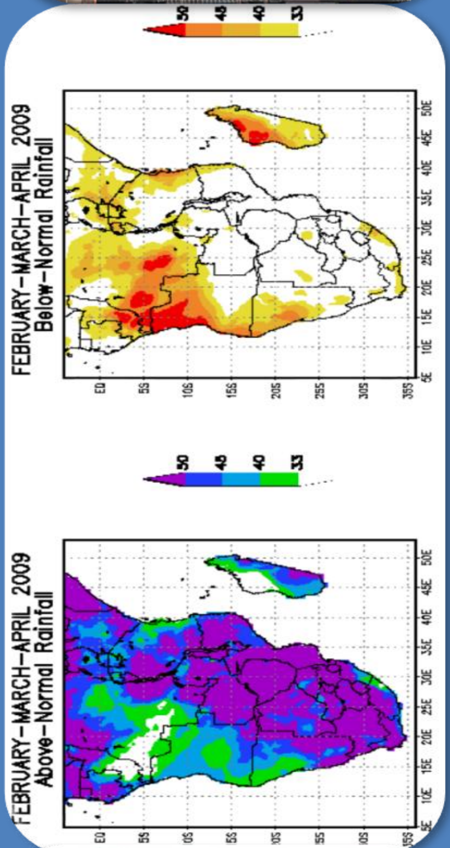

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CLIMATE CHANGE ADAPTATION PLAN

City of Johannesburg

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Contact

It is likely that this document is updated and improved over time. Should you have any suggestions please email suggestions to Linda Phalatse at LindaP@joburg.org.za

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EXECUTIVE SUMMARY

There is broad international consensus that some degree of climate change, including an increase in extreme weather, is almost certain to be experienced due to past and present emissions of greenhouse gases and regardless of any emission reduction measures that may now be undertaken.

Climate model projections for the City of Johannesburg (CoJ) indicate that the local climate is likely to become both significantly hotter and more humid in future. The models suggest that temperatures for the CoJ may increase by around 2.3°C by the near future (2056 - 2065) and by around 4.4°C by the far future (2081 - 2100). Additionally, there is a substantial risk that the CoJ will experience an increase in annual rainfall characterised by a higher frequency of storm events and a longer rainy season (finishing later in the autumn and possibly starting earlier in the spring).

As a result of these and other projected climatic changes, a number of risks have been identified and which have been categorised according to a four-tiered scale (or 'Action Level') based upon the potential magnitude of the risk's impact as well as the likelihood of the risk eventuating. The tiered action levels are:

- Action Level A: Prioritise for Adaptation
- Action Level B: Review Opportunities / Adapt within Constraints
- Action Level C: Surveillance Monitoring
- Action Level D: No Concern

The risks identified as Action Level A - Prioritise for Adaptation are:

- Risk T1: Increase in Heat-Related Deaths
- Risk T2: Increased Energy Demand
- Risk T3: Increased Water Demand (within the CoJ)
- Risk TP5: Biodiversity Impacts on Disease Vectors (Health Risks)
- Risk P1: Urban Flood Risk - Damage to Water Supply & Sanitation Infrastructure
- Risk P2: Urban Flood Risk - Damage to Property, Personal Injury and Impacts on Livelihood
- Risk P3: Urban Flood Risk - Increased Road Accidents and Traffic Congestion
- Risk P4: Urban Flood Risk to Electrical & Telecom Infrastructure
- Risk X1: Disruption to Water Security (arising from outside the CoJ)
- Risk X2: Climate-Change-driven Refugees and Migrants

An additional twelve Action Level B-rated risks were also identified and which will warrant further attention in future, including the risk of increased shack and veld fires and the risk of disruption to food security. This report (the first iteration of the climate change adaptation plan for the CoJ) has focused on the highest priority (in terms of climate change) Action-Level A-rated risks.

A key issue highlighted in this study is that much of the CoJ's climate change-related vulnerability stems from the fact that several of the systems considered most likely to be impacted upon by climate change are already severely stressed under existing climatic conditions. This is particularly true for the CoJ's stormwater infrastructure - of the ten Action Level A-rated risks, four are related directly to the threat of an increase in urban flooding. It is the existing strain on the stormwater infrastructure that potentially gives rise to the greatest cause for concern.

A wide range of adaptations have been developed for each of the Action Level A-rated risks and with consideration to the specific needs, constraints and requirements of the CoJ. In addition to these risk-specific adaptations, a number of strategic-level adaptations have also been identified which have the potential to address a broad number of risks across multiple sectors. These strategic adaptations are regarded as being fundamental for the CoJ's effort to effectively adapt to evolving threat of climate change. The strategic adaptations focus on the following areas:

- Integrating climate change adaptation into existing strategic planning mechanisms
- Developing alternative financing options for the funding of adaptations
- Developing an Information Management System to support ongoing climate change risk assessment and cost-benefit analysis
- Maintaining and expanding stakeholder engagement

Effective implementation of these and other risk-specific adaptations will require commitment at both the planning and resource level from a broad range of CoJ departments, municipal entities and other stakeholders. More importantly, it will rely on effective communication and coordination among the different role-players. Hence it is advised that the Department of Environment take an active role in facilitating this coordination and communication wherever the need arises.

This report also makes a start to the process of assessing the relative prioritisation of adaptations. This process will have to be developed further, both in terms of additional stakeholder engagement with senior CoJ management and in terms of identifying and collating the metrics necessary for determining baseline and future projected costs/benefits. However, it is noted that even with substantial future effort in collating relevant metrics there is likely to be numerous instances where there is insufficient information to allow for accurate cost-benefit analysis (as is typically the case for most cities globally). Therefore future prioritisation of risks and adaptations will also require the use of economic tools other than traditional cost-benefit analysis. The absence of specific damage cost estimates should not provide a basis for inaction. This report presents a preliminary qualitative estimate of both costs and benefits of adaptation actions, which in turn provides sufficient support for decision-makers within the CoJ to prioritise actions and resources during the preliminary phases of adaptation while simultaneously developing and strengthening the framework for more comprehensive cost-benefit analysis in future.

1. INTRODUCTION

1.1 Background

Most policy, action and debate on climate change to date has been concerned with mitigation, that is to say, limiting the severity of the long term consequences of climate change by reducing greenhouse gas emissions. By contrast, adaptation recognises that regardless of any action we might take, some degree of climate change and an increase in extreme weather is already inevitable due to our past emissions. Consequently, it is prudent for any society to consider their potential vulnerability to climate change impacts and to adopt sensible adaptations.

This project is aimed at addressing the adaptation requirements for the City of Johannesburg (variously referred to as the CoJ or the City) and its people. Hence its focus is on adaptations applied from within the City's municipal structures. This report, the City of Johannesburg Climate Change Adaptation Plan (CoJ CCAP), includes an assessment of climate model projections for the CoJ region, a risk assessment based upon that analysis and an integrated adaptation plan cutting across all the major sectors of the CoJ. The plan seeks primarily to provide an indication on the scale and nature of the climate change vulnerabilities facing key sectors, to prioritise the associated risks, to propose adaptive actions including identifying where further studies are required, and to provide a preliminary indication of the scale of potential costs and benefits associated climate change adaptation for the CoJ. The project has been undertaken with input from the various municipal departments and structures, both via published reports as well as through stakeholder participation, for example through the CoJ Joint Climate Change Coordination Committee. Stakeholders external to the CoJ have been identified where possible for future engagement.

Johannesburg hospital and skyline

1.2 Policy Framework

South Africa is by far the largest emitter of greenhouse gases (GHGs) in Africa and is one of the most carbon emission-intensive countries in the world due to its energy intensive economy and high dependence on coal for primary energy. In world terms we are the 11th highest emitter of greenhouse gases (National Climate Change Response Policy, 2009).

In August 1997, the South African Government ratified the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Under this convention, developing countries such as South Africa, while not obligated to reduce greenhouse gases, agreed to fulfil specific commitments, a number of which were directly related to adaptation, namely:

- To formulate and implement national and, where appropriate, regional programmes to mitigate climate change and facilitate adequate adaptation to climate change; and
- To co-operate in preparing for adaptation to the impacts of climate change.

The Department of Water Affairs and Environment (DWAE, formerly the Department of Environment and Tourism or DEAT) has been designated as the responsible governing body to address climate change within South Africa. However, to achieve this DWAE requires support and involvement of other national, regional and local governing bodies. This is particularly important when considering that the implementation of adaptation plans are typically specific to local areas and are therefore better formulated, managed and implemented at the municipal level.

In an effort to meet their responsibility DEAT, in 2004, developed 'A National Climate Change Response Strategy for South Africa'. The strategy is aimed at government and its associated institutions, including all public sector funding and implementing agencies, requiring that they access appropriate funds - such as investment through the Clean Development Mechanism (CDM) and financing institutions linked to government (i.e. the Industrial Development Corporation and the Development Bank of South Africa) - for the implementation of the climate change programme, and in particular for adaptation purposes This Strategy therefore, places an obligation on the CoJ to address climate change adaptation. More recently, the National Climate Change Response Policy was issued as a discussion document in March 2009, which marks the commencement of a policy development process which will ultimately result in a legislative, regulatory and fiscal package on Climate Change for South Africa. The first step in this process will be the publication of a Green Paper for public comment in April 2010.

The CoJ has already begun to take action. This is evidenced by the development of the Johannesburg Climate Change Strategy and Action Plan produced in 2008. The strategy identifies Johannesburg's emissions and recommends ways to reduce or mitigate these emissions. In addition, the strategy encourages the City to continue its efforts to identify future impacts of climate change and to begin the process of adapting to these impacts.

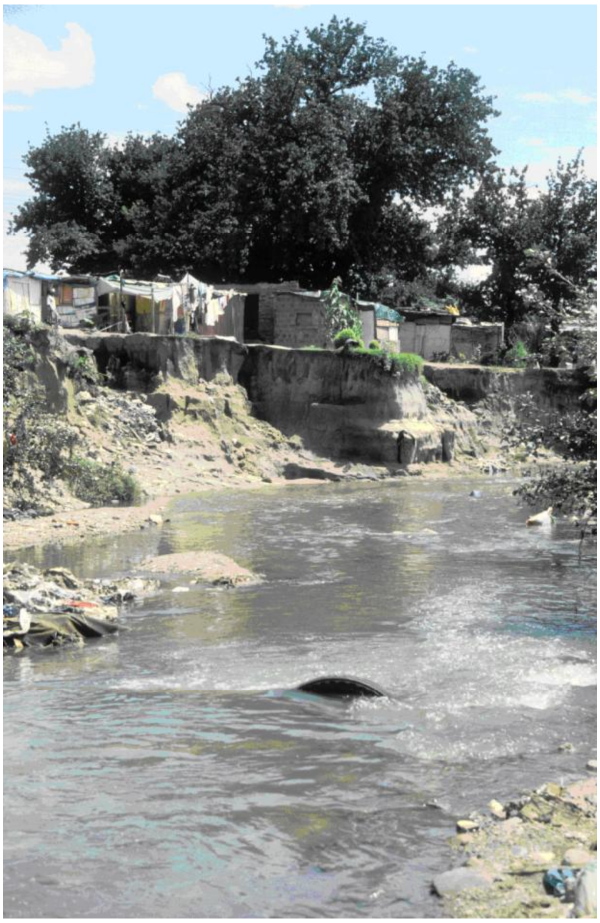
In addition to the above commitments, the CoJ is part of the international C40 initiative whereby officers in charge of environmental policies from 40 of the largest cities in the world co-operate in tackling climate change and sustainability issues. At the C40 Tokyo Conference on Climate Change in October 2008, the CoJ committed to, among other actions, the following joint actions which relate either directly or indirectly to climate change adaptation:

- Joint Action 1: Keeping cities cool - urban development to save energy and reduce waste heat;
- Joint Action 4: Promotion of water leakage prevention and provision of technical information;
- Joint Action 5: Sharing information on activities to expand reuse of wastewater;
- Joint Action 6: Promotion of flood control measures to adapt to effects of climate change;
- Joint Action 7: Establishing evacuation and information delivery systems for disasters;
- Joint Action 10: Appealing to central governments about worldwide food issues; and
- Joint Action 12: Developing heatwave plans for urban areas.

1.3 Mitigation versus Adaptation

Adaptation is often seen as secondary to mitigation. However, the development of future policy needs to address this in order to ensure that the appropriate balance between adaptation and mitigation is achieved. In 2007 the International Panel on Climate Change (IPCC) 4th Assessment Report highlighted that impacts and risks of climate change are more imminent and severe than previously thought and between 2050 and 2100 climate change could have a disastrous impact on economies, society, security, development and social safety net systems, particularly in poor countries. Therefore, it is essential that actions such as building climate change resilience (i.e. adapting) take place in parallel with efforts aimed at mitigation.

1.4 Comparative Vulnerability of the CoJ



By international standards, and even within South Africa, Johannesburg has relatively limited exposure to the most severe consequences of climate change. This is largely due to the fact that Johannesburg is not located on a coastline nor is it in an area heavily affected by major weather-related natural disasters such as hurricanes or typhoons. An assessment undertaken in 2008 by Mastercard Worldwide Insight[1] rated Johannesburg as the fourth best placed city out of 21 major cities from Asia, the Middle East and Africa in terms of exposure to climate change-related risks.

Despite this, the projected impacts for the CoJ may nevertheless be significant and substantial. In the context of the CoJ, climate change can generally be seen as one of several significant pressures, although not necessarily the most important in the short term. In some instances, the CoJ's climate change vulnerabilities arise from serious existing issues such as urban flooding, which may potentially be exacerbated by relatively moderate changes in climatic conditions. In order to prevent these issues becoming even more acute in the future, the CoJ will have to integrate consideration of the effects of climate change with both policy and operational activities.

The CoJ may also be significantly exposed to climate change impacts that occur elsewhere in the world, in particular with respect to food and water security and climate change-driven migration/refugees. These issues will also need to be considered and integrated into current planning.

[1] Urbanisation and Environmental Challenges in Asia/Pacific, Middle East and Africa - Ranking of Worldwide Centers of Commerce. Mastercard Worldwide Insight, 2008.

2. METHODOLOGY

2.1 Risk Assessment Methodology

Risk assessment methodologies applied to adaptation planning both in South Africa and internationally are generally comparable and are based upon similar founding principles. This assessment has, in broad principle, adopted the UK Climate Impacts Programme (UKCIP) standard[2] as the basis for the risk assessment methodology. Reference has also been made to other adaptation planning initiatives internationally as well as elsewhere in South Africa at both the municipal and provincial level, and methodologies and tools have also been borrowed from these efforts where appropriate. The risk assessment methodology has been developed with consideration to the UK Risk Management Standard[3] developed by, among others, the ALARM National Forum for Risk Management in the Public Sector.

The flow chart below summarises the UKCIP decision making process for the adaptation planning. It emphasises the role of feedback and interaction between the different decision-making stages. The CoJ adaptation plan presented here accounts for stages 1 - 5 of this process.

In terms of identifying the potential impacts of climate change, methodologies generally rely either upon Vulnerability Assessments - identifying risks based upon historic vulnerabilities to weather events - or upon Scenario Analysis - identifying risks based upon scientific modelling of future climatic conditions under different socio-economic scenarios and assessing

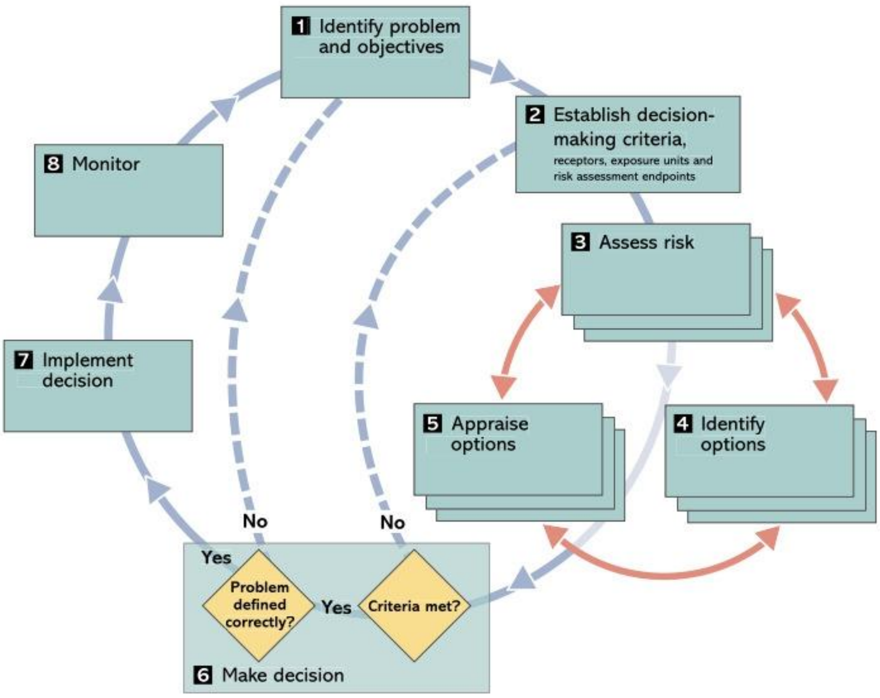


Figure 1: Decision Making Framework (UKCIP, 2006)

[2] Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report, May 2003

[3] A Risk Management Standard. AIRMAC, ALARM & IRC, 2002

potential impacts. This assessment has relied upon a combination of both techniques for identifying potential risks to the CoJ. A glossary containing many of the terms commonly used in vulnerability assessment and/or adaptation planning is included in Appendix A.

2.2 Climate Modelling Methodology

At the time of commissioning this adaptation plan, the information available regarding predicted climate change for the CoJ region was relatively limited. Consequently, one of the primary objectives of this project was to commission an extensive analysis of current and predicted climatic trends for the CoJ region. The climate modelling was undertaken by the University of Cape Town (UCT) Climate Systems Analysis Group (CSAG), whose members include contributors to the IPCC Working Groups I and II. The CoJ technical climate modelling report is included as a supplementary technical report; the results are summarised further on in this report.

The climate modelling technique is based upon the statistical downscaling of seven internationally accepted climate models or General Circulation Models (GCM's) - each of which have their own underlying assumptions and biases. The database used for the statistical downscaling was built up from historic data sourced from eight weather stations based in and around the CoJ. These stations were subjected to stringent quality control checks with respect to their data before being accepted for use in the modelling. The use of seven GCM's allowed for seven separate climate projections to be made for any particular time slice. Hence the modelling results indicate the spread of values as predicted by these different models for each time period.

The climate modelling was applied to three time periods: a control period (1961 - 2000)[4]; the near future (2046 - 2065); and the far future (2081 - 2100) for a range of climatic variables such as temperature and precipitation.

It is worth noting that by 2100, or even by 2050, the world will have changed in ways that are difficult to predict. The Intergovernmental Panel on Climate Change (IPCC), in their Special Report on Emissions Scenarios (SRES), has developed four scenarios for the future where each scenario assumes a distinctly different direction for future development and hence for factors that affect the climate model output. This study has adopted the A2 scenario for its climate modelling projections. The A2 scenario essentially represents a continuation of the world as it is or a 'business as usual' scenario and it may therefore be regarded as the most realistic and defensible of the scenarios. This is particularly true for the "near future" timescales we are considering (i.e. by mid-century), where it is unlikely that any amount of carbon emission reductions that may (realistically) be achieved would significantly change the broad projected outcomes from a climate change perspective, due to the lag in response between changes in emissions and climate change.[5] Further information regarding the various IPCC/SRES scenarios is included in Appendix B while further comments regarding inherent uncertainty and other limitations of the modelling methodology is included in CSAG supplementary technical report.

The climate modelling analysis also included an assessment of existing trends in temperature and precipitation in the CoJ region, based upon historic data from the Krugersdorp weather station (see CSAG supplementary technical report for details). This station was selected as it was the only station with sufficient (in terms of both quantity and quality) historical data within or nearby to the CoJ region to allow for a statistically rigorous analysis[6]. The trend analysis was performed over the period 1961-2006.

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[4] The analysis of the control period involves a statistical computer-generated prediction of the weather conditions for the period 1961 - 2000, and is not the actual historical weather conditions experienced at that time (although it produces results similar to the historical data). The control period output is used to provide a measure of the predicted change in climatic variables when compared to the statistical projections for the near and far future periods.

[5] Differing future scenarios are likely to be more relevant for the long term modelling projections i.e. for the "far future" (2086 - 2100).

[6] Additional weather station data may be incorporated in future as data accumulates, provided appropriate quality control measures are in place.

3. CLIMATE CHANGE AND THE COJ

3.1 Geography of the CoJ

The CoJ Metropolitan Municipality is located on the north-eastern plateau of South Africa known as the Highveld, at an elevation of approximately 1,700 metres above sea level, within the Province of Gauteng. The landlocked Province of Gauteng is both the smallest and wealthiest of South Africa's provinces.

Johannesburg is the largest city in South Africa. It is the commercial, industrial and financial hub for the country and is home to the Johannesburg Securities Exchange, Africa's largest exchange and the seat of the provincial government for Gauteng. Johannesburg, almost uniquely for a major metropolis, is not located on a navigable river or estuary, nor does it have a seaport. Include photo of New JSE

The municipal area of the CoJ covers approximately 1,640 sq kilometres[7]. According to the 2001 national census, the population of the CoJ was estimated at 3.2 million people. In 2007, the City of Johannesburg was home to close on 3.9 million people. When compared to 2001, translating into an average rate of expansion of 110 480 people per annum. Population estimates for the CoJ by 2010 have varied from 4.3 - 4.6 million people (SoER, 2008).

Spatially, densities differ between locations and income groups, with the highest densities found in the City's informal settlements. Administratively, the CoJ is divided into seven decentralised regions (Regions A - G) which differ in character from highly densified urban areas to low density peri-urban regions. Each region is operationally responsible for the delivery of health care, housing, sports and recreation, libraries, social development, and other local community-based services.

Figure 2: Map of Municipalities of Gauteng[1]

[7] Source: http://www.joburg.org.za/content/view/92/58/ accessed 24 June 2009

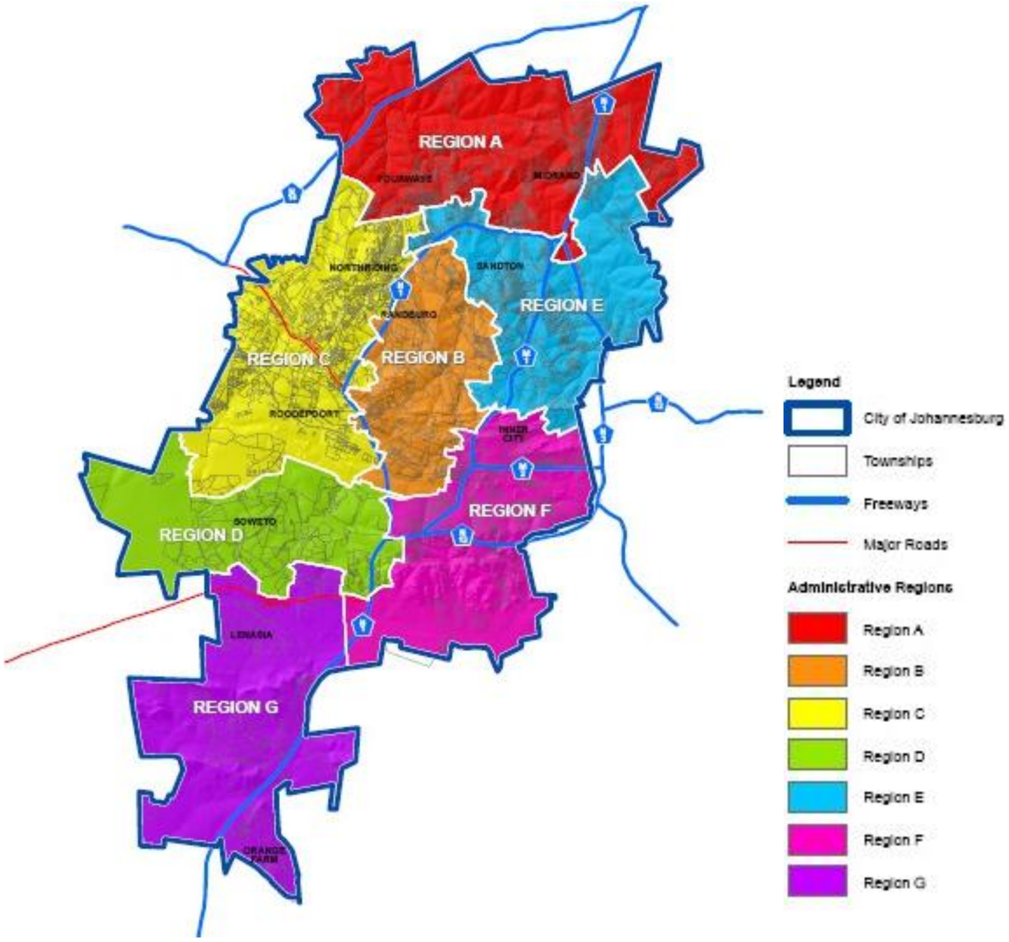

Figure 3: Map showing the administrative regions of the City of Johannesburg (Source: State of the Environment Report, CoJ, 2009)

3.2 Current Climate

The City enjoys a relatively dry and sunny climate. Temperatures in Johannesburg are usually fairly mild due to the City's high altitude, with an average maximum daytime temperature of 25 °C in the summer, dropping to around 17 °C in winter. In winter the temperature occasionally drops to below freezing at night, causing frost. Snow is a rare occurrence, having been recorded on six occasions in the past 60 years.

The CoJ is located in the summer rainfall region of South Africa with a very clear seasonal cycle; rain events typically occur in the form of late afternoon downpours in the months of October to April, although infrequent showers do occur through the course of the winter months. The annual average rainfall is 713 millimetres, mostly concentrated in the summer months.

Table 1: Climate Data for the CoJ for the period 1961 - 1990

Climate data for Johannesburg							
Position: 26° 08' S 28° 14' E			Height: 1694m		Period: 1961-1990		
This climatological information is the normalised values and, according to World Meteorological Organization (WMO) prescripts, is based on monthly averages for the 30-year period 1961 - 1990							
Season[1]	Temperature (° C)				Precipitation		
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Recorded	Average Monthly (mm)	Average Number of days/month with >= 1mm	Highest 24 Hour Rainfall (mm)
Summer	35	25	14	4	107	14	188
Autumn	32	21	10	-3	53	8	92
Winter	26	17	5	4	6	2	31
Spring	33	24	11	-3	72	10	110
Year	35	22	10	-8	713	99	188

Source: www.weathersa.co.za - South African Weather Service (Department of Environment and Tourism).

[1] Seasonal values adapted from monthly data as follows: summer - Dec, Jan & Feb; autumn - Mar, Apr & May; winter - Jun, Jul & Aug; spring - Sep, Oct & Nov.

3.3 Temperature

3.3.1 Current Trends in Temperature

An investigation of existing trends in temperature (as well as in precipitation) in the CoJ region was undertaken using data from the Krugersdorp weather station, as part of this study (see CSAG supplementary technical report for details).

The results showed a clear overall warming trend over the past 45 years. This trend was particularly noticeable for night-time temperatures. While average minimum night-time temperatures rose by up to 0.6℃ per decade, the greatest increase was recorded in the lowest winter minimum nigh-time temperature - which showed an increase of up to 1℃ per decade.

In the CoJ region, the climatology of lowest minimum temperature hovers just below 0℃ during the winter months; therefore this trend of up to 1℃ could potentially be important in determining the number of frost days experienced in the region.

It is noted that attribution of these changes to human-caused climate change is not an automatic conclusion. These changes may be due in part to other factors such as the urban heat island effect and land surface change.

Table 2: Trends in Temperatures 1961-2006 (Krugersdorp weather station)

Season	Average Maximum Day-time Temperature	Average Minimum Night-time Temperature
Summer	-	small ↑ trend
Autumn	↑ (up to 0.5°C per decade)	↑ (up to 0.6°C per decade)
Winter	small ↑ trend	↑ (up to 0.6°C per decade)
Spring	-	small ↑ trend

- no clear trend identified

Ref. CSAG technical report in CSAG Supplementary Technical Report

3.3.2 Future Trends in Temperature

Based upon the climate models, there is a strong indication that temperatures within the CoJ can be expected to increase significantly over the next four to five decades, with this trend continuing into the following century. The warming trend will have a significant impact on average seasonal temperatures.

The average of the seven climate model projections indicates an annualised temperature increase in the order of 2.4°C by the "near future" and 4.5°C by the "far future", with the largest increases occurring in spring: an increase of 5°C and 5.2°C in average maximum day-time temperature and average minimum night-time temperature respectively by 2081-2100.

Table 3: Increase in Average Maximum Day-Time Temperature[1]

Season	Near Future 2046 - 2065 [2] (Low / Hi [3])	Far Future 2081 - 2100 [2] (Low / Hi [3])
Summer	+2.1°C (1.6 / 2.7°C)	+3.8°C (2.9 / 5.1°C)
Autumn	+2.3°C (1.7 / 2.8°C)	+4.5°C (3.4 / 5.6°C)
Winter	+2.3°C (1.8 / 2.8°C)	+4.5°C (3.7 / 5.0°C)
Spring	+2.6°C (2.2 / 3.0°C)	+5.0°C (3.7 / 5.9°C)
Annual	+2.3°C (1.8 / 2.8°C)	+4.4°C (3.4 / 5.4°C)

[1] The increases are between the modelled Control Period values and Near- and Far-future values.

[2] Represents the average of seven different GCM projections. See CSAG Supplementary Technical Report for details.

[3] Represents the lowest and highest projection among the seven GCM's.

Ref. CSAG supplementary technical report

Table 4: Increase in Average Minimum Night-Time Temperature[1]

Season	Near Future 2046 - 2065 [2] (Low / Hi [3])	Far Future 2081 - 2100 [2] (Low / Hi [3])
Summer	+2.3°C (+1.9 / +2.8°C)	+4.1°C (+3.2 / +5.1°C)
Autumn	+2.6°C (+2.2 / +3.0°C)	+5.0°C (+4.0 / +6.0°C)
Winter	+2.4°C (+1.8 / +2.9°C)	+4.6°C (+3.9 / +5.2°C)
Spring	+2.9°C (+2.2 / +3.2°C)	+5.3°C (+3.9 / +6.1°C)
Annual	+2.5°C (+2.0 / +3.0°C)	+4.8°C (+3.7 / +5.6°C)

[1] The increases are between the modelled Control Period values and Near- and Far-future values.
[2] Temperatures represent the average of seven different GCM projections. See CSAG Supplementary Technical Report for details.
[3] Represents the lowest and highest projection among the seven GCM's.
Ref. CSAGsupplementary technical report

3.3.3 Extreme Temperature

The climate models suggest that temperatures above 30°C will become relatively frequent by mid-century. By the period 2086 - 2100, temperatures above 30°C may account for as much as 30% of all summer days on average (1 in 3 days), compared to the 5% modelled for the control period. An even greater increase in frequency of days exceeding 30°C is projected to occur during the springtime, where nearly half of all spring days are projected to reach temperatures above 30°C by the turn of the century.

The temperature threshold of 35°C currently represents the highest temperature recorded by the South African Weather Service in the CoJ for the period 1961 - 1990 (ref Table 1). By the year 2100, this threshold may be expected to be exceeded on an annual basis, quite possibly during the spring as well as the summer.

Similarly, night-time temperatures are expected to rise significantly. The number of nights where the temperature drops below zero degrees (i.e. "frost days") may become very rare, perhaps disappearing entirely, by the turn of the century.

Extreme temperature is a relative as well as absolute concept. While there is a strong indication of increasing average temperatures, in absolute terms, the prediction for extreme temperatures, relative to the near-future and far-future averages, is more ambiguous. The models suggest that, in future, the frequency of days of relative extreme heat[8] may even fall somewhat during the summer period, while increasing during the spring. On an annual basis, little overall change in frequency is predicted by the models. However it is noted that these extreme temperature events can be expected to occur at significantly higher absolute temperatures than at present.

The frequency of extremely cold nights[9] is not predicted to change substantially even on a seasonal basis, although these may possibly also occur at higher absolute temperatures than at present.

It is noted that there is greater uncertainty with respect to the predictions for extreme temperature events compared to predictions for average temperatures in future.

[8] Measured as days with temperatures exceeding the 90th percentile.

[9] Measured as nights with temperatures below the 10th percentile.

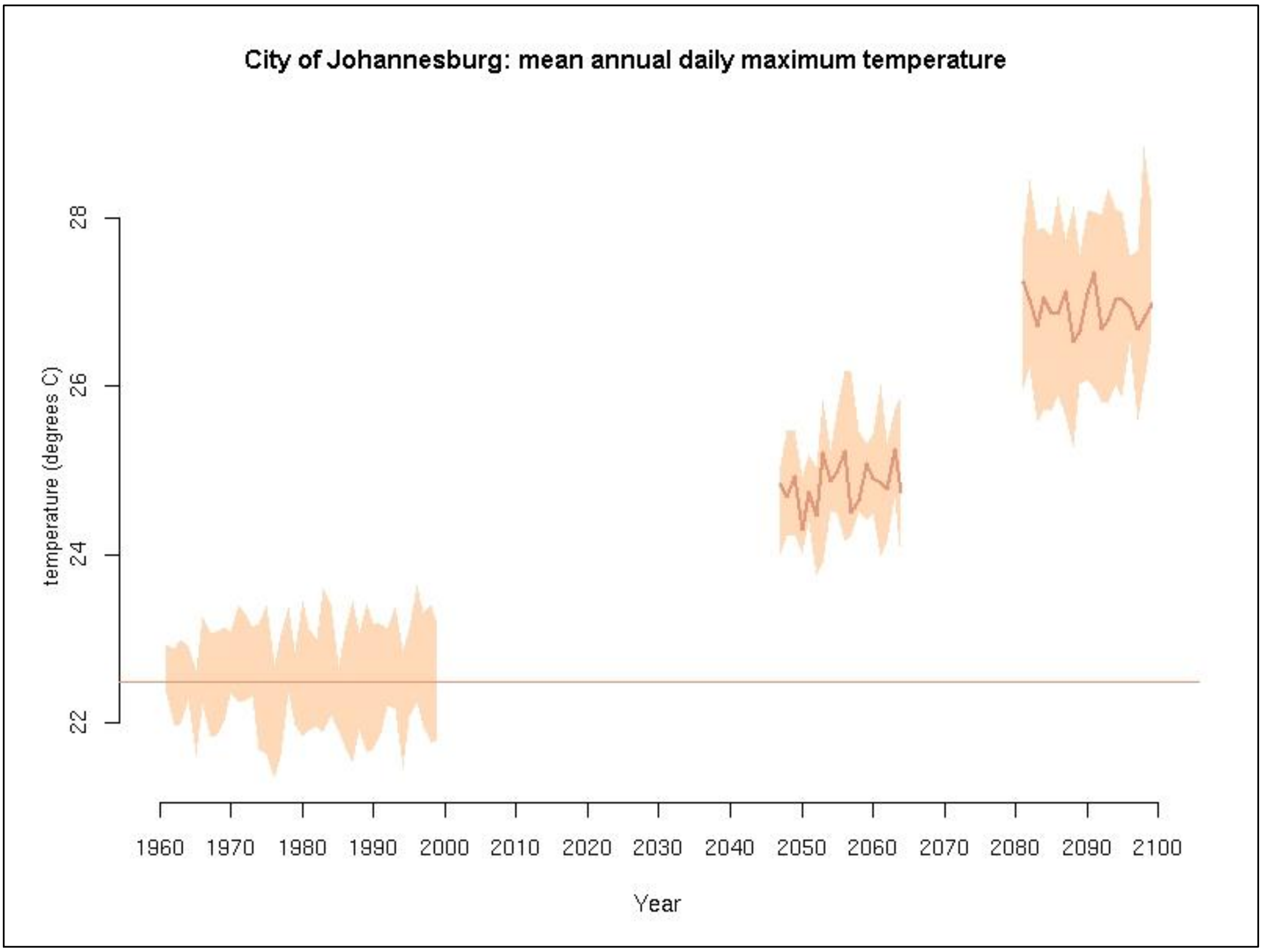

Figure 4: Time series of downscaled mean annual daily maximum surface temperature (°C).
1961-2000 (control period), 2046-2065 (near future) and 2081-2100 (far future) for Johannesburg. The horizontal line represents the long-term median value for the 7 model simulations of the control period. The dark line represents the median value for the 7 projections of the future climate. The shaded area denotes the envelope of these projections (CSAG, 2009).

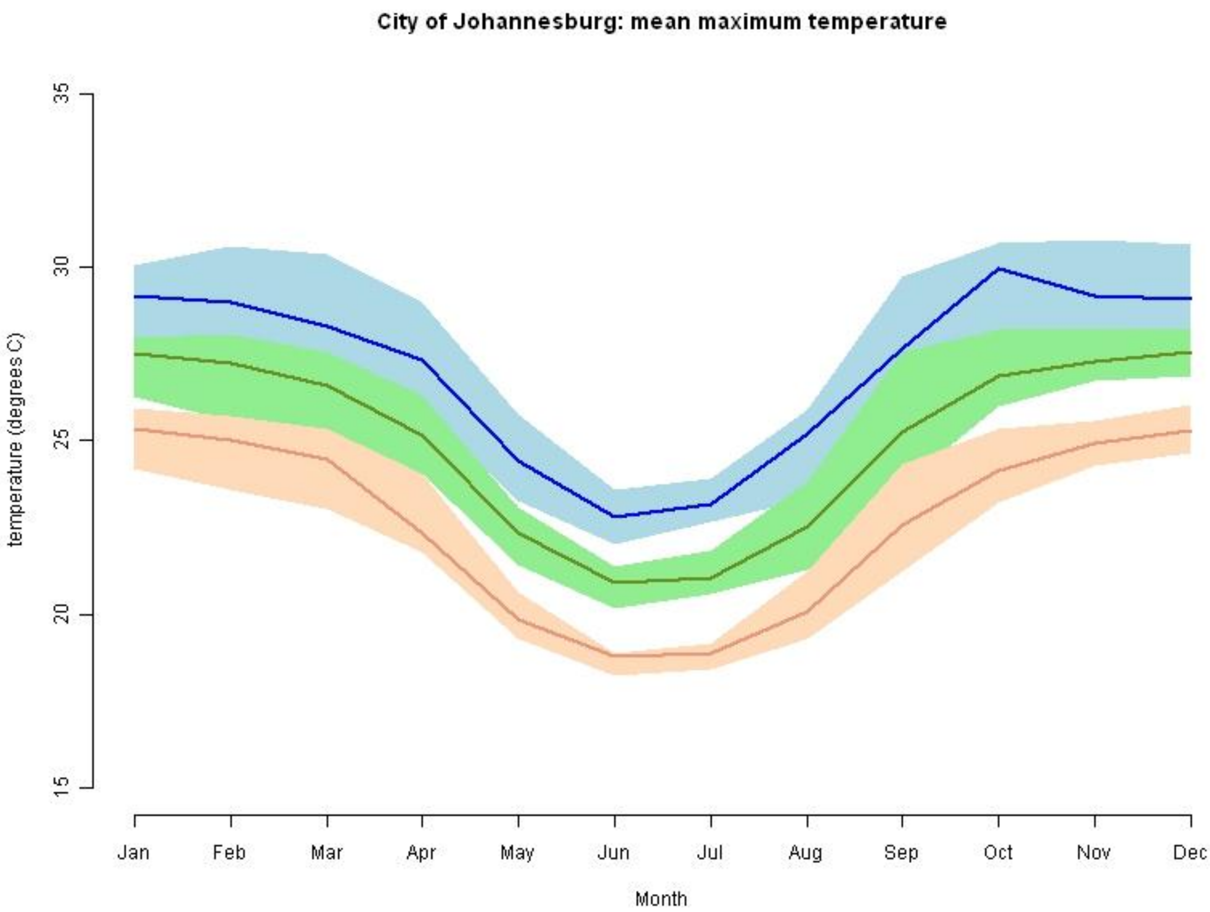

Figure 5: Mean seasonal cycle of downscaled daily maximum temperature (°C).
Control period i.e. 1961-2000 (in orange), the near-future i.e. 2046-2065 (in green) and far-future i.e. 2081-2100 (in blue) periods. The lines are the median values, while the shaded area represents the range or envelope of the seven CGM projections (CSAG, 2009).

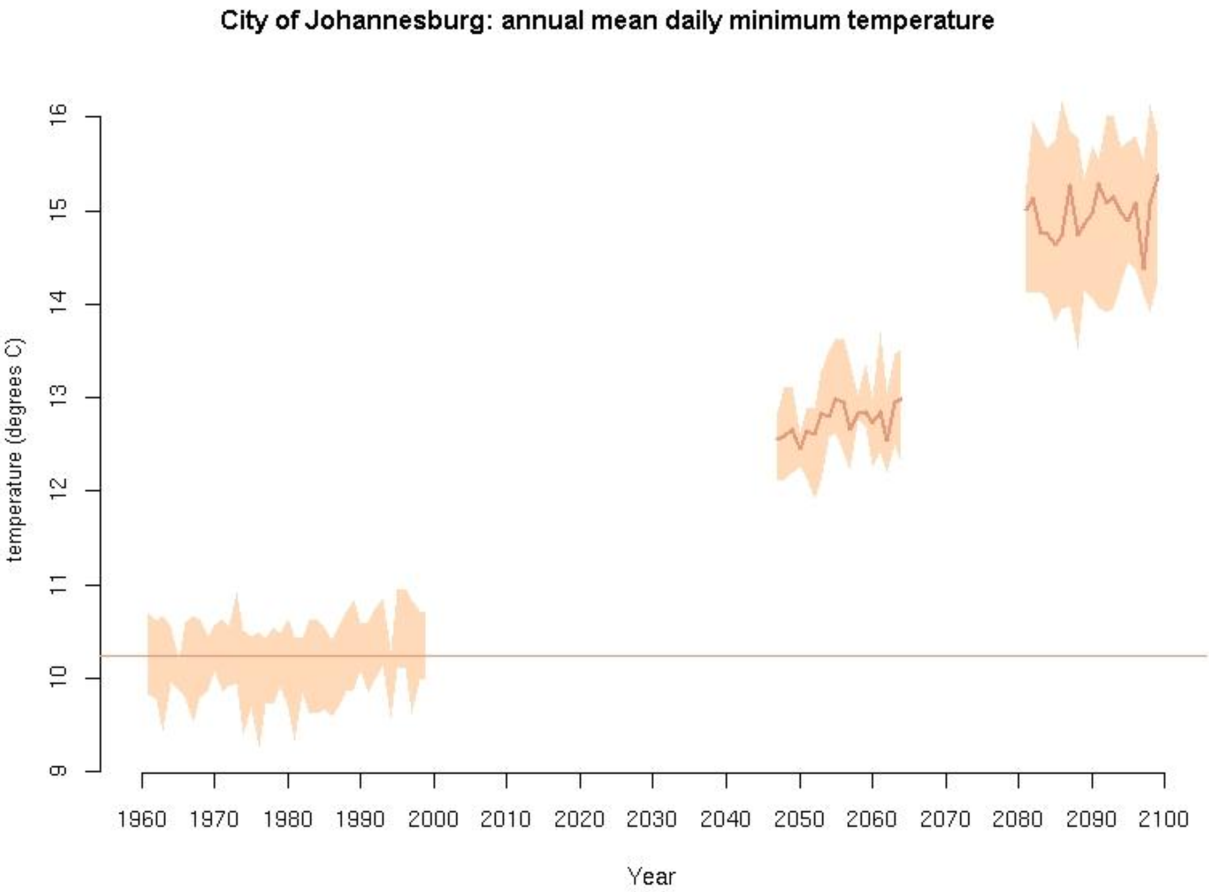

Figure 6: Time series of downscaled mean annual daily minimum surface temperature (°C). 1961-2000 (control period), 2046-2065 (near future) and 2081-2100 (far future) for Johannesburg. The horizontal line represents the long-term median value for the 7 model simulations of the control period. The dark line represents the median value for the 7 projections of the future climate. The shaded area denotes the envelope of these projections (CSAG, 2009).

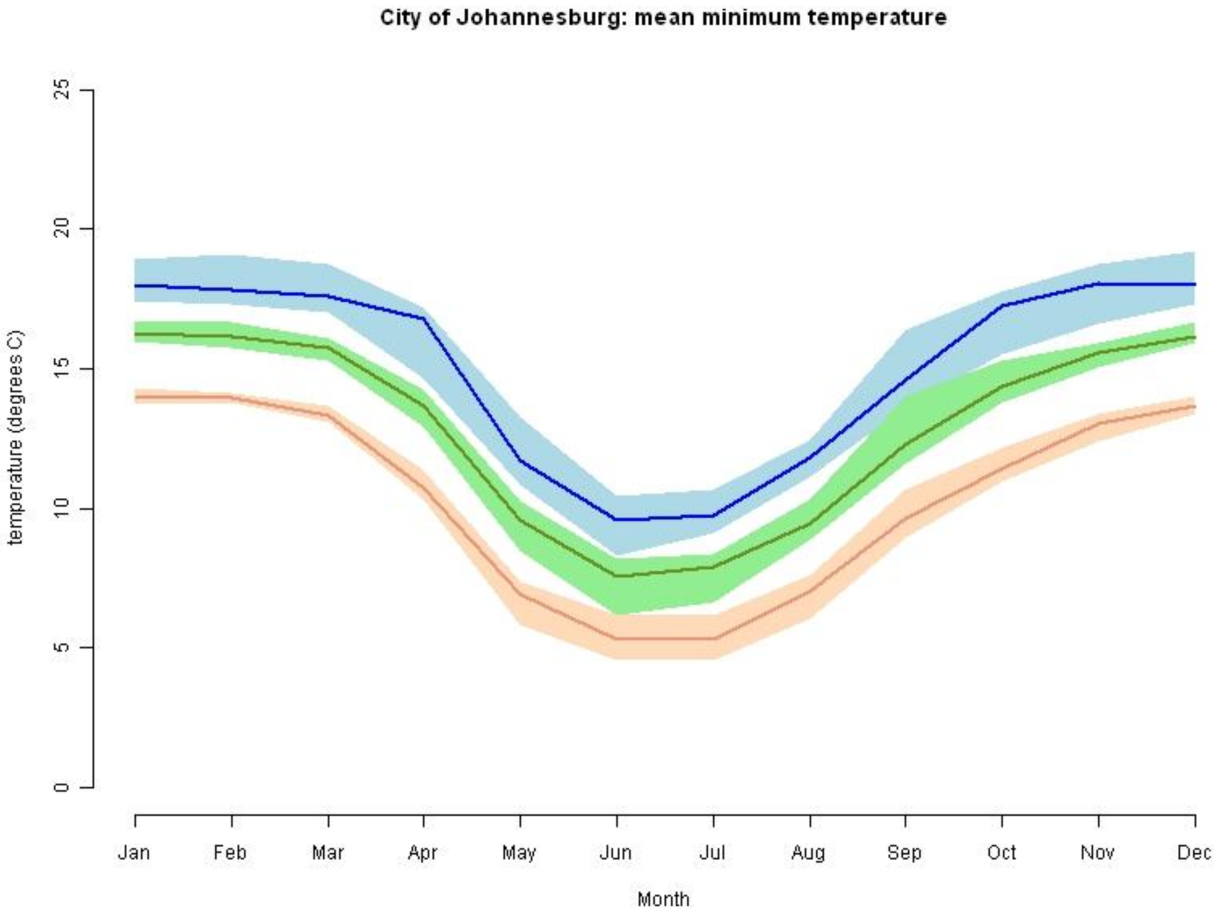

Figure 7: Mean seasonal cycle of downscaled maximum temperature (°C).
Control period i.e. 1961-2000 (in orange), the near-future i.e. 2046-2065 (in green) and far-future i.e. 2081-2100 (in blue) periods. The lines are the median values, while the shaded area represents the range or envelope of the seven CGM projections (CSAG, 2009).

Table 5: Frequency of Temperature Thresholds Exceeded (days/month)

Parameter	Season	Control Period[1,2] (1961 - 2000)	near future[1] (2046 - 2065)	far future[1] (2081 - 2100)
No. of days per month: Temperatures > 30°C	Summer	1.5	5.8	11.4
	Autumn	0.3	2.3	6.1
	Winter	0.1	0.4	2.0
	Spring	1.5	6.6	13.5
	Annual	0.9	3.8	8.2
No. of days per month: Temperatures > 35°C	Summer	0	0.2	0.7
	Autumn	0	0	0.3
	Winter	0	0	0.1
	Spring	0	0.2	1.9
	Annual	0	0.1	0.8
No. of frost days per month: Temperatures < 0°C	Summer	0	0	0
	Autumn	0.3	0.1	0
	Winter	1.2	0.3	0.1
	Spring	0.1	0	0
	Annual	0.4	0.1	0

[1] Values represent the average of seven downscaled climate model projections. See CSAG Supplementary Technical Report for details.
[2] The Control Period values are the climate model-generated simulation for the period 1961 - 2000, and not the actual historical data. They provide a baseline for assessing the projected increase over time.
Ref. CSAG supplementary technical report

3.4 Precipitation

3.4.1 Current Trends in Precipitation

An investigation into existing trends in precipitation in the CoJ region was undertaken based upon data from the Krugersdorp weather station (see CSAG Supplementary Technical Report for details).

Table 6: Trends in Precipitation 1961-2006. (Krugersdorp weather station)

Season	30 Day Total Rainfall	Rainfall per Rain-day	No. of Rain-days (>2mm/day)	No. of Rain-days (>10mm/day)
Summer	-	-	↓ 0.5 - 1.0 day/decade	-
Autumn	small ↓ trend	small ↓ trend	↓ 0.5 - 1.0 day/decade	small ↓ trend
Winter	-	-	-	-
Spring	-	-	-	-

- no clear trend identified, or trend not considered sufficiently robust Ref. CSAG Supplementary Technical Report

The trends in precipitation were less robust than those for temperature; however the analysis suggests that, if there has been a trend, it has been one of a general decline in rainfall from the 1960's to the present. This was most evident in the reduced number of rain-days occurring in late summer through to autumn. It is noted that the SoER 2008 reports that, based on South African Weather Service (SAWS) rainfall data for the CoJ as whole, there appears to be a trend of increasing rainfall in the CoJ. However, this is assessment was based on only a superficial assessment of meteorological data rather than a peer-reviewed or rigorous statistical assessment. Hence the differences between this and the Krugersdorp analysis cannot be readily evaluated.

3.4.2 Future Trends in Precipitation

As precipitation is a far more complex variable to model than temperature, projections for rainfall generally have a greater degree of uncertainty associated with them when compared to the projections for temperature. Despite the higher uncertainty associated with the rainfall predictions, the general indication of among the climate models analysed is that rainfall may be expected to increase moderately, but significantly, into the future[10]. This would potentially be accompanied by a lengthening of the rainy season, particularly into early autumn and potentially starting earlier in spring as well, and an increase in both the frequency and intensity of rainfall[11].

Alternatively, the change in the average of the seven downscaled model projections may be represented as percentages as in Table 8. The average precipitation projections for the seven climate models shows an 18% increase in annual rainfall by mid-century, with a slightly larger increase of 27% projected for the period 2081-2100. The data as summarised in table x is an admittedly crude simplification of the climate modelling data for the CoJ with a consequent high degree of uncertainty associated with the estimated magnitude (based on the average of seven different models). They are not intended to be presented as firm predictions of future rainfall. Despite this limitation, they nevertheless provide for a useful indication of the possible scale of the impacts of climate change on rainfall in the CoJ as well as indicating the probable trend i.e. for increased rainfall. Applying these percentages to the South African Weather Service data shown in table x, gives the following near-future and far-future projections.

There is also a general agreement among the models for an increase in the number of rain days going forward i.e. increased average rainfall may come not only in the form of more intense rainfall events, but also due to an increase in the frequency of rainfall events.

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10 The discrepancy between the potential lessening trend in rainfall at the Krugersdorp station and projected future trends in precipitation can be explained by physical climatic processes and mechanisms that may drive future increased rainfall and which are projected to occur in future but which are yet to have effect; for example the effects of future increased ocean surface temperatures which will significantly influence precipitation patterns for South Africa, including the CoJ region.

11 A different downscaling study using an alternative methodology to the study presented here has also projected the rainy season to extend later into the autumn but did not project the season to start any earlier than at present. (Tadross et al; 2005; On RCM-based projections of change in southern African summer climate, Geophysical Research Letters, Vol 32)

Table 7: Change in Precipitation Projections (mm/month) for the CoJ

Season		Near Future 2046 - 2065 [1,2] (Low / Hi [3])		Far Future 2081 - 2100 [1,2] (Low / Hi [3])
Summer		+6.4 (-2.9 / +17.4)		+9.6 (-0.7 / +21.9)
Autumn		+8.9 (-1.3 / +24.6)		+17.1 (+7.0 / +36.3)
Winter		+2.6 (-2.2 / +7.2)		+4.6 (-1.4 / +10.7)
Spring		+11.7 (+2.9 / +22.1)		+18.9 (+7.7 / +28.0)
Annual		+7.4 (-0.9 / +17.8)		+12.6 (+3.2 / +24.2)

1 The changes are between the modelled Control Period values and Near- and Far-future values.
2 Precipitation values represent the average of seven downscaled GCM projections. Ref. Table 7 -CSAG Supplementary Technical Report
3 Represents the lowest and highest anomaly among the seven downscaled GCM's.
Ref. CSAG Supplementary Technical Report

Table 8: Possible Mean Seasonal Increases (%) in Rainfall for the CoJ

Season		Near Future 2046 - 2065 [1]		Far Future 2081 - 2100 [1]
Summer		+8%		+11%
Autumn		+21%		+39%
Winter		+21%		+25%
Spring		+31%		+44%
Annual		+18%		+27%

[1] Percentages represent the change in the average of seven downscaled GCM projections between the modelled Control Period (i.e. the present) and the Near- and Far-Future.
- Values calculated from Table 6 in CSAG Supplementary Technical Report

Table 9: Mean Precipitation: historic and potential future rainfall figures

Parameter	Season	present[1] 1961 - 1990	near future 2046 - 2065	far future 2081 - 2100
Monthly Average (mm/month)	Summer	107mm	116mm	118mm
	Autumn	53mm	64mm	74mm
	Winter	6mm	7mm	7mm
	Spring	72mm	94mm	103mm
Total	Annual	713mm	841mm	906mm

[1] South African Weather Service. See Table 1.0 for further details. Near and far future figures calculated based on Table 6

Table 10: No. of Rain-days in the CoJ: Control Period vs. Future Periods.

Parameter	Season	Control Period[1,2] 1961 - 2000	near future 2046 - 2065	far future[2] 2081 - 2100
Monthly Average (rain-days/month) >2mm/day	Summer	7.7	8.4	8.6
	Autumn	4.7	5.6	6.5
	Winter	1.3	1.6	1.7
	Spring	4.6	5.8	6.4
Total (days/yr)	Annual	55.2	63.6	69.6

[1] Values represent the average of seven downscaled climate model projections. See Table 5 -CSAG Supplementary Technical Report for details.

[2] The Control Period values are the climate model-generated simulation for the period 1961 - 2000, and not the actual historical data. They provide a baseline for assessing the projected increase over time.

Ref. CSAG Supplementary Technical Report

3.4.3 Extreme Precipitation

Heavy rainfall days (over 10mm/day) are projected to increase moderately into the future. The average of the downscaled model projections is summarised in Table 9 (based on the climate model output in table. Further increases are projected to occur by the turn of the century, but these increases appear to occur predominantly in the autumn and spring. However, the model projections indicate only a marginal increase in the relative frequency of the heaviest of rainfall events (days with precipitation over the 90th percentile). It is noted that there is a significant degree of uncertainty with respect to the projections for extreme precipitation events.

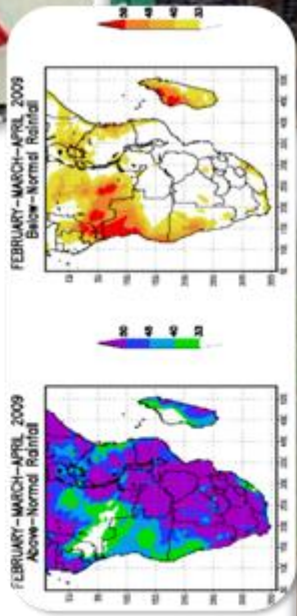
FEBRUARY–MARCH–APRIL 2009
Below–Normal Rainfall
FEBRUARY–MARCH–APRIL 2009
Above–Normal Rainfall

Table 11: No. of Rain-days in the CoJ: Control Period vs. Future Periods.

Parameter	Season	Control Period[1,2] 1961 - 2000	near future[1] 2046 - 2065	far future[1] 2081 - 2100
Monthly Average (rain-days/month) >10mm/day	Summer	3.1	3.4	3.5
	Autumn	1.9	2.2	2.5
	Winter	0.4	0.5	0.5
	Spring	1.7	2.3	2.5
Total (days/yr)	Annual	21.6	25.2	27.6

[1] Values represent the average of seven downscaled climate model projections. See Table 5 -CSAG Supplementary Technical Report for details.

[2] The Control Period values are the climate model-generated simulation for the period 1961 - 2000, and not the actual historical data. They provide a baseline for assessing the projected increase over time.

Ref. CSAG Supplementary Technical Report

The most notable increases appear to occur in the spring and autumn. The increases in winter are not regarded as significant as they come off a very small starting base. Once again it is noted that there is a high degree of uncertainty associated with estimating the magnitude of potential changes in precipitation for the CoJ and consequently this data is only used in order to provide an indication of the possible scale of impact.

Slight increases in the frequency for extreme rainfall events (>90th percentile events) are also projected to occur, although there is a relatively large degree of uncertainty regarding this projection.

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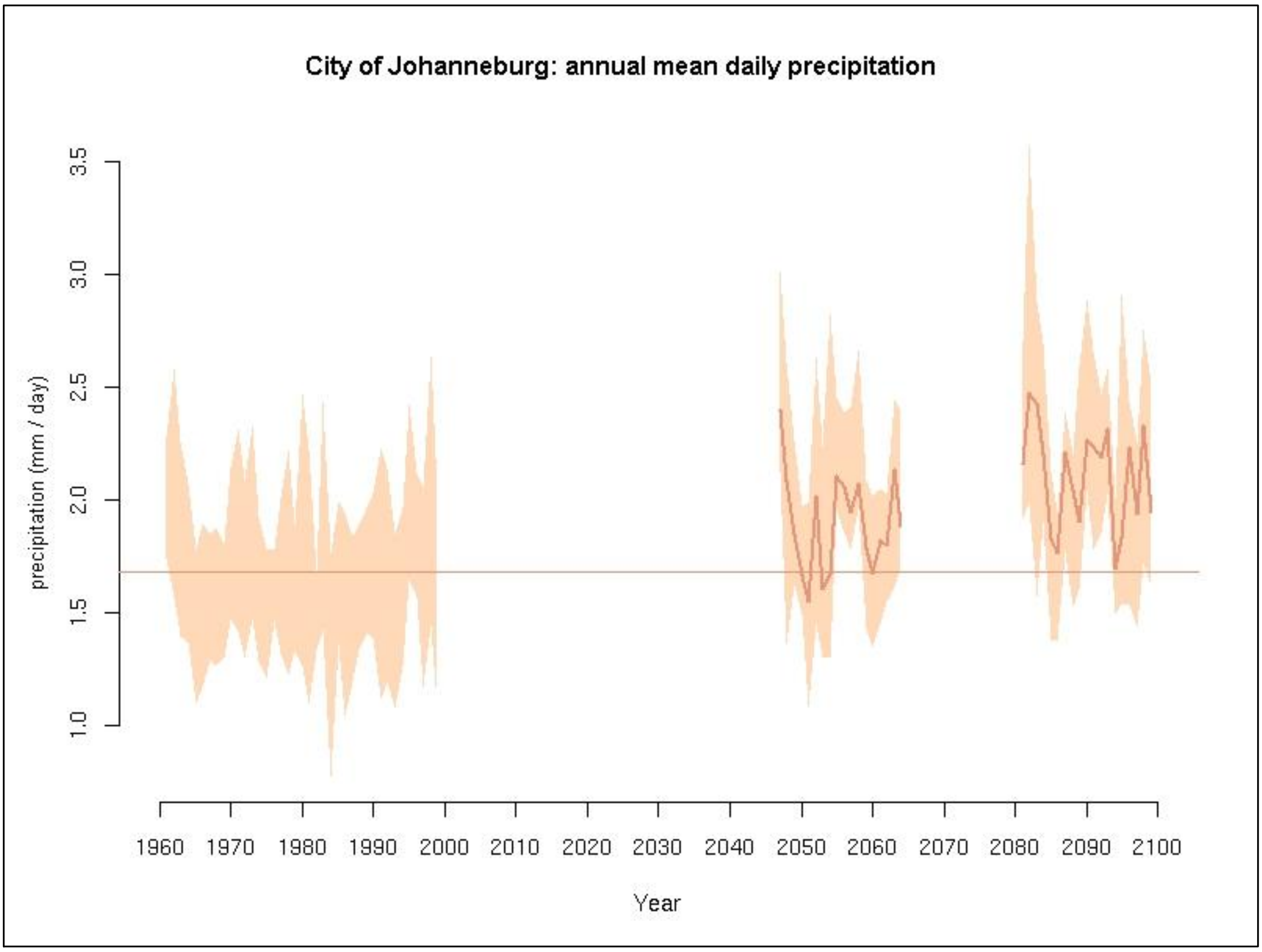


Figure 8: Time series of downscaled mean annual daily precipitation (mm).
Control Period: 1961-2000, near future: 2046-2065 and far future: 2081-2100 for Johannesburg. The horizontal line represents the long-term median value for the 7 model simulations of the control period (1961-2000). The dark line represents the median value for the 7 projections of the future climate. The shaded area denotes the envelope of these projections (CSAG 2009).

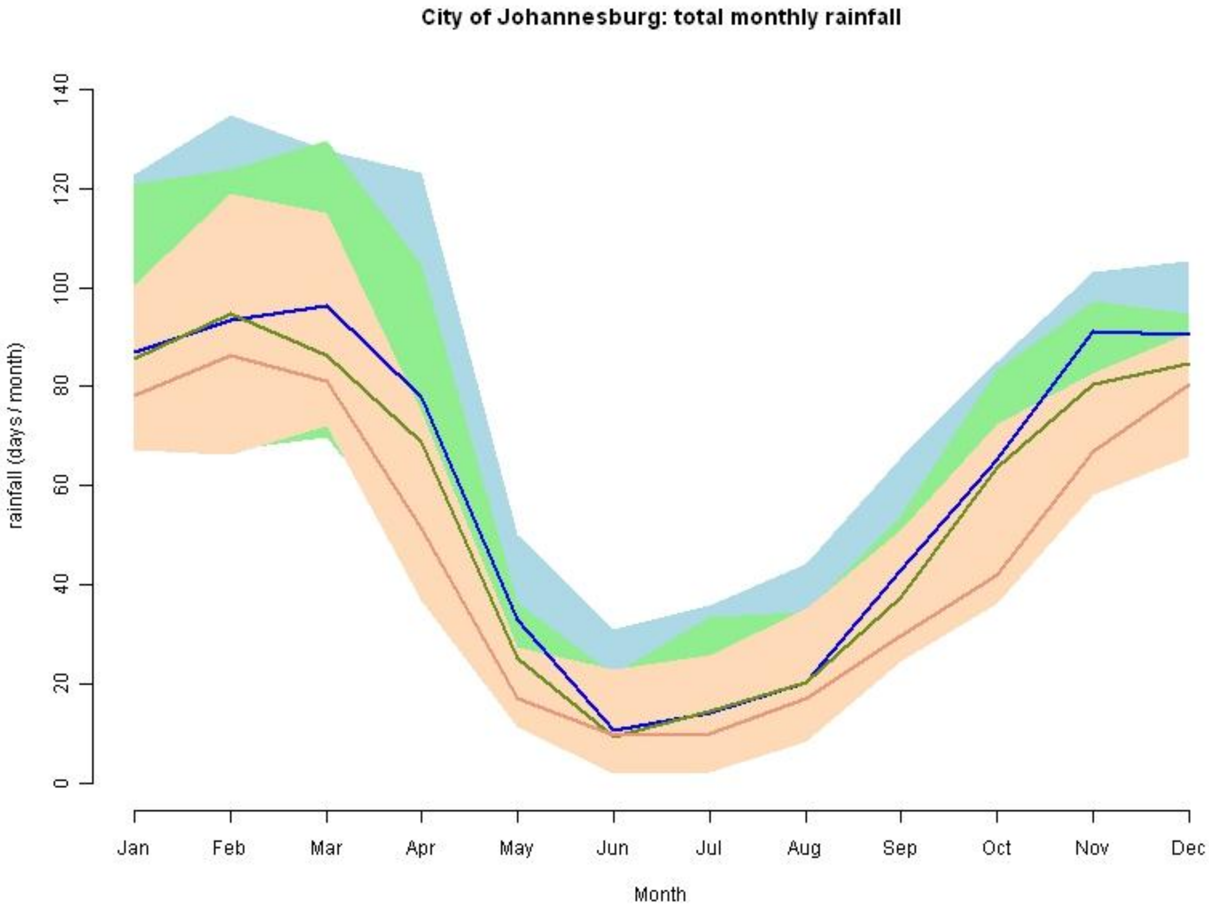


Figure 9: Mean seasonal cycle of downscaled monthly total precipitation (mm).
Control period: 1961-2000 (orange), the near-future: 2046-2065 (green) and far-future: 2081-2100 (blue) periods. The lines are the median values, while the shaded areas represent the range or envelope of the seven GCM projections for each period (CSAG 2009).

3.5 Other Climatic Variables

3.5.1 Evapotranspiration

Source: CoJ website

Potential Evapotranspiration (PET) is dependent on both the temperature and the moisture content (humidity) of the air. Moderate increases in PET are projected to occur in the near and far future. When considering that future precipitation is also projected to increase, it suggests that the water balance within reservoirs and that water moisture in soils may remain comparable to present levels. Further analysis of water balance effects and soil moisture is generally considered more important in agricultural/rural settings than within urban settings such as the CoJ. Hence this parameter has not been subjected to further detailed analysis in this study.

3.5.2 Humidity

While not specifically modelled for in the downscaling methodology, regional projections for southern Africa (Figure 10) indicate a significant increase in specific humidity for the CoJ region. Hence the projections for the CoJ are not only for a hotter climate but for a hotter and more humid climate than at present. An increase in humidity serves to (amongst other things) reduce evapotranspiration rates and to increase the apparent temperature in terms of human comfort (due to decreased efficiency of sweating) thus exacerbating heat-related medical traumas.

3.5.3 High Pressure Cell

Climate model projections for the region indicate some evidence for the strengthening of the Hadley pressure cell; this could result in an increase in occurrence of inversion layers (temperature inversions) over the CoJ region (Tadross et al, 2005).

3.5.4 Wind, Hail, Lightning and other Weather-related Events

There are numerous other climate- and weather-related variables which may be affected by climate change. In terms of the CoJ, hail damage in particular may be significant. However, modelling of these parameters is currently beyond the scope of the present analysis. As the state of science improves and as the necessary baseline data is accumulated, further assessment of these parameters may become possible in future.

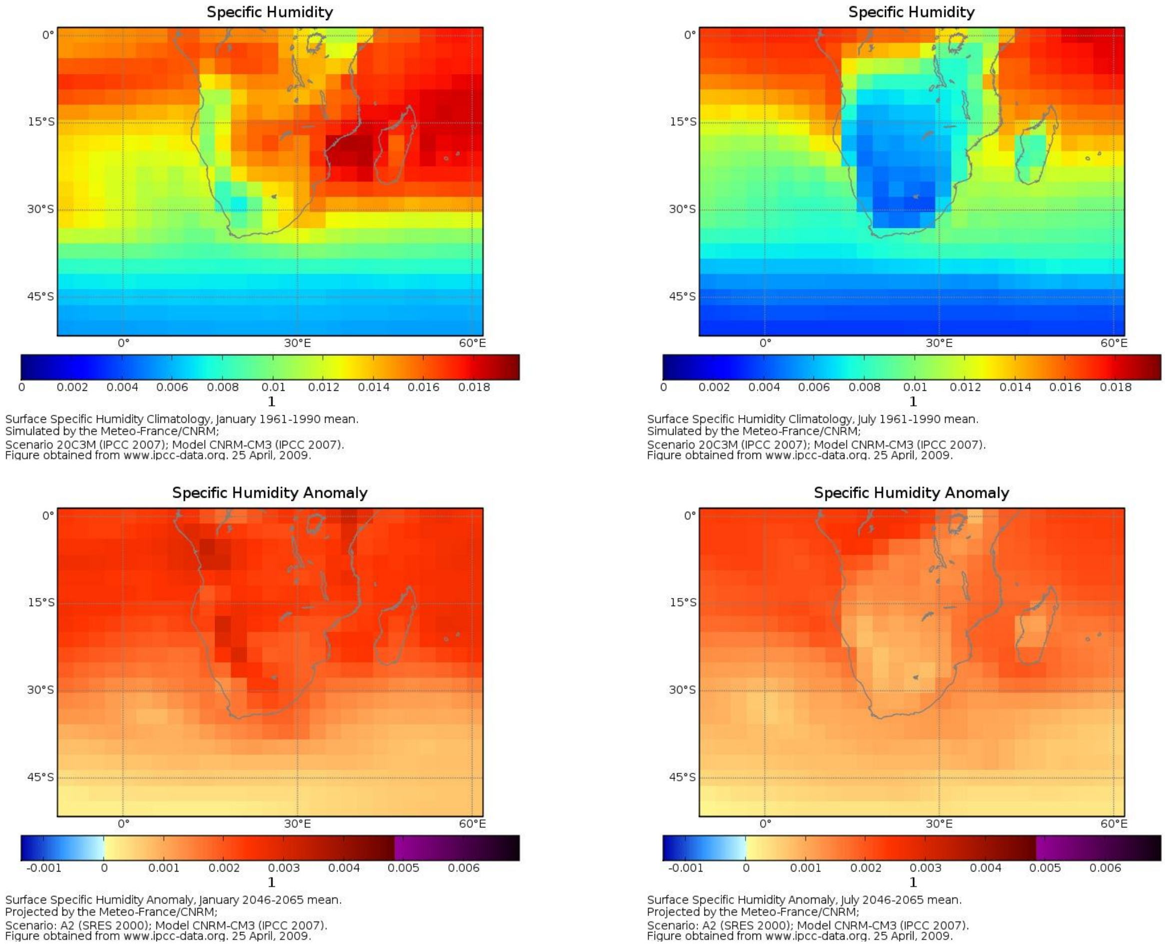


Figure 10: Surface specific humidity simulated by the Meteo-France/CNRM GCM.
January 1961-1990 mean (top left), July 1961-1990 mean (top right), anomaly (i.e. relative change), January 2046-2065 mean (bottom left), and anomaly, July 2046-2065 mean (bottom right).

4. VULNERABILITIES OF COJ KEY SECTORS

4.1 Introduction

This section presents a brief description of various key sectors within the CoJ and highlights some of the potential impacts that climate change may have on these sectors. These impacts are not elaborated on further in this section, however, as they are directly or indirectly addressed within the framework of the comprehensive risk assessment and risk analysis which follows in later sections of this report.

The key sectors (and sub-sectors) addressed are:

- Environment
  - Air Quality, Natural Water Resources, Biodiversity
- Health
- Infrastructure
  - Stormwater, Water Supply & Sanitation; Transport; Energy & Electrical; Built Environment & Urban Planning
- Disaster Management
- Finance & Economy
- Community Development & Livelihood
  - Employment, Housing & Living Environment; Food Security, Water Security, Migration

4.2 Environment

4.2.1 Introduction

The CoJ Environment Portfolio as set forth in the 2008/09 Integrated Development Plan comprises the Department of Environment with its various sub-directorates and two CoJ-owned Municipal Entities (ME's), namely the Johannesburg City Parks and Johannesburg Zoo. The Department focuses on the following areas: air quality & climate change; natural resource management, waste policy & regulation; policy integration & support; and ME service delivery compliance and monitoring. In fulfilling these functions, the Department typically engages closely with the other CoJ departments and hence is often well placed to facilitate projects (such as those related to climate change) whose impacts cross departmental boundaries. A summary of several environmental sub-sectors which are considered to be particularly sensitive to climate change impacts are summarised below. These summaries are based primarily on information contained in the 2009 State of Environment Report (SoER).

4.2.2 Air Quality

Poor levels of air quality are an ongoing issue within the CoJ. Primary sources of air pollution comprise vehicle emissions and domestic fuel burning (i.e. coal) in informal settlements and townships for both heating and cooking. Other significant contributors include industrial emissions, mining operations (including fugitive dust from closed mine dumps) and waste disposal and incineration activities.

The CoJ operates a network of six ambient air quality monitoring stations across the City: at Alexandra, Buccleuch, Delta Park, Jabavu (Soweto), Newtown and Orange Farm (SoER, 2008). The Delta Park station, located in the Delta Park Environmental Centre, was intended to be a background urban air quality station.

Recordings at the stations indicate that daily average PM_{10} concentrations are elevated across the City, exceeding the local guideline level. These levels are considered to pose a risk to human health particularly in areas where fuel burning takes place. Ambient O_3 (ozone) concentrations are also reported to be elevated across the City including at the Delta Park station. Sulphur dioxide levels are presently reported to fall just beneath the local guideline levels.

From a health-related perspective, those most at risk from air pollution include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children. Notwithstanding these direct health impacts, there are numerous secondary economic impacts arising from, among other issues: increased health costs, lost productivity, reduced tourism and lowering of property values. Loss of productivity due to pollution-related illnesses is also a direct economic cost.

Potential impacts of climate change on air quality include:

- Higher ambient temperatures may result in higher concentrations of ozone;
- The potential strengthening of the Hadley Cell may result in an increase in temperature inversions over the CoJ region, which will exacerbate smog events within the CoJ.

4.2.3 Natural Water Resources

This sub-sector is closely related to the sub-sectors Community Development & Livelihood: Water Security presented in Section 4.7.5 and Infrastructure: Water Supply & Sanitation presented in Section 4.4.2.

Surface water quality within the CoJ is at present severely impacted, primarily due to uncontrolled urbanisation, blocked sewers, aging infrastructure and littering transported by stormwater.

Many wetlands in the City have been either destroyed by urban development or transformed to the extent that they are no longer functioning effectively. These wetland areas, which had previously acted as natural stormwater retention and detention features, have been progressively in-filled and drained to accommodate the ever increasing demand for urban development. In addition, portions of natural watercourses have been canalised in an attempt to address degradation of the watercourses. These actions, together with the effects of increasing urbanisation have dramatically altered the runoff patterns and significantly increased peak flows in the rivers, resulting in continual degradation of the natural watercourses and the consequent decline in both the environmental integrity of the natural watercourses and water quality, with concomitant adverse effects for human health and welfare.

The influx of people attracted to the CoJ from rural areas of South Africa as well as from elsewhere in Africa has led to the establishment of many informal settlements where the residents frequently depend directly on local surface waters for basic resource requirements, such as for sewerage and waste disposal.

Failure of aged and outdated sanitation infrastructure is also leading to an unsustainable maintenance situation affecting natural surface waters. Downtime at wastewater treatment facilities (due to electricity outages or other maintenance issues) is leading to retention ponds operating over capacity and eventually flooding. Untreated wastewater is consequently being discharged into receiving surface waters and is a major, if only occasional, source of acute and large scale water contamination.

Cholera, typhoid, diarrhoea, dysentery and bilharzia are some of the most common water-borne diseases associated with raw sewerage contamination. The high-flow period (peak rainfall season) is where the bacteriological contamination of surface waters is reportedly at its worst, primarily due to stormwater runoff that enters the sewerage infrastructure (often exceeding the carrying capacity of the system). Contamination and blockages caused by littering transported by rain is also an issue; while the peak rainfall season also coincides with the most active growth season for plant roots, which have been cited as a leading cause of sewer blockages throughout the City.

The main problematic areas with respect to bacterial contamination includes where the Jukskei River flows northwards out of Alexandra and where the Klipspruit flows southwards out of Soweto. Almost the entire reaches of these two river systems are reported as being highly contaminated by bacteria to levels that pose a significant risk to human health.

Rehabilitation measures which are reportedly being planned or are underway in order to improve the overall bacteriological contamination risk of the surface waters throughout the CoJ include: the improvement, repair and upgrading of sewerage infrastructure; stricter enforcement of laws pertaining to activities leading to water contamination; and relocation of informal settlements to areas of lesser ecological sensitivity.

Secondary but significant issues impacting on surface water quality within the CoJ also includes mining sector wastewater discharge into the Klip River catchment and discharge from the commercial and industrial sector concentrated in the Modderfontein area into the Modderfonteinspruit and its tributaries.

Potential impacts of climate change on natural surface waters include:

- An increase in rainfall and lengthening of the rainy season is likely to exacerbate existing issues noted above and contribute to further deterioration in water quality, particularly where these issues are related to stormwater and sanitation impacts. These impacts include:
- Increased volumes of stormwater, especially during periods of flooding, entering the already stressed and overloaded sewerage infrastructure, resulting in failure of the carrying infrastructure;
- Additional littering transported into surface waters and causing blockages of sewerage infrastructure;
- Combined with higher humidity and temperature levels, it is possible that plants may experience increased rates of growth over a longer period of the year, resulting in increased blockages of sewage infrastructure;
- Second-order effects such as flooding leading to additional electricity and wastewater treatment facility failures, which would in turn result in additional discharges of untreated sewage into receiving water courses;
- All of the above points are likely to result in further episodes of bacterial contamination, posing a significant risk to human health as well as to aquatic biodiversity, such as it exists within the CoJ at present.
- The increased risk of water-borne diseases from sewage contamination may be further exacerbated by future climatic conditions which are more favourable for disease-related vectors than presently exists within the CoJ (such as for bilharzia).
- Increase in uncontrolled run-off leading to loss of habitat diversity and consequently species diversity e.g. development of extensive monoculture reed beds.
- Deterioration of morphological characteristics of rivers, with excessively rapid deepening or widening of channels, associated with excessive and unbalanced erosion and sedimentation. Sediment may also build up in dams with consequent high maintenance costs both to the City and private owners.

4.2.4 Biodiversity

The CoJ is, for the most part, highly urbanized and densely populated and hence the natural land cover has experienced significant transformation. Despite this, a fair amount of biodiversity remains within the boundaries of the CoJ. Dominant ecological systems habitats present within the CoJ include: Wetlands; Rivers; Grasslands; Ridges and the Urban Environment (SoER, 2008).

Ongoing urbanisation (both formal and informal) continues to pose the most serious threat to the remaining biodiversity within the CoJ. In view of the challenges posed by this urbanisation trend combined with limited resources, the present conservation strategy enounced by the CoJ is focused on the identification of biodiversity hotspots and on the implementation of action plans to maintain these identified areas.

Some potential effects of climate change on biodiversity have been touched on in the preceding section dealing with surface waters. In addition to those points, the following should be borne in mind when considering the impacts of climate change on biodiversity:

- It is particularly difficult to assess and predict the nature and scale of the climate change impacts due to the complexity of the systems involved. Insofar as these impacts will be negative, they are likely (within the context of the CoJ) to be on a lesser scale to the risks posed by the pressures for further urban development (both planned development and uncontrolled development);
- The same measures which would act to preserve and safeguard biodiversity from other threats, including urbanisation, are also likely to be the most valuable measures for improving the resilience of local ecosystems in the face of projected climate changes (such as creating and maintaining ecological corridors connecting natural spaces).

Picture by Brendon Webber

4.3 Health

Health issues are closely linked with poverty and economic development in developing countries. As with education, it is both a prerequisite for and an outcome of sustainable, equitable economic growth and poverty alleviation. Invariably it is the poorest (i.e. the informal settlement residents within the CoJ) that are most exposed to the greatest health risks, including those related to climate change such as extreme weather events - flooding, heatwaves - and disease. Most of these health risks affecting the vulnerable can only be addressed through a multi-faceted approach targeting improved access to economic opportunities, improved primary health care delivery and improved access to basic infrastructure (in particular, stormwater, water supply and sanitation).

The CoJ Department of Health is responsible for the following key functional areas: primary healthcare (although this may become a function of provincial government in future); HIV and Aids; public health; environmental health; and management support. The key strategic interventions which have been identified by the Department for the next few years include: reducing incidents of childhood infectious disease; reducing incidents of health problems amongst the youth; and decreasing the incidents of Aids, STD's and tuberculosis (IDP, 2008/09).

The population of the CoJ is extremely young, with over 65% of the population being 35 years or younger (23% of whom are aged 0 - 14 years) and only 4% of the population aged 65+ (2001 national census). The elderly and very young typically have the most complex health needs within a community.

Health in the CoJ is faced with many serious challenges including: HIV/Aids; staff retention issues; uncertainty over primary health care control (which may be moved to provincial government control); a lack of infrastructure in some areas; and strain due to refugees / migrants. Other communicable diseases such as cholera are also a cause of concern and attention within the CoJ. Public access to municipal-led medical facilities is via the City's eighty seven clinics and one satellite clinic distributed around the CoJ, plus an additional nine mobile clinics for Region's D and G. The mobile clinics are especially important for Region G which suffers from a lack of clinics due to infrastructure limitations.

The CoJ reportedly has robust vector control mechanisms in place, including a Vector Control section in Region A and vector control mechanisms for 160 identified hotspots.

As with many other sectors within the CoJ, this sector is already a highly stressed system even before considering the potential impacts of climate change. Potential impacts of climate change on the health sector within the CoJ include:

- A potential increase in heat-related deaths, particularly among the elderly, the poor, those with existing heart, lung and other medical conditions and, to a lesser extent, among children. This risk is potentially exacerbated by air quality issues;
- Climate change may create a more favourable environment for various disease vectors (such as mosquitoes) either within the CoJ or within surrounding areas (which would nevertheless result in some spill-over effect into the CoJ), and which may in turn lead to increasing incidences of related diseases;
- Increased rainfall and floods may lead to an increase in sewage contamination of surface waters resulting in outbreaks of cholera, dysentery and other diseases;
- The potential for more flooding and fires may put additional strain on emergency services and the health sector as a whole.

4.4 Infrastructure

4.4.1 Stormwater

This sub-sector includes stormwater collection, distribution, detention and retention infrastructure. It interlinks closely to both the Environmental: Natural Surface Waters sub-sector (Section 4.2.3) and the Infrastructure: Water Supply and Sanitation sub-sector (Section 4.4.2). Reference should be made to these sections as well.

Stormwater management is a particular cause for concern for the City predominantly due to an increase in urban flash floods and the knock-on effects of poorly managed stormwater flows on receiving surface waters (i.e. resulting in sewage discharges). It is particularly high on the agenda at present due to the recent flooding in Soweto

Rainfall in the 2008/2009 summer season was especially heavy in Johannesburg. In addition, in 2008 rain started earlier and there was rain in the winter months.

It is not clear whether this heavy rainfall period can be attributed to a one in four or one in seven year flood, or changing rainfall patterns due to climate change. However, regardless of the cause, this rain overwhelmed the Johannesburg Road Authority's (JRA) standby emergency crews and depots.

The flooding problem in Johannesburg (predominantly associated with the City's frequent summer thunderstorms) has arisen due to a multitude of interacting causes such as increased hard surfacing, development over natural drainage areas like wetlands, loss of natural open spaces and inadequate stormwater infrastructure and maintenance. With the large number of informal settlements in the CoJ, there is a significant portion of human settlement that either does not have or has inadequate formal stormwater attenuation infrastructure. It is generally these areas which are subject to the worst of the City's urban flood events.

In the past, the approach to stormwater drainage has been to convey runoff as rapidly and efficiently as possible into the 12 river systems and 106 dams within the municipal boundaries. In some cases, detention or retention ponds have been and are still used as buffers for water entering the various watercourses, while wetlands and other natural features which fulfil similar functions have been severely degraded over the years.

In terms of municipal management, responsibility for stormwater infrastructure resides with the JRA. However, some developments within the CoJ, such as certain low-cost housing developments, are led by non-municipal agencies such as the provincial government, which has led in some cases to a lack of adequate integration of stormwater infrastructure within the development plans. There are concerns that some low-cost housing developments are being planned to proceed without adequate (or possibly without any) stormwater infrastructure in place.

An assessment of the City's sub-catchments completed to date clearly indicates that the condition of Johannesburg's major stormwater system is generally poor. In excess of 900 significant defects have been identified to date, of which 11% are considered critical, requiring immediate attention and a further 30% are considered urgent.

The JRA estimates that it spends approximately R25 to 30 million per year on clean up costs associated with rain and stormwater. By far the biggest cost relates to clearing stormwater drains from major blockages, a maintenance activity, amounting to over R6.2 million between June 2007 and March 2008. There has been a general increase in the maintenance of major blockages in comparison with everyday drain clearance work. The costs above are being incurred when JRA is experiencing major budget shortfalls due to an increase in prices of fuel, oil-based products and electricity, as well as other inflationary increases. It is anticipated that a budget shortfall of ±R34 million is inevitable in the 2008/9 financial year. The JRA had budgeted R4 million for emergencies in 2008/9 and this amount had already been spent by November 2008, a few months into the financial year.

It is therefore clear that stormwater management in the City of Johannesburg is both in poor condition and under-resourced in terms of expenditure on upgrades and routine maintenance. It is however also clear that the impacts of poor stormwater management are starting to be fully recognised by the CoJ and that policy and management adaptation plans have been incorporated in the development of new stormwater bylaws developed by the JRA.

In view of the above, the impacts of increasing rainfall as projected by climate models may provide a critical additional stressor on a system that is presently under severe stress in many areas; it is likely that substantial commitment and expenditure will be required to return to a functional and sustainable system.

Many of the potential impacts of climate change on stormwater infrastructure have already been mentioned in Section 4.2.3 relating to surface waters. Some of the potential impacts of Climate Change on stormwater infrastructure are:

- Increased risk of urban flooding as additional stormwater systems reach and exceed their carrying capacity in more areas;
- Increased maintenance costs and/or increased risk of urban flooding associated with additional blockage and failure of stormwater drainage system components (e.g. kerb inlets)
- A potential increase in blockages associated with plant roots (which may have a more active and longer growth season due to the combination of higher temperatures, humidity and rainfall);
- The failure of critical stormwater infrastructure is likely to have wide-ranging and broad knock-on effects on natural water quality, aquatic biodiversity, sanitation infrastructure, human health and other sectors.

4.4.2 Water Supply & Sanitation

This sector is also closely related to the sub-sectors: Infrastructure: Stormwater; Environment: Natural Surface Waters; and Community Development & Livelihood: Water Security. Reference should be made to these sections.

Primary responsibility for this sector at the municipal implementation level is the Infrastructure and Services Department (ISD). In terms of water and sanitation services, the CoJ owned Johannesburg Water (under the oversight of the ISD) is mandated to provide these services to the residents of Johannesburg. JW is widely recognised as a well run operation, despite operating under very challenging circumstances.

The CoJ water supply is largely recycled rainwater, most of which it buys from neighbouring areas, via the Rand Water Board. The availability of the water provided by the Rand Water Board is generally adequate for the City, and the quality meets SABS standards for potable water. Less than 1% of the City's population are without potable water on tap; these residents rely either on above ground water courses (in poor communities), which is often the cause of waterborne disease, or on borehole water (in agricultural areas). Many informal settlements have communal standpipes available for potable water access.

The CoJ experiences high levels of water losses, largely due to leaks and illegal connections, although some initiatives have been undertaken in the last few years to reduce this. It is also noted that the Gauteng Province is predicted to experience a water shortage by 2015 due to anticipated population growth trends notwithstanding any impacts of climate change on water security.

In terms of sanitation, much of Johannesburg's wastewater can flow by gravity to its treatment works. The City's underground piped sewer system delivers the sewer water to six wastewater treatment facilities within the catchment areas of the two rivers (two within the Jukskei catchment, and four within the Klip River catchment). Both the Jukskei/Crocodile River catchment in the north; and the Klip/Vaal River catchment in the south to which wastewater is eventually discharged are classed as sensitive to the discharge of waterborne pollutants. Most of the City is catered for in this way, except for large parts of many informal settlements, which rely either on chemical toilets or self established pit latrines. These often result in the contamination of surface water and rivers during summer rainfall periods (for example, parts of Alexandria, Soweto and Diepsloot). In other cases, sewer infrastructure in areas has deteriorated (blocked or damaged) to the extent that wastewater escapes and enters directly into the stormwater systems (or vice versa), for example in parts of Soweto and the CoJ CBD. In addition, failure and overloading of the stormwater system (due to heavy rain events and urban floods) also results in excess water entering the sanitation system, causing burst sewage pipes, and release of untreated sewage.

The City's wastewater treatment works have been reported to fail upon occasions, largely due to a lack of adequate maintenance, resulting in flooding of untreated wastewater into natural water courses. This causes significant pollution to rivers, is the cause for waterborne disease and threatens river based ecology. However, the wastewater works at times other than these periodic failures are able to maintain an acceptable quality standard of effluent water flowing into the rivers.

Some potential impacts of climate change with respect to water supply and sanitation are listed below:

- Higher temperatures will increase the water demand i.e. for air-conditioning heat rejection, irrigation, swimming pool top-up etc. leading to increased strain on the water supply network;
- Higher temperatures are also likely to result in higher rates of evaporation from CoJ reservoirs, although this loss may be mitigated to some extent by a potential increase in rainfall;
- Higher temperatures can also exacerbate the effects of drought (if and when these do occur, most likely in the spring), with greater evaporation resulting in lower levels of bulk potable water storage within CoJ dams. At the same time greater temperatures will increase the water demand for cooling etc., adding to the threat of depleting the CoJ's potable water supply;
- The increased risk of urban flooding (due to increased rainfall) may result in additional damage to potable water supply and/or sanitation infrastructure, and cause flooding of one into the other.

4.4.3 Transport

This sub-sector includes road, rail and air transport infrastructure. The key municipal stakeholders in this sector are the CoJ Transportation Department and the two CoJ-owned entities, namely the JRA and Metrobus.

In terms of road infrastructure, the CoJ has a well established and well distributed hierarchical road network, which allows for good access to all parts of the City, and through the City. Due to rapid urban growth, many sections of this road network are currently under major pressure at peak traffic times or in accident conditions. There are significant road works underway on all the major highways at present. The roads are generally well maintained. The JRA manages all road infrastructure in the CoJ. As part of the City's public transport plan, a bus rapid transport system is currently being developed along various key routes, and is scheduled to be completed by 2010.

The existing rail networks, while not controlled by municipal entities, nevertheless play an important role within the City, particularly for industrial and mining purposes. Johannesburg's metro railway system connects central Johannesburg to Soweto, Pretoria, and most of the satellite towns along the Witwatersrand. The metro railway system transports significant numbers of workers daily; however, the railway only covers areas in the City's south. The northern areas, including the business districts of Sandton, Midrand, Randburg, and Rosebank, currently lack rail infrastructure and public transport.

The Gautrain is a major rail public transport initiative to be completed in 2010, which aims to create a crucial new public transport link between Johannesburg and Pretoria, with stations at the OR Tambo airport, Johannesburg CBD, Rosebank, Sandton, Midrand, Centurion and central Pretoria.

OR Tambo, to the east of the CoJ, is the country's primary airport hub and is consequently the main airport servicing the CoJ for both passenger and freight transport. It forms a vital link for domestic as well as international travellers, whether destined for Johannesburg or surrounding areas, or continuing on via connecting flights to elsewhere in the country. Lanseria airport is a much smaller secondary passenger and freight airport in the north east of the CoJ. There are a number of other small local airfields in the CoJ, used for small private airplanes.

Some potential impacts of climate change on the transport infrastructure are summarised below:

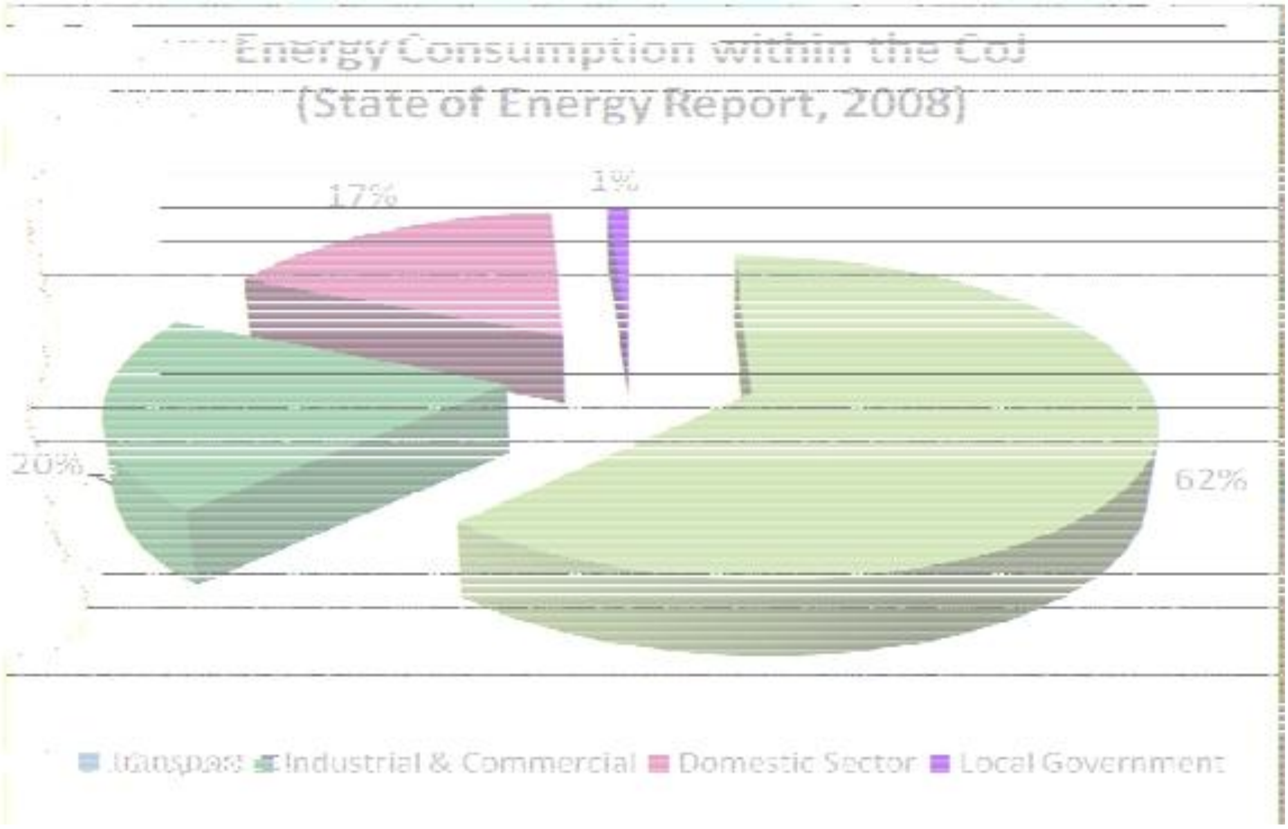
- Potentially increased rainfall and urban flooding will cause increase in road accidents and general worsen traffic congestion on road, as well as affecting public transport systems;
- Higher temperatures may result in increased maintenance costs associated with the transportation infrastructure (i.e. increased warping and buckling of rail tracks);
- Discomfort levels in non-air conditioned public transport can be expected to increase significantly;
- Blackouts and power failures (due to heat, storms or flooding) are likely to impact on electrified trains and traffic signals;
- Higher temperatures may affect allowable loadings of aircraft at airports supporting the region.

4.4.4 Energy, Electrical and Telecommunications

This sub-sector includes electrical supply infrastructure, power plants, liquid & gas supply infrastructure, bulk IT / Telecoms infrastructure, and coal.

According to the CoJ State of Energy Report 2008, demand side annual energy consumption is dominated by transportation, primarily in the form of petrol, diesel and other fuels. Domestic sector energy consumption is mostly in the form of electricity used for the cooking, heating & lighting, but with some reliance on paraffin, and coal in poorer communities.

Electricity coverage within the City's area is estimated at 77% of households. Johannesburg's electricity is supplied via both Eskom and the CoJ's electricity supply company (City Power) - City Power (under the oversight of the Infrastructure and Services Department) provides approximately 50% of the City's electricity. City Power purchases about 90% of its electricity from Eskom, about 8.5% directly from the Kelvin power station, and less than 1% from Erkululeni Municipality. Electricity is distributed via 12,500 distribution transformers over an area of 815 km^2. Various parts of the network in the north and east of the City are under pressure due to the rapid development occurring in these areas. Certain informal settlements also do not have access to electricity, and thus make use other fuel sources (usually paraffin, coal or biomass). In some cases, these informal settlements may be located in unsuitable areas i.e. within floodplains, and hence it would be inadvisable to electrify these areas.



Power outages have been a regular feature within the CoJ over the past few years, both due to load-shedding (planned) and unplanned disruptions to the network. While the situation has improved in recent times, the security of electricity supply is still somewhat uncertain. Among the many national and municipal initiatives to address this situation, City Power is reportedly planning to refurbish 3 gas turbines (probably to diesel) to generate power within the City boundary (approximately 120MW, which is about 60% of City Power's load-shedding requirement by Eskom). Adding to the stress on the CoJ electricity security due to national problems, is the fact that City Power's administration and maintenance, from an external perspective, seems to be in a very poor state. Issues raised include: non functional or incorrectly calibrated meters; faulty or poorly maintained sub-station equipment; outdated equipment still in place beyond its life; administration staff not responding to phone calls or letters; and regular outages occur in Sandton and other key business areas.

Approximately 45% of the CoJ electricity supply is consumed by the residential sector and the remainder by industrial and commercial sector. Of the commercial component the highest proportion is due to business and financial services. About 12% of City Power's electricity consumption can be attributed to system losses, which is relatively high compared to other cities. City Power is actively targeting residential demand side management to reduce the electrical demand of this sector through various initiatives including energy efficient lighting and ripple control of hot water cylinders.

Coal is the predominant fossil fuel used for power generation in South Africa, and is used to a very limited extent in poorer homes for heating and cooking purposes, including within the CoJ. Disruptions to the CoJ electricity supply in the past have been linked to wet coal stockpiles

No significant large renewable energy supply projects exist in the CoJ despite the potential for these, and even though significant smaller scale pilot projects have been or are currently being undertaken (such as solar hot water installations at the Cosmo City development and the solar street lighting initiative in Zandspruit).

Potential impacts of climate change on this sub-sector include:

- Higher temperatures will cause a significant increase in summer and spring-time energy consumption, largely from air-conditioning and refrigeration installations. The potentially higher humidity levels in future could also contribute to additional air-conditioning and comfort control, and thus additional energy consumption. This will put significant pressure on an already stressed electrical infrastructure, and national energy supply shortage.

The above provides for the potential for increased stress on electricity supply, with resultant power outages, and loss of production and income, during summer and spring.

Higher temperatures may result in increased capital costs for air-conditioning and refrigeration plant.

Damage from storms and floods may result in damaged infrastructure and unplanned blackouts.

While a serious flood-induced electrical failure is yet to occur in South Africa, the UK floods of 2007 resulted in a substation servicing 50,000 homes being flooded and required the army to be called up in order to prevent the flooding of a second substation. It was estimated that losing this second substation may have left over half a million homes without electricity for up to five days.

This report does not address issues surrounding the climate change impact of coal as an energy source; however, it is noted that increased rainfall could have a negative impact on coal storage, and thus could have a negative impact on power generation security (as was experienced in 2008 at various power plants, where wet coal was identified as being potentially partially responsible).

Related infrastructure such as bulk IT, telecommunications and security (i.e. CCTV) systems may also be at risk of damage and disruption due to increased flood events.

4.4.5 Built and Urban Environment

The built and urban environment, for the purpose of this report, includes all buildings and urban spaces. The CoJ consists of a variety and mix of urban development, including mostly residential, business and industrial development, with some mining development and a small percentage of urban agriculture. There is a divide between the wealthy property markets in the north, and the less active under developed property markets in the south of the CoJ. These developments have stimulated worsening traffic congestion and inadequate road infrastructure in the premier nodes, especially along east-west linkages (SoER 2008).

There are significant areas of informal settlements, and also areas of urban decay, where old buildings have been illegally occupied or left vacant, for example in the City centre. A significant part of the CoJ is considered as open space (about 25%), but in many cases, these areas are under threat from development or illegal settlement. There are a number of urban renewal projects and initiatives throughout the City, which are having a positive impact on the City's urban fabric. Crime is still a major obstacle to creating a more open and free urban environment that allows people to freely move and occupy public and private spaces.

Responsibility for the upgrading programme for informal settlements is held jointly by the CoJ Housing Department and CoJ Department of Planning and Urban Management (DP&UM). Urban planning is implemented via the City's Spatial Development Framework and the seven Regional Spatial Development Frameworks (RSDF) as well as precinct plans and Urban Development Frameworks (UDF) for key development nodes such as the Gautrain precincts (IDP 2008/09). The DP&UM has oversight responsibility for the Johannesburg Development Agency (JDA) and plays a key role in urban renewal projects such as in Alexandra, the inner City and the Cosmo City development, which is an ambitious R3.5 billion low cost housing initiative undertaken by the CoJ in partnership with the Gauteng provincial government.

Potential impacts of climate change within this sector include:

Increased temperatures will result in a greater urban heat island effect in areas of the CoJ with predominantly hard surfaces and little to no vegetation.

The effects of climate change will reinforce the need for adequate stormwater infrastructure as well as other climate change adaptation measures (such as energy and water efficiency measures) to be incorporated into low cost housing developments;

Flood line measurements may be liable to alteration as changing precipitation patterns due to climate change impact on river flood lines.

Basic infrastructure supporting buildings, especially in low cost housing developments, being built to inadequate standards resulting in failure and property damage and/or in prohibitively expensive retrofitting costs.

Increased rainfall and resultant additional floods may result in significant property damage.

4.5 Disaster Management

Disaster management in Johannesburg is primarily the responsibility of the CoJ Emergency Management Services (EMS) supported by the Johannesburg Metro Police Department (JMPD). Weather-related emergencies, particularly floods, are already a serious issue for EMS, while load-shedding and unplanned blackouts have resulted in additional stresses on both the EMS and the JMPD.

The EMS focuses on fire-fighting, medical emergency response, hazardous materials accidents, operational disaster response and disaster management planning and mitigation. In 2006, EMS was reported to receive around a quarter of a million calls per annum.

Fires, frequently shack fires within informal settlements, are relatively common in the winter (i.e. the dry) season. They are generally related either to cooking/heating using paraffin, biomass or coal fuels; or are a result of criminal activities. Due to the densities within these settlements, the fires tend to spread rapidly among the shacks. The lack of infrastructure (including basic features such as street names and house numbers) in these settlements means that a longer time can pass before the alarm is raised, and that access to the emergency is impeded.

In the summer, the primary weather-related disaster is flooding, which again tends to impact most heavily on the informal settlements. Locals living in these settlements are generally aware of the danger points (i.e stormwater drains, dangerous crossing points of rivers etc.) during these flood events; however, there are often a large number of migrants both in the City and in informal settlements, and these people tend to be less informed and consequently more at risk.

Members of the EMS are represented on CoJ Joint Climate Change Committee (JCCC) and are relatively well informed of and sensitive to climate change-related issues.

Potential impacts of climate change for disaster management in Johannesburg include:

- Additional weather-related disasters, particularly related to flooding and the effects of flooding in informal and township settlements;
- Effects of weather-related events affecting the transport sector - increased accidents, traffic congestion impeding access for emergency vehicles and failure of the public transport system; and
- Blackouts leading security concerns and increase in emergencies/accidents.

All of the above are already issues with which the CoJ disaster management sector has to contend.

4.6 Finance & Economy

Johannesburg is the financial capital of South Africa, and is the biggest financial centre in Africa. The table below indicates the relative contribution of different sectors to the CoJ economy:

Table 12: Relative contribution of different sectors to the CoJ economy for 2000 & 2007

Sector	2000	2007
Financial Services, Insurance, Real Estate & Business Services	25%	29.2%
Wholesale & Retail Trade, Hotels & Restaurants	17.7%	18.1%
Construction	3%	4.8%
Transport, Storage & Communication	8.1%	8.7%
Manufacturing (Food & Non-Food)	20%	17.8%
Mining & Quarrying	2.0%	1.3%
Agriculture, Hunting, Forestry & Fishing	0.4%	0.2%

Source: IDP 2008/9

Despite economic growth above the national average over the past few years, it is recognised that there are significant structural and infrastructural constraints within the CoJ economy (IDP 2008/9) which prevents the City from achieving even higher rates of growth. The reliability of electricity supply, telecommunications costs, cost and efficiency of freight (which is affected by road congestion, road quality and management during load-shedding), and the poor availability of public transport are some of the factors constraining growth in the CoJ economy.

One of the key objectives of the CoJ Department of Economic Development is to support and foster a continuous improvement in the general business environment for firms operating within the CoJ. Risk management, including accounting for the risks associated with climate change, will undoubtedly be a key component in achieving this goal.

Potential impacts of climate change on this sector include:

- Climate change-related effects are likely to add additional strain to a wide range of infrastructural sub-sectors (as described earlier), including the electricity supply and the transport sector. These stressors may add additional constraints to economic growth within the CoJ;
- Without (or even with) adequate adaptations, there may be a significant increase in insurance costs within the CoJ, for private, public and household sectors, particularly insurance for weather-related property damage (i.e. hail, flooding etc.);
- Climate change adaptation measures, as well as the damages arising from not undertaking adaptation measures, will result in a greater demand on government expenditure and budgets;
- There may be a an increase in "non-productive" expenditure (for all sectors of the economy including government) associated with law suits and potential legal liability arising from not having undertaken adequate duty of care in avoiding damage associated with foreseen climate change impacts;
- Within the economy, there will be both "winners" and "losers" as a result of climate change impacts. If the business community (as well as households and the public sector) is better informed, and that information is based upon good quality data, it will result in a better level of preparedness for potential climate change impacts. This will improve the chances of maximising the economic "wins" and minimising the economic "losses" (through proper risk management) within the CoJ economy

4.7 Community Development & Livelihood

4.7.1 Climate Change and Urban Poverty

Climate change will pose serious challenges and risks to the livelihoods of CoJ residents across all socio-economic classes. Nevertheless, it is the poorest (i.e. the informal settlement residents within the CoJ) that are likely to be most at risk from the impacts of climate change. Socio-economically poorer communities are more vulnerable to climate change because they lack the resources (i.e. health, education, financial and physical resources) to easily adapt or to engage in common risk reduction measures (such as purchasing flood damage insurance). Hence, within the context of South Africa and the CoJ, it should be understood that poverty alleviation, including the relocation of settlements located within floodplains, the extension of basic housing and infrastructure, the expansion of job opportunities, and the improvement in education and primary health care delivery services are arguably the most important measures that can be undertaken to reduce the exposure of these communities to the impacts of climate change. In fact, without these measures, there may arguably be little in the way of meaningful adaptation that can be undertaken for these communities beyond improving disaster management responses. Insofar as measures can be taken, it will rely on direct engagement with these communities to determine the needs, priorities and constraints within each individual community and to ensure 'buy-in' by the community for any proposed adaptation such as planting of trees or locating flood early warning telemetric systems within their area. Without direct engagement and buy-in, even these simple measures are likely to fail (the trees may be used for fuel, while telemetric equipment may be vandalised).

Poverty alleviation is already recognised as possibly the highest priority goal within South Africa today and is currently integrated into the CoJ service delivery and capital investment strategy. A key element to climate change adaptation within poorer communities will be to ensure that when new infrastructure is rolled out within these communities, this infrastructure is already 'climate-proofed'; likewise urban planning for the housing/relocation/upgrading of settlements will also have to integrate climate change adaptation measures into the urban masterplan.

4.7.2 Employment

The impact of climate change on employment in the CoJ is difficult to determine as employment nature and numbers are dependent on so many other unpredictable variables such as migration, world economic situation, education, government policy, foreign investment etc. The direct impact of a changing climate will not be felt by many who have secure employment especially those whose activities are weather-independent. Informal traders who have temporary sites or shelters are particularly averse to rainfall. An increase in rainy days or heavy rainfall would lead to an increase of non-selling days, and consequently a loss of income. The impacts of increased temperature is also an issue - if the number of extremely hot days increases, the impact on informal shoppers and the discomfort of the traders may result in fewer sales.

One industry that could suffer more downtime due to rain delays is the construction industry. There are no current records of the number of rain days leading to construction delays. Another industry that may potentially be impacted is the tourism sector, insofar as transitory tourism passing through Johannesburg to the Kruger Park and other areas may be impacted by the increased risk of malaria in these places. The impacts of climate change on employment will undoubtedly be closely linked to the effect of climate change on the economy as a whole (ref. the preceding Finance & Economy Sector).

Potential impacts resulting from climate change include:

> As with the economy as a whole, there will be both "winners" and "losers" as a result of climate change impacts. If the business community (as well as households and the public sector) is better informed, and that information is based upon good quality data, it will result in a better level of preparedness for potential climate change impacts. This will improve the chances of maximising the economic "wins" and minimising the economic "losses" (through proper risk management) within the CoJ economy.

4.7.3 Housing and Living Environment

The risks to housing and the living environment are essentially those that threaten their homes and surroundings. Considering that many dwellings are left standing empty during working hours any damage to the dwelling through fire or water could not easily be prevented, which often tends to increase the impact of such disasters. Complete destruction of a dwelling is a regular occurrence and the financial, social and emotional effect on the residents is huge.

Increased rainfall, and more importantly the increased likelihood of intense rainfall pose threats of flooding. Already it has been observed how informal settlements are situated in low lying areas, or even in flood plains. The attraction of a vacant piece of land during the dry season does not inform residents of the dangers of flooding during the rainy season.

Increased temperatures will affect residents in two ways. Firstly their heating requirements will diminish. This in itself is a good thing, reducing expenses ands the risk of fire. However a countering effect of increased temperatures and extremely hot days is the increased risk of uncontrolled fires. The CoJ has an effective Emergency Management Services Department that recognises the current risk of fires, but that may not be able to cope with future increases.

Potential impacts of climate change on this sector include:

> More frequent flooding due to more intense rainfall may cause significant damage to residential properties. This is more likely to impact upon low-income and informal settlements, who are unlikely to be afforded protection through insurance, but generally poses a risk to all socio-economic groups. The increased strain on municipal resources in general due to climate change may impact on service delivery and maintenance of basic infrastructure which is critical to establishing a positive living environment.

4.7.4 Food Security

Food security is a complex concept that involves the supply, availability[12], access and affordability of enough food to sustain the human body. In this respect it includes home grown vegetables, roadside fast food, as well as the myriad of manufactured and processed foodstuffs. Most of the supply of food raw materials for the CoJ emanates from outside the CoJ. Agriculture does not contribute much to the CoJ (0.6% of the provincial GDP, SOER 2008); however the City is a major channel for food distribution, handling 32% of all fresh produce in SA.

The processing sector is generally concerned with the availability, affordability and shelf-life of the products, while the domestic consumer is concerned with access, availability and affordability.

The impact of climate change on regions from which food supplies originate cannot be adequately addressed without an in-depth study of projected rainfall and temperature changes in those areas, but it is noted that, with respect to climate change, agriculture is arguably the most sensitive of all the major economic sectors. It can also be safely assumed that any increase in costs in the agriculture source regions will lead to increased prices in the CoJ.

In terms of food produced within the CoJ, Johannesburg is characterised by a variety of agricultural areas with varying potential. The City supports the promotion of sustainable land-use policies and sustainable agricultural methods. The Community Development and Economic Development Departments (CDEDD) of the CoJ Metro are currently undertaking a number of food garden and commercial agricultural projects. The SoER (2008) suggests that innovative land-use planning strategies are needed to conserve areas suitable for agriculture, which may lead to efficient use of land in terms of rate of return of land and an improvement in food security, especially among the less well off within the CoJ communities. It also recommends sustainable and practical use of the environment to ensure long term resources for the population. Practical use of viable agricultural land still available in the City could contribute to the local agricultural economy and to employment.

Data obtained for the land cover map (CoJ SoER 2008) indicates that only 41.26% of the area under high agricultural potential is cultivated; 29.98% and 26.21% of areas under low and very low agricultural potential respectively are cultivated. It is not clear from the Regional Services Development Framework 2009/10 (RSDF) what plans are in place to develop agriculture in the CoJ as there are plans to densify and increase the extent of the urban areas as informal settlements are replaced by more formal housing. There has been mention of agricultural projects food gardens (mostly poultry and vegetables) and it is here that the impacts of climate change may be most apparent.

Potential Impacts:

> Climate change is likely to impact, in both positive and negative ways, on the potential for urban agriculture within the CoJ (while urban agriculture is not relevant for the majority of the CoJ residents, is does hold the potential to provide security for some of the most vulnerable of its residents).

Disruption to the food supply chain from outside of the CoJ could cause significant hardship for its residents, through increased prices and inflationary pressures. This would simultaneously increase the number of individuals reliant on food aid (government and private) while increasing the costs and hence constraining the ability of organisations to assist these individuals.

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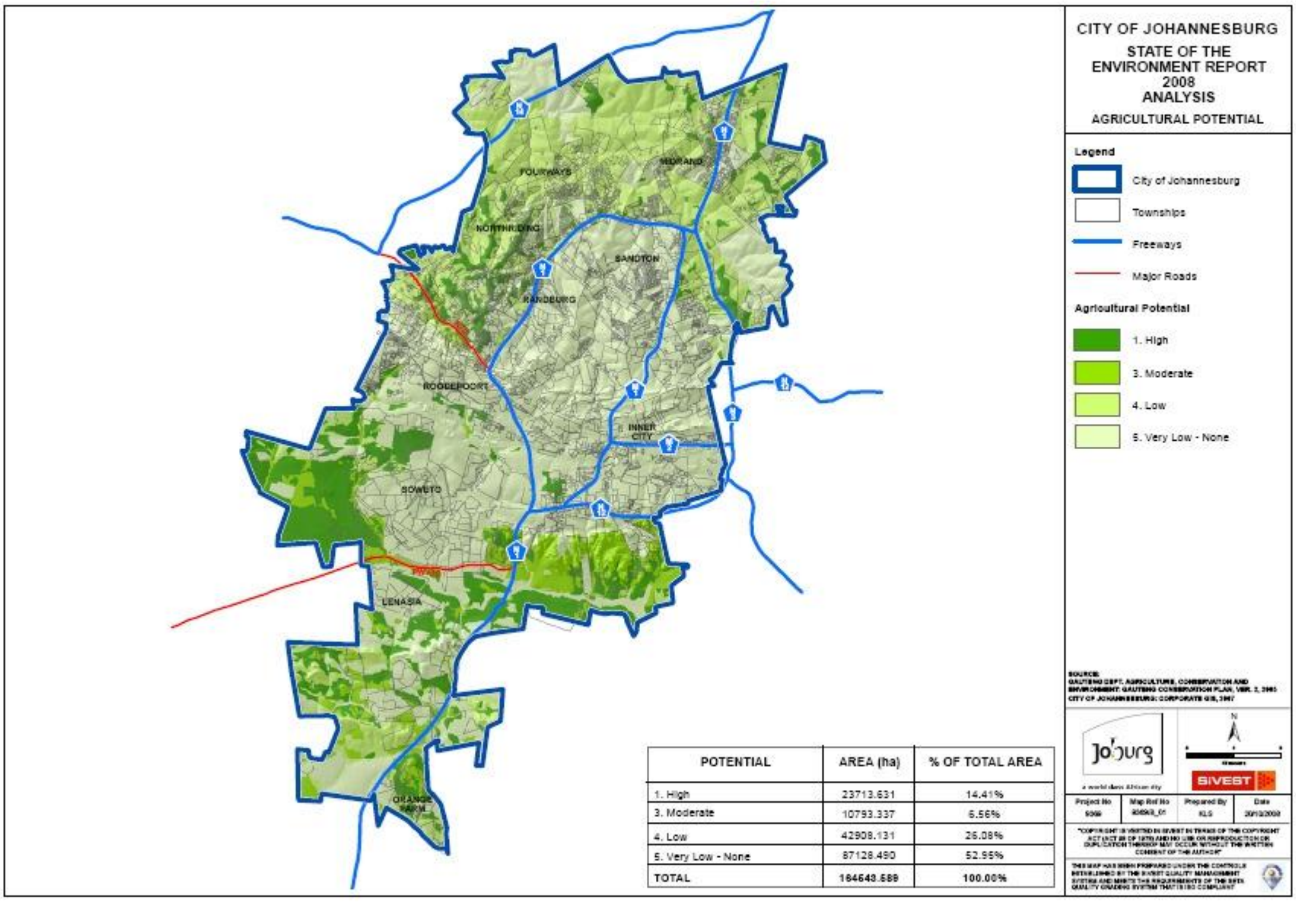
[12] Availability is the presence of the goods on the shelf, so to speak, while access is the proximity of the goods to the consumer and the ease (and cost) of retrieving them



4.7.5 Water Security

This sub-sector is closely related to the sub-sectors Infrastructure: Water Supply & Sanitation (which focuses on water infrastructure located in Johannesburg and maintained by the CoJ Metropolitan Municipality); and Environment: Natural Surface Waters. Reference should also be made to these sections. This section deals with water security in the broader context, also looking at water supply from regions outside of the CoJ.

Access to water for drinking, washing and sanitation is a basic human need. In recognition of this, Johannesburg Water introduced (in 2001) free basic water to all households to the amount of 6,000 litres of water per household. The free basic water campaign forms part of the national government's poverty alleviation programme aimed at providing relief to poverty stricken households. In addition, water supply is essential for business (both small and large) and industry within the CoJ.

Johannesburg as a city, together with the other Metropolitan areas in Gauteng, requires more water than can be provided from the local rivers. In addition, Johannesburg is not located near a large water source. This means that potable water for the region, which is purchased in bulk from Rand Water, has to be pumped about 50 km from the region of the Vaal River. In order to supplement this main source, water is now transferred from Lesotho into the tributaries of the Vaal River.

The Lesotho Highlands Water Project, which delivers water from the highlands of Lesotho to South Africa's Vaal River system and generates hydropower for Lesotho is Africa's largest ever water transfer project as well as the largest ongoing bi-national construction project on the continent. Lesotho Highlands, with its high rainfall and surface area of high basalt mountains - the Maloti - is an outstanding catchment area allowing the Lesotho Highlands Water Project to capture most of the excess water from rainstorms in the Orange/Senqu River catchment and transfers it to the Vaal River system, at the same time ensuring the sustainability of life forms dependent on flows downstream of its storage dams.

The impact on the CoJ due to climate change in regions from which water is transferred is one issue that cannot be adequately addressed without an in-depth study of projected rainfall and temperature changes in those areas, but it can be assumed that the increases in temperature leading to increased evaporation and hence reduced run-off will lead to increased competition for available water.

The threat of climate change to water supply is recognised in the CoJ SoER 2008 as is the relative buffer that a city offers to resident through the regulated supply of piped water. Supply of water can be controlled and adjusted according to the demand and also the constraints on rainfall and in-basin transfers.

It is recommended in the SoER that as demand for water in Johannesburg increases relative to the existing supply, it is imperative that a strong focus on water conservation and demand management be maintained. It is also deemed important to support conservation of water by the continued investment in the upgrading and maintenance of the City's aging water supply infrastructure. It pointed out that a variety of demand management techniques were available, including variable tariff structures, rebates for water conservation technologies and public education programs associated with water conservation.

Potential impacts of climate change on this sector include:

- A reduction in the CoJ's water supply from sources outside of the CoJ (such as Lesotho) as a result of climate change impacts in these areas;
- Increased stress on the City's water supply and sanitation infrastructure (due to increased rainfall and urban floods); and
- Increased stress on the City's natural surface water bodies due to contamination from failed sanitation and stormwater infrastructure.

4.7.6 Migration

According to the 2008 SoER, migration is one of the key factors that exert pressures at Metropolitan level (including on service delivery and state of the social / physical environment). In-migration into Gauteng, in addition to normal population growth, has resulted in an increase in population, estimated at approximately 10.5 million people in 2007. As a highly urbanised province, Gauteng is subject to significant pressures emanating from this in-migration both in terms of South African and non-South African migrants. It is estimated by the Centre for Development and Enterprise (CDE)'s survey data that the number of foreigners in Johannesburg in 2006 was around 550,000. (By end of 2008, this figure was expected to have grown to perhaps 600,000 or 700,000 in response to the crisis in Zimbabwe and the 'pull factor' of economic growth in South Africa. This is not a firm finding, however and CDE adheres to its estimate of around 550 000 in 2006.) Officially South Africa deports about 7000 illegal Zimbabwean immigrants per month (2007/8).

A survey of 4,654 Zimbabweans in Johannesburg, conducted in mid-2007 produced the following key findings:

- 92% of the sample had migrated between 2000-2007
- For 2002-2006, the majority cited political reasons
- For 2007: the majority cited unemployment as a main driver
- The majority of migrants were aged between 21 and 40 years.
- The top need cited by migrants was for access to refugee status, with the second need being the expressed desire for assistance with setting up a business

It is hoped by many that the situation in Zimbabwe will recover to such an extent that the migration rate will slow and possibly reverse. The situation in SA is exacerbated by the racism and xenophobia displayed by local people towards the immigrants. However, it is expected that within South Africa migration will continue regardless, and may well be exacerbated by climate change impacts.

It has been suggested that migration from rural to urban areas is driven by the belief that the city (and Johannesburg in particular) is a centre of employment, social interaction, education and prosperity. The anonymity that a large city such as Johannesburg offers may also facilitate the escape from discrimination and exploitation that is often experienced in smaller rural towns. One of the push factors that drive people out of the rural areas towards the urban environment is quoted as "Weather factors: Erosion, droughts and flooding" with the associated pull factor of "Safer environment, relatively free from natural disasters".

It is a fact that increasing urbanisation in the South African context leads to informal settlements with poor living conditions lacking in basic infrastructure which leads to, among other issues, less opportunity for growing food or collecting fuel or water, and relatively higher incidences of HIV/Aids. These problems are all exacerbated by a higher population density and result in living conditions which in many senses are not an improvement on conditions in the rural areas from where migrants originated.

Potential impacts of climate change on this sector include:

- Climate change acting as an additional stressor driving increased migration into the CoJ
- Environmental degradation is often a contributing factor to political and economic instability. Hence climate change may also indirectly increase the flow of migrants and refugees moving into the CoJ as a result of political and economic unrest.
- Increased migration is likely to add additional strain on service delivery and municipal resources.
- Increased or continued migration is likely to result in increasing/continued establishment of informal settlements.
- Increased social strains (xenophobia etc.)
- Many other impacts typical of the illegal immigration phenomenon.

5. RISK ASSESSMENT

5.1 Introduction

This section presents the results of the risk identification and prioritisation process undertaken as part of the adaptation plan. The purpose is to identify the potential primary (i.e. initial) impacts resulting from climate change (within the context of the CoJ) and to then evaluate the cascading series of consequences that arise from this initial impact, and which may include a variety of sub-risks with economic, social, health, environmental and/or other consequences.

Thereafter, these risks are assessed in order to determine their relative priority with respect to the potential negative consequences for the CoJ and its residents arising from these risks.

5.2 Risk Assessment Framework

5.2.1 Risk Identification

Risks have been identified through a series of workshops run both internally (within the technical project team) and externally with role-players within the CoJ local government. A key advantage in undertaking this assessment has been WSP's large team of experienced engineers (including road, railway, energy, HVAC, stormwater and others), environmental specialists (including sustainability, air quality, water quality, solid waste, ecological and human health risk consultants) and urban design & planning specialists ('green' architects and engineers), many of whom are based in Johannesburg and who have been engaged to provide insight within their specific field.

The engagement with role-players within the CoJ via workshops included key personnel and managers from the Department of Environment, Department of Transport, DP&UM, EMS, City Power, ISD, Development Planning and Facilitation, the JRA, Metrobus, Department of Finance, Region C and Region G, in addition to a number of external consultants assisting the CoJ on various projects. Other departments contacted (although they did not participate in workshops) included the Department of Health.

The risks indicated in this report do not represent an exhaustive list of all the climate-change risks facing the CoJ. Climate change is likely to impact upon almost every facet of life within the CoJ and hence it is probable that present and future CoJ managers, engineers and other role-players will encounter difficulties that were not foreseen. Nevertheless, the risks identified are likely to comprise the most significant ones facing the CoJ across a wide range of technical fields.

5.2.2 Risk Prioritising

An initial risk screening process has been applied whereby risks have been rated in a 3x3 risk matrix of Likelihood versus Magnitude. Likelihood is defined as the probability of the risk eventuating while the Magnitude of the risk is defined as the scale of the impact on the CoJ (as a whole) should the risk eventuate. Both of these measures take into account the current stress in the system (risks are more likely to eventuate when systems are already operating at or near capacity) as well as the effectiveness of current adaptation plans in place.

Magnitude and Likelihood for specific risks have been rated from 1 to 3. Qualitatively, these can be considered as: 1 - Low; 2 - Medium; and 3 - High.

The overall rating assigned to each risk reflected the consensus view among the technical project team and specialists referred to above. It should be kept in mind that the risk ratings do not represent a comprehensive assessment of that risk. Rather, it provides for a preliminary risk screening and risk prioritisation tool in order to determine the relative urgency and the order in which various risks should be more thoroughly assessed.

Likelihood versus Magnitude Graph

High	B	A	A
Med	C	B	A
Low	D	C	B
	Low	Med	High

The risk rating results in four different action levels, A - D, as follows:

Action Level A: Prioritise for Adaptation

This action level requires attention at both senior management (i.e. director) level and at operational level within relevant departments. Consequences arising from climate change are considered to be probable and the impacts are likely to be very serious for the City.

Action Level B: Review Opportunities/Adapt within Constraints

Current adaptations and controls, if any, should be reviewed to see whether there is room for improvement. If no controls are in place at present, some recommendations can be made to implement these. When capacity is available, risks at this level should be given more comprehensive attention. Risks should be periodically monitored through a regular review function (i.e. once every two years). The party responsible for monitoring the risk should be clearly defined.

Action Level C: Surveillance Monitoring

Risks should be periodically monitored to ensure that the risk assessment has not changed (i.e. once every two years). The party responsible for monitoring the risk should be clearly defined.

Action Level D: No Concern

Not regarded as a significant issue.

5.3 Risks due to Changes in Temperature

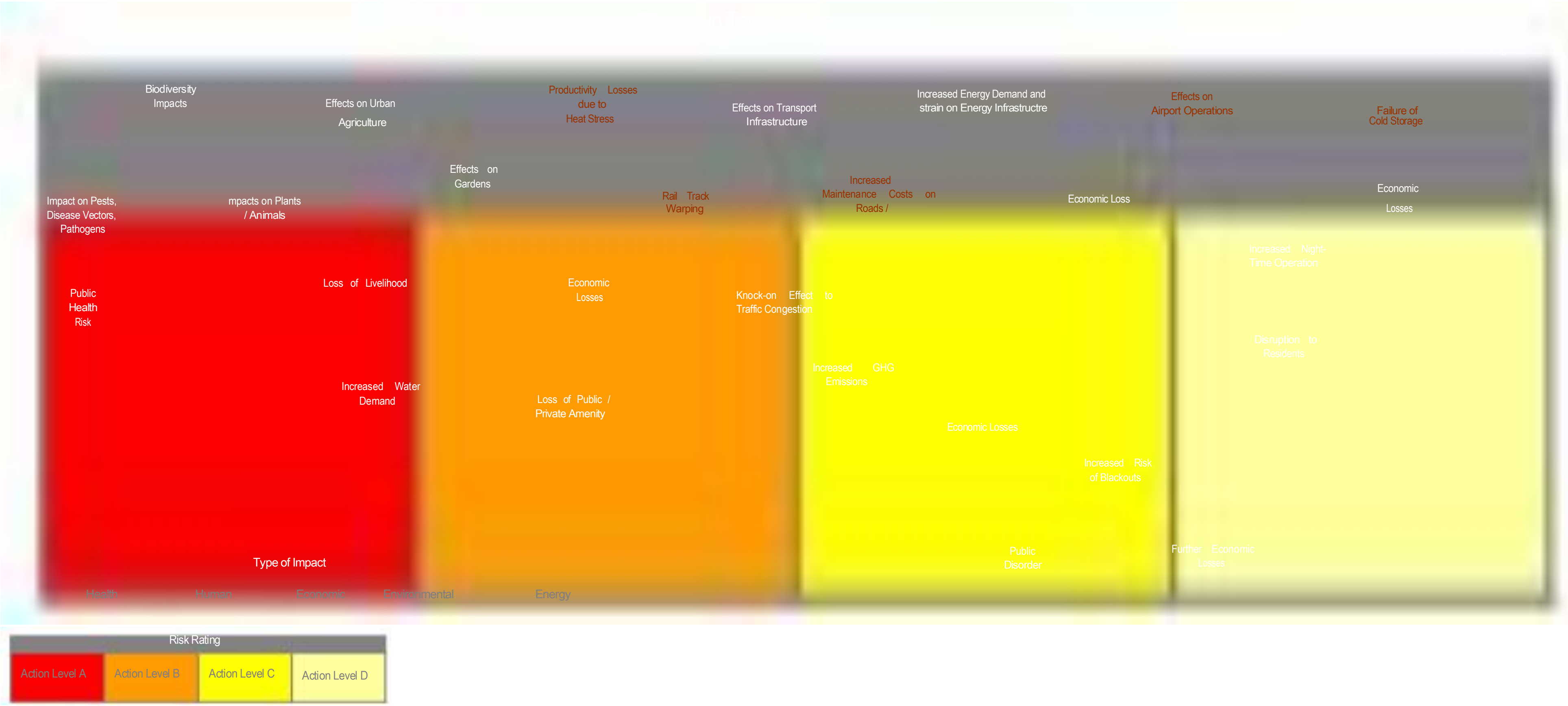
Risks due to projected changes in temperature within the CoJ region are summarised on Table s10a - d. The table below lists the rankings of these risks.

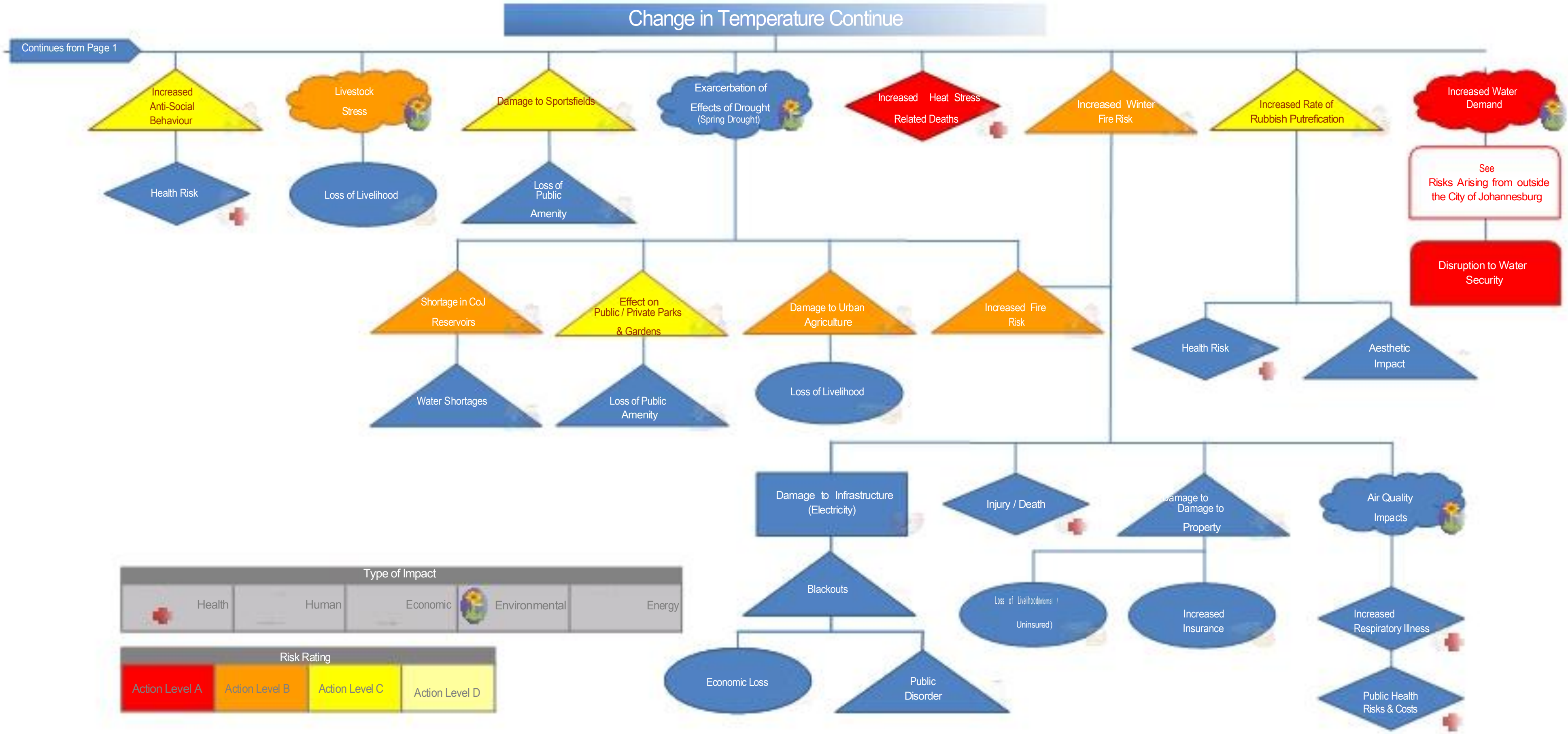
Table 13: Risks due to predicted changes in temperatures within the CoJ region

Change in Temperatures (including Extreme Heat Wave Events)					
Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(T1) Increased Occurrence of Heat-Related Deaths	2 - 3	2 - 3	Medium - High	Health, Disaster Management, Community Development & Livelihoods	Action Level A
(T2) Increased Energy Demand (includes effects of increased humidity)	3	2	High	Infrastructure, Environmental	
(T3) Stress on Water Supply from Increased Water Demand (See related Risk X1 in Table 10d)	2 - 3	2	Medium - High	Infrastructure, Community Development & Livelihoods, Environmental	
(TP4) Biodiversity Impacts - Health Risks (increased habitat range of disease vectors for malaria, bilharzias etc. Includes effects due to changes in precipitation & humidity)	1 - 2	2 - 3	Medium	Environmental, Health, Community Development & Livelihoods	
(T5) Increased Urban and Veld Fire Risk	1	3	Low - Medium	Disaster Management, Community Development & Livelihoods, Infrastructure	Action Level B
(TP6) Biodiversity Impacts - Degradation of Ecosystems (Includes effects due to changes in precipitation & humidity)	2	1 - 2	Medium - High	Environmental	
(T7) Disruption to Public Transport: Increased Rail Track Warping	1 - 2	1 - 2	Medium	Infrastructure, Community Development & Livelihoods	
(T8) Air Quality Impacts - Increased ozone levels (vehicle emissions etc.)	1 - 2	1 - 2	Low -Medium	Environmental, Health, Community Development & Livelihoods	

Change in Temperatures (including Extreme Heat Wave Events)

Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(T9) Livestock Stress	1 - 2	1	Medium	Community Development & Livelihoods	
(T10) Economic loss due to reduced aircraft loadings at Joburg airports	2	1	Medium	Infrastructure, Finance & Economy	
(T11) Productivity Losses due to heat stress	1 - 2	1	Low - Medium	Finance & Economy	
(T12) Increased Failure of Cold Storage	2	1	Medium	Infrastructure	
(T13) Damage to Sports Fields	2	1	Medium	Community Development & Livelihoods	
(T14) Public Nuisance due to Increased Rate of Solid Waste Putrefaction	1 - 2	1	Medium	Infrastructure	
(T15) Increased Damage to Road/Bridge Infrastructure	1	2	Medium	Infrastructure	
(T16) Rail Track Warping	1	2	Medium	Infrastructure	
(T17) Spring drought effects on public/private gardens	1-2	1	Medium	Environmental	
(PT10) Impact on Urban Agriculture	see "Change in Precipitation" for risk rating				


Biodiversity Impacts
Effects on Urban Agriculture
Productivity Losses due to Heat Stress
Effects on Transport Infrastructure
Increased Energy Demand and strain on Energy Infrastructre
Effects on Airport Operations
Failure of Cold Storage
Effects on Gardens
Impact on Pests, Disease Vectors, Pathogens
mpacts on Plants / Animals
Rail Track Warping
Increased Maintenance Costs on Roads /
Economic Loss
Economic Losses
Public Health Risk
Loss of Livelihood
Economic Losses
Knock-on Effect to Traffic Congestion
Increased Night-Time Operation
Disruption to Residents
Increased GHG Emissions
Increased Water Demand
Loss of Public / Private Amenity
Economic Losses
Increased Risk of Blackouts
Public Disorder
Further Economic Losses
Type of Impact
Risk Rating
Action Level A
Action Level B
Action Level C
Action Level D



Change in Temperature Continue
Continues from Page 1
Increased Anti-Social Behaviour
Livestock Stress
Damage to Sportsfields
Exacerbation of Effects of Drought (Spring Drought)
Increased Heat Stress Related Deaths
Increased Winter Fire Risk
Increased Rate of Rubbish Putrefication
Increased Water Demand
Health Risk
Loss of Livelihood
Loss of Public Amenity
See Risks Arising from outside the City of Johannesburg
Disruption to Water Security
Shortage in CoJ Reservoirs
Effect on Public / Private Parks & Gardens
Damage to Urban Agriculture
Increased Fire Risk
Health Risk
Aesthetic Impact
Water Shortages
Loss of Public Amenity
Loss of Livelihood
Damage to Infrastructure (Electricity)
Injury / Death
Damage to Property
Air Quality Impacts
Blackouts
Loss of Livelihood(Informal / Uninsured)
Increased Insurance
Increased Respiratory Illness
Economic Loss
Public Disorder
Public Health Risks & Costs
Type of Impact
Health
Human
Economic
Environmental
Energy
Risk Rating
Action Level A
Action Level B
Action Level C
Action Level D

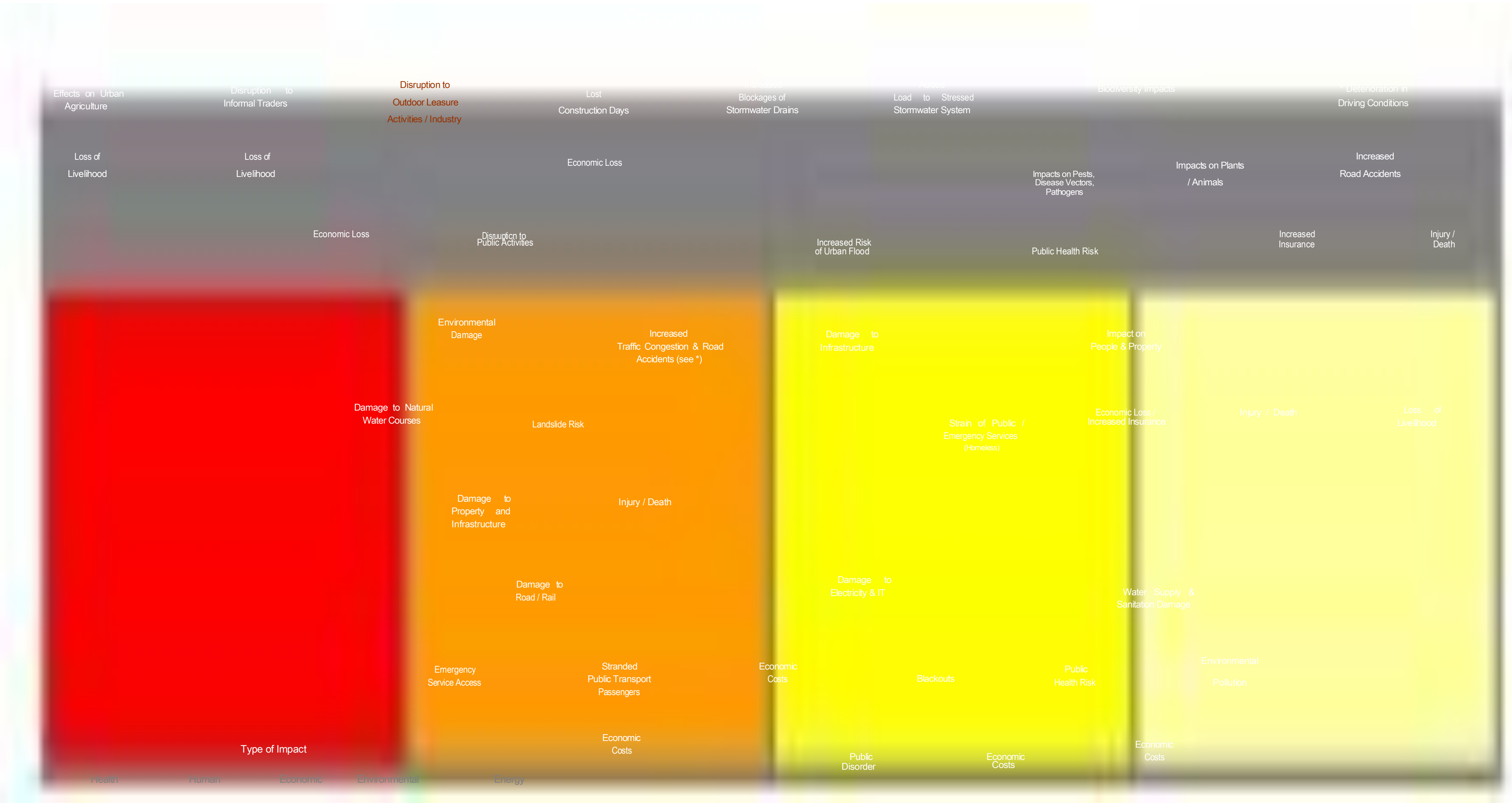
5.4 Risks Due to Changes in Precipitation

Table 14: Risks due to predicted changes in precipitation within the CoJ region

Change in Precipitation Patterns (Including Flooding and Spring Drought Events)					
Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(P1) Urban Flood Risk - Damage to Water Supply & Sanitation (including related human health risks)	2 - 3	3	Medium	Infrastructure, Disaster Management, Community Development & Livelihoods, Environmental,	Action Level A
(P2) Urban Flood Risk - Damage to property, personal injury and loss of livelihood	2 - 3	3	Medium	Infrastructure, Disaster Management, Community Development & Livelihoods	Action Level A
(P3) Urban Flood Risk - Increased traffic congestion and road accidents	2 - 3	3	Medium	Infrastructure, Disaster Management , Community Development & Livelihoods	Action Level A
(P4) Urban Flood Risk - Damage to Electricity & IT	2	2 - 3	Medium	Infrastructure, Disaster Management, Community Development & Livelihoods	Action Level A
(P5) Urban Flood Risk - Damage to Road & Rail Infrastructure	2	2	Medium	Infrastructure, Disaster Management, Community Development & Livelihoods	Action Level B
(P6) Increased Urban Flood Risk - Other Impacts: Environmental Damage	2	2	Medium	Infrastructure, Environmental, Community Development & Livelihoods, Disaster Management	Action Level B
(P7) Water Supply Shortage in CoJ Reservoirs (Spring Drought)	1 - 2	2	Low - Medium	Infrastructure	Action Level B
(P8) Lost Construction Days	2	1 - 2	Low - Medium	Finance & Economy	Action Level B
(P9) Business Disruption to Informal Traders	2	1 - 2	Medium	Community Development & Livelihoods, Finance & Economy	Action Level B

Change in Precipitation Patterns (Including Flooding and Spring Drought Events)

Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(PT10) Impact on Urban Agriculture within the CoJ (Precipitation - see Temp for additional)	2	1 - 2	Medium	Community Development & Livelihoods	
(P11) Impact on Outdoor/Leisure Industry	1	1	Low - Medium	Finance & Economy, Community Development & Livelihoods	
(TP4) Biodiversity Impacts - Health Risks (increased habitat range of disease vectors for malaria, bilharzias etc. Includes effects due to changes in precipitation & humidity)	see "Change in Temperatures" for risk rating				
(TP6) Biodiversity Impacts - Degradation of Ecosystems	see "Change in Temperatures" for risk rating				

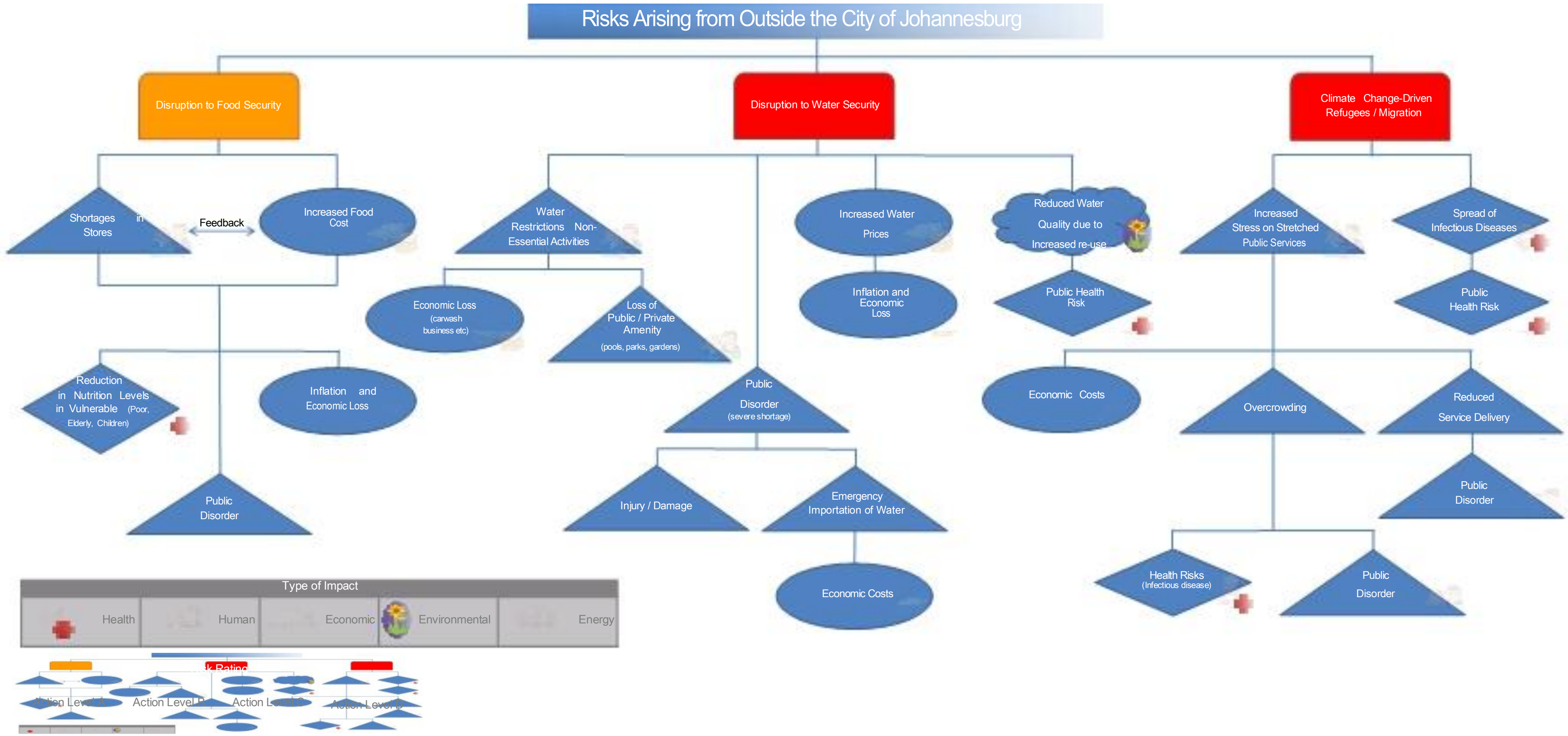


Risk Rating			
Action Level A	Action Level B	Action Level C	Action Level D

5.5 Risks Arising from Climate Change Impacts outside the CoJ Boundaries

Table 15: Risks due to climate change impacts outside of the CoJ region

External Risks					
Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(X1) Disruption to Water Security (from resources located outside of the CoJ)	1 - 2	2 - 3	Low-Medium	Community Development & Livelihoods, Infrastructure	
(X2) Climate Change-driven Refugees / Migrants	1 - 2	2 - 3	Low-Medium	Community Development & Livelihoods, Infrastructure	
(X3) Disruption to Food Security	1	2 - 3	Low-Medium	Community Development & Livelihoods	



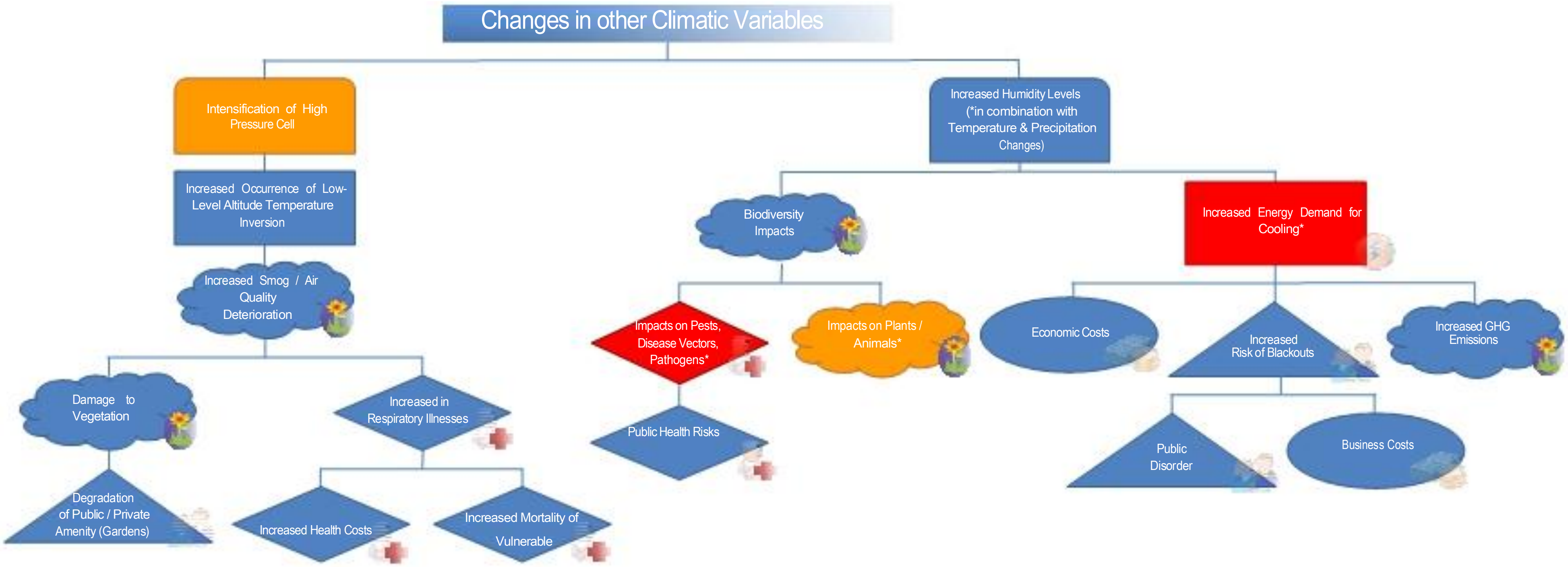
Risks Arising from Outside the City of Johannesburg
Disruption to Food Security
Disruption to Water Security
Climate Change-Driven Refugees / Migration
Shortages in Stores
Feedback
Increased Food Cost
Reduction in Nutrition Levels in Vulnerable (Poor, Elderly, Children)
Inflation and Economic Loss
Public Disorder
Water Restrictions Non-Essential Activities
Economic Loss (carwash business etc)
Loss of Public / Private Amenity (pools, parks, gardens)
Public Disorder (severe shortage)
Injury / Damage
Emergency Importation of Water
Economic Costs
Increased Water Prices
Inflation and Economic Loss
Reduced Water Quality due to Increased re-use
Public Health Risk
Increased Stress on Stretched Public Services
Spread of Infectious Diseases
Public Health Risk
Economic Costs
Overcrowding
Reduced Service Delivery
Public Disorder
Health Risks (Infectious disease)
Public Disorder
Type of Impact
Health
Human
Economic
Environmental
Energy

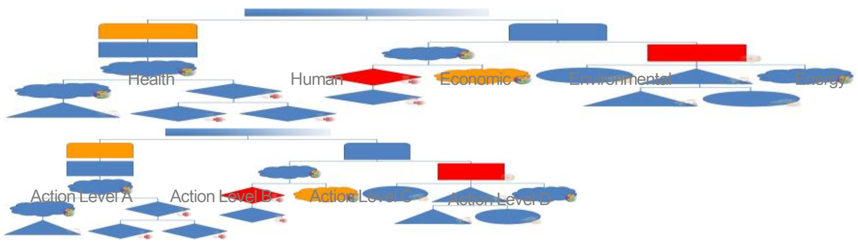
5.6 Risks Due to Changes in Other Synoptic & Climatic Variables

Table 16: Risks due to predicted changes in other synoptic/climatic variables

Changes in Other Synoptic & Climatic Variables

Risk	Likelihood	Magnitude	Confidence Level in Prediction	Key Sector	Overall Risk Rating
(O1) Increased occurrence of air temperature Inversion - Air Quality Impacts (high pressure cell)	2	2	Medium	Environmental, Health	
(T2) Increased Energy Demand (includes effects of increased humidity)	see "Change in Temperatures" for risk rating				
(TP4) Biodiversity Impacts - Health Risks (increased habitat range of disease vectors for malaria, bilharzias etc. Includes effects due to changes in precipitation & humidity)	see "Change in Temperatures" for risk rating				
(TP6) Biodiversity Impacts - Degradation of Ecosystems (Includes effects due to changes in precipitation & humidity)	see "Change in Temperatures" for risk rating				


Changes in other Climatic Variables
Intensification of High Pressure Cell
Increased Occurrence of Low-Level Altitude Temperature Inversion
Increased Smog / Air Quality Deterioration
Damage to Vegetation
Degradation of Public / Private Amenity (Gardens)
Increased in Respiratory Illnesses
Increased Health Costs
Increased Mortality of Vulnerable
Increased Humidity Levels (*in combination with Temperature & Precipitation Changes)
Biodiversity Impacts
Impacts on Pests, Disease Vectors, Pathogens*
Public Health Risks
Impacts on Plants / Animals*
Increased Energy Demand for Cooling*
Economic Costs
Increased Risk of Blackouts
Increased GHG Emissions
Public Disorder
Business Costs


Health
Human
Economic
Environmental
Energy
Action Level A
Action Level B
Action Level C
Action Level D

5.7 Summary

The results of the risk screening process indicate that there are ten risks rated as Action Level A: Prioritise for Adaptation. These are listed below:

- Risk T1: Increase in Heat-Related Deaths
- Risk T2: Increased Energy Demand
- Risk T3: Increased Water Demand (within the CoJ)
- Risk TP5: Biodiversity Impacts on Disease Vectors (Health Risks)
- Risk P1: Urban Flood Risk - Damage to Water Supply & Sanitation Infrastructure
- Risk P2: Urban Flood Risk - Damage to property, loss of livelihood and personal injury
- Risk P3: Urban Flood Risk - Increased Road Accidents and Traffic Congestion
- Risk P4: Urban Flood Risk to Electrical & IT Infrastructure
- Risk X1: Disruption to Water Security (arising from outside the CoJ)
- Risk X2: Climate-Change-driven Refugees and Migrants

The analysis of these high priority risks and possible adaptations are developed further in Sections 6 and 7 below. It is expected that future revisions to the adaptation plan will build on these assessments and will also prioritise expanding the assessment to include the lower order risks, in particular the Action Level B-rated risks.

It is noted that there are a further twelve risks identified as Action Level B: Review Opportunities/Adapt within Constraints. Of these, Risk P7: Water Supply Shortage from Reservoirs within CoJ is closely interrelated to the Action A-rated Risks T3 and X1 listed above. Similarly a further two risks (Risk P5: Urban Flood Damage to Transportation Infrastructure and Risk P6: Urban Flood Damage to the Environment) are closely interrelated with the other four Action A-rated Urban Flood risks listed above (Risks P1 - P4). A natural consequence of these interrelations is that adaptations which address the Action A-rated risks are likely (although not certain) to also contribute to mitigating the risk posed by the associated lower order risks. To a lesser but nevertheless significant extent, there are also synergies between adaptations for all heat-related risks and adaptations that address Risk T1: Increase in Heat-Related Deaths, insofar as these adaptations act to reduce the temperatures in the local micro-climate.

Of the twelve Action B-rated risks, Risk T5: Increased Risk of Urban & Veld Fire and Risk X3: Disruption to Food Security are regarded as potentially the most serious and worthy of attention in future updates.

6. KEY FINDINGS - HIGH PRIORITY RISKS

6.1 Introduction

The following assessment presents the key findings for the high priority risks (i.e. the ten Action Level A-rated risks) identified in the preceding section. These key findings form the foundation for the adaptation plan presented in the following section (Section 7). The key findings are presented here in some detail and within the context of investigating a specific risk whose impacts are likely to cut across several of the CoJ Key Sectors. Hence some points from the broader vulnerability overview (Section 4) have been repeated in order to properly characterise the risk. It is anticipated that the key findings may be of practical assistance to and provide a context for CoJ planners when designing and implementing adaptation plans for the specific risks addressed.

6.2 Risk T1: Increase in Heat-Related Death

KEY FINDINGS:

Scale of the Risk:

Heat is a leading cause of weather-related deaths worldwide. According to the UK Climate Impacts Programmes, the 2003 Europe heatwave event is estimated to have resulted in more than 30,000 deaths. Economic losses associated with this heatwave have been estimated to be in excess of £7.5 billion.

Statistics from the National Oceanographic and Atmospheric Administration (NOAA) indicate that heat is the leading cause of weather-related deaths in the U.S. (greater than mortality from hurricanes, floods, tornadoes etc.) and was responsible for an estimated $565 million worth of damage between the years 1988 and 1999[13]. The Centers for Disease Control (CDC) in the U.S. estimates that heat-related mortality in the U.S. was responsible for more than 3,400 fatalities between 1999 and 2003. Other studies have indicated that this may be a significant underestimate.[14]

A study19 undertaken in the U.S. attempted to quantify the projected increase in heat-related mortality due to climate change for 21 U.S. cities, under a "business as usual" scenario (the same scenario used for the climate modelling in this study). The findings indicated that for most of the cities studied, climate change is projected to more than double the average number of summertime heat-related deaths.

An Australian study[15] found that daily mortality of people aged +65 increased by 15 - 17% when the mean daily temperature exceeded 30 degrees. A similar increase was found when daily minimum (nights) exceeded 24 degrees.

The UK National Health Service has cited strong evidence that excess deaths during heatwaves are not just deaths of those who would have died anyway in the next few weeks or months due to illness or old age but that heat-related deaths are indeed 'extra' i.e. the result of heat-related conditions (ref. Heatwave Plan for England. NHS, 2009).

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[13] *It is noted that this is actually quite a modest cost. By comparison, NOAA estimated that floods were responsible for around $41 billion worth of damage for the same period.*

[14] An Analysis of Potential Heat-Related Mortality: Increases in U.S. Cities under a Business-as-Usual Climate Change Scenario. *Kalkstein and Greene, 2007.*

[15] Towards a City of Melbourne Climate Change Adaptation Strategy: A Risk Assessment and Action Plan. *Maunsell, 2008.*

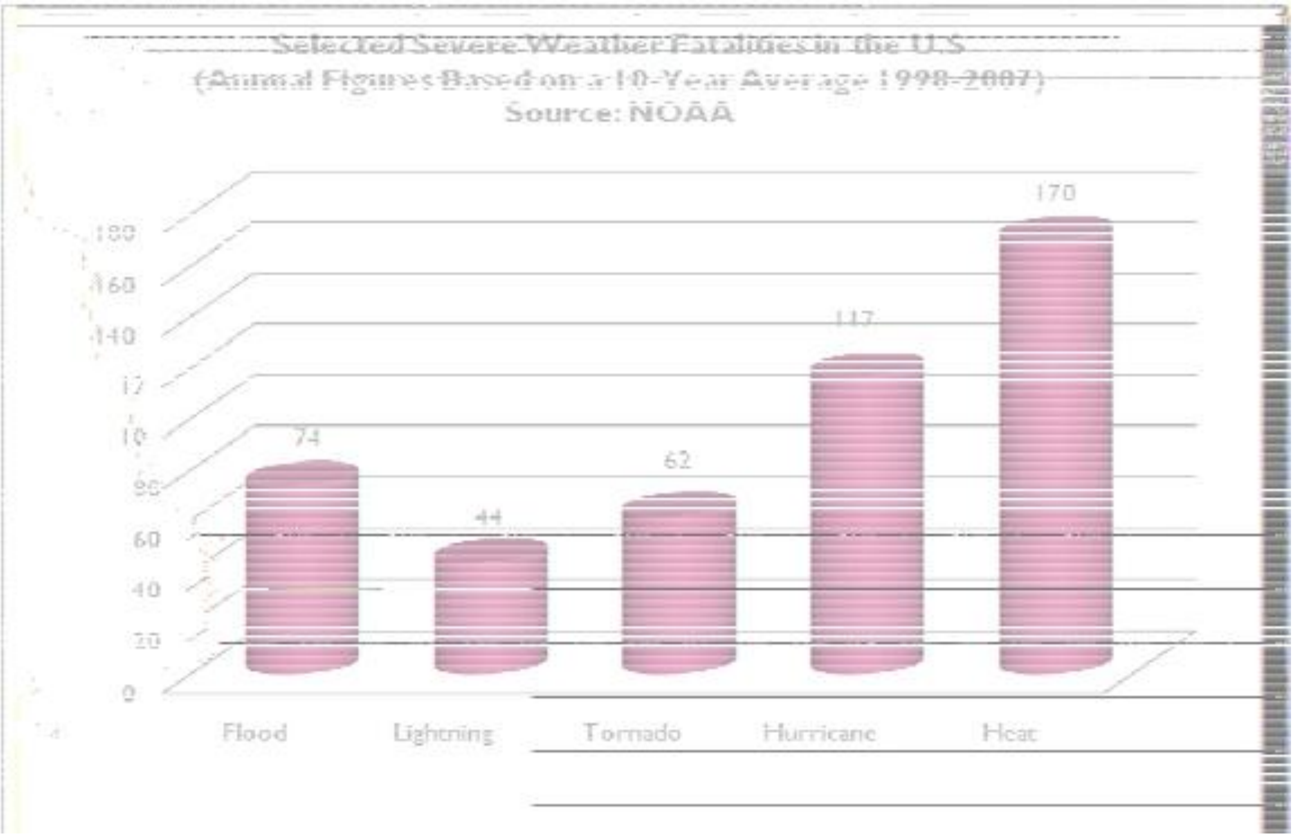

Figure 11: Weather Fatalities in the U.S.

Risk Factors:

Heat-related mortality rates, while related to high average temperature levels, are predominantly related to sudden and extreme deviations from average temperatures (for that time of year). This is because most people have the ability to physiologically acclimatise to hot conditions over a period of days or weeks.

Hot nights contribute significantly to heat-related deaths. Consequently, heat-related deaths may be more likely to occur within urban areas due to the urban heat island effect, as this increases the temperatures at night as compared to rural areas. Socio-economic conditions are a key parameter in determining vulnerability in short events; whereas age is the more critical parameter for longer events. Those suffering from existing cardiovascular and respiratory difficulties and other illnesses (i.e. Alzheimer's) are also at risk. These risk factors are cumulative. Air quality issues are also likely to exacerbate the risk posed by heatwaves to vulnerable groups.

The 2001 national census indicated about 131,400 people within the CoJ aged 65+ (or around 4% of the population); this group is considered to be among the most vulnerable.

CoJ Context:

In South Africa, a heatwave is defined as when the temperature is five degrees higher for three consecutive days than the highest average maximum temperature for the area. However, heat-related mortality can also be expected to increase during heat events shorter than this.

Higher average temperatures in future for the CoJ will mean that when a heatwave does occur, it is likely to have far more severe consequences than at present. The projected increase in humidity for the CoJ will also exacerbate this risk. Higher humidity results in higher "apparent" temperatures for the human body, since humidity makes it harder to lose excess body heat (through evaporative sweating).

In future, the greatest risk of heatwaves may arise in the spring, based upon the climate modelling. This is due to the high projected increases in average temperatures for day and night, the projected increase in extreme heat events in spring (>90th percentile heat events), and the greater natural temperature variability in this season.

There are no heat-related mortality statistics for the CoJ (that the authors' of this report are aware of). It is likely that the scale of heat-related deaths is under-appreciated in South Africa. It is acknowledged that heat-related mortality statistics are difficult to measure; as is often the case with air pollution-related deaths, very few deaths are certified as heat-related. Increases in deaths during heat episodes are most likely reported as from cardiovascular, cerebrovascular and respiratory disease.

Any increase in heat-related mortality may potentially be offset by a decrease in "low temperature"-related mortality. However, heat-related mortality should be treated as a discrete cause of death and mitigated accordingly.

Despite the lack of CoJ statistics, there is sufficient indication based on the climate modelling and overseas studies that this risk should be taken seriously within the CoJ. However, without CoJ-specific statistics, it is difficult to assess the relative priority of this health risk compared to other pressing health-related issues within the CoJ.

There is currently no heatwave response plan for the CoJ.

Likelihood: 2 - 3 (medium - high)

Based upon overseas studies referenced above and upon the climate modelling for the CoJ, which projects significantly increased day and night-time temperatures, a significant increase in heat-related deaths by mid-century is considered to be likely.

Magnitude: 2 - 3 (medium - high)

Statistics on heat-related deaths in CoJ are not at present available. However, overseas statistics clearly demonstrate that heat-related mortality is a significant cause of death, particularly for vulnerable groups. The European heatwaves of 2003 and 2006 were responsible for the deaths of several thousand individuals even under conservative estimates. A study undertaken for 21 cities in the U.S. has suggested that heat-related deaths may double by mid-century due to climate change. Although the risk profile for the CoJ is different from cities in the Europe and from the U.S., in the absence of CoJ-specific data, the magnitude of the impact is considered to be medium to high.

Current Control Mechanisms:

The CoJ currently does not have a heatwave response plan in place. However, there are several programmes and factors which act to mitigate this risk to some extent:

Johannesburg is well known for being possibly the city with the most trees in the world. Trees act to provide shade during the day and reduce night-time urban temperatures by ameliorating the urban heat island effect.

Tree-planting programmes are also being rolled out in townships and areas which are generally regarded as socio-economically deprived (for example, the CoJ's Greening Soweto programme is aiming to deliver 300,000 trees in the City's largest township[16]).

Other positive factors include:

- Plans for the Gautrain to be air-conditioned. Cooling on public transport is considered to be a significant mitigation of heat-related stress.
- New building guidelines (proposed) for insulation and shading of buildings

Key Stakeholders:

Community clinics; organisations that deal with the elderly; community organisations in townships and informal settlements; Emergency Services; Public Transport operators, Municipal, Provincial and National Health departments; health & social care professionals.

[16] http://www.joburg.org.za/content/view/2095/222/

6.3 Risk T2: Increase in Energy Demand

KEY FINDINGS:

South Africa and Johannesburg have recently experienced significant energy shortages, resulting in unplanned and planned outages/load shedding. This resulted in loss of production and income for many industry sectors (SACOB estimated loss of business due to power outages and capacity problems nationally in 2007/2008 was in excess of R1.3 billion). These outages were largely related to shortfall of supply due to poor planning of capacity building, and also due to poor maintenance of existing generation and supply networks.

The impact of temperature increases on cooling via air-conditioners for buildings within the CoJ will result in an increase in cooling during the summer, as well as new periods of air-conditioning added throughout the year i.e. in the spring and autumn. WSP have estimated the CoJ air-conditioning load component to be 10-15% of the City's total electricity load[17] and an increase in this sector would have a significant impact on energy resources in the CoJ in the near- and far- future periods (ref. Box 2 for more details).

Energy consumption due to refrigeration installations for domestic and commercial property (estimated by WSP to account for around 4% of the CoJ energy consumption) is also likely to increase significantly as temperatures increase with time (see Box 2 again). Refrigeration units will also be at greater risk of failure, possibly resulting in millions of Rands worth of damage in spoiled goods.

There are likely to be other sources of increased energy consumption. The additional air-conditioning and refrigeration energy consumption implies that CO2 emissions (from coal fired power plants) will likewise increase. This may potentially undermine reaching energy efficiency and global warming mitigation targets for both the CoJ and for South Africa in future.

In the long term, if temperature rise does occur as modelled and if continue current traditional standard building and cooling design, it will likely result in significantly increased capital expenditure of cooling equipment.

Air-conditioning of vehicles typically increases fuel consumption of vehicles by about 15-30% (National Renewable Energy Laboratory, Washington USA). With an estimated far future rise in temperature of 4.5oC, fuel consumption of vehicles could expect to rise by approximately 4.5% with an associated increase in fuel demand within the CoJ.

Electrical cable current carrying capacity to some extent decreases with higher temperatures, and thus electrical networks are also at greater risk of failure at higher operating temperatures. Thus increased temperatures will increase demand while at the same time increasing the risk of failure.

It is noted that peak electricity demand in South Africa (including the CoJ) typically occurs in the winter (due to heating requirements). Hence increased temperatures will have the benefit of reducing energy demand in the winter season. However, a substantial portion of maintenance on power stations and electricity infrastructure is undertaken during the summer, which results in lower energy availability during this period of the year. The interaction of decreasing electricity demand in winter and increasing demand in the spring and summer, in particular, will have important implications on the overall electricity requirements for the CoJ and on the scheduling of maintenance for infrastructure supplying the CoJ.

It is also noted that reduced overall electricity and energy usage within cities contributes to mitigating the Urban Heat Island effect (if combined with other measures).

Likelihood: 3 (high)

Energy consumption of mechanical cooling systems is proportional to the ambient temperature. The likelihood rating of this risk has been assessed as high due to the high confidence in the projection of significantly increased temperatures. It is noted that this applies particularly to the summer and spring time. Energy demand in the winter time is expected to fall.

Magnitude: 2 (medium)

[17] Based upon the relative share of total CoJ electricity consumption used by commercial buildings and the average air conditioning load within these buildings.

The predicted increases will add pressure to a national electricity system that is already severely stressed. It may result in increased risk of blackouts in the summer/spring, increased economic costs and create additional challenges in meeting energy efficiency and global warming mitigation targets.

Current controls:

The current control measures to the energy supply shortage in South Africa (and the CoJ) has been somewhat of a 'knee jerk reaction', with many organisations/property owners doing only the bare minimum to reduce energy consumption, and with many landlords and developers still operating in a similar way as prior to the Eskom power crisis of 2008.

Eskom's current reserve is at about 8%, which is significantly below the norm of 15% (ESKOM Annual Report 2008). Supply capacity is most likely to only be alleviated between 2012 and 2014. Longer term plans include a number of renewable energy projects and nuclear projects, but these have not been approved and programmed for completion yet.

There is a lack of enforced energy efficiency standards that exist in South Africa (and the CoJ). The SANS 204 (energy efficiency standard), which was released in 2008, has not yet been promulgated under any building codes or legislation. According to the chair of the SANS 204 committee, this is most likely only going to happen at the earliest by the first quarter of 2010.

Despite the above obstacles, the following measures are being pursued with respect to managing energy demand within the CoJ:

The CoJ is taking part in the Clinton Climate Change Initiative, part of which includes 12 city administration buildings which are being targeted for energy efficiency measures.

The CoJ has added their energy efficiency requirements to electrical supply applications from developers on new or refurbished developments.

The CoJ's IEMP refers to a target of 10% energy savings in all municipal buildings by 2010.

The CoJ is undertaking a retrofit of over 100 council buildings.

Policy has been developed to promote energy efficiency in land-use development. However, according to the CoJ, voluntary application of the recommended measures has been muted to date

Demand-side management bylaws for energy efficiency are currently being developed.

LED traffic and street lighting, in some cases connected to renewable energy sources, is currently being rolled out in some areas to save energy in the CoJ and ensure continued operation in times of blackout.

There are and have been some significant solar water heater projects undertaken in the CoJ (for example, an ambitious pilot scheme in Cosmo City).

A proposal for an energy saving programme on CoJ water pump systems exists.

In some cases supply upgrades and projects have been halted or delayed due to supply shortage - this is not a realistic or long term feasible option.

Eskom has implemented a national Demand Side Management programme. However, the programme has unfortunately recently had its budget cut significantly. It also has not been a simple process for projects and the general public to gain access to these initiatives and funds.

Key Stakeholders:

Eskom; City Power; ISD; DP&UM; Department of Environment; electrical consultants and design engineers.

Box 2. Preliminary Technical Analysis of the Impact of Increasing Temperatures on Electricity Consumption within the CoJ

Air-conditioning design to buildings is typically designed in Johannesburg to a summer set-point temperature of 2 24°C, and the winter design set-point temperature of 18-20°C, with intermediate range for spring and autum Modelled climate change temperature change for the far future (2086 - 2100) estimates that median temperature may rise to approximately 29.1°C in summer, 28.9°C in spring, 26.7°C in autumn, and 23.7°C in winter (thes temperature estimates are actually the mean of several different model projections - ref. Section 3.3 of th report). The impact of this will be that cooling via air-conditioners will be applied to a much greater extent i spring, autumn and even in winter (notably the spring median temperature is almost the same as the summ median). The autumn and spring periods are often periods where lower levels of heating or cooling are require at present. Therefore the far future energy increase predicted is not just a percentage increase on the current a conditioning load period, but contains substantial new periods of air-conditioning added throughout the year. Th far future median temperature increase of about 4.5°C represents an approximate increase of 20% in the averag heating load on buildings, which represents approximately 4.4% increase of heating load per 1°C increase. With a average conservative coefficient of performance (COP) of about 2.75, this additional heat load translates to about 1.8% electrical energy demand increase per 1°C increase. The overall combined effect is not easily modelled, but estimated at a total increase of energy consumption of 2.5-4% on the air-conditioning load of the CoJ per 1° increase in temperature. The CoJ air-conditioning load component is estimated at 10-15% of the total load of th city. A 2.5-5% increase here would thus have a significant impact on energy resources in the CoJ in the far future.

Similarly, refrigeration installations to domestic and commercial property will increase by approximately 2.5% f every 1 degree increase in temperature. Working with a total potential far future increase of median temperature of around 4.5°C translates into a total 11.25% increase in energy, assuming that the same systems/technology used as in the present day. The estimated percentage of electricity consumption of refrigeration systems for th CoJ is approximately 2-4% of the total energy consumption, based on the large residential and commercial/industrial components to the city, most of which have some refrigeration to them.

6.4 Risk TP4: Biodiversity Impacts on Disease Vectors - Health Risks

KEY FINDINGS

Malaria

Increased high rainfall thunderstorms and the increased risk of flooding can result in un-sanitatory conditions favourable for disease outbreak as well as for mosquito/vector habitat, particularly when coupled with high temperatures and resultant high humidity.

The key factor governing vector-borne diseases is the length of the tropical or sub-tropical climate. Humidity of greater than 60% and temperature ranges above 20 degrees are the optimal conditions required to support the life cycle of the host mosquito.

Cold dry winter conditions break the life cycle of the mosquito and thus high altitude cities in tropical Africa are free from malaria. The critical aspect is thus whether temperature change in winter is sufficient to eliminate frost.

It is unlikely that frost nights will disappear from Johannesburg in the near-future (2046 - 2065) and hence that Johannesburg will become part of an expanding malarial belt. However the surrounding areas to the east and north of Gauteng may see an increase in malaria, extending from a four to six month period over the wet season. However, there is greater uncertainty in predicting the frequency of frost days/nights in the far future (2086 - 2100) and consequently, the projections for the far-future while, on balance, still not favouring an expansion into the CoJ, are more ambiguous.

It is noted that a case of malaria was recently reported in individuals residing just outside of the CoJ municipal boundary (to the south of the CoJ). The South African National Institute of Communicable Diseases has reportedly investigated the case to determine whether the vector (i.e. mosquitoes) were breeding in a nearby nature reserve or whether they came into the area with a shipping container from elsewhere in Africa. The authors of this report are, however, not aware of the outcome of this investigation. The CoJ Health Department is aware of this incident. The spread of malaria is not only climate related but is influence by increasing drug resistance of some the strains of the disease and the reduced use of pesticide due to environmental concerns. Areas where vector control measures were once applied to eradicate the disease are now likely to see a re-occurrence. The influx of people as carriers of malaria from un-controlled high risk areas in the rural areas to the cities increases the risk of transmission.

As the City is a centre for population migration in southern Africa the increase in malaria will have an effect on the migrant population as infected people will requirement treatment in the CoJ hospitals. These people are often the poorest of the City's inhabitants with limited access to services; hence the impact of a malarial epidemic in the north-east part of South Africa will result in a high mortality rate, particularly amongst young children.

The cost of hospitalisation for malarial cases is estimated to be R4,000 per day at current rates. So there is an obvious economic cost, together with loss of production and income.

At present malaria is only fatal in less than 1% of cases (usually children). However the population at high risk of contracting the disease in southern Africa is expected to rise to 36 million people with a suggested additional 280,000 additional cases of malaria. Cost of treatment is estimated at R950 M by 2010 with a further R95 m in lost productivity.

Other Diseases

Other vector-borne diseases include Schistosomiasis (Bilharzia) which transmitted via a water snail. The spread of Schistosomiasis is related to high rainfall and can be expected to spread when floods are followed by high temperature allowing the water snail to increase its range. Although cold temperatures will break the life-cycle of the host, it is considered that the northern parts of Gauteng may see an increase in Schistosomiasis cases. Again, this may impact on the CoJ indirectly through the migration of infected individuals into the CoJ.

Cholera

While, strictly speaking, the risk of cholera is related more to flooding than to direct climate change-driven biodiversity and habitat impacts within the CoJ, it is considered more appropriate to discuss this risk in the context of the diseases mentioned above.

The dense urbanisation in Johannesburg with 33% of the population at present living in less than adequate housing with poor sanitation is a key factor in the spread of infectious diseases.

The risk of flooding and the consequent disruption of the water and wastewater systems bring with it the threat of Cholera.

Vibrio cholerae is the most common infectious disease to reach epidemic proportion in southern Africa.

Similar impacts can be expected for all forms of diarrhoeal diseases (the second biggest killer of poor children).

Recent outbreaks of the disease in neighbouring regions are associated with dense peri-urban populations along flood prone rivers. Cholera has reportedly previously been detected in the Jukskei River in Alexandra and elsewhere.

Cholera is associated with poor hygiene and has a complex mode of transmission as a water and food-borne disease. It is an infectious disease of poverty and most readily preventable by provision of proper sanitation.

Rising temperature and increased rainfall will tend to favour the spread of the disease and the reservoir of cholera in the zooplankton of water bodies. Cholera outbreaks have the potential to occur wherever clean water supplies are disrupted (which leads to unhygienic practices).

There is a possibility that climate change may increase cholera outbreaks and that the bacteria may become increasingly resistant to antibiotics over time, or new strains of the bacteria may emerge.

The settlements of Alexandra, Orange Farm and Ivory Park are typical of the more rural informal settlements where access to clean drinking water and waterborne sewerage does not extend to all inhabitants.

Likelihood: 1 - 2 (low - medium)

The likelihood rating of a malaria epidemic is low to medium, with the likelihood potentially increasing towards the far future (2086 - 2100). The primary risk in the near-future is due to the greater likelihood that adjoining regions will see an increase in vector-borne tropical diseases such as malaria, which may result in a secondary impact on the City's health services. A similar scenario is considered likely for Bilharzia.

The risk of a cholera epidemic is medium to high in the high risk dense peri-urban informal settlements, due to the strain on the water supply and sanitation infrastructure, combined with the effects of climate change.

Magnitude: 2 - 3 (medium - high)

Assuming that the incidence of tropical disease did significantly increase within the CoJ, the magnitude of the impact is rated as medium - high. However, the more likely impact due to "spill-over" effects from adjoining provinces and municipalities, especially to the north, is rated as low - medium magnitude.

Although unlikely to impact on formerly developed and more affluent parts of the City, the magnitude of a cholera outbreak is regarded as high, particularly in informal settlements.

Current controls:

- Water-borne diseases are controlled by disaster management plans related to restoring water services after a major disaster event.
- The CoJ Health Department is reported to be prepared in the event of a cholera outbreak.
- In terms of disease vectors, the CoJ Health Department has a vector control section in Region A (the most northerly CoJ region).
- Communicable diseases are monitored and assessed by the National Institute of Communicable Diseases (NICD).

The authors of this report have at present not been able to confirm to what extent the (NICD) is aware of the developing threat of tropical diseases (this is in part due to the NICD being occupied with the recent confirmation of swine flu in South Africa).

6.5 Risks P1 - P4: Increased Risk of Urban Flooding

KEY FINDINGS

Many of the key findings related to the urban flooding risk are detailed in Sections 4.4.1 and 4.4.2 describing the stormwater and the water supply & sanitation infrastructure as well as health (Section 4.3). Reference should also be made to these sections.

Rainfall Projections for the CoJ

- Climate model projections for rainfall for the CoJ suggest a moderate but significant increase in precipitation by the near-future (mid-century), with this trend continuing (although potentially at a slower rate) into the far-future.
- An increase in storm events frequency and magnitude is considered probable, due to the nature of rainfall in the CoJ region.
  - (Johannesburg rainfall is mostly in the form of storm events with intense rainfall over a short period (thundershowers), which produces high volumes of run-off in a very short space of time.)
- The projections indicate a lengthening of the rain season, extending into autumn and possibly starting earlier in the spring (although there is less confidence in this projection).

Risks Associated with Urban Flooding

- The risk of urban flooding gives risk to numerous sub-risks, including:
  - Risk P1: Damage to water supply and sanitation infrastructure;
- Significant human health risks are also associated with Risk P1, including the risk of cholera and diarrhoeal illnesses. (these are described in more detail under risk TP4, with other transmissible illnesses).
  - Risk P2: Damage to property, personal injury and loss of livelihood.
  - Risk P3: Disruption of traffic/public transport and an increase in road accidents; and
  - Risk P4: damage to electricity and telecommunications infrastructure.

The increased urban flooding can cause significant damage to a wide range of buried and above-ground essential infrastructure including buried water supply and sanitation pipelines, downstream water treatment plants, collapsed and damaged roads and railway lines, buried electrical and IT infrastructure and electric substations.

The increased urban flooding can also cause damage to natural waterways, also via erosion, undercutting and landslides.

Urban flood-related mortality (due to drowning and physical trauma) is generally low within the South African context. The most serious human health risks are related to the lack of or damage to basic water supply and sanitation infrastructure leading to contaminated water (natural and piped) and unsanitary conditions and the consequent spread of diseases, particularly in underprivileged communities (i.e. cholera, diarrhoea etc. - further details of the cholera risk are detailed under Section 6.3.3).

Despite the low direct mortality risk, these deaths are generally preventable and hence should be addressed where possible.

Flooding is, however, likely to be the leading weather-related cause of damage to property and loss of livelihood within the CoJ, in both informal and formal settlements as well as in established suburbs and commercial/industrial zones. Damage to property has extensive knock-on effects potentially resulting in significant financial hardship and possible loss of livelihood across all sectors of society.

Each of these risks may require some of their own specific measures. However, in the main, these risks are best addressed together, at the source of the problem.

In the context of the CoJ, the central causes of serious urban flood events are deficiencies in stormwater infrastructure (or a complete lack thereof) and inappropriate urban development i.e. development within floodplains (both planned and unplanned).

Urban Planning

The large amount of impermeable hardstanding (i.e. tarmac and concrete) in the City creates high run-off speeds, increasing uncontrolled run-off and flood damage, including within low cost housing and informal settlement communities, where hard surfaces cover 95% of the area (including roofs and hardened bare ground).

Diepsloot is a good example of this, where densities of dwellings are extremely high, and the open areas are mostly in the way of hard, bare ground (i.e. unvegetated).

Some informal communities have settled in areas within known watercourse flood lines, and are thus at serious risk of flooding and potential loss of life (as periodically occurs with the Jukskei in Alexandra).

Areas originally demarcated as open space (due to flood risk) have been settled due to pressures of urban settlement. This has further impacted on stormwater run-off flows during high rainfall events.

It has been noted that some low cost housing developments are reportedly proceeding without adequate stormwater infrastructure integrated into the design. The reasons for this are not entirely clear, but presumably are associated with the following issues:

Pressure to develop as many low cost houses as possible within the available budget

Housing projects are often led by other government authorities (i.e. provincial), which can lead to poor integration of stormwater design and urban planning at the municipal level, for example through inappropriate site selection.

Urban Planning - Floodline Assessments

Accurate assessment of floodlines has been identified as a problematic issue with present and past developments. Inaccurate floodline assessment leads to inappropriate development and higher risk of floods.

The projections for increased rainfall may impact on future floodlines.

At present, there is very little published research on mapping floodlines based on climate change projection data. The Environment Agency of the UK is in the process of developing a methodology and rolling out flood risk maps for the UK taking into account the effects of climate change, which may be used by the public and the insurance industry. It is unclear whether a similar system may be applied for floodline assessment for developments in the UK.

Floodline assessments for a small number of rivers in Germany and the Netherlands have also reportedly incorporated climate change impacts into their assessment. Details of these studies could not be located or verified.

Stormwater Management & Infrastructure

The CoJ stormwater system is already severely stressed. On an annual basis a number of stormwater systems are beyond peak capacity or are blocked/overgrown, and many others are close to peak capacity.

The JRA has highlighted the fact that inadequate maintenance due to budgetary pressures is arguably the most serious issue affecting the CoJ's stormwater system today.

There many areas which don't have any or have inadequate stormwater attenuation. These occur predominantly in the informal settlements and at some of the low cost housing developments, and thus with the projected increased rainfall, these areas will become even more vulnerable to uncontrolled run-off and flooding.

Stormwater systems are generally not designed to cope with "Act of God" events, i.e. extreme rainfall events. Designing for this criterion is generally considered as over-design and economically unviable. Hence, an element of disaster management will always be required with respect to flooding. Systems can, however, be designed to cope with the vast majority of rainfall events.

The JRA increased the minimum stormwater pipe size to 450mm in 2004 and is now considering increasing the minimum to 600mm. The climate model projections lend additional weight to the argument in favour of increasing the minimum size. However, a definitive answer on the most appropriate minimum pipe size under future precipitation conditions would rely upon additional detailed hydrological analysis. This analysis could be undertaken in conjunction with studies aimed at revising the MAP within the stormwater bylaws (see below).

The City of Johannesburg has implemented a number of strategies for address existing flooding and stormwater issues including the Catchment Management Plan, Integrated Stormwater Management Plan and Stormwater Bylaws.

The recently released stormwater bylaws are a positive step towards "climate-proofing" the CoJ stormwater system, particularly with its emphasis on retention and attenuation of stormwater at source.

However, without adequate investment and increased preventative maintenance, these bylaws and management initiatives will be insufficient to address the serious decline in the stormwater system. (The JRA anticipated that a budget shortfall of ±R34 million is inevitable in the 2008/9 financial year primarily due to high emergency and maintenance costs.)

The design criteria mean annual precipitation (MAP) mandated by the new stormwater bylaws is 750mm, which is generally considered conservative under present conditions.

Based upon the climate model projections, it is probable that the mean annual precipitation levels for the near-future (2046-2065) will significantly exceed this bylaw requirement (see Box 4 for a preliminary analysis of the impact of increasing the MAP from 750mm to 850mm for a major infrastructure project).

Should such an increase eventuate (without mitigation), it will seriously impact on road stormwater management, bulk stormwater management and attenuation facilities, with attendant economic costs and risks to human health.

This raises a dilemma:

Should the design MAP be kept at 750mm, and rainfall does significantly increase as projected, this will incur significant damage and economic costs.

Alternatively, if the design MAP is increased, this will entail significant additional capital costs in infrastructure.

At present, there is insufficient certainty in the magnitude of the potential increase in rainfall to justify modifying the design MAP by any given value[18].

A similar situation is likely to arise upon closer analysis of the impact of increased rainfall on floodline measurements.

Capital expenditure projects for the CoJ, including those related to stormwater and sanitation, are prioritised according to a graphical information system (i.e. GIS) based tool known as CIMS.

The authors of this report have only had the opportunity to undertake preliminary discussions regarding this system.

Understanding this system and its sensitivity to climate-change related issues is a key element in addressing the climate change vulnerability of the CoJ.

Preliminary feedback indicates that CIMS is generally considered to be an important and valuable tool for prioritising capital expenditure in the CoJ.

Some concerns were raised that assessment of stormwater infrastructure requirements and

[18] Recommendations for adjusting the MAP are likely to be based upon a more comprehensive statistical analysis of the climate modelling data as well as assessing the sensitivity of costs under a range of climate models and possibly for a range of IPCC scenarios.

priorities may not be accurately reflected under a GIS-based system.

If the system is not properly reflecting the relative priority of stormwater under present conditions, this is likely to have severe impacts in future should rainfall increase as projected, particularly considering the high economic costs associated both with flooding[19] as well as with the retrofitting of stormwater infrastructure.

However, at this preliminary stage, it is not possible to properly evaluate this concern without further investigation. Potentially "improving" CIMS to reprioritise stormwater infrastructure implies that budget will be redirected away from alternative sectors. This is obviously a sensitive financial issue, notwithstanding the technical complexities in assessing the relative priorities of infrastructure projects in different sectors.

Urban Flooding and Informal/Formal Settlements

Due to continued migration into the CoJ, and due to inadequate economic growth nationally, it is unlikely that informal settlements will be eradicated in the foreseeable future. These settlements are often home to the most vulnerable in terms of urban flood risk, especially as some of these settlements are located within known floodplains.

The risk of direct injury/death in informal settlements is typically greatest among recent migrants to the CoJ who are less aware of the danger spots during times of flooding.

The key element to protecting these communities from floods is to relocate them out of known floodplains.

Longer term solutions rely upon the extension of basic housing and infrastructure to these communities and general poverty alleviation strategies.

Shorter term solutions will rely upon effective disaster management supported by direct engagement with these communities to determine the most appropriate ways to assist. Protocols for effecting these will have to be developed by CoJ managers, including the ability to access sufficient emergency funding.

There is an identified difficulty in obtaining sufficient early warning of flooding, including the specific location of the flood. This is especially difficult in townships and informal settlements.

Likelihood: 2 - 3 (medium - high)

The likelihood that climate change will result in additional and/or worse urban flood events is considered as medium to high for Risks P1 - P3 and medium for Risk P4 (damage to electricity & telecom infrastructure), particularly in view of the fact that the CoJ stormwater system is already severely stressed. The likelihood has been rated as "medium-high" and not as "high" based upon the greater uncertainty regarding the climate model rainfall projections, as compared to the projections for increasing temperature.

Magnitude: 3 (high):

The magnitude of the impact of urban flooding on the CoJ is rated as high for Risks P1 - P3 (damage to water supply & sanitation infrastructure, damage to property and disruption to transport system & increased road accidents), and as medium - high for Risk P4 (damage to electrical & telecom infrastructure). This is due to the high economic costs generally associated with flooding, the potential health risks and risk of death, and the high costs associated with retrofitting stormwater systems.

Current controls:

Flooding is a recognised issue within the CoJ, particularly in view of the recent floods in Soweto and elsewhere. In addition, numerous reports have now raised the alarm regarding the stormwater and sanitation infrastructure within the CoJ. That these issues are now recognised by the CoJ is demonstrated by the recently adopted integrated stormwater management plan and by the preparation of the Stormwater Management By-Law which will be supported by the Stormwater Attenuation Design Guideline currently under preparation. This will provide detailed requirements for stormwater attenuation and for the submission of designs to the JRA for approval.

Several of the other current controls and initiatives currently in place include:

[19] For example, in the U.S., floods are associated with more damage than all other weather-related damages combined (excepting hurricane damage). NOAA has estimated damages of around $4 billion per annum for the 10-year period 1988-1998. Similarly, it is likely that floods are responsible for greater economic costs and damages within the CoJ than any other weather-related cause.

CoJ disaster management teams (EMS as well as JRA emergency crews) exist and respond to flooding incidents in the CoJ.

The JRA is planning the establishment of a wireless network of more than 60 rain gauges throughout the City, with the intention of linking this planned network to other wireless systems contemplated for the City. In the interim however, the JRA has erected warning signs at over 100 locations at which the general public is considered to be at risk from flash floods.

An education programme in schools has also been proposed, in addition to the preparation of information brochures.

Furthermore, there is a proposal to determine the 1:50 and 1:100 year floodlines revision of floodlines across the entire City, within the framework of a single project. (Currently floodlines are determined by developers, in a somewhat piecemeal approach).

Government (at all levels) has given high priority to the provision of alternative housing and infrastructure for residents of informal settlements, including several infrastructure upgrade programmes addressing water and sanitation backlog i.e. Project Thonifho,

The CoJ has initiated projects with to improve aquatic ecosystem health of both the Jukskei and Klip River catchment areas (the Jukskei Capital River Rehabilitation project and the Klip/Klipspruit 2010 Legacy projects)

The CoJ is developing a GIS-based flood risk assessment tool in order to identify areas potentially most at risk (based on hydrological features, socio-economic factors etc.)

The Johannesburg Roads Authority (JRA) also proposes that consideration be given to imposing a penalty tax on developments undertaken after 1984 which did not comply with the requirements for stormwater attenuation in terms of the Guideline for the Provision of Engineering Services and Amenities in Residential Township Developments.

Stakeholders:

Numerous CoJ departments and municipal entities including: CoJ Development Planning & Facilitation, JRA, EMS, CoJ DP&UM, CoJ Housing Department.

Also: provincial and national government bodies, professional bodies (civil engineers, architects, landscape architects, urban planners), developers, construction industry, community organisations (especially in informal settlements).

Box 4. Climate Change Stormwater Assessment: Hydrological Simulation

Using a project recently undertaken (2007/8) for ACSA and located at OR Tambo International Airport in which the brief of WSP was to model stormwater management system of the entire Airport site.

The total catchment area of the site is 1571 ha and comprises of seven sub-catchments some draining into each other and others draining individually from the site. The site has both pervious and impervious surfaces such as asphalt taxiways and runways, concrete aprons, short grass vegetation, open unlined drains and some gravel verges. Each of the surface types has different run-off characteristics and those of Manning's were used in the model run-off simulation.

For this exercise the 750mm MAP figure as specified by recent JRA by-laws was used in the run-off calculations. An estimated climate change variation in rainfall of +102mm for a 50 year Return Interval (RI) - i.e. the mid-century Near Future climate change scenario - was adopted for comparison. Two models were simulated viz 750mm and 852mm. Also the 5 and 10 year RI's were computed as well.

The simulated run-offs from the seven sub-catchments were calculated. The results show the variances in run-off and flow depth between the given MAP and the near-future MAP (due to climate change) with surprising results:

5 year RI shows average increases of 22.1% in run-off & 9.1% in flow depth.

10 year RI shows average increases of 16% in run-off & 9% in flow depth.

50 year RI shows average increases of 22.4% in run-off & 11.5% in flow depth.

The results show substantial increases in run-off and in the stormwater flow depth. These increases would necessitate substantial additional infrastructural investment to cope with the additional flow The cost estimates for these differing systems may be readily estimated, as well as the cost for retrofitting the stormwater system to meet the demands as modelled under the climate change scenario, and may provide a basis for further cost-benefit analysis.

6.6 Risks X1 & T3: Disruption to Water Security

This section deals with the risk posed to the water security of the CoJ due to climate change, arising both from internal threats arising from within the CoJ itself (i.e. Risk T3 - an increase in water demand within the CoJ) as well as external threats (i.e. Risk X1 - climate change-driven disruption to the supply network lying outside of the CoJ boundaries). These risks are closely interrelated, particularly in terms of required adaptations which focus on both water demand and water supply initiatives, and are consequently assessed together.

KEY FINDINGS: EXTERNAL RISKS TO WATER SECURITY

Johannesburg as a city, together with the other Metropolitan areas in Gauteng, requires more water than can be provided from the local rivers. In order to supplement the main water source (the nearby Vaal River), water is now transferred from Lesotho into the tributaries of the Vaal.

The Lesotho Highlands Water Project (LHWP), which delivers water from the highlands of Lesotho to South Africa's Vaal River system (including to the Vaal Dam) and generates hydropower for Lesotho, is Africa's largest ever water transfer project as well as the largest ongoing bi-national construction project on the continent. The project aims to address the needs of the rapidly expanding Gauteng province (which generates almost 60% of the country's industrial output and 80% of its mining output, and where over 40% of South Africa population is living). The Lesotho Highlands, with its high rainfall and surface area of high basalt mountains - the Maluti - allows the LHWP to capture most of the excess water from rainstorms in the Orange/Senqu River catchment and to transfer it to the Vaal River system.

Based on targets for Phase 1A and 1B of the LHWP, water diverted has been estimated at around 1 billion cubic metres per annum.

Disruption to water supply from Lesotho would seriously impact on CoJ water supply. Strategically-speaking, the CoJ is arguably more sensitive to the impact of climate change on rainfall patterns in the Lesotho region than on any other region outside of the CoJ itself.

The dependence on the water from these in-basin transfers to the supply source of CoJ is somewhat buffered by the management of the transfers which is affected by the demand of the CoJ. This demand is tempered by the actual weather conditions prevailing at the time and is a function of the controls placed on water consumption.

The threat of shortages rises dramatically during drought periods and periods when it is likely that the supply from local water supply sources will be limited. Hence there is an interrelation between water supply and demand within the CoJ and water transfer from the LHWP, and vice versa.

The existing climate change trends and predictions available for the catchment areas of regions supplying the Vaal system, including those from Lesotho appear similar to the CoJ, based on broad-scale analysis of the southern African region.

However, no detailed downscaled climate change analysis has been undertaken for the Lesotho region. Therefore there is a large degree of uncertainty regarding future rainfall levels in Lesotho. Furthermore there are only a limited number of weather stations and limited historical weather data available for the Lesotho region.

KEY FINDINGS: INTERNAL RISKS TO WATER SECURITY

The climate modelling undertaken for this report shows a potential temperature increase of 2oC (near future) and 4oC (far future), which will have a significant impact on water consumption of various aspects of the City described below.

- Increased rates of evaporation from dams within the region.
- Air-conditioning and refrigeration systems that rely on evaporative cooling will have increased water demand, due to the increased air-conditioning demand over hotter periods. A significant proportion of installations in the CoJ includes evaporative systems and will consequently be affected.

Projections for possible increases in rainfall in the CoJ may offset the above water losses by increasing the amount of water supplied to local dams and reservoirs. (There are 106 dams in total reported within CoJ catchments).

However, the CoJ region periodically suffers from droughts, particularly in the spring, which impacts upon local water supply (although supply is now regulated with inter-basin transfers from Lesotho). However, if the increased temperatures are combined with dry periods, the following will occur:

- The water demand of landscape and garden irrigation will increase due to higher evaporation rates, especially when the increased temperature is combined with dryer times.
- Swimming pools and water features will require filling more frequently
- Boreholes will be more susceptible to drying up, resulting in an increase in municipal water supply usage
- Higher municipal water demand in agricultural sector

Increased demand could result in water shortages which could have potentially significant consequences including:

- Water restrictions affecting non-essential business and private use (gardens, car wash businesses etc.
- In severe circumstances: restrictions on major water users and disruption of plans to expand service delivery.

Water loss due to pipe leakage is a major source of inefficiency within the water supply network.

No water efficiency and water recycling standards or by-laws exist in the CoJ or nationally.

Urban water demand fluctuates inversely with supply. In wet years, with adequate rainfall, demand, particularly from suburban gardens which make up a significant proportion of City of Joburg's water demand, decreases, while in dry years, when supply tightens, that demand increases.

Johannesburg has a 96% level of piped water to citizens (SoER 2008). Theoretically this should protect residents from inter-annual rainfall variability. This buffer does not absolve urban residents from water supply risks associated with drought. The combination of increased population and predicted increases in seasonal rainfall variability may lead to a greater stress on water supplies in the future.

The SoER states that, the government's best possible strategy to protect citizens from rainfall variability is to encourage urbanisation, thereby centralising and rationalising water supply. The climate change scenario of increased rainfall may well give rise to more years of above (historical) average rainfall, but perversely this may lead to a complacency which makes the impact of a drought and the inability to cope a much more serious threat.

External Risks (Risk X1):

Likelihood: 1 - 2 (low - medium)

Climate change is likely to impact upon rainfall in the Lesotho highlands. Regional scale models suggest that the effects may be similar to those predicted for the CoJ. However there is a large degree of uncertainty associated with those predictions,

Magnitude: 2 - 3 (medium - high)

Disruption of the water supply from external sources such as the Lesotho highlands, in the absence of any mitigation measures, is likely to have significant impacts both on the general economy as well as on the livelihoods and quality of life of CoJ residents. Any reduction in the water supply to the CoJ would severely constrain the planned intention of water (and sanitation) provision to all residents, especially in terms of coping with the backlog and future planning.

Internal Risks (Risk T3):

Likelihood: 2 - 3 (medium - high

There is a high degree of certainty in the projection for increased temperatures, and this is likely to cause some increase in water demand. The combination of current population growth, the impact of in-migration and the likely occurrence of droughts leads to a medium/high likelihood of a increased stress on urban water supply.

Magnitude: 2 (medium)

While the frequency of droughts in the CoJ has never caused prolonged problems and although the threats on supply and quality of water to the City are under threat, the magnitude of the risk would likely have a medium impact on the general economy of the CoJ including livelihoods and quality of life. The impact is also partially mitigated by the possible increases in rainfall projected for the CoJ, which may offset the impacts of likely increase in water demand due to higher temperatures. Furthermore, the CoJ receives water from outside sources such as the Lesotho highlands, to help regulate the supply. Nevertheless, any additional stress on the water supply/demand balance within the CoJ may impact on the planned intention of water (and sanitation) provision to all residents, especially in terms of coping with the backlog and future planning. The reduction in service delivery would certainly impact directly on the living quality within the City.

Current controls:

Threats to water security, whether from demand/supply issues internal to the CoJ or as a result of threats to external supply, can only be dealt with through a combination of both supply and demand initiatives.

Water conservation is generally a recognised issue within the CoJ. Particularly the issue of the high water losses through water leaks is now being appreciated and given higher priority. Some current control mechanisms currently in place include:

JW has recently begun implementing a large scale infrastructure programme to upgrade obsolete water supply and sanitation infrastructure.[20]

Operation Gcin'amanzi: The project is interrelated to the above initiative and includes a thorough

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[20] An investigation was conducted by Johannesburg Water in August 2007 to identify ageing infrastructure within the City of Johannesburg. A pipe replacement programme was identified in 32 suburbs. Following the study, the utility set aside about R100-million for pipe replacement across the city. The programme started in August 2008 with the replacement of 120 kilometres of water pipes in eight suburbs - Bryanston A; Bryanston B; Wynberg; Ferndale A; Ferndale B; Florida; Kibler Park; and Mondeor. Phase one of this programme was expected to be complete by October 2009 at a total cost of R82.5 million. Phase two began in April 2009 and is expected to be complete by June 2010. It involves replacing old pipes in Naturena; Lenasia; Kibler Park B; Mondeor B; Blairgowrie; Morningside; Northriding; Douglasdale; Newclare; and Northcliff. This phase would cost R100-million.The main objectives of the programme are to minimise the number of pipe bursts in the future and also to create stability of the water network. It is also expected to create a significant number of jobs through the Expanded Public Works Programme. http://www.joburg.org.za/content/view/3891/266/

check of the water infrastructure on each site, fixing leaking taps, broken water pipes and faulty geysers.

The CoJ is liaising with DWAE (formerly DWAF) to plan and regulate the security of supply to the City's industry, agriculture and residential consumers[21].

A demand side management strategy for implementation during shortages, including conservation, education and tariff structures.

The Tappie Road Show: an educational project for primary school children, aimed at teaching the children about the importance of saving water.

Demand-side management bylaws for water use are currently being developed.

Stakeholders:

Johannesburg Water, Rand Water, All water users, resource managers, water engineers, sanitation managers and planners in Johannesburg as well as Gauteng as a whole and possibly those in Lesotho.

[21] Regional Spatial Development Framework 2009/10

6.7 Risk X2: Climate Change-driven Refugees and Migrants

KEY FINDINGS:

At present, there it is not possible to predict the scale of climate change-driven migration in future, as this would require a comprehensive assessment of the entire sub-Saharan region.

There is no current research data to support the trend of migration due to climatic change as such, but anecdotal evidence shows that unfavourable rainfall seasons lead to increased urbanisation.

On balance, it is likely that climate change will significantly impact on sub-Saharan Africa, particularly in view of the low adaptive capacities in many of the countries in this part of the world.

Climate change will therefore be an additional but significant driver in "pushing" sub-Saharan migrants to seek better livelihoods in South Africa and the CoJ.

It is hoped that the through regional economic growth and as a result of the greater adaptive capacity within South Africa, climate change-driven internal migrants to the CoJ will be less of an issue within South Africa itself. However there is no actual research to support or refute this.

Ironically, foreign migrants being "pushed" by climate change are the likely to be among the most vulnerable residents within the CoJ in respect of climate change influenced weather disasters such as floods. Recent floods, for example, have already impacted on foreign migrants within informal settlements, which have obviously and unavoidably been located on flood-prone sites.

Ultimately increased migration would have the net result of negative impact on peoples' livelihood through poorer general infrastructure, and thus costing the City more. The unplanned, unmeasured and unpredictable migration of unskilled people into an area with already stressed infrastructures and high unemployment will further reduce the livelihood index of the region, unless counter-measures which can take advantage of increased numbers are introduced. The latter seems unlikely. The only long-term solution to this issue is for the source regions of migration to develop sufficient economic and other resources to provide their own citizens with an acceptable quality of life.

The ability of the CoJ, as a metropolitan authority, to influence or mitigate the overall migration trend (climate change-driven or otherwise) is severely constrained. However, that is not to say that the CoJ cannot make meaningful contributions within these constraints.

Likelihood: 1 - 2 (low - medium)

There is a better than not chance of migration increasing as a result of climatic factors. It would be highly unlikely that a reverse migration would take place even if the climate was perceived to be better in other areas.

Magnitude: 2 - 3 (medium - high)

The impact of increased migration, particularly illegal migration, is immediate and measurable in terms of negative impacts on livelihood and quality of life. The recent Zimbabwean crisis and the scale of the ensuing migration and its impact on the CoJ in terms of straining municipal resources, straining social cohesion and exacerbating human health and other risks.

Current Controls:

Identification of open spaces most likely to be targeted by informal dwellers[22].

A plan to improve the quality of human settlements

Financing for entrepreneurial endeavours[23].

Stakeholders:

City planners, health workers, law-enforcement, social workers, relief and aid agencies including international organisations etc.

[22] Regional spatial Development Framework 2009/10
[23] See Soweto Integrated Spatial Framework

7. ADAPTATION ACTIONS FOR COJ

7.1 Introduction

This section presents the adaptation plan for the ten Action Level A: Prioritise for Adaptation-rated risks identified above. The various adaptations are prioritised and summarised in table format in the final part of this section. The key findings which have informed the adaptation plan for each specific risk are presented in Section 5.8.

There is broad international consensus that some degree of climate change, including an increase in extreme weather, is almost certain to be experienced around the world (including within the CoJ), due to past and present emissions of greenhouse gases and regardless of any emission reduction measures that may now be undertaken. Hence it is essential to begin the planning and implementation of appropriate adaptation actions as soon as possible.

Downscaled climate model projections for the CoJ indicate that the local climate is likely to become both significantly hotter and more humid in future. The models suggest that temperatures for the CoJ may increase by around 2.3°C by the near future (2056 - 2065) and by around 4.4°C by the far future (2081 - 2100). Additionally, there is a substantial risk that the CoJ will experience an increase in annual rainfall characterised by a higher frequency of storm events and a longer rainy season (finishing later in the autumn and possibly starting earlier in the spring).

The Action Level A - Prioritise for Adaptation risks identified in this report are:

- Risk T1: Increase in Heat-Related Deaths
- Risk T2: Increased Energy Demand
- Risk T3: Increased Water Demand (within the CoJ)
- Risk TP5: Biodiversity Impacts on Disease Vectors (Health Risks)
- Risk P1: Urban Flood Risk - Damage to Water Supply & Sanitation Infrastructure
- Risk P2: Urban Flood Risk - Damage to Property Risk
- P3: Urban Flood Risk - Increased Road Accidents and Traffic Congestion
- Risk P4: Urban Flood Risk to Electrical & IT Infrastructure
- Risk X1: Disruption to Water Security (arising from outside the CoJ)
- Risk X2: Climate-Change-driven Refugees and Migrants

An additional twelve lower priority (in terms of the impact of climate change) risks were identified which also warrant further attention, including the risk of increased shack and veld fires and the risk of disruption to food security. These risks have been rated as Action Level B - Review Opportunities/Adapt within Constraints and are identified in Section 5 of this report.

A key issue highlighted in this study is that much of the CoJ's climate change-related vulnerability stems from the fact that several of the systems likely to be impacted are already severely stressed under existing climatic conditions. This is particularly true for the CoJ's stormwater infrastructure - of the ten Action Level A-rated risks listed above, four are related directly to the threat of an increase in urban flooding. It is the existing strain on the stormwater infrastructure that potentially gives rise to the greatest concern regarding the potential impacts of climate change in future. It is also worth noting that some sectors face multiple risks due to climate change, such as the electricity sector which will be liable to face a risk of increased energy demand for cooling (as well as possible heat-induced infrastructure failure) and an increased risk of flood damage to key infrastructure.

7.2 The Cost of Adaptations

7.2.1 Introduction

Decision-makers within the CoJ need to manage and adapt to the impacts of climate change. It is necessary for these decision-makers to have some view of the various costs associated with climate change impacts as well as the costs of adaptation, in order to make informed decisions.

According to the UKCIP implementation guidelines for costing climate impacts[24] and adaptation measures, there are several specific challenges:

- While climate change is already happening, it is predominantly a long-term risk issue, which will intensify over the coming decades. Hence discounted methods are required to account for the fact that individuals tend to attach more value to a cost/benefit in the present than they do to a benefit/cost in the future[25].
- Climate change impacts on one sector may result in knock-on effects in other key sectors. These have to be accounted for to allow for accurate costing.
- In certain cases, climate impacts may potentially be sufficiently significant that they result in changes to the prices of certain goods and services. These non-marginal impacts may also need to be incorporated into valuations (for example, the potentially inflationary impacts associated with an increase in demand - and associated rise in cost - for electricity within the CoJ.)
- There is uncertainty regarding both the nature and the potential magnitude of climate change and its various impacts, and uncertainty regarding how these impacts should be valued.

Furthermore, it is emphasised that effective valuation of benefits and costs requires is to a large extent dependent on at least having sufficient quality baseline data available. In many cases, this data is simply not available at this time.

The Climate Change Action Plan and Strategy for the Western Cape (DEADP, 2008), which acknowledged similar limitations regarding the lack of cost and benefit data within that province, indicated that:

"National-level preliminary estimates of unmitigated damage costs are only available as a research publication, and based on several critical assumptions that would need further research… It can therefore be stated that further work is required in the Western Cape to make defendable statements on the benefits of climate change action. This study, which is focused on action and response, is also in no position to attempt to do so."

In fact, the challenges in providing cost and benefit data at the adaptation level does not appear limited to adaptation planning within South Africa: a review of several adaptation plans from both Australia and the UK indicated that none of these had advanced to stage of providing cost-benefit analysis within the framework of the adaptation plan itself.

That said, the absence of damage cost estimates does not provide a basis for inaction. The combination of stakeholder input from the CoJ, literature review and technical expert opinion, allows for at least a preliminary qualitative estimate of both costs and benefits and adaptation actions, at least to the extent of allowing decision-makers within the CoJ to prioritise actions and resources in the preliminary phases of adaptation, as follows below.

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[24] Costing the impacts of Climate Change in the UK: Implementation Guidelines. UKCIP, 2004.

[25] While the authors of this report are not aware of agreed national discount rates for use within the South African public sector, it is likely that some recommended discount rates are available from other South African public sector costing studies for different future time periods.

7.2.2 Methodology

The methodology was based upon rating (1) the costs of implementing an adaptation and (2) the beneficial value derived from implementing that adaptation on a simple scale of 1 - 5, with 1 representing low cost, and 5 representing high cost as anticipated over the next five years. Broadly speaking, a scale of 1 reflects a cost estimate of under R1 million while 5 represents costs/benefits in the tens of millions of Rands, and with scales 2 - 4 falling in between. The basis of the cost estimate was the consensus opinion of the core technical project team (these estimates will need to be developed further with CoJ stakeholders). While admittedly not a rigorous technique, this method does allow for achieving the following important goals and objectives:

Identifying Quick Wins:

For some adaptations, it is clear that the benefits will outweigh their costs. They are the equivalent of assessing the cost benefits of "wearing a seatbelt" when you climb into your car. Identifying these quick wins allows for action to proceed on climate change adaptation while cost-benefit uncertainty exists surrounding other alternative adaptations.

Prioritising Further Assessment:

Even in the absence of comprehensive cost-benefit data, it is still necessary to identify which adaptation actions hold the most promise, and therefore are the most deserving of further technical assessment, investigation and research.

Prioritising Baseline Data Collection:

Similar to the above, it is also necessary to identify which adaptations should be prioritised in terms of collating baseline data which will be necessary for future costing/assessment of the adaptation costs versus benefits.

Empowering Individual Project Managers:

In some cases, individual project managers may be in a better position to undertake a cost-benefit analysis for a project within their limited domain (i.e. for a solar heater project in a particular development). By highlighting which adaptations the authors believe are likely to provide the most value, it provides these project managers with some guidance as to where to focus their energies.

7.2.3 Future Assessment of Costs and Benefits

It is noted that Cost Benefit Analysis (CBA) is only one of several techniques for valuing climate change adaptations. The UKCIP implementation guidance document for climate change costing indicates many of the strengths and weaknesses of the CBA as well as highlighting alternative/supplementary methodologies.

The fundamental requirement of CBA is that both the costs and benefits are expressed in monetary terms, which requires that risks are first quantified (both in terms of units impacted/affected and cost per unit). A key aspect to support future adaptation planning will be the collation of baseline data relevant to this quantification process.

The costing process is especially difficult when dealing with the complexities of climate change (for example, related to the valuation of non-market goods). These difficulties are exacerbated by the fact that even with dedicated efforts for collating data, there will be many circumstances where sufficient quantitative data will not be available. In these instances, utilising CBA will be either extremely difficult or impossible.

The UKCIP guidance recommends that consideration be given to utilising a variation of sensitivity analysis. Alternatively the more rigorous option of multi-criteria analysis (MCA) may be adopted. It is likely that future assessment of the costs and benefits associated with climate change adaptations will have to make use of these techniques in addition to or in place of traditional CBA.

7.3 Adaptations for High Priority Risks

7.3.1 Risk T1: Increase in Heat-Related Death

ADAPTATIONS

Strategy

While heat-related mortality may well be a significant and underappreciated cause of weather-related mortality within the CoJ, it is likely to be of lower significance than existing health issues such as HIV/Aids, tuberculosis and the risk of cholera. The nature of heat-related deaths, however, means that individuals suffering from the above diseases are within the group considered most vulnerable to heat-related stress. Nevertheless, in the absence of CoJ-specific or South African-specific statistics, it is difficult if not impossible to accurately determine the relative priority of this risk when compared to other pressing health issues within the CoJ. Therefore, the strategy should, for the present, focus primarily on developing a strategic framework for responding to heatwave events in future without significantly diverting essential human resources from pressing existing healthcare services.

Key Actions:

- Start recording heat-related mortality statistics. This is likely to be undertaken in a series of steps:
  - A study to determine what information is required in order to measure heat-related mortality. Information is likely to be required from both weather-related and medical sources, and will depend on internationally accepted techniques for statistically analysing this type of phenomenon.
  - Develop a strategy for gathering the required data.
  - Implement the strategy and start recording the relevant statistics.
  - This initiative should be undertaken jointly by the CoJ Departments of Health and Environment. This initiative may be undertaken in conjunction with a university, as part of an academic study, or as part of a larger programme to record mortality statistics for all weather-related events within the CoJ.
- Develop a CoJ Heatwave Response Plan, with particular focus on the elderly. This plan should be communicated to relevant health care and social care professionals and should:
  - Develop a heatwave warning system;
  - Develop guidelines for the identification of individuals at risk and advice for assisting these individuals;
  - Integrate this information with a communications and emergency response strategy;
  - Provide guidance for evaluating pre-emptive school closure measures and public events postponement;
  - Identify and communicate cost-effective and easy-to-implement mitigation measures to key institutions (i.e. providing indoor thermometers for old age homes as well as curtains for north-facing windows or planting trees outside these windows).
- Continue to roll out tree-planting programmes, particularly in historically socio-economically deprived areas such as townships. Trees have multiple benefits for the community including providing shading during the day and mitigating the urban heat island effect.

Other Actions:

- Integrating and prioritising shade-providing measures in public meeting locations i.e. at bus stops.
- Encourage other measures which may reduce the urban heat island effect (see Box 3).
- Including air-conditioning in future generation buses, taxis and trains (this measure is likely to have the highest cost implication of the all measures recommended above as well as increasing overall energy consumption within the CoJ).
- Improving compliance of new buildings with the City's Guidelines for Energy Efficiency in Buildings (for improved thermal performance of building fabric) and consider implementing some of these guidelines as by-laws. This may be an interim measure while evaluating SANS 204.

7.3.2 Risk T2: Increase in Energy Demand

ADAPTATIONS

Strategy

The key strategy for the proposed adaptations related to the risk of increased energy demand due to increased temperature is to ensure that users become more energy efficient, in particular relating to space cooling and refrigeration, and that the supply stability is continually maintained and monitored.

Key Actions:

Buildings

CoJ energy demand-side management by-laws are presently being developed. It is recommended that these bylaws take the following points into consideration:

- Promote energy efficient white goods (fridges, stoves, washing machines etc.)
- Replace all incandescent lamps with fluorescent lamps
- Ensure that not more than 20% of lights are burning during unoccupied times
- Show energy saving of 15% against set date in the past
- Penalties for failing to meet requirements
- Grants for meeting requirements

It is recommended that the bylaws under development make use of the SANS 204 energy efficiency standard (not yet promulgated) as far as possible. This will require City Power assessors to be trained in SANS 204 specifications, which contains a mix of aspects, including building morphology, building services and occupancy schedules. (SANS 204 currently contains some errors, which should be highlighted so they can be corrected before the standards are used as by-laws). If the SANS 204 is not selected as the appropriate standard, the CoJ should ensure that bylaw includes a focus both on passive design of buildings, and also active energy efficiency standards. The CoJ should evaluate achieving compliance with the same standard above for CoJ administration buildings

The CoJ could target a Green Star rating under the Green Building Council of South Africa for all its administration buildings, which is a voluntary independent environmental design rating that stringently assesses not just energy consumption, but also water consumption, emissions, materials use, ecology and land use, transport to the building, and even management of the building. This is currently the leading internationally recognised rating tool for South African buildings, and would allow the City to set a good example to other municipalities and the general public.

Improving compliance of new buildings with the City's Guidelines for Energy Efficiency in Buildings (for improved thermal performance of building fabric) and consider implementing some of these guidelines as by-laws.

Actions related to City Power:

Without correct and ongoing metering very little can be done in managing energy demand in the future. City Power should proceed with the full-scale rollout of smart meters (such as those currently being trialled at the Blair Gowrie site), which would allow for direct communication of real-time energy use information to the customer, provide added protection from theft and allow for the automated switching of elective loads. The system should allow for the collection of all metering data and reporting on trends and incidents, from an individual customer to any number of customer groups. It is acknowledged that this is an expensive programme and will require coordination with Eskom regarding load factors (especially if a time-based tariff is also rolled out).

If the smart meter programme is not rolled out full-scale, it is advised that the CoJ investigate ways to encourage the uptake of alternative real-time energy monitoring devices by consumers.

A critical focus of the CoJ should be on preventative maintenance and upkeep of the electrical infrastructure, to ensure that service is maintained at current temperatures, never mind, raised temperatures.

City Power should on a 5 year basis review the design temperatures on which their cable sizing is based on, to ensure that the correct ambient temperatures are applied to designs for future or replacement networks which will be installed.

The CoJ should investigate establishing a means of effectively communicating to customers during peak times (particularly hot afternoons) to warn them of various peak levels and potential action to be taken.

Refrigeration & Cold Rooms:

The CoJ could establish an education strategy for energy efficiency on refrigeration / cold rooms within the CoJ, in conjunction with the CoJ-owned Johannesburg Fresh Produce Market - the largest fresh food market in Africa - which could include seminars hosted by experts in the field, using the media to some extent and publishing various technical papers etc. to inform and educate operators and designers.

Establish a means of effectively communicating to large customers during peak times (particularly hot afternoons) to warn them of various peak levels and potential action to be taken.

Other Actions:

Increase tree and garden planting schemes (low water demand indigenous vegetation) in communities and along streets where these are lacking - they can provide shade to buildings and also reduce the urban heat island effect.

Build on the momentum derived from the solar heater pilot scheme in Cosmo City and expand the project to other communities.

7.3.3 Risk TP4: Biodiversity Impacts on Disease Vectors - Health Risks

ADAPTATIONS

Strategy

The key strategy for the proposed adaptations relies on addressing the issues of stormwater management and flood control. Other key strategies rely on improved housing and sanitation services, and on ensuring that CoJ Health Department officials are aware of and are monitoring climate change-related risks.

Key Actions (Tropical disease):

It is noted that the CoJ Health Department is not formally part of any climate change committee or structure. At the same time, many of the significant potential impacts of climate change are health-related. It is recommended that some formal mechanism for keeping the Health Department aware of potential climate change impacts and developments be developed.

The CoJ Health Department should continue to monitor research into this field and consider information-sharing with health departments in municipalities north of the CoJ.

Specific measures include the biological control of vectors, reasonable pesticide use in a controlled inventory, and vaccination. These measures and other response to be coordinated as both a disaster management activity and planned as a longer term adaptation

Key Actions (Cholera):

Ensure sufficient capacity of the health services to respond to emergency situations and that close cooperation between disaster management units within the CoJ and the Health Department are maintained.

Cholera is a disease of poverty; poverty alleviation measures are the primary steps to be undertaken, the most important of which is:

- Improve provision of basic housing, water supply and sanitation amongst the poorest communities living in the high risk areas of dense human settlements within flood plains; and
- Improved stormwater management.

7.3.4 Risks P1 - P4: Increased Risk of Urban Flooding

ADAPTATIONS

Strategy

The overall strategy focuses on identifying key broad-scale initiatives, identifying current proposed initiatives which are considered the most critical, and on identifying additional key opportunities. The strategy supports a shift in mindset whereby rainwater may be viewed initially as a potential resource and only afterwards as a 'waste product'. Hence the strategy must be integrated with other initiatives relating to water usage (ref. Section 7.3.5).

It is a measure of the success of integrated water management when a holistic approach is taken to reduce one risk by not replacing it with another. The investment in stormwater infrastructure should not further risk damage to the watercourses' environmental integrity, which themselves provide useful stormwater management functions.

Key Actions: Broad-scale Initiatives

Inadequate maintenance is arguably the biggest issue facing the CoJ stormwater infrastructure. The scale of preventative maintenance and planned upkeep of existing water infrastructure needs to be increased, in order to prevent even more expensive failures in future (similar to what has occurred recently within the electricity sector due, in part, to insufficient preventative maintenance).

In terms of mitigating the impacts of flooding, the primary infrastructure requiring maintenance is both the stormwater and sanitation networks.

A realistic and advanced strategy should continue to be pursued in order to extend infrastructure to informal settlements.

In terms of past poor engineering practices and their effect on surface waters, it is not feasible to attempt to return the system of rivers and wetlands in the Metropolitan area to their original pristine state. It is, however, a very feasible and achievable goal to reduce further deterioration, and to help the system achieve a new state of dynamic equilibrium that minimises future costs to the City and ensures that the water courses, wetlands, and water bodies, become an asset to residents, and that scarce water resources are conserved.

Key Actions: Current Proposed Initiatives

The proposal to determine floodlines throughout the CoJ, in the form of a single project, should be implemented. Besides addressing current flood risks and development issues, a comprehensive baseline floodline assessment will be an invaluable tool in assessing the impacts of climate change in future.

The CoJ should engage directly with hydrological consultants tasked with undertaking floodline assessments to ensure that uncertainty over future rainfall is incorporated into the floodline assessment presently being planned for the CoJ. This may be supported by the climate modelling data presented in this report and the CSAG supplementary technical report.

Despite any uncertainty over future floodlines, if the CoJ can ensure that no developments are located within floodplains/floodlines under existing rainfall conditions, this will already be a big step forward in improving the CoJ's resilience to urban flooding, when combined with improved stormwater management.

To ensure "climate-proofing" of the floodline determination, this initiative should be revisited on 10 year forward cycles. This requirement should be formalised.

This may also allow for the potential incorporation of climate modelling data in future.

Early warning systems for identifying the location of urban floods should be further investigated and supported where such initiatives have already been proposed.

- The most promising systems appear to be electronic/telemetric systems. These have been successfully applied elsewhere in developing countries (Jamaica, Indonesia).
- Real-time satellite warning systems do not yet appear to be sufficiently developed although they are a point of research and development. Effective deployment and operation of telemetric systems will require community support (including in informal settlements). Lack of community buy-in may result in increased risk of vandalism and disrepair.
- A flood risk warning system may not be considered as a high priority in many of disadvantaged communities, when compared to the daily difficulties they face; hence community buy-in may be difficult. Consequently, it may be best to roll out early warning systems in a series of pilot project installations in high flood risk areas where there is positive community engagement. There may even be scope for providing some local employment for basic maintenance of the system.

The JRA is considering increasing the minimum pipe size for stormwater infrastructure from 450mm to 600mm. The climate change projections for potentially increased rainfall within the CoJ lend further weight to the argument in favour of increasing the minimum pipe size. However, further modelling should be undertaken in order to determine more conclusively the appropriate pipe size. This should be undertaken as part of the study to determine the appropriate design MAP referred to below.

Key Actions: Specific Initiatives

The new JRA stormwater by-laws must be implemented for all new developments within the CoJ, without exception. Provincial and other government bodies involved in developments (i.e. for RDP housing) within the City should be engaged with directly to ensure buy-in and proper alignment with this initiative.

A research project should be implemented to assess stormwater design MAP's based on climate modelling data.

- The JRA and the CoJ's climate change consultants/modellers will need to discuss and develop the scope and data requirements for the re-assessment of MAP's based upon climate model projections.
- It is noted that additional climate modelling data (including for rainfall) is expected as part of the CoJ adaptation plan, based on an updated and improved statistical downscaling methodology. This data may be accessed for the proposed research project. Timescales for receiving this data are not available at present. The project should evaluate via cost-benefit analysis, the impacts of various MAPs.
- Mandatory JRA stormwater design MAPs should be assessed on at least 5-year forward cycles. This requirement should be formalised.

The implications of climate change for the CIMS prioritisation tool should be assessed.

- The purpose of such a study would be to ensure that the managers and implementers of the CIMS system are provided with a strategic framework and understanding of how the evolving threat of climate change may impact on capital investment decisions for the CoJ or, in other words, to "climate-proof" the CoJ's primary capital investment tool.
- The concerns raised regarding stormwater prioritisation under CIMS could be addressed within the scope of this broader context.

Implement a CoJ sustainable urban drainage system (SUDS) trial project, such as permeable pavers in public open spaces.

- There are many emerging examples of the effective use of SUDS overseas - Chicago, for example, replaced a whole series of tarred alleys that were regularly flooding with permeable pavers. The UK is well advanced in developing SUDS technical guidance documents, with numerous projects implemented across the country.
- A trial project is an essential first step for the CoJ to better understand potential benefits, construction methods, costs, and maintenance requirements as well as to determine the appropriateness of SUDS to CoJ conditions (see Box 5 on SUDS).
- If successful, it could be considered to mandate a certain level of SUDS on certain roads/public open spaces and private property, ensuring for greater on site infiltration and reduced run-off speeds and volumes (including groundwater contamination prevention).
- A successful application would also encourage increased investment in SUDS by private developers (by reducing perceived risk in this relatively new technology), particularly as the new stormwater by-laws already provide a good framework to support their uptake.

The retrofitting of Integrated Stormwater Management designs in existing developed networks.

Experience has shown that retrofitting is both difficult and costly. However, every opportunity to do so needs to be explored. One such opportunity would be the utilisation of bulk contributions to facilitate the establishment of attenuation facilities and/or artificial wetlands in existing open areas. Such an approach was in fact taken in the establishment of Monte Casino, where the developer was required to provide for attenuation on the Fourways stream to prevent the flooding of the Fourways Mall. Mechanisms (mandatory or otherwise) need to be considered in order to encourage such retrofitting.

A detailed stormwater infrastructure vulnerability assessment for the CoJ should be undertaken to highlight which are the problem areas. The report should consider proposing methods of addressing problems, with budget cost implications.

Until such time that sufficiently accurate data regarding the extent, nature and condition of both the major and minor stormwater systems is obtained from the catchment audits and accurate topographical data is obtained to facilitate the hydrological and hydraulic modelling of the entire system, the evaluation and prioritisation of maintenance and upgrading requirements is based on the results of the audits and sundry studies of individual problem areas identified.

Key Actions: Informal Settlements

Prevent further settling in flood-prone areas, insofar as this is possible.

Relocating dwellings from flood basins to safe areas for settlement. It is understood that this is a sensitive issue. However, there is no other realistic or responsible long-term alternative other than to eventually relocate these communities that are within existing floodlines, especially in view of the projected increase in rainfall.

This initiative will rely on the proposed floodline assessment referred to above, in order to identify communities at risk.

Considering the levels of legal as well as illegal migration into the CoJ, it is unlikely that the backlog in providing formalised housing will be eliminated within the foreseeable future.

Disaster management will therefore remain the primary means of managing flood risk in informal communities.

Primary measures to assist disaster management include:

Development of early warning systems

Informal settlements should be educated and engaged with directly through available community forums and other measures. Engagement should involve an ongoing (i.e. annual) educational programme, particularly to ensure that "non-local" migrants are also educated about the local risks of flooding.

Some measures previously indicated above will also help address this issue, such as at least preserving existing functions of surface water/wetland features.

Direct engagement with the vulnerable communities is an essential part of pro-active flood disaster management. The CoJ should consider appointing a Community Liaison Officer from within CoJ disaster management (i.e. ERM). This person can be tasked with talking directly to those affected by flooding in order to (1) get feedback on disaster management response after flood events and get the community's views on ways in which this response can be improved, and (2) assist with communicating flood prevention advice to the community.

Careful attention should be paid to urban planning in low cost housing and informal settlement communities, where densities of dwellings are too high, and lack of stormwater infrastructure exists. The following key aspects should be addressed in the planning:

Implement Stormwater Bylaws for all relocation and formalised housing initiatives

Monitor progress on trial SUDS projects. It may be an appropriate option, in future, to use permeable pavers/surfaces on smaller internal roads within low cost housing developments.

Continue to promote inclusion of appropriate vegetation that can assist with containing run-off to these communities in low cost housing developments.

Promote the inclusion of absorbent landscaping (i.e. public/private gardens) and encourage suitable spacing between roofed structures.

Other actions:

Undertake a basic electrical infrastructure vulnerability assessment with respect to flood risks, in order to highlight where problem areas are throughout the City. The report should propose methods of addressing the problems, with budget cost implications.

This will also rely in the outcome of the proposed floodline determination project.

Increase traffic control measures and information systems to guide traffic prior to and during high rainfall incidents on highways and critical transport connections.

Mandate a limited quantity of rainwater capture for various property types.

Box 5. Sustainable Urban Drainage Systems

Sustainable Urban Drainage Systems (SUDS) are designed to reduce the potential of flooding on new and existing urban developments, while providing various environmental benefits.

Traditional stormwater drainage techniques aim to direct water off surfaces (roads, roofs etc.) as quickly and efficiently as possible into stormwater pipes which discharge the stormwater, usually into natural water ways or into the sea, often contributing to pollution, soil erosion, silting up of streams and other environmental problems. During periods of heavy rainfall, this technique often results in large quantities of water moving at high speeds impacting on sites located downstream of where the rain has originally fallen.

By contrast, SUDS emphasise managing stormwater at the site where it first falls as rain. It does so by: minimising the creation of impervious ground cover; capturing and storing stormwater on-site before releasing the stormwater in a controlled fashion; and by stormwater infiltration into the ground. The new stormwater by-laws recently developed by the Johannesburg Road Agency have many elements of the SUDS philosophy embedded in its approach.

SUDS include both traditional and new engineering techniques such as permeable paving, green roofs, absorbent landscaping, bioswales, soakaways and groundwater replenishing wells. Some, like permeable pavers, can also be used to capture and store rainwater in the layerworks for re-use elsewhere. This effectively allows one to use paved areas, such as parking lots, as a large rainwater tank. Other SUDS, like green roofs, provide biodiversity benefits while reducing energy requirements for cooling. SUDS are particularly useful for retrofitting stormwater systems, where digging up and replacing pipes of traditional systems with larger pipes is too expensive.

7.3.5 Risks X1 & T3: Disruption to Water Security

ADAPTATIONS

Strategy

The strategy relies on taking leadership with respect to the implementation of the water demand management strategies on the one hand (with a strong educational component to encourage water use efficiency, conservation, recycling and waste prevention) and a strategic policy to ensure security of supply on the other.

Key Actions: Demand-side Management

The CoJ is presently developing CoJ demand-side water management bylaws. It is recommended that these include items such as:

Use of water efficient fittings (taps, showers, toilets), which is a low cost but highly effective initiative.

Use of water efficient HVAC and refrigeration systems.

Use of indigenous and endemic vegetation in landscaping, not requiring water for irrigation beyond establishment (which is normally one year).

Incentivise the use of drip irrigation systems, which are in most cases use 30-60% less water than conventional sprinkler systems. Moisture sensors can also be used in the soil to control irrigation. (These are not recommended for open public landscaped areas, where they might be at risk of damage or theft.)

The CoJ should pilot many of the above initiatives in their buildings, and measure and market the results of these to the public.

For example, the use of waterless urinals (using a non-return valve) could be mandated in all CoJ administration and public buildings - existing urinals can easily be converted at minimal cost (approximately R500/urinal). One waterless urinal can save thousands of litres of water per annum (depending on its use), and also generally require less maintenance than a standard urinal.

The CoJ could target a Green Star rating[26] under the Green Building Council of South Africa for all its administration buildings.

Without correct and ongoing metering very little can be done in managing energy demand in the future. JW should consider a review their metering strategy to assess the possibility of implementing a system that allows for immediate checking, management, monitoring, repairs and reporting of all meters, and a long term remote metering control centre that is able to collect all metering data and report on trends and incidents, from an individual customer to any number of customer groups.

A critical focus of the CoJ should be on preventative maintenance and upkeep of the water supply infrastructure and reduce pipe bursts and leakages. The programmes implemented in this regard should continue to receive support at all levels of the CoJ.

Key Actions: Supply-side Management

The CoJ should continue and, where possible, expand their capital investment programme aimed at water pipe leak reduction, which accounts for a substantial (and possibly the greatest) portion of the City's water loss.

The CoJ should introduce integrate supply-side management into the water efficiency bylaws currently under development. These initiatives should focus on supply-side management of key commercial and industrial consumers, including items such as:

Monitoring consumers' use of ground water as far as possible so as to better understand the supply and demand of borehole water.

Stormwater/rainwater recycling inititiatives. This may have to be integrated with the JRA stormwater by-laws. A possible limitation to be considered is that irrigation water is mostly required in the dry winter months, and thus storage of summer rainfall is often unrealistic for such purposes, unless it is via some large facility such as retention dams or other large reservoirs.

Mandate greywater capture and re-use. Specific minimum requirements should vary for different users, to ensure a realistic application and penetration of this in the City.

Where ongoing irrigation is required, even through winter and after establishment, captured greywater from wash hand-basins, showers, and baths should be used (which must be filtered to an acceptable quality as per national/local water quality standards).

The CoJ should engage with the Lesotho authorities, including the Lesotho Highlands Development Authority, to ensure that the Lesotho role-players become cognisant of the potential risks of climate change and begin to take action.

There is a direct linkage between the level of climate change resilience and preparedness of the Lesotho region and the resilience of the CoJ's water security to negative climate change impacts. The CoJ is obviously limited in the role they can play with a foreign government. Nevertheless, some potential initiatives to be considered include:

Assisting Lesotho in sourcing funding from donor organisations or elsewhere for additional weather stations (there is an acknowledged lack of weather stations for climate change modelling in Lesotho).

Assisting with training of relevant individuals such as weather station technicians, through internships at the CoJ

Engaging with Rand Water and other water managers involved in trans-boundary and intra-basin transfers to determine security of supply in the face of climate change projections and local data.

[26] Green Star is a voluntary independent environmental design rating that stringently assesses water consumption, energy consumption, emissions, materials use, ecology and land use, transport to the building, and even management of the building. This is currently the leading internationally recognised rating tool for South African buildings.

7.3.6 Risk X2: Climate Change-driven Refugees and Migrants

ADAPTATIONS

Strategy

International and local experience has shown that migration cannot be fully controlled, even at a national government level. The strategy for the CoJ must recognise that it can play a meaningful and transformative role while also recognising its limitations. The strategy focuses mostly on management of the most severe consequences while taking preventative measures where possible.

Key Actions:

Measures addressing the most severe consequences of migration within the CoJ are similar to measures which generally address poverty alleviation i.e. engaging directly with informal settlement communities, assisting entrepreneurial activities where possible, providing basic health services including sanitation, and maintaining an effective disaster management unit. Preventative measures should focus on engaging with sub-Saharan African municipalities and government authorities in order to assist and support them with capacity building and climate change adaptation in general. This could also be undertaken through co-operation with other international aid organisations and government bodies in South Africa.

It must be recognised that the more resilient our neighbours are to climate change, the better the prospects are for the CoJ with respect to climate change-driven migration. Possible initiatives to improve resilience of our neighbours include:

- Capacity building through foreign internships for training.
- Workshops with other non-South African municipalities with respect to climate change adaptation (possibly supported by international agencies).

The CoJ should consider setting up a task team who will actively support climate change initiatives with key strategic bodies outside of the CoJ. This task team should also engage with provincial and national government in order to represent the CoJ's interests and concerns with respect to climate change impacts beyond the City's borders.

7.4 Strategic Adaptations

Some adaptations are strategic rather than operational in nature. Many of these strategic adaptations have not been explicitly covered in the above risk assessment, in part because they apply across the board to several, if not all, of the Action A-rated risks as well as to numerous other risks not expanded on in this report. Because they apply address multiple risks, these adaptations may be regarded as being of especially high value.

These adaptations include:

Strategic Adaptations - Planning:

Review organisational structures required for effective implementation of climate change adaptation projects.

Effective implementation of climate change adaptation projects is likely to require new organisational structures and mechanisms that emphasise cross-departmental coordination.

The JCCC already provides a good foundation for cross-departmental coordination of climate change adaptation (as well as mitigation) projects.

This should be expanded, possibly in the form of dedicated task teams (drawn from the JCCC members as well as from outside the JCCC, where necessary), who are formally tasked with driving forward various projects. For example, the CoJ may form: an Climate Change Information Management task team - as discussed further on - who would be responsible for gathering relevant data, championing research projects and data collection; a Financial task team (coordinating cross-departmental funding of projects, developing CDM opportunities, developing municipal bonds etc.); a Flood Risk Adaptation task team (coordinating flood adaptation projects); and an Institutional/Strategic Management task team (responsible for monitoring the effectiveness of climate change adaptation initiatives within the CoJ and championing structural changes to improve implementation.

It is recommended that the Department of Environment, in conjunction with Development Planning & Facilitation, take a leadership role in facilitating coordination between departments with respect to climate change adaptation projects and the establishment of dedicated cross-departmental task teams to pursue adaptation initiatives.

Incorporate climate change adaptation into the CoJ CIMS capital expenditure system

The sensitivity of the CIMS system to climate change should be investigated. If appropriate, a climate change-sensitive risk management layer should be incorporated into the CIMS system.

CIMS is the primary mechanism for assigning capital budget expenditure within the CoJ. Understanding this system and its potential sensitivity to climate change-related issues will be a key element in addressing the vulnerability of the CoJ. Incorporating a climate change-sensitive layer into this system would potentially provide for a sophisticated, integrated and flexible climate change adaptation tool for financial planning.

Integrate Urban Heat Island mitigation into the CoJ's urban planning strategy

Temperatures within the built up areas of the CoJ, especially the former CBD, are likely to be several degrees higher than in surrounding areas. Undertaking integrated action to mitigate the urban heat island effect within the CoJ urban planning strategy is likely to provide widespread benefits for most, if not all, future heat-related risks. It may be worthwhile to further investigate and quantify the scale of the urban heat island effect within the CoJ in order to better assess the various costs and benefits associated with mitigating this effect. However, many adaptations which locally offset the urban heat island effect (such as increased vegetation - trees, "green" roofs etc. - and reduced energy consumption) are clearly advantageous and should be pursued regardless.

Strategic Adaptations - Financial:

Develop alternative sources of funding to finance climate change adaptations.

It is clear that the CoJ is under significant budgetary constraints. In view of these constraints, the ability to access innovative and previously untapped sources of funding will be a critical advantage.

Funds are potentially available through various donor and international aid and development organisations. Compelling, fact-based cases (see Strategic Adaptations - Information Management Systems) must be brought to attract funding from these organisations, targeting the highest value adaptations. These organisations may also be more willing to support fundamental climate modelling research in the developing world i.e. expansion of weather station in Lesotho or other data collection needs in the CoJ etc.

Income derived from carbon credits (CDM/CER as well as voluntary credits) from accredited climate change mitigation projects should be directed to support climate change adaptation initiatives, if at all possible. It is noted that several climate change adaptation actions act to mitigate climate change as well and hence may themselves qualify for CDM or other accreditation. These would include energy efficiency initiatives, solar heating and other non-grid renewable technologies and tree-planting.[27]

The CoJ is at present undertaking a carbon inventory which is one of the first and most important steps in qualifying for carbon credits. Further initiatives should be explored to develop this potential source of income.

A relatively new concept in public finance being implemented in parts of the United States (and reportedly under consideration by a number of European local authorities), relates to the use of municipal bonds for financing environmentally beneficial improvements to properties, with the property owners financing the bonds through repayments to the City. Use of these types of instruments (which have been referred to as Voluntary Environmental Improvement Bonds - VEIB's) may provide a significant increase in private residential (most likely upper-middle income group) uptake of solar heaters and other beneficial improvements. Theoretically, these instruments could be used to incentivise rainwater recycling installations or any other beneficial adaptation. If applied to the commercial sector, it may have a roll to play in financing the retrofitting of integrated stormwater systems and other expensive but long lifespan infrastructural adaptations.

[27] It is noted that the CoJ is presently undertaking a greenhouse gas inventory, which will provide an important foundation for developing CDM opportunities in future, as well as allowing the CoJ to better manage their carbon footprint.

The authors of this report have not had the opportunity to closely assess the suitability of this instrument for the CoJ, but this and other novel financing schemes should all be fully explored.

Strategic Adaptations - Information Management System:

Set up a Climate Change Information Management taskforce whose brief is to develop an information management plan which will identify data required for:
(a) further climate change risk assessment; (b) cost-benefit analysis of adaptations; and (c) fundamental climate change modelling research. The taskforce, via the management plan, will coordinate the gathering as well as dissemination of climate change-related data and will also monitor quality control of gathered data.

This key adaptation is based upon the maxim that "what can be measured can be managed". Conversely, if only limited data is available, the CoJ will be unable to critically evaluate where to best invest its limited financial and human resources.[28] Even worse, the CoJ may invest resources in potentially wasteful and damaging initiatives if erroneous data is utilised. Measures in support of this adaptation include:

- Periodically reviewing quality control measures for the recording of data at all weather stations and other environmental monitoring points.
- Evaluating the potential for adding additional capabilities such as wind measurement instruments, expanding the network of river flow monitors etc.
- Determine the appropriate and specific data required for assessing costs related to floods, fires, air pollution-related mortality, heat-related mortality etc. and coordinate the collection of this data. Collection of this data will allow for accurate cost-benefit analysis and will assist in directing funds to where they are most needed. It may be worthwhile to engage with the insurance industry to some degree in terms of data collation.

[28] As an example of the need for proper data management, it is noted that in the analysis of present climatic trends (undertaken by the CSAG research group as part of this project), quality control screening found that only the Krugersdorp weather station provided a sufficiently lengthy and complete weather data set to allow for a statistically thorough analysis. This provides for an unfortunate constraint, considering that there are several weather stations in and around the CoJ, and yet the trend analysis has been forced to rely on a single weather station only.

The plan should include the maintenance of a central database of climate change mitigation and adaptation-related projects across all CoJ departments.

As part of their brief, the taskforce will also be required to identify and support climate change adaptation-related research and development projects within the CoJ.

Update climate change projections and the adaptation plan for the CoJ.

This project expedited region-specific climate change analysis[29] which is critical to reducing uncertainty and improving the factual base for decision-making. As the state of science advances and methodologies improve, it is considered essential that ongoing budgetary allocation be provided for the updating of the CoJ-specific climate change projections as well as for other relevant scientific assessment. This is required to ensure that decision-makers are able to continue making properly informed choices as the climate change risks evolve.

This project represents the very first adaptation plan for the CoJ. An update of this plan is required in order to expand on some of the issues raised in this report but not fully explored, to reassess potential risks as the quality of climate change projections improves and to monitor the progress, or the lack thereof, on key recommendations.

It is recommended that an external progress review be undertaken on an annual basis.

It is recommended that a comprehensive update of the CoJ climate change adaptation plan be undertaken 2 years from the issuing of this report.

Strategic Adaptations - Stakeholder Engagement (Internal):

Maintain and, where appropriate expand, interdepartmental cooperation mechanisms such as via the JCCC. The Department of Environment should actively develop a role of facilitating interdepartmental communication relating to the implementation of climate change adaptation strategies.

This relates closely to the first strategic adaptation discussed above for reviewing management structures within the CoJ. Climate change will, without any doubt, impact on every sector and department of the CoJ. Therefore, mechanisms for establishing the optimal actions and strategies for adapting to climate change will rely on effective communication between departments. On the most basic and critical level, this is fostered by creating human linkages between departments. This allows synergies to develop between the strategies of the different departments and ensures that strategies are properly aligned and implemented across departmental boundaries.

It is recommended that the Department of Environment take a leadership role in facilitating communication between departments with respect to climate change adaptation projects.

Disseminate the CoJ Climate Adaptation Plan widely among CoJ departments, municipal owned entities and other key player and. Create a formal but simple feedback mechanism.

Many technical experts and managers throughout the CoJ and other relevant organisations may identify additional vulnerabilities in their fields, based on the findings of this report. A simple feedback mechanism (i.e. an email address) for recording feedback will be an invaluable tool, particularly for future revisions of the adaptation plan.

Strategic Adaptations - Stakeholder Engagement (External):

Set up a mechanism for strategic engagement of stakeholders outside of the CoJ with respect to climate change adaptation. Stakeholders should include: Gauteng and National government, Rand Water, Lesotho Highlands Authority and other sub-Saharan municipalities (in order to support them in capacity building).

Similar to the previous high value adaptation, there will be significant value in establishing strategically appropriate linkages with other governmental organisations, both within South Africa and outside of South Africa i.e. sub-Saharan municipalities.

[29] This refers to the downscaled climate modelling undertaken by the CSAG research unit of the University of Cape Town, which provided the scientific basis for much of this report. Ref. Appendix X.

7.5 Summary of Key Adaptations

The adaptations (or actions) highlighted in the preceding sections will require the involvement of a broad range of CoJ role-players. In order to provide a preliminary view of the potential costs and benefits associated with each of these adaptations, as well as an indication of who the likely role-players are, these key adaptations have been summarised in the table below.

The methodology and recommended framework for assessing costs and benefits (or value) within the context of climate change adaptation is expanded upon at the start of Section 6 and reference should be made to this section. It terms of the cost and value ratings presented below, these do not represent a comprehensive cost benefit analysis but rather they represent the technical project team's preliminary opinion as to which adaptations are regarded as most likely to provide substantial benefit and at what cost.

The purpose of this is to assist the CoJ in prioritising which adaptations should be subjected to further technical assessment including more comprehensive cost-benefit analysis. Further steps required in developing this initial stage of prioritisation and assessment will include engaging with CoJ stakeholders to workshop these cost and value estimates and determining what metrics would be most valuable in developing the costing further in future. It is likely that CoJ managers will, in many instances, have the best view of costs associated with various adaptations and hence this process is likely to add substantial value in developing the relative prioritisation of key adaptations further.

A wide range of adaptations have been developed for each of the Action Level A-rated risks and with consideration to the specific needs, constraints and requirements of the CoJ. These adaptations are summarised in Table 18. In addition to these risk-specific adaptations, a number of strategic-level adaptations have also been identified (see Table 17) which have the potential to address a broad number of risks across multiple sectors. These strategic adaptations are regarded as being fundamental for the CoJ's effort to effectively adapt to evolving threat of climate change. The strategic adaptations focus on the following areas:

- Integrating climate change adaptation into strategic planning mechanisms such as:
  - Reviewing the effectiveness of existing management structures with respect to implementing climate change adaptation projects and possibly forming new structures such as dedicated task teams.
  - Investigating the implications of climate change in relation to the CIMS capital expenditure system
  - Integrating concepts for mitigating the Urban Heat Island effect into strategic urban planning
- Developing alternative financing options for the funding of adaptations such as:
  - Continuing to explore CDM, voluntary carbon market (i.e. VCS2 credits), and municipal bonds (Voluntary Environmental Improvement bonds) as alternative financing options.
- Developing an Information Management System to support ongoing climate change risk assessment and cost-benefit analysis:
  - Developing an climate change Information Management Plan
  - Identifying and supporting climate change-related research projects within the CoJ
  - Periodically updating climate change projections for the CoJ
- Maintaining and expanding stakeholder engagement:
  - The Department of Environment to take an active role in facilitating communication between departments on climate change adaptation related projects.
  - Providing a simple feedback mechanism (with respect to climate change adaptation planning) for all CoJ departments and municipal entities Engaging with other government bodies on climate change adaptation including national and provincial government and adjacent municipalities.
  - Engaging with non-South African governments (i.e. Lesotho, sub-Saharan municipalities etc.) and assisting them where possible with adaptation capacity building and planning.

Effective implementation of these and other risk-specific adaptations will require commitment at both the planning and resource level from a broad range of CoJ departments, municipal entities and other stakeholders. More importantly, it will rely on effective communication and coordination among the different role-players. Hence it is advised that the Department of Environment take an active role in facilitating this coordination and communication wherever the need arises.

This report also represents a start to the process of assessing the relative prioritisation of adaptations, insofar as this relates to costing the relative benefits of various adaptations. This process will have to be developed further, both in terms of additional stakeholder engagement with senior CoJ management and in terms of identifying and collating the metrics necessary for determining baseline and future projected costs/benefits. However, even with substantial future effort in collating relevant metrics, and as is the case for most cities globally, there is likely to be numerous instances where there is insufficient information to allow for accurate cost-benefit analysis. Therefore future prioritisation of risks and adaptations will also require the use of multi-criteria analysis and other economic tools to ensure that the CoJ is appropriately prepared for the impacts of climate change.

More importantly, the absence of specific damage cost estimates should not be used as a basis for inaction. The combination of stakeholder input from the CoJ, literature review and technical expert opinion - and the resulting cost/value estimates as summarised in Tables 17 and 18 - allows for at least a preliminary qualitative estimate of both costs and benefits of adaptation actions, which in turn provides sufficient basis for decision-makers within the CoJ to prioritise actions and resources during the preliminary phases of adaptation. This approach will allow various adaptations and actions to be fast-tracked and implemented while the framework for economic cost-benefit analysis is further developed for other adaptations.

Table 17: Strategic Adaptations for the CoJ and Preliminary Cost/Value Rankings[1]

Strategic Adaptations	Risks Addressed	CoJ Departments	Value Added by Adaptation[2]	Cost of Adaptation[2]
Strategic Adaptations - Planning			1 2 3 4 5	1 2 3 4 5
Review organisational structures required for effective implementation of climate change adaptation projects and, where appropriate, form new structures such as dedicated task teams.	All Risks	Dep Env, Development Planning & Facilitation	n/a	1
Incorporate climate change adaptation into the CoJ CIMS capital expenditure system: Investigate the sensitivity of the CIMS system to climate change. Integrate climate change risk management layer into the CIMS assessment.	P1, P2, P3, P4, T1, T2, T3	Dep Env, Development Planning & Facilitation	n/a	1
Formally integrate Urban Heat Island mitigation into the CoJ's urban planning strategies.	Most, if not all, heat-related risks	DP&UM, Dep Env	n/a	1
Strategic Adaptations - Financial			1 2 3 4 5	1 2 3 4 5
Develop alternative financial sources for funding adaptation initiatives (Clean Development Mechanism, Voluntary Environmental Improvement Bonds etc.)	All Risks	Dep Env. Finance Department	n/a	2-3
Strategic Adaptations - Information Management System			1 2 3 4 5	1 2 3 4 5
Set up a Climate Change Information Management taskforce. The taskforce is to: Develop an information management plan which (a) identifies data required (across all departments) to support cost benefit analysis for key specific risks and adaptations; (b) ensures quality control of data collected in support of climate-modelling; and (c) coordinates the gathering and dissemination of climate change-related data. Identify and support specific climate change research projects within the CoJ.	All Risks	Dep Env. Other departments	n/a Regarded as a Minimum Requirement	1-2 (2-3 if including expenditure on R&D and capital expenditure on scientific equipment)

Strategic Adaptations	Risks Addressed	CoJ Departments	Value Added by Adaptation[2]	Cost of Adaptation[2]
Periodically update climate change projections and the climate change adaptation plan for the CoJ.	All risks	Dep Env. Other departments	n/a Regarded as a Minimum Requirement	1-2
Strategic Adaptations - Stakeholder Engagement			1 2 3 4 5	1 2 3 4 5
Internal Stakeholder Engagement: Maintain, and where appropriate, expand interdepartmental co-operation mechanisms (such as via the JCCC). The Department of Environment to actively facilitate interdepartmental communication and cooperation relating to implementation of climate change adaptation strategies. Disseminate the CoJ Climate Adaptation Plan widely among CoJ departments and municipal owned entities and create a formal but simple internal feedback mechanism.	All Risks	Dep Env. Other departments	n/a Regarded as a Minimum Requirement	1
External Stakeholder Engagement: Set up a mechanism for strategic engagement of stakeholders outside of the CoJ in climate change adaptation. Key external stakeholders should include Gauteng and National government, Rand Water, Lesotho Highlands Authority, other southern African municipalities.	X1, X2, all external risks	Dep Env.	n/a Regarded as a Minimum Requirement	1

[1] - The preliminary cost and value rankings will require further development by the CoJ adaptation technical team as well as engagement with relevant CoJ stakeholders. This assessment is based on the consensus best estimate of the adaptation team at present and does not represent a technical analysis of potential costs and value added. Further sector specific studies will be required to determine the validity of these estimates. Further details of the methodology are described in Section 6.2

[2] - Scale of 1 - 5, where 1 is low cost/value and 5 is high cost/value. A value of 1 is regarded as <R1 million .and 5 > R50 million over a 5 year period. The 5+ rating indicates where adaptations are critical.

- "Value Added" considers the overall value added by the adaptation for the CoJ as whole. Costs are implementation costs for the CoJ municipality. Costs for the CoJ economy may be different. "Minimum Requirement" indicates that this is regarded as the minimum level of adaptation required to support effective risk management.

n/a - not applicable

Table 18: Key Adaptations for the CoJ and Draft Preliminary Cost/Value Rankings[1]

Key Adaptation Actions - Action A-rated Risks	Risks Addressed	CoJ Departments	Value Added by Adaptation[2]	Cost of Adaptation[2]
Adaptations for Risks P1 - P4: Increased Risk of Urban Flooding			1 2 3 4 5	1 2 3 4 5
Implement new stormwater bylaws for all developments within the CoJ, including low cost housing and provincial/national government-led initiatives	P1, P2, P3, P4	JRA, DP&UM, Dep Housing, Dep Env., Development Planning & Facilitation	5+ (Regarded as Minimum Requirement)	4-5
Budget for and implement pro-active & preventative maintenance of stormwater and sanitation infrastructure	P1, P2, P3, P4	JRA, Dep. Infrastructure, JW, Development Planning & Facilitation	5+ (Regarded as Minimum Requirement)	5
Continue infrastructure upgrades to all informal settlements and relocation of settlements within floodplains	P1, P2	DP&UM, Dep Housing, Dep. Infrastructure, JW, JRA, other departments	5+ (Regarded as Minimum Requirement)	5
Reduce further deterioration of CoJ wetlands, rivers and other natural waterways	P1, P2, P3, P4	Dep Env., DP&UM, JRA, other departments	5+ (Regarded as Minimum Requirement)	4-5
Encourage retrofitting of Integrated Stormwater Management designs	P1, P2, P3, P4	JRA, DP&UM	5+	5
Determine floodlines for CoJ (including incorporating climate change uncertainty analysis into the project)	P1, P2, P3, P4	Dep Env, DP&UM, JRA, Development Planning & Facilitation, Dep Housing	5 (Regarded as Minimum Requirement)	4
Revisit floodline determination on 10-year forward cycles	P1, P2, P3, P4	Dep Env, DP&UM, JRA, Dep Housing	5	4
Comprehensive stormwater vulnerability audit	P1, P2, P3, P4	JRA, Dep. Infrastructure, Dep. Env.	4-5	3-4
Undertake research project to evaluate climate change-based MAP	P1, P2, P3, P4	Dep. Env. JRA	4	2
Direct engagement initiatives with informal settlements regarding flood risk management	P1, P2	EMS, Dep. Env.	4 (Regarded as Minimum Requirement)	2
Implement SUDS pilot project	P1, P2, P3, P4	Dep Env. JRA, Other departments	4	3
Implement telemetric early warning system for floods (pilot project or full-scale)	P1, P2, P3, P4	JRA, EMS, Dep. Env. Other departments	3	2
Basic electrical infrastructure flood risk assessment	P4	City Power, Dep. Env.	3	3

Key Adaptation Actions - Action A-rated Risks	Risks Addressed	CoJ Departments	Value Added by Adaptation2	Cost of Adaptation2
Adaptations for Risk T1: Increase in Heat-Related Deaths			1 2 3 4 5	1 2 3 4 5
Develop a Heatwave Response Plan	T1	Dep Health; Dep Env.; EMS	n/a Regarded as Minimum Requirement	1
Record heat-mortality statistics	T1	Dep Health; Dep Env	n/a Regarded as Minimum Requirement	1
Continue and expand tree-planting programmes	T1, T2	Dep Env.; DP&UM; Dep Housing	3-4	3
Provide shade features in public places	T1	DP&UM	1-2	1-2
Include air-conditioning on future buses/taxis	T1	Dep Transport, Metrobus	2	4
Adaptations for Risk T2: Increase in Energy Demand			1 2 3 4 5	1 2 3 4 5
Budget for and implement pro-active & preventative maintenance	T2	City Power	5+ (Regarded as Minimum Requirement)	5
Establish and implement energy efficiency by-laws	T2	City Power, DP&UM, Dep Env	4-5 (Regarded as Minimum Requirement)	1
Expand solar heater programme	T2	City Power, DP&UM. Dep Housing, Dep Env.	4-5	3
Establish advanced electricity metering strategy	T2	City Power, DP&UM, Dep Housing	4-5	5
5-year review of design temperature for cable sizing	T2	City Power, Dep Env.	3-4	1
Improve compliance with City's Energy Efficiency Guideline for Buildings	T1, T2	DP&UM, Dep Housing, Dep Env.	3	1
Achieve Green Star rating in CoJ administration buildings	T2, X1, T3	City Power, Dep Env, other departments.	2	2-3
Achieve SANS 204 compliance in CoJ administration buildings	T2	City Power, Dep Env, other departments.	2	2-3
Energy efficiency education initiative for Johannesburg Market	T2	Johannesburg Market, City Power, Dep Env.	1-2	1

Key Adaptation Actions - Action A-rated Risks	Risks Addressed	CoJ Departments	Value Added by Adaptation[2]	Cost of Adaptation[2]
Adaptations for Risk TP4: Biodiversity Impacts on disease Vectors - Health Risks			1 2 3 4 5	1 2 3 4 5
Formalise mechanism for acquiring Dep. Health input regarding Climate Change	TP4, TP1	Dep Health, Dep Env	n/a Regarded as Minimum Requirement	1
Dep Health to monitor Climate Change impacts on public health	TP4, TP1	Dep Health, Dep Env	n/a Regarded as Minimum Requirement	1
Adaptations for Risks X1 & T3: Disruption to Water Security and Increased Water Demand			1 2 3 4 5	1 2 3 4 5
Budget for and implement pro-active & preventative maintenance of infrastructure (in particular for leakage reduction)	X1, T3	JW, Development Planning & Facilitation	5+ (Regarded as Minimum Requirement)	5
Establish water efficiency & recycling by-laws (including recycling of rainwater and greywater)	X1, T3	JW, Dep Env.	4-5 (Regarded as Minimum Requirement)	3-4
Review of Johannesburg Water metering strategy and establishment of advanced metering system	X1, T3	JW, Dep Env.	4	4
Engage with Lesotho stakeholders and Rand Water regarding climate change vulnerability & adaptation; assist with adaptive capacity building. See - Strategic Adaptations: External Stakeholder Engagement.	X1	Dep Env., JW	n/a (Regarded as Minimum Requirement)	2
Installation of water efficient measures in CoJ administration buildings	X1, T3	JW, Dep Env. Other departments	3	2
Adaptations for Risk X2: Climate Change-driven Refugees and Migrants			1 2 3 4 5	1 2 3 4 5
Engage with external stakeholders; support sub-Saharan municipalities with capacity building. See - Strategic Adaptations: External Stakeholder Engagement	X1, X2	Dep Env.	n/a Regarded as Minimum Requirement	2

[1] - The preliminary cost and value rankings will require further development by the CoJ adaptation technical team as well as engagement with relevant CoJ stakeholders. This assessment is based on the consensus best estimate of the adaptation team at present and does not represent a technical analysis of potential costs and value added. Further sector specific studies will be required to determine the validity of these estimates. Further details of the methodology are described in Section 6.2

[2] - Scale of 1 - 5, where 1 is low cost/value and 5 is high cost/value. A value of 1 is regarded as <R1 million .and 5 > R50 million over a 5 year period. The 5+ rating indicates where adaptations are critical.

- "Value Added" considers the overall value added by the adaptation for the CoJ as whole. Costs are implementation costs for the CoJ municipality. Costs for the CoJ economy may be different. "Minimum Requirement" indicates that this is regarded as the minimum level of adaptation required to support effective risk management.

n/a - not applicable

Appendix A: Glossary

Adaptation - See climate adaptation.

Adaptation Plans - Development of a framework setting out key risks with associated actions for adaptation.

Adaptive Capacity - The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of changes in climatic conditions. (1)

Climate Adaptation - Building climate change resilience. A process whereby individuals and communities seek to respond to 'actual or expected climatic stimuli or their effects'. The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits, associated with climate variability and climate change. See also mitigation. (1)

Climate Change Scenarios - A coherent and internally-consistent description of the change in climate by a certain time in the future, using a specific modelling technique and under specific assumptions about the growth of greenhouse gas and other emissions and about other factors that may influence climate in the future. (1) See also IPCC Scenarios.

CoJ Metropolitan Municipality - Came into being as a result of a merger of Greater Johannesburg Metropolitan Council and its substructures. It is South Africa's largest municipality in terms of population and contribution to GDP. It is the main centre for finance, business services, and information and communication technology in the Country.

Communicable diseases - Illnesses caused by micro-organisms and transmitted from an infected person or animal to another person or animal.

Confidence - An estimate or measure of (un)certainty. May be expressed descriptively and/or semi-quantitatively, or quantitatively. (1)

Cost Benefit Analysis (CBA) - Analysis which quantifies in monetary terms as many of the costs and benefits of a project as possible, CBA is designed to show whether the total advantages (benefits) of a project or policy intervention exceed the disadvantages (costs). This essentially involves listing all parties affected by the policy intervention and then valuing the effect of the intervention on their well-being as it would be valued in money terms by them. It may include items for which the market does not provide a satisfactory measure of economic value. (2)

Discounting - Discounting is the technique used to add and compare environmental costs and benefits that occur at different points in time. It is the practice of placing lower numerical values on future benefits and costs as compared to present benefits and costs. It arises because individuals attach less weight to a benefit or cost in the future than they do to a benefit or cost now. (2)

Downscaling - Refers to techniques that enable the results of GCM's to be made relevant to local decision-makers and impact assessment. Downscaling techniques generally involve statistical methods of data interpolation, multivariate regression, weather circulation typing, and weather generators. (1)

Evapotranspiration - Term used to describe the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves. Evapotranspiration is an important part of the water cycle.

Forecast/prediction - An extrapolation or projection of the state of a system, or value of a variable, based on available knowledge or information and defined assumptions. Forecasts are usually either temporal and/or spatial extrapolations. Temporal extrapolations can be forward (forecast) or backward (hindcast). Where uncertainty can be estimated and a level of confidence can be assigned to a climate or other projection (see below), it becomes a forecast or prediction. (1)

Global Climate Model (GCM) - Computer models designed to help understand and simulate global and regional climate, in particular the climatic response to changing concentrations of greenhouse gases. GCMs aim to include mathematical descriptions of important physical and chemical processes governing climate, including the role of the atmosphere, land, oceans, and biological processes. The ability to simulate sub-regional climate is determined by the resolution of the model. (1)

Greenhouse gases - A number of anthropologically produced and naturally occurring gases whose presence in the atmosphere traps energy radiated by the Earth. Carbon dioxide is the most important greenhouse gas. (1).

Heatwave - Defined as when the temperature is five degrees higher for three consecutive days than the highest average maximum temperature for the area.

Humidity - The amount of water vapour or moisture in the air.

High Pressure Cell - A high-pressure area is a region where the atmospheric pressure at the surface of the planet is greater than its surrounding environment. Winds within high-pressure areas flow outward due to the higher density air near their center and friction with land.

Impact - A beneficial or (more usually) detrimental consequence. (1)

IPCC - The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change.

IPCC Scenarios - Due to the fact that the future is uncertain it is not possible to predict climate change with any level of accuracy. Therefore the IPCC developed scenarios to cover a range of the driving forces of future green house gas emissions, from demographic development, socio-economic development to technological change and economic developments. See Appendix B.

Likelihood - A general concept relating to the chance of an event occurring. Generally expressed as a probability of frequency. (1)

Load-shedding - A controlled way of rotating the available electricity between all customers. It involves cutting off the electric current on certain lines when the demand becomes greater than the supply.

Magnitude - Magnitude of the risk is defined as the scale of the impact on the CoJ (as a whole) should the risk eventuate.

Mitigation - In the context of risk management, mitigation refers to any action to reduce the probability and magnitude of unwanted consequences. Hence, adapting to climate change is a strategy undertaken to mitigate the risks associated with future changes in climate. There is scope for confusion in using this term since mitigation, as used in climate change policy, typically refers to the reduction in greenhouse gas emissions (as in climate change mitigation), which is a specific example of risk management (1)

Multi-criteria analysis (MCA) - Describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several (i.e. multiple) objectives. Approaches are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. It can encompass non-monetisable impacts and additional criteria that can be difficult to incorporate within a CBA. Compensatory MCA techniques combine assessments on separate criteria into an overall assessment, allowing trade-offs to be modelled (i.e. lesser scores for an option on some criteria can be offset by greater scores on other criteria). Simple weighted averaging models are compensatory, while lexicographic methods are not. Lexicographic models provide a general approach to the ordering of preferences in which options are compared based on a judgement or agreement as to the most important criterion. The best option is chosen unless other options tie for first place, in which case evaluations based on the second most important criterion are considered to break the tie. If that is not possible then the third most important criterion is consulted and so on until one option can be chosen. (1)

Percentile - The value below (or above) which falls a specified percentage (e.g. 95%) of a set of values. (1)

Resilience - The ability of a system to recover from the effect of an extreme load that may have caused harm. (1)

Risk - A situation in which the probabilities that certain states or events will occur (or have occurred in the past) are precisely known. Also a characteristic of a system or decision where the probabilities that certain states or outcomes have occurred or may occur are precisely known. Risk is a combination of the chance or probability of an event occurring, and the impact or consequence associated with that event. Decisions that involve risk are a special case of uncertain decisions where the probabilities are precisely known. (1)

Sensitivity - Refers to the change that results (in a system or variable) from a specific perturbation in an input value, parameter value, or other assumption. Therefore climate sensitivity is the degree to which a system would be affected, either adversely or beneficially, by climate-related stimuli. (1)

Stakeholder - People, including organisations, who have an investment, financial or otherwise, in the consequences of any decisions taken. (1)

Uncertainty - A situation in which the probabilities that certain states or events will occur (or have occurred in the past) are not, or can not, be precisely known. (1)

Urbanisation - The physical growth of urban areas from rural areas as a result of population immigration to an existing urban area. Effects include change in density and administration services.

Urban heat island - A metropolitan area which is significantly warmer than its surrounding rural areas. The temperature difference usually is larger at night than during the day and larger in winter than in summer, and is most apparent when winds are weak. The main cause of the urban heat island is modification of the land surface by urban development; waste heat generated by energy usage is a secondary contributor.

Vulnerability - Refers to the magnitude of harm that would result from a particular hazardous event. The concept recognises, for example, that different sub-types of a receptor may differ in their sensitivity to a particular level of hazard. Therefore climate vulnerability defines the extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It depends not only on a system's sensitivity but also on its adaptive capacity. Hence arctic alpine flora or the elderly may be more vulnerable to climate change than other components of our flora or population. (1)

Sources:

(1) Climate Adaptation: Risk, uncertainty and decision-making. UKCIP, 2003.

(2) Costing the Impacts of Climate Change in the UK. UKCIP, 2004.

IPCC Scenarios Explained

The long-term nature and uncertainty of climate change and its driving forces require scenarios that extend to the end of the 21st century. In 2000, the International Panel on Climate Change (IPCC) produced a 'Special Report on Emissions Scenarios' (SRES) which presents the scenarios and how they were developed.

Due to the fact that the future is uncertain it is not possible to predict climate change with complete accuracy. Therefore the SRES scenarios presented within the Special Report cover a range of the driving forces of future greenhouse gas (GHG) emissions, from demographic development, socio-economic development to technological change and economic developments. These scenarios seek to capture a wide range of possible future situations. Therefore scenarios are alternative images of how the future might unfold and are an appropriate tool with which to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties.

It is noted that despite the uncertainties involved in predicting future socio-economic trajectories and the resulting GHG emissions scenario, there is at present broad international consensus that any action we may take in the next few years will have only a limited effect on altering climate change projections for the next 40 - 50 years. However, our actions over the next 10 - 20 years are likely to have a profound impact on the extent of climate change in the second half of this century[30]. This lag is due to both GHG emissions that have already been emitted as well as to the long lead in time between taking the necessary policy decisions and seeing those decisions converted into large scale engineering projects and behavioural change on the ground.

The IPCC SRES predicts four possible futures. Each has been described by means of a storyline which presents the various relationships between the driving forces and their GHG emissions. Each storyline, namely A1, A2, B1 and B2 represents a different combination of driving forces (demographic, social, economic, technological, and environmental developments) which would be viewed positively by some people and negatively by others. All the scenarios based on the same storyline constitute a scenario "family". For each storyline several different scenarios were developed using different modelling approaches to examine the range of outcomes arising from a range of models that use similar assumptions about driving forces.

Six models were used that resulted in 40 SRES scenarios which together encompass the current range of uncertainties of future GHG emissions arising from different models, in addition to the uncertainties that arise from scenario driving forces. Thirteen of these 40 scenarios explore variations in energy technology assumptions.

A description of the four storylines has been provided below which was taken directly from the Special Report. A1

Storyline and Scenario Family - Rapid Growth

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B). Balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies.

A2 Storyline and Scenario Family - Heterogeneous World

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower than in other storylines.

[30] Stern Review: The Economics of Climate Change. HM Treasury, UK, 2006.

B1 Storyline and Scenario Family - Global Solutions

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

B2 Storyline and Scenario Family - Local Solutions

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The graphs below indicate the resulting projected global GHG emissions for the various scenario families (Pg 13. Special Report Emissions Scenarios: Summary for Policymakers. IPCC, 2000).

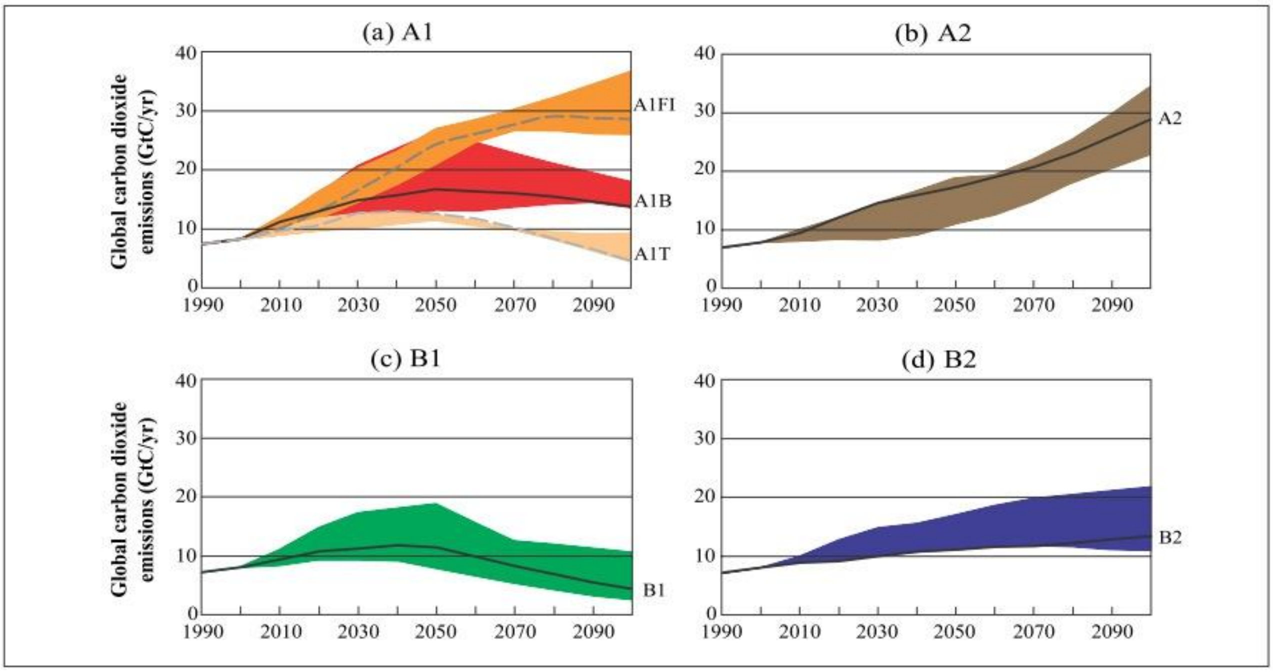

Figure 3: Total global annual CO_2 emissions from all sources (energy, industry, and land-use change) from 1990 to 2100 (in gigatonnes of carbon (GtC/yr) for the families and six scenario groups. The 40 SRES scenarios are presented by the four families (A1, A2, B1 and B2) and six scenario groups: the fossil-intensive A1F1 (comprising the high-coal and high-oil-and-gas scenarios), the predominantly non-fossil fuel A1T, the balanced A1B in Figure 3a; A2 in Figure 3b; B1 in Figure 3c, and B2 in Figure 3d. Each colored emission band shows the range of harmonized and non-harmonized scenarios within each group. For each of the six scenario groups an illustrative scenario is provided, including the four illustrative marker scenarios (A1, A2, B1, B2, solid lines) and two illustrative scenarios for A1F1 and A1T (dashed lines).