall events further in land. In addition, an unprecedented increase in water demand by surrounding uranium mines has surpassed the potential of sustainable water extraction from the Kuiseb aquifers. This has necessitated the construction of a desalination plant north of Swakopmund to alleviate the pressure on freshwater resources (CSIR 2009).

Sanitation is provided by the Municipality under their Department of Water, Waste and Environmental Management. All erven receive sanitation services but the level of these services differs and some communities (primarily in Walvis Bay North) receive only communal sanitation. The level of migration to the city, while reduced from previous levels, keeps the population growth at a rate at which a housing and serviced erven backlog will continue for some time to come (SIAPAC 2002)

Impacts and vulnerabilities

With a projected rise in mean sea level and an increase in sea storm surges, several impacts to the water and sanitation sector are anticipated. As water is currently drawn from aquifers recharged by the Kuiseb River, the risk of permanent salt-water intrusion into the freshwater aquifers is high and in some places has already been experienced (see also case study 1 and 2). This may render some aquifers unusable, reducing the potential of the Municipality to store water. Alternate water sources will then need to sought, either prospecting further up the Kuiseb River away from the salt-water intrusion, or further investing in water infrastructure such as increasing the capacity of the desalination plant. Recycled 'grey water' could become salinised and thus unsuitable for use for watering gardens or being used for irrigation. Salt crystals that build up in aquifers and cause blockages to extraction pipes and rust in delivery pipes would increase the need for maintenance thus increasing the budget required by the WBM to manage water extraction. A reduction in the quantity of potable water due to a decrease in quality would lead to poor or limited water supply to residents and businesses. This would have several cascade effects on livelihoods as many businesses are water dependent.

A combination of sea storm surges, coastal intrusions and flooding from the Kuiseb River is likely to lead to changes in the ground water level making it difficult for the WBM to assess potential capacity and plan for future shortages. This also damages water infrastructure and abilities to extract water as described in case study 3. A benefit of increased likelihood of floods may increase the strength and sustainability of the aquifers but the anticipated variability means this may not be reliable.

There is a risk that sewerage effluent may become a surface health hazard if flooding becomes more prevalent as there is no storm water drainage (see case study 4). In addition, sanitation treatment facilities may have insufficient water to continue their operations where there are existing water shortages caused by reduced flow, elevated extraction or limited power to extract water from aquifers.

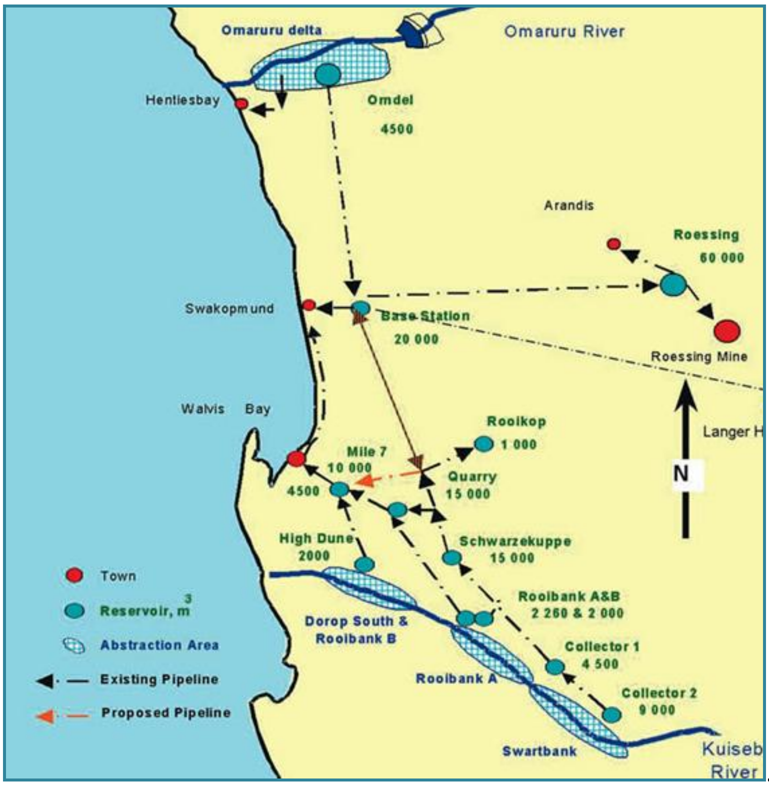

Figure 6. The Kuiseb River aquifers that supply Walvis Bay and Swakopmund with fresh water[12].

Table 1 identifies likely impacts on water and sanitation sector as a result of mean sea level rise and sea storm surges.

Table 1. A summary of likely impacts on the water and sanitation sector.

Impacts upon Water and Sanitation	Impact on livelihoods
• Salt water intrusion into freshwater systems in coastal zones is anticipated to increase. • Increased salinity levels of recycled ‘grey’ water. • Flooding causing strong water flows in aquifers thus increasing capacity for water • Decreased availability in freshwater for domestic and industrial use • Sedimentation of aquifers • Ground water level changes; the system is already reduced to extraction by Walvis Bay and Swakopmund. • Reducing quality of water in aquifers • Reduced ability to extract water if infrastructure is flooded • Water treatment capacity will decrease if insufficient fresh water is available • Poor and limited water supply for domestic and industrial use • Floods will damage private and municipal infrastructure	• Increased pressure and stress on fresh water supply. • Impacting water sanitation in the vulnerable areas • Cascade effect on health as a result of increased likelihood of contamination of fresh water sources. • Poor water access and poor water quality

[12] http://www.rossing-com.info/images/page_pics/central_namib_map_large.jpg

Case studies

1. A number of international urban coastal areas are experiencing similar impacts from mean sea level rise and sea storm surges causing impacts on fresh water supply. In the **United States of America**, New York, Philadelphia and much of California's Central Valley obtain some of their water from portions of the rivers that are slightly upstream from the coast, however, with rises in sea level, during drought period's, sea water is pushed upstream increasing the salinity of fresh water estuaries. The Florida Everglades are slowly being submerged by rising sea levels. The fresh water Everglades recharge Florida's Biscayne aquifer and is the primary water supply to the Florida Keys; as sea levels rise, the aquifers become saline which is reducing the availability of fresh water supply (USEPA 2010).

2. **The Gambia**, on the northwest coast of Africa, is vulnerable to mean sea level rise affecting their coastline, agriculture and fresh water aquifers. In the 1970's the borehole supplying Banjul, the capital city, was sealed off primarily as a result of salinisation (Jallow *et al.* 1997). Loss of land and a decline in agricultural production has resulted, due to sea level rise (Conteh 2008). Currently, fresh water is being pumped through pipes from a nearby town called Cape St. Mary's.

Figure 7. Workman laying down new pipes along Long Beach after storm damages water networks in February 2009.

3. **Walvis Bay** had a fresh water supply crisis in February 2009 when a storm crippled 75% of the NamWater borehole infrastructure (Fig. 8). The flash floods caused the strongest flow of water in the Kuiseb River within the decade. The flooding caused extensive damage to power lines, which stopped pumps, boreholes were submerged in sand from river sedimentation and pipelines linking the boreholes to the reservoirs were destroyed. Roads to boreholes were unreachable due to the extensive amount of water in the area. This necessitated the use of helicopters to carry experts and equipment to the boreholes in order to do the necessary emergency maintenance (Hartman 2009). In conjunction with the flood, the reservoirs that supply Walvis Bay with water were only at 30% capacity, and in order to return the municipal water supply to normal, at least 60% of the boreholes had to be fixed. Walvis Bay residents were left without fresh water supply and had to collect water from fire hydrants and water tanks supplied by the municipality at various locations, with thousands of cubic meters of water trucked from Swakopmund (Hartman 2009).

4. Another instance of the local climate affecting the water and sanitation provisioning by local government: heavy rainfall (January 2011) left the streets of **Walvis Bay** waterlogged, with residents and businesses in the industrial areas reporting their properties flooded. Only 6 mm of rain fell but it left large pools of water that slowed traffic flow at numerous locations. The sewage system was compromised as the normal sewage flows were compounded by the inflow of excess rain water. The Municipality of Walvis Bay had to request all producers of industrial effluent/water to limit the discharge of effluent into the municipal sewer system. Walvis Bay does not have a storm drainage network as the annual rainfall is only between 4 and 10 mm per year and such a system would be costly and underutilised under current climatic conditions (WBM 2011).

5.3. Transport

Background

Walvis Bay, as the major port of trade for Namibia, has a strong transport network link to both major local economic centres and neighbouring countries. This network consists of highways, district roads, railways and air links both local and international. The Ministry of Works and Transports (MWT) in Namibia supervises the implementation of infrastructure projects, ensures the alignment of road network development and maintenance with technical (civil engineering related) standards applicable to the Road Authority (MWT 2010). Walvis Bay municipality has partnered with Walvis Bay Corridor Group to facilitate and promote transport and trade along the corridor network to adjacent cities and countries leading from the Walvis Bay port.

Impacts and vulnerabilities

Mean sea level rise and sea storm surges impact on all transport routes along a coastline, causing delays in transport in the case of a damaged or flooded road and causing long term erosion to roads, railway lines and bridges in the vicinity of the sea. Coastal networks may need complete replacement or upgrades (new bridges, culverts). The expected increase in the frequency of extreme events will further increase damage to infrastructure, loss of life, and financial burdens to governments. However, transport equipment also poses threats to climate change. New types of fuel (second generation bio-fuels[13], hydrogen, electricity, solar energy) will be needed to replace petroleum/oil. In addition, the effect of transport infrastructure on the environment, especially land stability and water courses will have to be minimized. Sustainable transport will have to be fostered at the transport-policy level (UNECA 2010).

[13] First generation biofuels such as from sugar starch and vegetable oil (e.g. from corn, soybeans) are problematic sources of fuels as they compete for landuses and food security. However, second generation biofuels are more sustainable, and have less of a negative impact as they are produced from sustainable feedstock residues and algae.

In Walvis Bay the following have already been noted as potential transport issues in the view of a rising mean sea level and storm surges (UNFCCC-NAM 2009):

- Sea storm surges have already caused erosion to road infrastructure, damaging the road between Walvis Bay and Swakopmund, the only road connecting the two centres and an important transport route for commuters and goods being moved to and from the port. A small mean sea level rise has resulted in the coastal road becoming permanently inundated and leading to the development of a new road (~10 years ago) between the two coastal towns. This new road is positioned at a higher elevation to reduce the risk of future inundation and erosion in the short term;
- An increased frequency of strong wind events reducing visibility as a result of windblown desert sand and causing delays for all transport types (road, sea, rail and air) was noted; and
- Sparse erratic rainfall events leading to road closures as a result of stagnant water on roads, causing slippery salt roads and development of potholes.

It is anticipated that roads, particularly the salt roads, are vulnerable to climatic changes, particularly an increased frequency of flooding from storm surges. This will slow movements of goods and people, increase wear on alternate roads and require a greater budget allocation or maintenance. With time as sea-level rises, a new roadwork network further inland may need to be developed as inundation makes roads impassable. The rail system is likely to be impacted by flood damage to the tracks. The airport is unlikely to be affected as it is about 15 km from the coast but if business in and around Walvis Bay becomes less attractive to investors the airport is likely to see a decrease in business. The port, being so central to the Walvis Bay economy, is vulnerable to sea storm surges and rising sea levels. The port currently boasts zero business days lost to weather causing weather delays but this may change if storm frequency and intensity increases and if the Pelican Point spit is lost to erosion. Storms may lead to days-at-sea being reduced if conditions are too dangerous to leave port. This will impact both the fishing and cargo sectors of the harbour business. Vessels anchored may be damaged during sea storm surges and much of the current port area will be completely inundated so any construction plans for extensions to the harbour needs to take the impacts of climate change into account when planning and budgeting, most importantly at the feasibility level.

Table 2 identifies likely impacts on the transport services and infrastructure as a result of mean sea level rise and sea storm surges.

Table 2. Summary of impact on transport for both mean sea level rise and sea storm surge.

Type	Impacts upon Transport	Impact on livelihoods
Road	• Blockage of roads, in particular the seafront highway joining Swakopmund and Walvis Bay. • Flooding causing diversions. • Traffic congestions and accidents. • Inundation of roads by water or sand. • Erosion of bridges, pavements and roads adjacent to the coast.	• Limits access routes • Delays to the work place and markets • Work hours lost– reducing income • Risk to public safety
Rail	• Erosion of railway infrastructure. • Inundation of railways by water or sand. • Reduced use of rail as a sustainable public transport system.	• Causes delays and cancellations of trains • Unable to reach destination • Work hours lost– reducing income
Air	• Reduction in business transacted through Walvis Bay and the surrounding areas that the airport services.	• Reduces accessibility to airports • Delay in exports/imports
Port	• Erosion to coastal infrastructure and equipment. • Damage to boats at sea if storms are more intense as expected, with additions to the Skeleton Coast wrecks likely. • Erosion to harbour wall. • Damage to boats anchored at port, both private yachts and commercial vessels.	• Days at sea lost • Work hours lost – reducing income • Delay in exports/imports

Case studies

Port Elizabeth, Durban and Cape Town, **South Africa**, are a few urban coastal hubs that have already experienced damage to transport routes due to mean sea level rise and extreme events such as sea storm surges.

In August 2008, the southern coast of South Africa experienced one of the worst storms in seven years recorded by the South African Weather Service (SAWS). Sea storm surges and extreme weather warnings were issued in Cape Town regarding the cold front off the west coast on the 30 August 2008 (Figure 8). The National Sea Rescue Institute (NSRI) issued warnings for the coastline and advised all seafarers to be cautionary. This cold front created chaos along the southern coast with large storm surges crashing against the coastline of Cape Town at the end of August and making its way around the coast to Port Elizabeth where large waves damaged roads and railway lines a few days later. Below are images capturing the destruction of roads and railways along the southern (Figure 8 a,b) and east coast (Figure 9 a,b) of South Africa impacting upon transport infrastructure, disturbing and delaying the day-to-day activities these services provide.

Figure 8. a) and b) Waves against the Sea Point Wall in Cape Town during the storm[14].

Figure 9. a) and b) Sea storm surges reaching Port Elizabeth on the east coast of South Africa on the 3 September 2008[15].

Figures 10-13 demonstrate how sea level is currently affecting Namibia's soft shorelines and how infrastructure, transport routes and development are under threat and at risk. Coastal erosion is caused by wave action, tidal currents, wave currents, drainage of sea water which are further amplified by sea storm surges. Surges during rough seas are fast moving volumes of water that cause large losses of soft coastal material; sand and dunes. These softer materials are obviously more

[14] © capedailynews.com.
[15] Damage to railway line along the coast. Source: © Port Elizabeth Daily Photo. http://portelizabethdailyphoto.blogspot.com/2008/09/more-spring-tides.html.

erodible than rocky coasts and therefore are extremely vulnerable to sea level rise and sea storm surges.

From top left and clockwise:
Figure 10. *Coastal erosion at Mile 14*[16]*.*
Figure 11. Erosion of a*blution facilities of the campsite at Mile 14*[6]*.*
Figure 12. Coastal erosion in Swakopmund*[6]*.
Figure 13. In 10 years, at least 20 m of coast removed by the sea at Guns – Long Beach*[6]*.

5.4. Health

Background

The number of reported weather-related natural disasters has more than tripled since the 1960s, globally (WHO 2010). This can in part be attributed to better reporting and a better ability to respond to such disasters in remote areas but the trend is evident despite this. Every year, these disasters result in over 60,000 deaths, mainly in developing countries (WHO 2010). Rising sea levels and increasingly extreme weather events are likely to destroy homes, medical facilities and other essential services. As more than half of the world's population lives within 60 km of the sea it is

[16] NACOMA © *Nathalie Cadot.*

expected that theses climatic events will continue to claim lives. People may be forced to move, which in turn heightens the risk of a range of health effects, especially communicable diseases.

Impacts and vulnerabilities

An increase in mean sea level rise and extreme events such as sea storm surges affects populations living in coastal regions. Some communities are more vulnerable and prone to impacts and risks than others in these regions; however, sea level rise and sea storm surges are likely to impact on health directly and/or indirectly. Direct affects would be deaths from drowning, electrocution if live electricity wires become flooded, and accidents caused by flooded transport infrastructure or failing household infrastructure. Health is more likely to be impacted by indirect impacts. For example people who rely on water supply from estuaries and aquifers may become ill if the fresh water source becomes inundated and saline. Inundation of sea water may create areas of stagnant water in places, which could cause the spread of diseases in particular cholera (see case studies 1 and 2). Climatic conditions strongly affect water-borne diseases, diseases transmitted through insects, snails, lizards and other cold blooded animals. Any changes in climate are likely to lengthen the transmission seasons of important vector-borne diseases and alter their geographic range (WHO 2010). Although Walvis Bay currently falls outside malarial risk areas, increased flooding may result an incidences of malaria, along with other vector spread diseases such as dengue fever.

Rise in mean sea level and sea storm surges are likely to impact upon coastal infrastructure, transport networks and even medical facilities in close proximity to the shoreline, which is likely to cause indirect impacts on health and the accessibility to health care.

The following concerns have been already been noted in Walvis Bay (UNFCCC-NAM 2009):

- Sea water intrusion into underground aquifers impacting upon the quantity, quality and availability of fresh water leading to health and hygiene issues;
- Strong winds associated with an increased frequency of sand storm events is thought to be increasing incidents of primary and secondary health problems within the Walvis Bay Municipality human population. Primary impacts such as an increasing number of reported car accidents (due to reduced visibility from windblown desert sand) and asthma were among the few points that were raised. Secondary impacts such as eye infections, allergies and human discomfort were also discussed;
- Increased differences between nocturnal and diurnal temperatures have reportedly increased influenza casualties and
- Increased temperatures have resulted in heat exhaustion, dehydration and an increase in flies and insects.

Evidence and anticipation of adverse health effects should strengthen the case for pre-emptive policies, and will guide priorities for planned adaptive strategies (McMichael *et al.* 2006). Most at risk are the young, infirm, immune-compromised and low-income individuals. The IPCC (2007) warns that the health status of millions of people will be affected by climate change, particularly those with low adaptive capacity. In Walvis Bay, the Topnaar community and the Kuisebmond and Narraville townships will need special attention in this regard as they already have a low adaptive capacity. Kuisebmond was designated as a 'black' township and Narraville as a 'coloured' township under the apartheid government. Since Independence in 1992, large-scale urbanisation has occurred as people are attracted to Walvis Bay and Swakopmund to seek employment in the fishing, mining, and construction and transport sectors. Walvis Bay has a housing shortage, and the majority of migrants who come to Walvis Bay settle in informal housing - backyard shacks in Kuisebmond, which now have the highest housing density in Walvis Bay, with some plots having up to ten informal residences on them. These crowded living conditions are conducive to the spread of tuberculosis, HIV/AIDS and a variety of social ills, including alcohol abuse (Hoadley 2008). In 2006 the HIV prevalence rate in Walvis Bay was 22.1%, higher than the national rate (19.9%) and that of neighbouring Swakopmund (17.3%) (GRN 2007). For these communities the loss of a breadwinner in a family to casualty or death has massive repercussions for family, community and individuals' health and livelihoods.

Table 3 identifies likely impacts on the health sector as a result of mean sea level rise and sea storm surges.

Table 3. Summary of impacts on health due to mean sea level rise and sea storm surge.

Impacts upon Health	Impact on livelihoods
• Large waves, storms and flooding cause injury or death from drowning, electrocution, carbon monoxide poisoning and communicable diseases that often arise in the cleanup stage after such events when clean water and sanitation delivery is still affected. • Increased deaths from heat waves. • Increased pressure on emergency services in extreme events, with service delivery backlogs in clinics and hospitals. • Chemical Hazards: contamination of flood water with oil, diesel, pesticides, fertilisers etc. • Spread of infectious diseases within communities as sanitation provision deteriorates and water contamination occurs: skin (cutaneous leishmaniasis) and respiratory diseases and diarrhoeal disease (cholera), of particular risk to the young and infirm. • The altered spatial distribution of some infectious disease vectors may come into play as climate change is expected to have some mixed effects, such as a decrease or increase in the range and transmission potential of malaria in Africa (IPCC 2007a). • Increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone related to climate change (IPCC 2007).	• Increased causalities with associated social and economic costs • Hours of work lost thus business productivity decreases • Medical bills to pay, particularly by vulnerable communities for whom this may be an expense they can't meet • Poor and limited water supply to residents leading to compromised immune systems, disease and morbidity

• Increases in malnutrition and consequent disorders, with implications for child growth and development (IPCC 2007a). • Harmful Algal Blooms (HAB) outbreaks may increase posing a threat to those who collect mussels and other seafood along the coast. These pose a threat to both human and marine life (Tibbets 2007).	

Case studies

1. A review of cholera seasonality globally from 1974 to 2005 suggests that climate change may well lead to less predictable patterns of cholera outbreaks. In **Benin**, West Africa, detailed analyses of diarrhoeal disease patterns have established expected relationships between risks of diarrhoea and lack of good-quality water supplies. Thus the consequences of future climate change scenarios, leading to large-scale population displacements, may be predicated on resource considerations, such as water supply, at migratory destinations (Byass 2009).

2. In the Umkhanyakude District Council, north-eastern KwaZulu-Natal, **South Africa**, the interrelationships between human vulnerability, health, and environmental change have been shown. The district is situated in a remote rural area. It has a high poverty rate, limited access to services, a vulnerable population, and lies in a subtropical zone in close proximity to Mozambique and Swaziland. Large numbers of orphans and households are reported to be cared for by young children because of the high incidence of HIV and AIDS in the area. The district has an unemployment rate of 54% and more than half of the households lack potable water and sanitation, which contributes to frequent cholera outbreaks. These overlapping factors have contributed to a range of environmental factors that affect human vulnerability in Umkhanyakude. If predictions of increasing levels of rainfall in the eastern parts of South Africa become a reality, then vulnerability to malaria could increase in districts such as this, despite efforts to mitigate its spread through pesticide control. The rapid increase in tuberculosis (TB) has compounded these problems in north-eastern KwaZulu-Natal, increasing human vulnerability in Umkhanyakude (DEA-RSA 2007).

5.5. Energy

Background

The mission statement of the Ministry of Mines and Energy (MME) is 'to ensure the adequate and affordable energy supply in a sustainable manner taking advantage of our natural resources in support of the nation's socio-economic development.' NamPower, the national power utility company, was founded in 1964 as the 'South West Africa Water and Electricity Corporation' (SWAWEK) by the government of South Africa. NamPower currently generates its power from three main sources; the thermal coal-fired Van Eck Power Station outside Windhoek (120 MW); the hydroelectric plant at Ruacana Falls in the Kunene Region (240 MW), and the standby diesel-driven Paratus Power Station at Walvis Bay (20 MW). Namibia does import most of its electricity from South Africa and other countries in the region and thus alternatives such as the offshore Kudu Gas Plant and the proposed Baynes hydroelectric plants are of economic importance to Namibia (MME 2010).

Impacts and Vulnerabilities

Climate and weather affect both energy supply and demand. In general, prolonged droughts reduce river flows, which in turn reduce hydropower supply; floods and strong winds damage network cables thus cutting off energy supply; and extreme high and low temperatures increase the demand of energy (Wilbanks *et al.* 2008). Reduced river flow will have bearing on the proposed hydro plant on the Kunene River and both fresh water and salt water flooding, will impact Walvis Bay.

Already flooding events along the Kuiseb river delta have caused damage to energy infrastructure. Overland pylons that support electrical cables, supplying Walvis Bay Municipality with electricity have been knocked over by rushing waters during flash floods and flood events. This resulted in the disconnection of the distribution networks. With climate change, the storms that caused this flooding are expected to increase in frequency. Flood inundation is also eroding coastal power lines by causing a softening of the soil surrounding poles, resulting in the instability of energy network pylons. Inundation by either salt or freshwater is also likely to cause damage and losses to energy production facilities and infrastructure such as sub-stations and transmission lines (UNFCCC-NAM 2009).

Increasing frequency and intensity of wind events have caused an increase in the number of power outages due to accumulation of windblown sand, causing sand piles around the pylons and making contact with the overhanging electrical wires. This has caused shorts in the power supply (UNFCCC-NAM 2009). The anticipated increased mean temperatures are likely to cause an increased demand for energy as the need for climate control in homes and commercial and industrial space increases (Wilbanks *et al.* 2008, UNFCCC-NAM 2009).

Any failure in transmission will lead to the pumps on boreholes that supply the Municipal water shutting off (see case study 1). In addition to no water, blackouts will lead to a loss of refrigerated produce for those without backup generators and thus a loss of economic gain. This is of particular importance to the fish processing plants. Most fresh produce to Walvis Bay is imported and so cold storage is vital to the supply of fresh produce. Storage and landing facilities for the import of fossil-fuel energies needs to be able to withstand increased storm frequency and potential inundation to prevent spillage causing loss of fuel and damage to an ecosystem that is already compromised (Wilbanks *et al.* 2008).

Changing to alternative energy production mechanisms such as solar and wind must be done with careful consideration for climate change (see case study 2) as cloud cover frequency may change reducing the use of solar energy at the coast. Change in strength, direction and duration of sea currents will need to be taken into consideration for any proposed wave-generated energy schemes (Perez 2009).In addition, changes to wind dynamics will need to be take into consideration for wind farms.

Table 4 identifies likely impacts on the energy distribution within a city to its inhabitants as a result of mean sea level rise and sea storm surges.

Table 4. Summary of impacts on the energy sector for rising mean sea level and sea storm surges.

Impacts upon Energy	Impact on Livelihoods
• Erosion of coastal power lines - it has already been reported that mean sea level rise is causing a softening of the soil surrounding poles, resulting in the instability of energy network pylons. • Flood inundation would cause damage and losses to energy production facilities and infrastructure (power stations, high voltage lines etc) and reduce or negate their ability to meet energy needs. • May cause an increased demand for energy - as temperatures rise or fall the need for climate control in homes and commercial space increases. • Power outages due to floods destroying power lines. • Energy supply cut for bore hole water pumping. • Loss of fresh produce from cold storage. • Storage and landing facilities for import of fossil-fuel energies needs to be able to withstand increased storm frequency and potential inundation to prevent spillage. • Changing to alternative energy production mechanisms such as solar and wind need careful consideration to ensure they are sustainable even in the face of a changing climate.	• Limited fresh produce for consumption • Limited water supply for drinking, agriculture or industry • The Walvis Bay economy relies heavily on fishing and fish processing plants for jobs and income; the ability to freeze and store fish must be protected from energy uncertainties • Power-outs can impact the functioning of hospitals

Case studies

1. **Walvis Bay** has already experienced power outages caused by a sea storm surge combined with flooding. The flooding sparked a power outage in the Kuiseb borehole system in February 2009 and affected the water supply being pumped from the Kuiseb aquifers to reservoirs which supply the industries, municipality and rural areas of Walvis Bay with fresh water. As a result of the disconnection in energy, water capacity of reservoirs became low impacting on businesses, residents and communities in the area.

2. In **California**, U.S.A, policies are being put in place to govern the positioning of any new energy plants or transmission infrastructure to ensure they remain beyond the reach of predicted mean-sea

levels. This poses a problem, however, when intake pipes are required. The Diablo Canyon Power Plant is located on a coastal terrace well above sea level but cooling water is pumped from an intake pipe in the rocky intertidal zone that takes the full brunt of northern swells from Pacific storms. The facility has had to curtail power during storm events on average twice per storm season. Both generating units are cut back to 20% power as a preventative measure to avoid shutting down (or tripping) the units if intake flow is impeded by debris build-up on the intake screens and these units can be down anywhere from 18 to 24 hours to several days. The more frequent the storms or the greater the intensity, the more likely that the facility would have to cut power due to debris generated by the storms (Perez 2009).

6. Conclusion

The severe physical, social, environmental and economic impacts of climate change, both directly and indirectly, are anticipated to be felt with greater intensity in the cities of Africa. A changing climate will affect people's access to, and the quality of, basic goods and services such as water, shelter and food as well as other key priorities for human wellbeing such as education, employment and health. Africa is particularly vulnerable as the situation is aggravated by the interactions of 'multiple stresses'. These 'multiple stresses' include endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These heavily reduce Africa's adaptive capacity (IPCC 2007).

Namibia is no exception and Walvis Bay will be the city most affected by the impacts associated with a rising sea-level and an increase in the frequency and intensity of storm sea surges. Walvis Bay has already observed some increase in sea-level and flooding and it is projected that these outcomes will intensify with time, regardless of global mitigation efforts.

Salt water intrusion and inundation will affect the water and sanitation, transport, energy and health sectors. Flooding from the Kuiseb River or local surface flow will also affect all sectors (see Table 5 for a summary). If the city is unable to adequately meet its mandate of basic service provision, these impacts are likely to mean, that for an average resident of Walvis Bay, a decrease in quality of life and ability to make a living is inevitable. Already the city is shown to be unable to meet the needs of some sectors, particularly the burgeoning informal settlements and it means that these people will be most vulnerable to the changing climate.

It is important to make plans now to ensure as much resilience as possible to prevent major catastrophe and to allow local government sectors to continue to meet their mandate of basic service provision and thus allow the inhabitants of this port town to continue to make the best livelihoods they can, and to improve their opportunities. Besides mitigating and reducing emission and energy, adaptation is a vital component in order to prepare and increase resilience towards the risks and impacts. Walvis Bay local authorities need to adapt and plan strategically to build resilience against climate change specifically to variability and extreme cases of temperature. There is a need for adaptation strategies and preparedness in protecting local communities and the environment on which they depend upon for their livelihoods and well-being.

In an IIED report (Moser, C. and D. Satterthwaite, 2008) it was highlighted that strengthening, protecting and adapting the assets and capabilities of individuals, households and communities is far more important in low- and middle-income countries than in high-income countries, because of the following:

- The limitations in urban governments' adaptive capacity, especially in providing needed protective infrastructure and services to low-income populations.
- The unwillingness of many city or municipal governments to work with low-income groups, especially those living in informal settlements, which usually include those most at risk from floods and storms.
- The key role of assets in helping households and communities to cope with disasters.

Adaptive capacity relates to the ability of households and community organizations to make demands on local governments and, wherever possible, to work in partnership with them (Moser and Satterthwaite 2008).

This report on Walvis Bay focused specifically on impacts and vulnerabilities associated with sea level rise and is one of a suite of five reports. The others reports deal with extreme temperature (Cape Town), drought (Dar es Salaam), flooding (Maputo) and tropical cyclones (Port Louis). These baseline studies and literature reviews will, when combined with the findings of the ICLEI Tadross and Johnston (2011) report: *Projected climate change over southern Africa; Mauritius, Mozambique, Namibia, South Africa and Tanzania*, GIS modelling and cost-benefit analysis, form the Risk Assessment. This will then form the basis from which the adaptation framework for the city will be developed. With this framework the city will be better able to better plan for future development and be better prepared for any climate-related crises. This is best done through participatory action at the local level local via government, researchers and communities and in this regard Walvis Bay can lead the way for Namibia.

Table 5 provides a summary of all the likely impacts associated with sea level rise and sea storm surges across all four local government sectors (water and sanitation, transport, health, energy and livelihoods) within this study.

Table 5. General impacts associated with sea level rise and storm surges upon municipal sectors.

Water and sanitation	• Salt water intrusions into freshwater systems in costal zones are anticipated to increase.
	• Increased salinity levels of recycled water.
	• Decreased availability of freshwater for domestic and industrial use
	  ○ Increased pressure and stress on fresh water supply.
	  ○ Water treatment capacity will increase.

	○ Water sanitation in the poorer, vulnerable areas will be affected ○ Cascade effect on health as a result of increased changes of contamination of fresh water sources.
Transport	• Rising sea level, increased frequency and intensity of storm surges are likely to result in direct impacts on roads and rail infrastructure in coastal areas through inundation and erosion. • Coastal flooding is likely to cause diversion, delays and even suspension of transport services for the public, businesses and transfer of commodities. • Destruction, damage and disturbance to city-managed harbours, jetties, boat ramps and other infrastructure such as roads, electrical substations, main water pipes, beachfront promenades.
Health	• Sea level rise will impact upon the heath sector as a result of increased deaths from: ○ Drowning ○ Electrocution ○ Carbon monoxide poisoning in the clean up stages after flood events • Increased pressure on emergency services. • Service delivery backlogs in clinics and hospitals • Chemical Hazards: contamination of flood water with oil, diesel, pesticides, fertilisers etc. • Spread of infectious diseases: skin and respiratory diseases and stomach ailments.
Energy	• Damage and losses to energy production facilities and infrastructure (power stations, high voltage lines etc). • May cause an increased demand for energy for upgrades and adaptation • Clean up operations • Rebuilding of infrastructure and housing.
Livelihoods	• Threat to homes, infrastructure, transport, safety and basic services. • Increased groundwater level in coastal and low-lying areas • Further exacerbation of erosion impacts on informal settlements and damage to informal housing • Inundation of salt water reducing freshwater resources supply • After sea storm surge events or heavy rainfall water may not be able to disperse / run-off and water may become stagnant leading to disease outbreaks. • Rising seas may also reduce natural resource capital on which the local inhabitants are heavily dependent.

7. Glossary

Anthropogenic changes: Human activities that change the environment

Adaptation: In natural or human systems adaptation is a response to actual or expected stimuli, e.g., climate change or their effects, which moderates harm or exploits beneficial opportunities. In natural systems adaptation is reactive. In human systems adaptation can be both anticipatory and reactive and can be implemented by public, i.e., government bodies at all levels and private actors, i.e., individuals, households, communities, commercial companies and NGOs.

Adaptive capacity: The ability of people and systems to adjust to environmental change, e.g., by individual or collective coping strategies for the reduction and mitigation of risks or by changes in practices, processes or structures of systems. It is related to general levels of sustainable development such as political stability, material and economic well-being, and human, institutional and social capital.

El Niño-Southern Oscillation (ENSO): The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basin wide warming of the tropical Pacific east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño-Southern Oscillation, or ENSO. It is often measured by the surface pressure anomaly difference between Darwin and Tahiti and the sea surface temperatures in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global tele-connections. The cold phase of ENSO is called La Niña.

Resilience: Amount of change the exposed people, places and ecosystems can undergo without permanently changing states. That is, their ability to recover from the stress and to buffer themselves against and adapt to future stresses and perturbations.

Sensitivity: The degree to which people, places and ecosystems are affected by the stress, including their capacity to anticipate and cope with the stress. The effect may be direct or indirect.

Subsistence: The action or fact of maintaining or supporting oneself at a minimum level.

Vulnerability: Vulnerability is the degree to which a system or unit (such as a human group or a place) is likely to experience harm due to exposure to risk, hazards, shocks or stresses. In relation to the concept of poverty, vulnerability is more dynamic since it captures the sense that people move in and out of poverty.

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