Local Action for Biodiversity (LAB), City of Cape Town Biodiversity and Climate Change Assessment Report

Step 1 of LAB Pioneer Biodiversity and Climate Change Project

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Executive Summary

Cape Town is located in the Cape Floristic Region global biodiversity hotspot in one of the world's five Mediterranean-climate regions. The municipal area covers 2,460 km^2 and is home to 3.8 million people. Cape Town has a 307 km coastline, two mountain chains, lowland hills and plains and supports a wide range of natural ecosystems, habitats and species.

The Mediterranean-climate regime dates from about 28 million years ago. This long time-span together with the diverse physical environment resulted in diversification of the flora and fauna that we observe today. However, this unique biodiversity is under threat, primarily from habitat conversion to agriculture and urban development, with invasive alien species being the second-most important impact. Global climate change also poses a significant threat to biodiversity.

Global climate change is driven by increasing atmospheric carbon dioxide levels, resulting from the burning of fossil fuels and the destruction of natural vegetation cover. The general public is aware of the former, but less so of the latter driver of climate change.

In Cape Town the climate is predicted to change in a number of ways:

- Altered rainfall patterns: overall drying with a shorter winter rainfall season, but more intensive, heavy rainfall events or storms. These changes will differ between mountain and lowland environments.
- Increased temperature, especially for the December-March and July-September periods, with predictions of +1.5 °C at the coast and +2-3 °C inland of the coastal mountains.

It is also predicted that the prevailing summer south-east wind will become stronger. At a global scale, the sea level is expected to rise 0.2 m by 2020 and 1.0 m by 2100. This, coupled with the predicted increase in frequency and severity of storm surges, is expected to have a significant and detrimental impact on Cape Town's coast. Second-order impacts of climate change include flooding, droughts, increased fire risk and invasions by alien species as well as socio-economic impacts arising from the loss of ecosystem services.

Whereas we are certain that global climate change will impact on biodiversity, both at the species and ecosystem level, it is not yet clear how biodiversity will react, as natural variability does allow for some local adaptation. The projected reduction in winter rainfall and increase in droughts will negatively impact seasonal wetland communities. The rise in sea level and increase in storm surge events will erode coastal ecosystems, including dune strandveld vegetation. Many of these ecosystems already are reduced to narrow strips or are confined by urban development and cannot retreat inland.

The City of Cape Town relies on many ecosystem services provided by biodiversity. Maintaining healthy ecosystems in the face of global climate change is thus essential in creating a resilient city. Worldwide, ecosystem-based approaches to climate change adaptation and mitigation have been shown to be cost-effective and generate social, economic and cultural co-benefits while helping to conserve biodiversity.

Adaptation is defined as proactive actions that will reduce the risk of impacts from climate change. An example is ecosystem-based coastal defence strategy: more effective regulation of coastal development and activities to protect and retain coastal dune ecosystems, as well as the restoration of degraded coastal ecosystems, which will in turn provide improved protection of existing infrastructure. Another example is the control of invasive alien plants in natural vegetation areas: this will promote recovery of native plant communities so that they become more resilient to climate change impacts and can resume delivering ecosystem services.

Mitigation is defined as actions taken to alleviate or reduce the continuation of climate change. Natural ecosystems play a critical role as carbon sinks. Ecosystem-based approaches include good management of nature reserves and other natural open spaces and the restoration of degraded vegetation areas. Research indicates that local ecosystems (such as fynbos and renosterveld) sequester more carbon than degraded land and agricultural areas.

The City of Cape Town is involved in several pro-active climate change adaptation and mitigation initiatives, such as the "Climate Change Think Tank" and the "Energy and Climate Action Plan". More directly related to biodiversity and climate change, the Coastal Protection Zone Policy will limit future ribbon developments along the coastline, thus retaining ecological resilience and thereby promoting coastal defence. Recent stormwater policies manage stormwater quality and quantity impacts arising from urban development throughout the catchment and further, limit development in wetland and riparian buffers thus retaining resilience in these ecosystems, important for flood control.

The systematic conservation plan for the city (Biodiversity Network) encompasses terrestrial and freshwater ecosystems and natural corridors. Future iterations of this plan will ensure that climate change adaptation measures are incorporated as far as is possible. The City of Cape Town's Biodiversity Management Branch has adopted tools to manage City-owned nature reserves effectively and policy to control invasive alien species. Future plans include ecological restoration in degraded areas of the Biodiversity Network.

All these activities are crucial in adapting the city to climate change. Furthermore, maintaining and restoring functioning ecosystems will also ensure the flow of ecosystem services and contribute to climate change mitigation.

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1.0 Introduction

The City of Cape Town is internationally recognised for its natural beauty, Mediterranean climate and unique biodiversity (Holmes et al. 2008). Located in the Cape Floristic Region (CFR) global biodiversity hotspot, which is also a World Heritage Site recognised by the International Union for the Conservation of Nature (IUCN), Cape Town welcomes a constant flow of visitors every year from around the world. With this rich natural environment and a highly complex social and economic urban fabric, climate change brings further challenges to efforts in protecting biodiversity.

The City of Cape Town Municipality (City) is one of the Local Action for Biodiversity (LAB) pioneer cities and hosts the ICLEI Cities Biodiversity Centre. The City opted to continue into the LAB Phase 2 Pioneer Biodiversity and Climate Change project for a number of reasons, including:

- Conserving biodiversity and ecosystems is central to the area's resilience in a changing climate
- Communicating the role of biodiversity for a climate-resilient city to politicians and decision-makers is a powerful tool in motivating for biodiversity conservation
- To review and stimulate thinking around the implications of climate change for biodiversity
- To determine the links between biodiversity and climate change adaptation and mitigation, in order to align these for efficient planning and implementation.

1.1 Introduction to the City of Cape Town

The City of Cape Town is situated at the south-western tip of Africa and in 2011 is home to approximately 3.8 million people. The City is a recent amalgamation of a number of local municipalities into one metropolitan area, or unicity, and administers an area of 2,460 km^2. Like all South African cities and towns, Cape Town developed within the context of apartheid policies and laws in the 20th century, resulting in an urban city that today has many social and economic inequalities. As a result, Cape Town is a mix of well-developed, advantaged suburban and urban areas surrounded by impoverished, environmentally-poor disadvantaged areas characterised by large numbers of informal settlements and urban sprawl.

Cape Town does not have significant and major industry comparable to that of other large South African or global developing cities. It has an active port, financial sector, hospitality, film, textile and fishing industries, as well as wine farming and limited sand mining as the main contributors to the economy. Much of the city's economy and growth is supported and underpinned by its natural beauty and heritage. This recognition has stimulated and resulted in a growing and significant tourism industry, rapidly increasing property values and increased high-income development in Cape Town. With its beautiful natural environment, 307 km of coastline and the Table Mountain National Park within the City's boundary, there is an increasing global desire to live and work in Cape Town. Therefore it is imperative that the natural resources and landscapes of the city are protected and enhanced so as to protect and manage its greatest economic and social asset.

The city is located within the Cape Floristic Region (CFR), one of only six floral kingdoms in the world and the richest for its size. The CFR is also a global "biodiversity hotspot", because it has a high proportion (70%) of endemic species (i.e. confined to the area) that are under high threat of extinction owing to habitat loss (Myers et al. 2000). This places an international responsibility on all three tiers of South African government to ensure that this unique biodiversity and natural heritage is adequately conserved for future generations.

Cape Town is an exceptionally rich part of the CFR, owing to its diverse range of terrestrial, fresh water, coastal and marine habitats. The city lowlands (Cape Flats) supports a rich and unique array of terrestrial and aquatic ecosystems, but has experienced massive transformation through agricultural and urban development. Today these ecosystems are highly threatened and under-conserved (Rebelo et al. 2011).

1.2 Overview of Cape Town's Biodiversity

Geology, topography, soils and climate together provide the unique setting for the evolution of the CFR's plants and animals. Whereas the landscapes and substrata of the CFR have existed in near modern form for tens of millions of years, the onset of the current phase of summer-dry climates is more recent and probably dates from about 28 million years ago (Linder 2003). Prior to this, the climate history suggests large scale fluctuations between summer-wet and summer-dry climates. The last 8-15 million years has seen the rapid radiation of the modern Cape flora (Linder 2003). The flora today exhibits a high level of species turn-over, and many species occupy narrow ranges, with edaphic specialisation being one of the main drivers of the observed diversity (Cowling et al. 1992). For example, 190 plant species are confined to Cape Town alone.

During the past two million years of glacial-interglacial cycles, the CFR has experienced mild climate changes with mostly cooler and wetter conditions during glacial times. None of the mountain ranges were high enough to experience glacial conditions and the maximum depression of mean annual temperature was about 5 °C lower than at present (Deacon et al. 1992). This relative climate stability has resulted in the persistence of many range-restricted, locally rare species with limited dispersal ability, and of climate-sensitive relict species, especially in wetland areas. In addition, highly specialised mutualisms have evolved in the flora and fauna of the region.

Cape Town contains 19 major national vegetation types; six of these are endemic to the city and therefore can only be conserved within the City's boundary. Under the latest national ecosystem assessment (DEAT 2009), 17 are listed as threatened, mostly because of habitat transformation, but also owing to their high number of Red List threatened species. The natural vegetation falls into five main structural groupings, in order of prominence: fynbos, renosterveld, strandveld (including thicket), wetlands and forest (Holmes et al. 2008). Except for estuaries and large vleis (i.e. seasonal or permanent lakes), wetlands form communities within the other four structural types. Fynbos and renosterveld are fire-prone ecosystems that require fire in summer in order to maintain biodiversity long-term. The fire-return interval varies depending on the particular vegetation type, but whereas fynbos has some slow-maturing species that require 4-5 years to flower and set seed and has an average fire-return interval of about 15 years, renosterveld can cope with higher fire frequencies. By contrast, strandveld which is a coastal type on alkaline sands, and forest, are not fire-prone and fire is not essential for biodiversity maintenance. Too-frequent fires in these systems can lead to structural changes and biodiversity loss.

Habitat loss, with its associated fragmentation effects, is the primary threat to biodiversity in the city; invasion by alien species is the second most important threat (Rebelo et al. 2011). Natural vegetation remnants have been less impacted on the mountains than in the lowlands (Figure 1). If loss of critical biodiversity areas could be halted, and areas already degraded by invasive species and poor land management practices restored, then an improvement in the health of Cape Town's ecosystems could be achieved and result in enhanced ecosystem resilience to climate change.

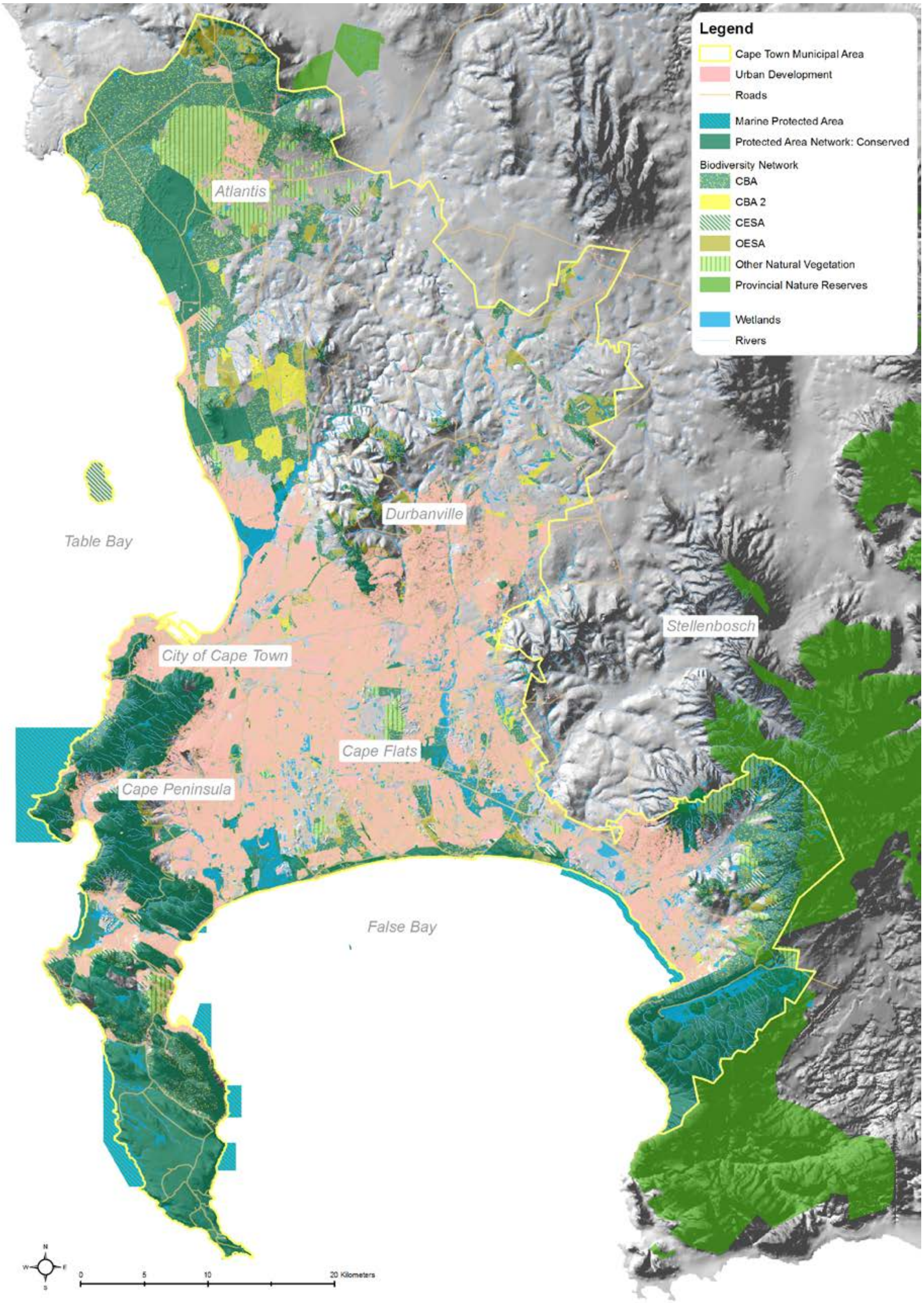

Figure 1. The Cape Town Municipal Area showing Marine Protected Areas, the Biodiversity Network: Protected Areas, Critical Biodiversity Areas (CBA), Ecological Support Areas (ESA); and other natural remnants.

A picture panel to show a range of Cape Town's landscapes and natural ecosystems.

Fynbos and renosterveld species are usually restricted to one soil type and only a small proportion of species are generalists that can bridge major soil ecotones. Many of the IUCN Red List threatened species (of which there are a staggering 319 in Cape Town alone, Rebelo et al. 2011) are habitat specialists confined to particular communities within a vegetation type. This being the case, such species will need to adapt within their particular habitats as they will be unlikely to move across edaphic boundaries. Such species could be at greater risk from climate change impacts than more widespread species, but could still move short distances to more favourable microsites within their habitat (Randin et al. 2010). Conservation strategies should retain flexibility in order to be able to respond to unpredictable climate changes. In applying the precautionary principle for threatened species, conservation management should aim for minimum viable populations in order to promote local adaptation, as well as countering other negative impacts such as invasive alien species. At the community level it is likely that wetland and seepage zone areas vulnerable to a reduction in rainfall may be impacted most by climate change. Examples include Cape coastal lagoons, estuarine and seasonal wetlands communities.

The Biodiversity Network (Figure 1) is the fine-scale systematic conservation plan for the city and encompasses connectivity as well as ecosystem and species targets. For large parts of the city, natural linkages no longer exist and the best available faunal movement corridors are degraded rivers and road verges. The Cape Peninsula is nearly cut off from the interior owing to large-scale coastal and suburban development, particularly in the Cape Town Central Business district that severs the link to the north. The False Bay corridor that links the Cape Peninsula and Helderberg region is also under threat from development, but collaborations with other line functions, especially spatial planning, are on-going to try and retain at least a viable faunal movement corridor.

1.3 Current Understanding of Climate Change in Cape Town

Most City politicians, staff and the general public have heard about climate change through the mass media and have some understanding of the role that human activities have played in speeding up climate change and altering the world's climate. It is understood that rising atmospheric carbon dioxide (CO_2) levels, as a result of burning fossil fuels, is driving global warming. However, there is probably less understanding of the role of global deforestation and vegetation clearance in contributing to climate change.

The City has initiated several climate change projects with an emphasis on infrastructure, disaster management and coastal risk. Service provision and energy security are also being aligned to account for climate change. However, there is still a gap in highlighting the links between biodiversity conservation and climate change adaptation and mitigation. Awareness-raising around the risk of climate change to the city has been initiated and is primarily driven through the Climate Change Think Tank. Efforts have also been made to raise awareness through education programmes; for example, the Disaster Risk Management Centre (DRMC) has been doing some outreach in schools regarding climate change risks.

There is a growing awareness of the services that natural ecosystems provide, but still a need for taking the value of these ecosystem services and the long-term costs of their loss into account in decisions about how natural resources are used. There is a need for placing a financial value on the benefits of these services, in order to promote natural ecosystem maintenance, as well as determining their value in our efforts to combat climate change (Hamilton et al. 2007; de Wit et al. 2010).

2.0 Climate Change Impacts on Cape Town

In their fourth assessment, the Inter-Governmental Panel on Climate Change (IPCC, 2007) found observational evidence from all over the world that natural systems are being affected by regional climate changes, particularly temperature increases. It is widely accepted that these changes are being driven by anthropogenic global warming, caused by increasing greenhouse gas (GHG) emissions. There is a global consensus on the urgent necessity to prepare ourselves for a rapidly changing climate.

2.1 Observed Changes in Cape Town's Climate

The evidence that the climate is changing and that climate change will continue to occur in ways that affect the planning and day-to-day operations of the City's line functions and communities is now overwhelming. Based on international opinion it is anticipated that climate change will manifest in Cape Town in the following ways (Midgley et al. 2005, Mukheibir & Ziervogel 2006, Brundit 2009, Cartwright et al. 2008 & 2008a, Fairhurst 2008):

- Altered rainfall patterns both in distribution and intensity
- Rising mean temperatures
- Sea level rise, both permanent inundation and discrete sea level rise (storm surge) events
- More frequent temperature extremes
- Heat waves
- Drought periods
- Intensification of wind (predominantly south-easterly)

Climate changes are already occurring, and while GHG emission reduction both globally and locally can help slow the rate (although there is no evidence to suggest reduction is taking place) climate change cannot be prevented entirely.

A number of previous disasters and events have been associated with weather conditions and should serve as a warning for future conditions given current projections of such events occurring on a more frequent and intensive basis. These include the Cape Flats floods (1994 and 2001), the Manenberg wind storms (1999 and 2002), South Peninsula fires (2000, 2009, 2010), Joe Slovo informal settlement fires (2000, 2009), cut-off low severe sea storms (2003, 2004, 2005) and severe drought (such as 2002-2005) (Mukheibir et al. 2006; Rowswell & Fairhurst 2011). The South Peninsula fires were good ecological fires; however, nearby housing was not sufficiently fire-proofed and significant damage was incurred. In addition, some areas of dense, woody, invasive alien vegetation burnt with high severity causing soil damage and subsequent soil erosion. Summer fires were the natural regime prior to urban development in Cape Town; in natural vegetation areas these latest fires were of an intensity to stimulate excellent recruitment of fynbos.

To address climate change risks, the City has initiated the development of a Climate Adaptation Plan of Action (CAPA) based on sector plans for each functional area of City responsibility. These sector plans identify both the risk as well as proposed adaptation measures.

2.2 Overview of Climate Risks: 1st Order Impacts

Atmospheric circulation

Through observing the recent historical trends (1958-2001) in the Western Cape, significant changes in the frequency of daily atmospheric circulation patterns (high and low pressure systems) are evident (DEA&DP 2008) namely:

- A decrease in frequency of low pressure system winter storms (April - June) and January storms
- An increase in frequency of high pressure systems (September – February).

Climate model projections identify two main changes:

1. Increases in precipitation in the interior and to the east of the province (late summer), with strongest changes associated with topography
2. Decreases in early and later winter precipitation for the south-west of the province (i.e. Cape Town); suggesting that the core season of the south-west winter rains are likely to shorten in duration.

The observed trends and model projections in atmospheric circulation have the following implications for the city:

- Conditions conducive to “brown haze” and smog will increase, leading to deterioration in air quality. This results from reduced dispersal of pollutants associated with weaker synoptic forcing (local thermally-driven weather circulations)
- Potential increase in hot, dry “berg wind” conditions, increasing fire risk - especially following a dry winter period
- A warmer atmosphere will hold more moisture (about 8% more for every 1°C increase in temperature), so there is potential for heavier extreme rainfall under global warming. This theory is further supported by the projected increases in magnitude of rainfall events in the mountainous regions of the Western Cape. However, overall there is a prediction for lower annual rainfall in Cape Town as a result of winter drying.

Temperature

Temperature has been steadily increasing globally and there is a relatively high degree of confidence in the temperature projections, both at Global Circulation Model and down-scaled levels. The full range in global temperature increase over the six scenarios used in the fourth IPCC assessment was 1.1 – 6.4 °C (IPCC, 2007). In the south-western Cape, significant warming trends were found for T_{min} (daily minimum temperature) for December to March and July to September. Significant warming trends were also observed for T_{max} (daily maximum temperature) during May and August in analyses comparing monthly data from 1967 – 2000. Very warm days have become warmer or have occurred more regularly during the last decade, particularly during January, April and August. Projected temperature rises are approximately 1.5 °C on the coast and 2-3 °C inland of the coastal mountains by 2050 (Midgley et al. 2007).

Increases in average temperatures are anticipated to impact the city in the following ways:

- Increased frequency of the occurrence of extremely hot and cold days
- Increased evaporation from soils, natural surface water systems, ponds and water storage facilities
- Increased risk of wildfires resulting from increased dryness through increased evaporation
- Impacts on ecosystems resulting from changes in fire regime, and indigenous and alien species' relative tolerances to changed temperature
- Increased risk of ground and building subsidence due to lowered groundwater levels and clay soil shrinkage
- Potential increase in energy demand for cooling
- Increased risk of thermal discomfort and heat stress
- Increased demand on water resources for drinking and irrigation
- Increased potential for health problems resulting from heat waves and an increase in spread of diseases.

Rainfall and Precipitation

Regional changes in precipitation and rainfall are multifaceted and complicated. While large-scale circulation drives precipitation, there are often systematic variations in the projected rainfall within regions, for example as a result of mountain ranges. At high spatial resolutions there still remains a low degree of confidence in the rainfall projections. There is greater confidence in the pattern of projected change than there is in the magnitude. Nevertheless, there is a tendency for the following trends and projections for the south-western Cape (DEA&DP 2008):

- Winter drying resulting from a shortened duration of the low pressure, cold front system characteristic of winter
- In conjunction with the drier winters, a higher frequency or intensity of heavy rainfall and storm events, i.e. when it occurs, rain is predicted as heavy, patchy downpours. Increased humidity in mountainous regions but reduced humidity in low lying regions.

Accompanied by these trends and projections of rainfall and precipitation, the associated impacts are:

- Increase in the probability and severity of drought resulting from less consistent rainfall and increases in temperature and evaporation
- Reductions in stream base flows resulting from reduced rainfall
- Increased fire risk resulting from drier and warmer conditions
- Increased risk of ground subsidence, structural and building collapse resulting from groundwater levels lowering and clay soil shrinkage
- Increased pressure on fresh water resources as a result of the predicted overall drying and warming, with associated water shortages and inability to meet demand

- Riverine flooding and river bank erosion as a result of increased intensity of sporadic heavy rainfall events, compounded by increased surface water runoff over hard surfaces and soils that have become water-repellent
- Increased risk of water contamination from pollutants such as sewage as a result of flooding of sewerage pump stations, treatment infrastructure and ponds, overflowing and reduced treatment time and also agricultural chemicals resulting from increased surface water runoff
- Increased risk of vector-borne diseases spreading through the various communities relating to:
    - Increased demand on fewer water sources i.e. if contamination occurs, more people using the same resource
    - Flooding events and increased exposure i.e. low income communities without the ability to leave flooded areas
- Impacts on ecosystems through re-settlement by people impacted by floods.

Changes in wind velocity

Average wind velocity is expected to increase, particularly in summer (DEA&DP 2008). This does not mean all days will be windier but that the prevailing summer south-easterly wind will likely be stronger. This is associated with a stronger and more dominant south Atlantic high pressure system. The increases are most notable in coastal regions.

Sea level rise

The rise in sea level around Cape Town is likely to be similar to the global projections of sea-level rise by the IPCC Fourth Assessment (IPCC, 2007). The rate of mean sea level rise is expected to increase over time as thermal expansion and melt rates of Greenland and Antarctica are anticipated to increase linearly with future temperature increases. It is likely that changes in mean sea level will only have clearly identifiable impacts as time elapses and mean sea level continues to rise over time. Sea level could rise 20 cm by 2020 (Brundit 2009) and is predicted to rise 100 cm by the end of the century (2100).

Storm surge frequency and intensity is also expected to increase over time; however, it is and will probably be the most visible impact relating to the sea and the first to be noticed. When considering these factors in combination, a raised mean sea level will require smaller storm events to overtop present protective measures and coastal dune ecosystems.

These projections of sea-level rise and increased frequency in storm surges are anticipated to have the following impacts:

- Increased vulnerability to coastal erosion
- Increased risk of damage to coastal infrastructure
- Reduction in coastal river water quality resulting from salt water intrusion into estuaries and aquifers
- Coastal lowland inundation

- Reduction in extent of coastal habitats
- Destruction, damage and disturbance to harbours, jetties, boat ramps and other infrastructure such as roads, stormwater outlets, electrical substations, main water pipes, beachfront promenades; thus reduced service delivery
- Increased vulnerability of coastal informal settlements, private property and industry
- Increased salt water intrusion and raised groundwater along the coast
- Greater tidal influence by the sea
- Increased flooding events – both in frequency and extent
- Potential tourism loss resulting from damage to infrastructure and loss of beaches
- Insurance loss due to damaged private and public infrastructure
- Increased municipal rates to support protective measures
- Increased pressure on emergency services
- Loss of coastal wetlands resulting from saline inundation, increased erosion and landslides.

Areas within Cape Town that are particularly at risk from sea level rise and storm surge impacts are those situated in low lying areas or close to estuaries and include Milnerton Lagoon, Fish Hoek, Strand, Gordon's Bay and Sea Point (Cartwright et al. 2008).

2.3 Overview of Climate Change Risks: 2nd Order Impacts

Increased fire risk

Climate modelling suggests that there will be more days conducive to ignition, as well as more days conducive to high intensity fires (DEA&DP 2008). This could lead to more frequent fires. However, fires need fuel to burn and most natural fynbos ecosystems have insufficient fuel until the vegetation is at least four years post-fire age. In areas where a drying trend is predicted, as in the Cape Town lowlands, vegetation growth rate and accumulated biomass will be lower, and to some extent this could counter the more fire-prone weather conditions that are predicted to increase fire frequency.

Flooding

It is anticipated that longer dry periods interspersed with sporadic high intensity rain storms and the possible additional influence of coastal storm surges will significantly alter the city's runoff modelling, master planning, and engineering design approaches. An increase of 15% in design rainfall intensity has been predicted and is now being used in models for predicting run-off and flood scenarios in the Cape Town area (Schulze et. al 2010; RLH 2011).

Drought

Episodes of prolonged drought, and the projected shortening of the winter rainfall season, will have a pronounced impact on wetlands, particularly the seasonal wetlands. The climate change impacts on freshwater ecosystems will have indirect impacts on water provision and security mainly through salt water intrusion into groundwater and changes in rainfall regimes. Groundwater dependant wetlands will also be affected by the lowering of the water table.

Increased invasion by alien species

Invasive alien species are successful partly as a result of colonising a new area without their baggage of pests and parasites which limit their productivity and distribution in their native range. For this reason, they have a competitive advantage over local indigenous species, and consequently they can achieve a wider ecological distribution away from their native region. Under climate change, invasive species are likely to adapt quicker than the native counterparts owing to their release from pests and parasites and their ability to adapt to and colonise a wider range of habitats. It is also possible that new invaders, or established alien species that are currently not invasive (i.e. "sleepers"), could suddenly take advantage of a changing climate to out-compete local species. Invasive plants are not only detrimental to native biodiversity but often pose a major threat to water security by using more water than indigenous plants.

Social impacts

The most vulnerable to the impacts of climate change on biodiversity are the poor communities who depend on ecosystem services for food, fuel and income. Through increased occurrence of fires and air pollution, the health and livelihoods of communities are indirectly affected. Furthermore the poor depend on climate-sensitive sectors and resources such as agriculture, fisheries, fresh water and tourism (UNEP, 2010). It is predicted that agricultural productivity will decrease by 25% in South Africa (Cline, 2007). Similarly, food security in vulnerable communities dependent on growing their own food may also be threatened. The projected increase in occurrence of droughts will impact water provision. Extreme weather events and loss of biodiversity may also lead to a decrease in the importance of the tourism sector as an employer. The vulnerable communities will suffer first and most severely from the degradation of biodiversity as their livelihoods, food security and health will be directly affected. Therefore it is important to enhance the resilience of biodiversity to climate change impacts in order to alleviate poverty.

2.4 Climate Change Impacts on Biodiversity

Climate change is likely to have significant impacts on biodiversity: on ecosystems, species, genetic diversity within species, and on ecological interactions. There is an ever-increasing body of evidence demonstrating that the distribution, composition, structure and function of ecosystems are starting to respond to changes in temperature, precipitation and increased CO_2 levels (Campbell et al. 2009). While we are quite certain of the changes already being observed, there is still a significant level of uncertainty regarding how exactly ecosystems will react to projected climate change. Natural variability makes it difficult to predict how biodiversity will be affected both on the whole as well as at the individual species level. An impending question in the City's efforts to prepare for climate change is whether species and ecosystems will be able to adapt in situ or migrate according to the predicted rate of change. While this remains a complex question that cannot be answered with currently available information, efforts should be made in understanding if species' adaptive capacity will be outdone by the rate of climate change (see below).

Much of the city is low-lying, particularly the Cape Flats and the west coast lowlands areas (Figure 1). Much of the low-lying Cape Flats historically comprised seasonal wetlands during the winter rainfall season. The majority of these wetlands have been irreversibly altered for agricultural and urban development through drainage and storm water measures, the latter converting seasonal systems into perennial wetland systems. As a result, these highly impacted and fragmented systems are even more vulnerable to being lost completely in a changing climate.

The high economic and biodiversity importance of the coast and coastal ecosystems, and the primary impacts of climate change through sea level rise and increased storm surge events, prompted a study to model the risks of sea water inundation to coastal properties and infrastructure (Cartwright et al. 2008). In the medium term (towards the end of the 21st century) projected sea level rise will impact on coastal terrestrial vegetation, reducing remnants of threatened Cape Flats Dune Strandveld and eroding beach vegetation on the primary dunes. In many places the primary dune systems have little room to move inland owing to existing developments and are likely be lost from our landscape completely. It will be necessary to replace these natural systems with artificially-maintained landscaping and/or physical structures, but in some cases developments may need to be demolished. All these options have cost implications. Estuaries and other coastal wetlands could also be negatively impacted, especially where suburban development precludes a natural migration of wetland communities inland.

3.0 Creating a Resilient City with Biodiversity

3.1 Ecosystem-Based Approaches to Climate Change Adaptation and Mitigation

Using biodiversity to adapt to the adverse effects of climate change is possible through the application of ecosystem-based adaptation strategies. This approach integrates the sustainable use of biodiversity and ecosystem services into the overall adaptation strategy that can be cost-effective and generate social, economic, and cultural co-benefits as well as contribute to biodiversity conservation (AHTEG 2009). Protecting forests, wetlands, coastal habitats, and other natural ecosystems can provide social, economic, and environmental benefits, both directly through more sustainable management of biological resources and indirectly though protection of ecosystem services (World Bank 2009).

The potential of ecosystem-based adaptation options as contrasted with technological solutions should be considered, and include the following:

- Terrestrial vegetation restoration, including invasive species control
- Proactive wetland and estuary rehabilitation
- Dune cordon stabilisation and planting (see Box 1)
- Beach replenishment
- Kelp forest protection as a means to absorb energy from storm surge events thereby reducing the erosive potential of storms along the coast
- Retention of kelp wrack on beaches where this has minimal social and health impacts: kelp not only traps wind-blown sand and raises the beach profile (reducing erosion), but it is important to beach ecology and the functioning of dune systems. Dune systems provide important natural buffers against storm surges.

Box 1. Witsands Beach Rehabilitation – An Example of Successful Management

The three year Witsands beach rehabilitation project was initiated in an effort to rehabilitate the sand dune system which was once used as a landfill site for household refuse until its closing in the 1980s. Years later, remaining litter was still being exposed by wind, sea and rain events. The project's goal was rehabilitating the dune system to adequately cover the landfill site while monitoring and manipulating the water channels as needed in winter. Mitigation measures were regular picking of litter on the beach and back dune area and stabilising the sand with rows of brushwood. In 2009, a progress report demonstrated four points of success; (1) waste from the landfill was no longer visible, and the health and pollution risks had been minimised; (2) the dune system had been rehabilitated to a more natural state; (3) the redirection of the flow of water from the back lagoon had recharged the reed beds, and resulted in a more natural flow regime; and (4) the wetlands were healthy and functioning and supporting a wide range of plant and animal life. The photos below demonstrate the stark contrast of the before and after of this project.

(Photographs provided by Wally Peterson, KEAG)

3.2 Biodiversity's Role in Climate Change Adaptation

Adaptation is defined as proactive actions that will reduce the risk and impact of climate change. Adaptation strategies tend to focus on technological, structural, social and economic measures; and the linkages between biodiversity and adaptation are often overlooked (Campbell et al. 2009). Nevertheless, biodiversity is linked to climate change adaptation in the following ways. Firstly, biodiversity can play a role in societal adaptation. There is evidence that ecosystem-based adaptation can provide cost-effective strategies across the major sectors involved in adaptation (e.g. coastal defence, water sector, agriculture). Secondly, societal adaptation strategies can have significant impacts on biodiversity. In many instances these impacts are negative, but where appropriate natural resource management is used, for example in improved agricultural practices, adaptation strategies may prove beneficial for biodiversity.

Efforts for adapting the city to climate change could have positive spin offs that would help achieve biodiversity conservation goals and also increase the city's resilience. Protecting and restoring healthy ecosystems would have a multiplicity of benefits in this regard. Spaces that are well managed would increase resilience of the city to climate change risks as well as ensure that biodiversity is conserved. The City is working towards building resilience to possible disasters. Disaster risk reduction efforts are prioritised in respect of potential climate change-related extreme events (e.g. heat waves, floods, droughts, storm surges).

Measures of resilience should be proactive, and not solely reactive. In other words, disaster avoidance should be a priority in preparing the city for the threats presented by climate change (DEA, 2010).

Some of the key principles of biodiversity's role in climate change adaptation are:

- Intact terrestrial ecosystems are more resilient to climate change impacts than degraded or transformed land cover
- Intact riparian and wetland vegetation is more resilient to drought and flooding cycles than degraded or transformed vegetation
- Connectivity is an element of ecosystem health. Keeping natural environments connected allows for a more resilient network of biodiversity whereby species are able to move from one area to another.

Using ecosystems for coastal defence

Intact coastal ecosystems are more resilient to storm-surge events and sea level rise than artificial structures. Hard structures such as sea walls, dykes, and tidal barriers are one engineering response to observed and projected risks yet ecosystem-based adaptation can also play a role in coastal protection strategies (King 2007). Coastal wetlands can absorb wave energy and reduce erosion through increased drag and resistance against water motion, a reduction in the direct wind effect, and directly absorbing wave energy. The accretion of sediments also maintains shallow depths that decrease wave strength (AHTEG 2009). Engineered structures can provide the temporary solution to coastal maintenance but can be detrimental to the integrity of ecosystems around them. These structures can interrupt the natural processes and cause long-term damage as well as require costly repairs and upgrades (UNFCC 2009). A considered balance between engineering solutions and reliance on coastal ecosystems to provide the necessary level of protection to coastal communities is required.

Biodiversity and Societal Adaptation to Climate Change

Current literature indicates that although the entire local human population is impacted upon during extreme climatic events, it is those who are impoverished who find it harder to recover as they have limited access and choices with regard to natural, socio-political, human, physical and financial capital that are integral to our holistic livelihood assets. Deprivation of these assets increases vulnerability to climate change, and the consequences of climate change in return will increase deprivation. Understanding the basis of their livelihood assets determines the ability of people to cope with climate-induced vulnerabilities. The key goal is to reduce the vulnerability to climate induced changes and to sustain and enhance livelihoods of people, with particular attention to the poor through adaptation and coping mechanisms (Rowswell & Fairhurst, 2011).

It is widely recognised that maintaining biodiversity promotes the continued provision of ecosystem services under environmental change (AHTEG 2009). Therefore it is important to maintain the functioning of ecosystems in order to build their resilience and this should be stressed as a necessary part of adaptation strategies, particularly for vulnerable communities (Campbell et al. 2009; Wiens & Bachelet, 2010). For example, poor populations living in low-lying informal settlements (e.g. Cape Flats) are most vulnerable to climate change risks such as flooding and sea level rise.

There is a growing body of literature which demonstrates that there is a positive relationship between human health and access to green spaces, particularly natural open spaces. Findings from various studies state that proximity of green space improves levels of physical activity of all age groups, which in turn has positive effects such as promoting well-being and recovery from stress. Social cohesion, coping with major life issues in deprived areas, cognitive and social benefits in children were all positively linked with green space (Bell et al. 2008). The cultural and aesthetic services that our natural environments provide us are paramount in our social adaptation to a changing climate. In addition, adaptation measures against climate change can generate jobs for the poor and engage local community members. For example, invasive alien species removal projects have provided employment to a significant number of previously jobless citizens in Cape Town.

Box 2. Case Studies from the Western Cape on the Role of Biodiversity in Climate Change Mitigation
(A. J. Mills, personal communications 2011)

Carbon stocks in fynbos, pastures and vineyards on the Agulhas Plain

In 2008, a team of scientists performed a study to measure the differences in carbon (C) stocks of natural versus transformed land cover. They measured the above and below ground C stocks in Fynbos, pastures, and vineyards on the Agulhas Plain. The three vegetation types measured were: Elim Asteraceous Fynbos, Overberg Sandstone Fynbos, and Limestone Fynbos. They found that: (i) differences in soil C between land uses of different fynbos types was not statistically significant; (ii) root C was greater in fynbos than vineyards; (iii) root C was greater in fynbos than pastures; and (iv) above-ground C (litter and biomass) was greater in fynbos than pastures. These results indicate that the conversion of fynbos to pastures and vineyards resulted in a total loss of above ground and root C of 15 – 25 t C per hectare, depending on vegetation type. Conserving fynbos therefore contributes to the conservation of carbon in the landscape.

Capturing C and connecting renosterveld: a practical conservation incentive for the Overberg, Cape Floristic Region

Renosterveld, a biodiversity-rich vegetation type of the Cape Floristic Region, has been reduced to less than 10 % of its original extent. Payment for sequestering carbon in fallow lands could potentially facilitate the creation of conservation corridors between remaining intact fragments. To assess this potential, a team of scientists set out to measure ecosystem carbon (C) stocks in active fields, fallow fields and intact renosterveld at sites of the Overberg, South Africa. They found that C stocks were significantly smaller in active fields than in fallow and intact renosterveld. A sensitivity analysis, assuming a range of fallow period from 10 to 25 years, showed that carbon accumulated at 0.9 – 3.6 t C per hectare of shrub canopy per year. Their results suggest that the carbon market has the potential to facilitate a change in land use in the region, particularly on marginal lands, from cropping of winter cereals to fallowing of lands for conservation and livestock farming. Such fallowing could facilitate the restoration of large tracts of renosterveld and contribute significantly to the conservation of this critically endangered vegetation type.

3.3 Biodiversity's Role in Climate Change Mitigation

Mitigation is defined as actions taken to alleviate or reduce the continuation of climate change. Biodiversity options for mitigation focus upon the restoration of natural vegetation as carbon sinks. Ecosystem-based approaches can contribute to climate change mitigation by conserving carbon stocks, reducing emissions from ecosystem degradation and loss, and enhancing carbon sequestration in biomass and soils. While more needs to be studied on the role of Cape Town's marine and coastal ecosystems in this regard, it is widely accepted that functional terrestrial ecosystems can help mitigate climate change by sequestering more carbon than transformed landscapes (AHTEG 2009; Box 2). Protection of existing natural ecosystems and restoration of degraded ones are therefore important climate change mitigation actions that would simultaneously benefit biodiversity and delivery of ecosystem services.

As the case studies in Box 2 indicate, the planting of native shrubland vegetation would have a positive impact in sequestering carbon (C), compared to degraded or formerly farmed areas.

Afforestation is considered an ecosystem-based mitigation strategy and has been applied to Cape Town in the form of tree-planting. While controversial in temperate areas, tree planting can provide positive benefits in built areas of cities through moderating local weather conditions, for example cooling of sidewalks in summer; as well as mitigating air pollution and contributing to carbon sequestration (Brack 2002). However, afforestation of natural areas in Cape Town with tree plantations, or invasions by alien trees, has significant adverse ecological impacts and involves complex trade-offs (Midgley et al. 2010). Our understanding of these trade-offs needs to be fully assessed before further policies of this nature are considered (Box 3).

Box 3. Invasive Alien Trees in the Cape Floristic Region: Australian Wattle

In the 19th Century, *Acacia saligna,* commonly known as the Port Jackson willow, was introduced to Cape Town as a source of tan bark and to stabilise the Cape Flats sands after the indigenous fynbos had been cut down for firewood and degraded. The plant proliferated at an uncontrollable rate, stimulated by fires, and soon formed dense stands that replaced the indigenous vegetation across large tracts of the lowlands. *Acacia saligna* displaces native species through direct shading, by changing the fire regime and dominating the soil-seed bank. Today, the plant can be effectively managed by a combination of biological, mechanical and chemical control, yet it remains an example of the dangers of plant translocations (Le Maitre et al. 2011). Several pine species introduced for plantation forestry have also become rampant invaders in the Cape Floristic Region.

3.4 Adapting the Biodiversity Agenda to Climate Change

Biodiversity conservation strategy is also required to incorporate climate change adaptation considerations. Biodiversity strategy which includes improved protected area design, maintenance of optimal ecosystem functioning in the wider landscape, and reduction in negative anthropogenic impacts should aim to increase the resilience of biodiversity to climate change (Campbell et al. 2009). The City recently reviewed its systematic biodiversity planning methodology, as one of its LAB Biodiversity and Climate Change projects, to ensure that climate change adaptation is addressed as far as possible in the Biodiversity Network (City of Cape Town 2011).

Strategic environmental assessments (SEA) and environmental impact assessments (EIA) should be broadened to address climate change impacts and to focus on how development can assist with practical climate adaptation and mitigation measures such as ecosystem restoration, carbon sequestration, use of green engineering and low impact technologies. This could stimulate societal behavioural change by offering sustainable development choices and options. The value of biodiversity and ecosystem services also should be considered in the environmental and land-use decision-making processes. This would involve placing financial and non-financial value on ecosystem services and including them in the overall City budgets, as has been done elsewhere (TEEB 2010). Cape Town's natural assets are under increasing pressure, with this likely to be further exacerbated under climate change. More intensive management and ecological restoration may be required to maintain these services. It has been demonstrated that there is a strong economic rationale for investing in management and maintenance of these natural assets as they provide free services to the City and underpin many aspects of the economy (de Wit et al. 2010).

Climate change adaptation decisions should allow for monitoring and adaptive management approaches. Current projects which monitor species composition and changes in distribution should be encouraged long-term in order to fully understand current and future impacts of climate change, as there is a lack of credible evidence on this at present (Midgley et al. 2007). The City should collaborate and align with initiatives underway by the South African National Biodiversity Institute and the South African Environmental Observation Network.

4.0 Climate Change Initiatives in Cape Town

The establishment of the City's Energy Committee as well as the launch of the City's Development Strategy process has yet to leverage the political support needed to highlight the links between climate change and biodiversity. Current political focus from a climate change perspective is to reduce energy consumption, secure energy supply and reduce disaster risks. The Coastal Protection Zone work has progressed significantly but if successful will provide only a measure of protection to ecosystems and biodiversity sites located directly along the city's coastline.

4.1 Current Initiatives

Climate Change Think Tank

The Climate Change Think Tank was launched in 2009 to establish a climate change mitigation and adaptation research group that creates on-going collaboration, interface and dialogue between academic institutions, researchers, specialists and local government officials to inform, shape and drive the implementation of progressive, pragmatic and effective policies, programmes and on-the-ground interventions at the local level in understanding and preparing for climate change.

Energy and Climate Action Plan

Although termed the Energy and Climate Action Plan (ECAP), this plan includes mainly climate change mitigation related projects, focused primarily on energy efficiency: reducing wastage and future demands and maximising renewable energy sources. For example, Objective 1 is a city-wide 10% reduction in electricity consumption on unconstrained growth by 2012 using a range of tools from metering to limiting supply to new developments and promoting green building design. Growth in energy demand is to be focused on renewable energy supply. This is a cross-cutting plan across line departments and will apply to the Council itself as well as the city at large. It is not clear how this initiative will benefit the local ecosystems and biodiversity of Cape Town; in fact renewable energy generation methods such as wind and hydro power do have significant negative biodiversity impacts at a local level. The benefit to biodiversity would likely play out at a much larger scale and over a longer time-frame through the eventual reduction in CO_2 emissions mitigating global warming effects.

Climate Adaptation Plan of Action

The City's Climate Adaptation Plan of Action (CAPA) takes a sector-based approach to adaptation actions, with strong links to biodiversity's role in maintaining the resilience of ecosystems, thus reducing risk to climate change impacts. This is still in the draft stage and should be finalised and ready to take through Council later in 2011. This will be reviewed every 5 years.

Coastal Protection Zone

Due to the high desirability of Cape Town's coastline, it is becoming subject to increasing pressure. Increased levels of coastal erosion, permanent loss and destruction of dune systems, loss of fauna and flora, loss of recreational opportunity, loss of sense of place and aesthetic appeal and increasing levels of wind-blown sand problems have made the coastline extremely unstable. These coastal risks are only expected to increase into the future as a result of a changing climate and an increase in sea level rise and storm surge events (City of Cape Town, 2010). The proposed Coastal Protection Zone is currently being established by the City as a means to protect, manage and formalise its coastal zone with the intent of protecting its economic future and social opportunity, lowering environmental and social risk, reducing current and future management costs, complying with legislation and ensuring equitable coastal access and opportunities for all into the future. Overall, the intent is to retain the coast as an asset to the City, rather than an economic burden.

Sustainable stormwater management through policy measures

The City's "Floodplain and River Corridor Management Policy", approved in 2009, provides for the protection of property as well as the environment by requiring that developments are set back beyond the flood prone area or the river-wetland buffer zone, whichever is the greater. Development and associated activities are permitted, conditionally permitted or prohibited within the floodlines depending on the "type" of development. The requirement that a buffer is established adjacent to rivers and wetlands could potentially assist with climate change adaptation since the integrity and resilience of these aquatic ecosystems should, in part, be ensured by the buffer.

In a broader context, the City has embedded within its Spatial Development Framework the concept and philosophy of Water Sensitive Urban Design (WSUD) which requires that urban areas and their potable water, sewage and stormwater systems are purpose-built and designed in a manner that mimics natural hydrological and ecological processes, and integrates them within the urban landscape. WSUD provides the framework for a second policy entitled "Management of Urban Stormwater Impacts", also approved in 2009, which is focused specifically on urban stormwater and is applicable throughout the catchment, not just adjacent to aquatic ecosystems like the first policy mentioned above. It requires that new developments take steps to ensure that stormwater quantity and quality are addressed on site using various best practice structural and non-structural controls which are collectively known as Sustainable Urban Drainage Systems (SUDS). By ensuring that the volumes and rates of stormwater leaving a development site are reduced and that stormwater quality is improved, the impacts of urban stormwater on receiving aquatic environments will also in theory be reduced. The policy also encourages infiltration (determined on a case specific basis depending on the suitability of the site and the anticipated quality of stormwater). Thus this policy may also indirectly assist with ensuring integrity and resilience of aquatic ecosystems.

It is also relevant that the City has taken the view that its "urban stormwater system" does not only comprise the built infrastructure such as gutters, inlets, pipes, but actually includes the network of natural/ semi-natural rivers and wetlands traversing the city. This definition of Cape Town's stormwater system requires a holistic management approach that is grounded in the philosophy of integrated urban water management.

Biodiversity Strategy

It has been widely recognised that reaching biodiversity conservation goals through climate change adaptation and mitigation efforts offers many opportunities. Other City initiatives could result in climate change adaptation and mitigation as co-benefits. These include the following:

- Management Effectiveness Tracking Tool (improved management of reserves)
- Invasive Alien Species Policy and implementation thereof
- Ecological restoration. Only small interventions and research projects exist at this stage. Sections of nature reserves and other Biodiversity Network sites are degraded and in need of ecological restoration. For example, in Table Mountain National Park, harvesting of pines has resulted in these areas of formerly species-rich Cape Flats Sand Fynbos and Peninsula Granite Fynbos being restored. The Working for Wetlands Programme which uses manual labour to rehabilitate degraded wetlands is a national initiative currently running projects within the city.

4.2 Future Initiatives

Under impending climate change and knowledge of the high threat to the city's biodiversity, several additional projects should be undertaken to enhance resilience:

- **A review of the Biodiversity Network with regard to maximising climate change adaptation and identifying terrestrial and wetland habitats requiring urgent restoration.** There is a need to develop a methodology to identify (1) where functional ecosystems persist in Cape Town and (2) the type of ecosystem services delivered. A pilot study on this topic was recently completed (O'Farrell & Le Maitre 2011) as one of the LAB Biodiversity and Climate Change projects. It is planned to extend this study to cover additional ecosystem services. Maps of these ecosystems and related services, and categorising the feasibility of securing and restoring them, would allow for establishing targets.
- **Restoration of degraded terrestrial (including coastal dune systems) and wetland sites in order to promote biodiversity and ecosystem services as well as improve climate change adaptation.** Linking these projects to disaster risk adaptation could help leverage funding for this proactive approach.
- **Communication to politicians and officials on the importance of biodiversity in climate change adaptation and mitigation.** This will form part of Cape Town's Communication, Education and Public Awareness (CEPA) project.

5.0 Acknowledgements

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