Developing a Municipal Adaptation Plan (MAP) for climate change: the city of Cape Town [1]

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ABSTRACT

Climate change increases the likelihood of extreme weather events such as droughts, floods and heat waves, as well as more gradual changes in temperature and precipitation. The city of Cape Town (South Africa) is at risk from projected climate-induced warming and changes in rainfall variability. This makes resource management and infrastructure planning more challenging and increases the urgency of the need to adapt city-level operations to both current climate variability and future climate change. To date, however, the main focus of adaptation planning has been at the national level, and has not adequately addressed municipal-scale adaptation. This paper presents and discusses an overarching framework that would facilitate the development of a Municipal Adaptation Plan (MAP). The example of the city of Cape Town illustrates some of the sector-level assessments and potential climate threats, as well as resource mobilization issues that need to be addressed during the development and implementation of a MAP. In conclusion, a number of barriers to developing a MAP are discussed.

KEYWORDS

adaptation / climate change / climate variability / impacts / municipal / planning / Cape Town

[1] This study is based on a report compiled by the authors for the city of Cape Town entitled "**A Framework for Adaptation to Climate Change in the City of Cape Town – FAC^{4}T"**. At the time of writing this paper, the proposed framework for the Municipal Adaptation Plan (MAP) had been tabled with the city council for approval.

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I. Introduction

Scientific evidence confirms that climate change is already taking place and that most of the warming observed during the past 50 years is due to human activities.[(1)] In Southern Africa, climate change projections suggest increased variability in rainfall, more frequent extreme events and increased temperatures.[(2)] These will occur even if global emissions were to be reduced in accordance with the Kyoto Protocol. In Cape Town, a significant number of past disasters and events have been associated with weather conditions.[(3)]

In recent years, reducing vulnerability to climate change has become an urgent issue in low- and middle-income countries and is at the forefront of any sustainable development policy agenda. Adaptation to climate change is a process whereby individuals and communities seek to respond to "…*actual or expected climatic stimuli or their effects*".[(4)] This process is not new and throughout history, people have adapted to changing climate conditions. What is new is the incorporation of climate change and its potential impacts into policy making and planning on a range of scales.[(5)]

National Adaptation Plans of Action (NAPA) have been developed recently under the United Nations Framework Convention on Climate Change (UNFCCC) for Least Developed Countries (LDCs).[(6)] However, to date there has not been a consolidated or coordinated approach to adaptation to projected climate impacts on a municipal scale. This needs to be addressed urgently as it is at this level that many people are directly affected by climate-induced impacts, and it is at this level that institutional solutions can be introduced that target wide numbers of people.

This paper presents an overarching framework for a municipal level approach to adapting sectors to climate impacts, and it highlights examples of potential impacts for the city of Cape Town. Some potential adaptation actions and possible interventions have been suggested. However, as this is the initial framework for developing and implementing a plan, no stakeholder consultation or assessment of the city's capacity to plan and implement an adaptation programme has been made.

II. Background To Climate Change

In this paper, both climate change and climate variability are considered and therefore it is important to understand the distinction between the two.

Climate variability can be thought of as the way climatic variables (such as temperature and precipitation) depart from some average state, either above or below the average value. Although daily weather data depart from the climatic mean, the climate is considered to be stable if the long-term average does not significantly change. On the other hand, climate change can be defined as a trend in one or more climatic variables characterized by a fairly smooth continuous increase or decrease of the average value during the period of record.[(7)]

Climate change studies inherently have to consider the significance of uncertainty. This does not mean that there is no confidence in the understanding, or that the understanding is not certain enough to allow for the development of appropriate adaptation strategies and policies for resource management. Rather, current research would suggest that the political and planning response is lagging behind the understanding of climate change. Four sources of uncertainty currently limit the detail of the regional projections:[(8)]

- **natural variability**: due to the finite historical records from which the range of natural variability at different scales of time and space has been defined, it is not possible to set the definitive limits of natural variability nor to establish how much of the change in variability is due to anthropogenic factors;

- **future emissions**: much of the projected change is dependent on how society responds to reducing greenhouse gas emissions;
- **uncertainty in the science**: current understanding of the regional dynamics of the climate system of the African sub-continent is limited; and
- **downscaling**: this is the development of regional-scale projections of change from the global models. These projections introduce an uncertainty that limits the confidence in the magnitude of the projected change, although the pattern of change can be interpreted with greater certainty.

Using the regional downscaled projections from the Climate Systems Analysis Group, the most relevant change in atmospheric circulation observed for the Western Cape has been a decrease in the frequency of low pressures, typically associated with winter storms, during early winter. These trends have resulted in spatially varying trends in precipitation. Furthermore, the trend of fewer low pressure systems during early winter can lead to weaker synoptic forcing and conditions conducive to brown haze and smog in the Cape Town area.(9)

III. Towards A Framework For Adaptation To Climate Change At Municipal Level

The political discourse on climate change has been debated through the UNFCCC, but in the past the agenda has focused mainly on mitigation of greenhouse gas emissions. Recently, there has been a shift in focus, where policy makers and academics have begun to debate the issues surrounding adaptation to future climate impacts and to consider the implications for the future.(10) In addition, all parties to the Convention, including South Africa, agreed to adopt national programmes for mitigation and adaptation and describe these in "national communications".(11) However, this has been focused mainly at the national level, and the resources and capacity at local level to deal with the implementation and operational issues are not always considered. For the city of Cape Town, for example, the only relevant study has been the climate impact assessment for the Western Cape, commissioned by the provincial government.(12)

It is, therefore, necessary to develop a framework for adaptation to climate change at the municipal level in order to prioritize the most urgent local adaptation activities and identify the required local human and financial resources. If climate variability is to increase, it is necessary to understand how climate impacts on the different sectors and their resultant vulnerabilities. This will focus attention on where priority intervention might reduce the impacts of climate change, and help cities to adapt rather than react when the damage has already been done.

The adaptation policy framework developed by the UNDP is structured around four major principles, from which actions to adapt to climate change can be developed: (13)

- adaptation to short-term climate variability and extreme events is included as a basis for reducing vulnerability to longer-term climate change;
- adaptation policies and measures are assessed in a developmental context;
- adaptation occurs at different levels of society; and
- both the strategy and the process through which adaptation is implemented are equally important.

These principles should be reflected on continually, to ensure adaptation activities are achieving their desired goals.

A number of methodologies have been developed that are either national level in scale, such as the NAPA, or project focused, such as the SSNAPP methodology developed by SouthSouthNorth.[14] However, these methodologies do not institutionalize the approach at a local level.

The following 10 steps are presented to guide the development of an appropriate local level or Municipal Adaptation Strategy (see also Figure 1):

1. assess current climate trends and future projections for the geographical region;
2. undertake a climate vulnerability assessment of the municipal area. Many cities will not have collected and analyzed this information and would therefore have to develop this assessment from scratch:
    - identify current sectoral and cross-sectoral vulnerabilities based on current climate variability risks and trends;
    - identify future potential vulnerabilities based on future projected climate scenarios and future climate risks;
    - capture this information on local vulnerability maps using GIS and other tools. The climate impact assessment would include sea-level rise, drought and flood-prone areas;
3. review current development plans and priorities. Most municipalities would be able to find this information in their various strategic plans;
4. overlay development priorities, expected climate change, current climate vulnerability and expected future climate vulnerability using GIS for spatial interrogation, and other participatory and quantitative assessments for further analysis. These various overlays will assist in identifying hotspots where adaptation activities should be focused;
5. develop adaptation options using new and existing consultative tools. These options should integrate climate-sensitive responses with development priorities and focus on areas that are highly vulnerable to climate variability;
6. prioritize the adaptation actions using tools such as multi-criteria analysis (MCA), cost-benefit analysis (CBA) or social accounting matrices (SAM);
7. develop programme and project scoping and design documents together with associated budgets. This document will be the Municipal Adaptation Plan (MAP) (Figure 1);
8. implement the interventions prioritized in the MAP;
9. monitor and evaluate the interventions on an ongoing basis; and
10. regularly review and modify the plans at predefined intervals.

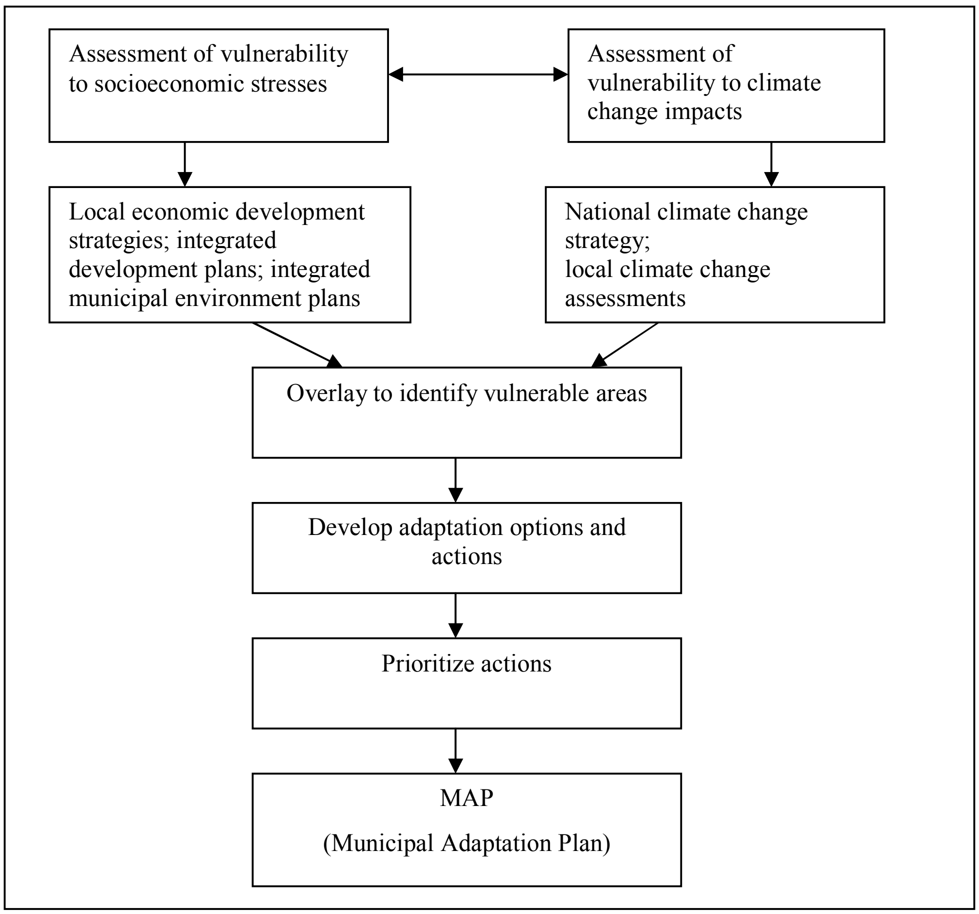
These ten steps should be complemented by two cross-cutting processes:

- **stakeholder engagement**: stakeholders should be engaged with in order to identify vulnerable sectors and existing and potential adaptation initiatives. This engagement process is also necessary to bring politicians and decision makers on board and to give them insight into the projected impacts and potential adaptation actions. Since some of the actions will be capital intensive or politically unpopular, it is necessary to build political will to fund and support adaptation measures. Furthermore, some actions may require certain tradeoffs on which the stakeholders would need to deliberate.
  In developing the MAP, various products would be produced, including a vulnerability assessment, a climate impacts assessment and a vulnerability map, highlighting hotspots where developmental priorities intersect with climate impacts. It is important that a broad range of expertise is drawn on to gather this evidence.
- **adaptive capacity assessment**: the capacity to adapt of the various sectors that would be affected by the impacts of climate change needs to be assessed. Adaptive capacity

can be defined as the potential or ability of a system to adapt to impacts of climate change. There are currently no methodologies for assessing the adaptive capacity of a sector, but this is a gap that should be addressed in future.

This process should also include an assessment of the local government's capacity to implement adaptation actions in terms of budgetary and personnel constraints, with and without explicit climate change adaptation strategies.[15]

Figure 1: Process for developing a Municipal Adaptation Plan (MAP)



Many tools and methods exist for undertaking vulnerability and adaptation assessments, both qualitative and quantitative. O'Brien et al.[16] explain that the definition of vulnerability determines how it is assessed. Vulnerability can be viewed as an "end point", where climate change results in vulnerability, or as "starting point", which determines adaptive capacity and the impact climate change will have. Eriksen and Kelly[17] provide an assessment of the different types of vulnerability indicators developed for climate policy assessments, and highlight the fact that some approaches emphasize the physical more than the social aspects and vice versa. What is apparent is that the understanding of the causes of vulnerability is not always clear, and vulnerability assessment methods need further development and clarity. It is important that any assessment of vulnerability at the metropolitan scale should be clear about what is being measured and how this relates to the causes of vulnerability. The information needed from a metropolitan vulnerability assessment should help determine the appropriate tools. For example, the assessment of how one group or sector might be vulnerable to different types of climate variability might make use of matrices and expert opinion or focus groups. Formal assessments might include the use of vulnerability maps and agent-based models.

Assessing vulnerability to current climate variability is challenging because of the range of factors, in addition to climate, which contribute to vulnerability. Assessing vulnerability to climate change is even more challenging because of the dynamic nature of vulnerability. Although some attempts to evaluate adaptive capacity provide an indication of the ability to adapt to future change, it is impossible to define definitively future vulnerability – although some tools, such as scenarios, may help to evaluate future pathways of vulnerability.

Once the key vulnerabilities are identified, it is necessary to formulate an adaptation strategy consisting of a range of adaptation actions. These adaptation actions need to be developed for the local context in conjunction with key stakeholders, including those directly impacted, experts in the sectors and climate specialists who can comment on the nature of the climate variability. This is necessary in order to assess the secondary impacts of certain adaptation actions and to ensure there is equity and sustainability given the complex institutional arrangements of the city and its inhabitants. For example, in the city of Cape Town, Swilling highlights how infrastructure has been emphasized as key to economic growth and social development policy, yet the sustainability of this infrastructure planning is seldom engaged with at the level needed.(18) This critique provides important information that can be helpful in evaluating Cape Town's current and future infrastructure vulnerability and can contribute to an assessment of infrastructure vulnerability to climate change.

Once adaptation actions have been identified, they need to be prioritized. One method of evaluating which actions might be pursued first is multi-criterion analysis (MCA). This allows options to be evaluated using a range of criteria that include the analysis of unquantifiable factors, especially when distributional implications need to be considered. The purpose of using MCA is to aid decision-making rather than to evaluate options on monetary terms. It is useful in assessing options for adapting to climate change, as there are many factors that need to be considered, including equity, efficiency, short- or long-term benefits as well as many other non-monetary factors. Tools such as cost-benefit analysis (CBA) and social accounting matrices (SAM) are useful when determining the financial implications of an intervention, in terms of both cost and benefit to society. Issues such as the impact on GDP and employment can be assessed. At the same time, the limitations of these methods should be addressed. For example, although MCA might enable non-cost factors to be assessed, the stakeholders defining and evaluating the criteria may have biases. More flexible methods can therefore also be explored for choosing priority adaptation actions.

One of the first steps towards developing a MAP would be to consolidate and integrate existing adaptation initiatives to avoid duplication, and to work within budgetary and capacity constraints. An holistic approach to developing a municipal-level adaptation plan should also include reviews of both the direct impact on natural resources, and the secondary impacts on the socioeconomic environment and the livelihood of communities. Through stakeholder consultation and prioritization, these and other sectors could be included.

A key component of a framework for the climate change strategy is the ongoing monitoring of the programmes and projects that are prioritized and implemented. The effectiveness of the interventions should be regularly assessed and modifications made if necessary. Adaptation to climate change is not an event but rather, it is an ongoing process of social learning. The development of a MAP should lead to adaptation actions being integrated into development policy and planning at every level. It should not be an add-on or an afterthought. Development itself is key to adaptation, since adaptation should be an extension of good development practice and should reduce vulnerability. All levels of government should ensure that policies, programmes, budget frameworks and projects take account of climate change, since critical economic, social and ecological challenges can only be addressed effectively on a regional scale.[(19)] However, there is little evidence of this kind of integration, since low- and middle-income countries face two key barriers on this front: institutional constraints and technical capacity. [(20)] These are discussed further in the conclusion.

IV. Examples Of Potential Current And Future Municipal Climate-Induced Impacts For The City Of Cape Town

This section provides a few examples of current and future vulnerability to climate variability and change for the city of Cape Town. Due to the limited nature of this study, this has been based on a desktop assessment of existing reports. Some potential actions and possible interventions have been suggested. No stakeholder consultation or assessment of the city's capacity to plan and implement an adaptation programme has been undertaken.

a. Urban water supplies

The supply of water services in Cape Town faces a number of challenges, including eradicating a backlog in basic services, reducing demand, meeting wastewater effluent standards (thereby reducing impact on the water quality of urban rivers), managing assets and ensuring that development growth demands are met.[(21)] The greater Cape Town area has been identified by the Department of Water Affairs and Forestry (DWAF) as the first major urban region in South Africa where the demand for water will exceed the total potential yield for the area if the economic and population growth scenarios are realized or the expected impact of projected climate change manifests itself.[(22)]

Figure 2: Water supply and demand projections for Cape Town [23]

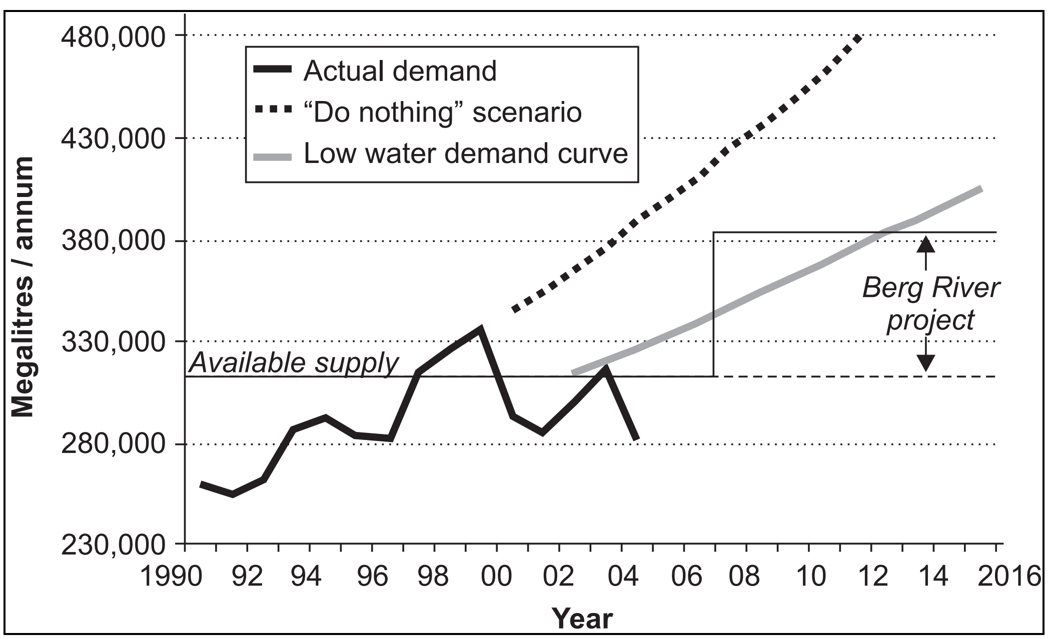
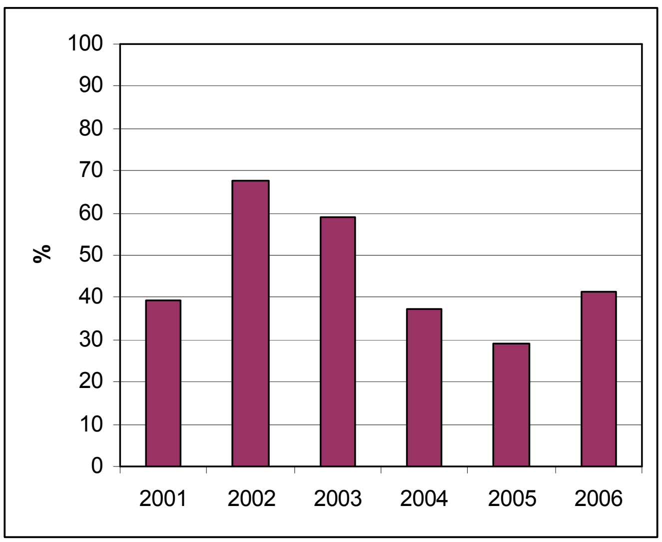


Figure 2 shows projected demand and also illustrates the relief that the Berg Water Project will bring under the "low water demand" scenario. The commissioning of a new dam on the Berg River in 2007 will increase the available supply by about 25 per cent. Under the "low water demand" scenario, however, the city will have a water deficit by 2013. Domestic consumption accounts for two-thirds of the city of Cape Town's demand. Any demand-side management strategy should focus initially on this sector. As shown by the "actual demand" curve, demand-side management initiatives, such as step tariffs and water restrictions during the recent drought periods, have reduced consumption quite considerably.

Impacts and vulnerabilities. Recently, the Western Cape has experienced a drought that can be attributed to climate variability. Climate variability is expected to alter the present hydrological resources in Southern Africa and to place added pressure on the adaptability of future water resources. During the past 20 years, most of Southern Africa has experienced extensive droughts, the last four being in 1986–1988, 1991–1992, 2000–2001 and 2004–2005. As shown in Figure 3, dam levels in the Western Cape were at their lowest in five years during 2005. This drought-induced water shortage placed stress on the water supply and management in the city of Cape Town and resulted in a demand-side management response.

Figure 3: Storage levels on 1 May 2001–2006 [24]



Adaptation initiatives. Current water management practice was developed to ensure that the existing supply of water meets the growing projected demand. Some of the mechanisms may be appropriate to deal with the future intermittent shortages that will be brought about by climate variation, but robust long-term strategies are required to ensure that water demand matches supply, even in times of reduced availability. In addressing future projected climate change impacts, some of the proposed measures may need to be introduced sooner than originally planned.

The Integrated Water Resource Planning Study, commissioned by the former Cape Metropolitan Council (CMC), identified the need to adopt an integrated water resource planning approach to manage the changing water demand as well as address the effects of population, economic growth and stresses on the supply of water.[25] The stresses on the supply of water should include projected climate impacts. In addition, there should be a strong focus on defence of the ecological reserve to ensure sustainability of wetland and river ecosystems. It has been proposed in the Berg Water Management Area (WMA) assessment study that no development or investment decisions should be made without taking into account the actual or potential effects of climate change on water resources.[26]

In addition, it is important that the impacts due to the changes in climate be monitored as a precautionary measure. Special attention is to be given to long-term monitoring of hydro-meteorological parameters in selected, benchmark sub-catchments. Water planners and managers need to use the available climate data to make strategic decisions on an ongoing basis.

It would be strategic to establish effective water demand-side management before undertaking further capital expenditure on developing additional sources of water. To this end, the Cape Metropolitan Council accepted in 1997 the following policy statement:

> "…to develop and manage, in a participatory manner, the implementation of a socially beneficial, technically feasible, economically effective, ecologically sustainable water demand management strategy, which will reduce the (DWAF 1994) projected demand in greater Cape Town by 20 per cent (or more) by the year 2010".[27]

The city of Cape Town has since (in 2004) outlined a ten-point plan for achieving greater water conservation to complement the existing city of Cape Town's water demand management strategy, and to achieve the objectives of the long-term, sustainable water conservation strategy currently being developed by the city of Cape Town in partnership with the Department of Water Affairs and Forestry.[28]

These initiatives include the following:

- **water restrictions**: in the past, the city of Cape Town has used measures such as restricting the use of water for some activities to specific times, and disallowing other activities, to reduce the demand on the limited water resources;
- **water tariffs**: market-based allocations are able to respond more rapidly to changing supply conditions and also tend to lower the water demand, conserve water and consequently increase both the robustness and resilience of the water supply system.[29] Water tariffs were effectively used during the 2005 water shortage to reduce the demand by the city of Cape Town;
- **reducing leaks**: in Cape Town, the unaccounted-for water was estimated at 23 per cent and 18 per cent for 2000 and 2001, respectively.[30] The upgrading and improvement of water supply lines, as is taking place in Khayelitsha through the Water Leaks Project, would bring these losses to within acceptable limits. Furthermore, the efficient use of water would reduce treatment and distribution costs;
- **pressure management**: with the introduction of pressure management systems, as in Khayalitsha, water lost from undetected leaks is reduced by lowering the off-peak water pressure in the pipes. This also reduces the water lost (unused) through leaks from pipes on private property;[31] and
- **awareness campaigns**: through the media and knock-and-drop pamphlets, the city of Cape Town has embarked on an awareness campaign in an attempt to reduce the consumption of domestic water.

A number of policies and measures could be implemented by the city of Cape Town to reduce water demand. The cost implications of these would require further investigation:

- **incentives**: these could be in the form of rebates for ratepayers and businesses that install rainwater tanks, re-use their grey water and install low-flush toilets; and
- **regulations**: building regulations should require that all new buildings be equipped with water-saving devices such as low-flush toilets and rainwater tanks.

Given the high growth rates projected for the area and the already insufficient resource capability, water demand management alone will not be sufficient to meet future water requirements. Other supply-side interventions will have to be resorted to. Some of these are discussed below:

- **Berg WMA schemes**: two schemes located on the Berg River are being developed, as described in a report by BKS;[32]
- **the Table Mountain group aquifer**: the current belief is that the Table Mountain group aquifer has great potential for water productivity and it is already significantly utilized for irrigation and for municipal use throughout the Western Cape. This option is also being considered for water supply to the Cape Town Metropolitan Area. However, much uncertainty still exists regarding the productivity, rate of recharge and sustainability of the aquifer;
- **other augmentation schemes**: other schemes that could be developed in the short-medium term include the Cape Flats aquifer, the Lourens River diversion scheme and the Eerste River diversion scheme;[33]
- **re-use of effluent**: currently, the city of Cape Town re-uses 9 per cent of its treated effluent.[34] There should be incentives to encourage industries and other wet-processing systems to recycle their wastewater. At a domestic level, the re-use of grey water should be encouraged;
- **water harvesting**: the installation of rainwater tanks in homes and commercial buildings for use in gardens, swimming pools and sewage could be encouraged with incentives;
- **modification of catchment vegetation**: the Working for Water Programme aims to remove invasive alien tree species (wattle, pine etc.) from catchments in South Africa. By modifying the vegetation in catchments where water-thirsty vegetation with high transpiration rates has reduced the stream flow, the available water supply could be increased. Invading alien plants cause the loss of some 7 per cent of the flow in South Africa's rivers each year;[35]
- **seawater**: the supply of seawater for certain domestic uses (e.g. swimming pools and sewerage) should be investigated further;
- **desalination**: the energy intensity and high financial costs of production have, so far, made this technology unviable. However, the unit price of desalinated water is dropping continually, as technology improves. The major stumbling block is that the Western Cape is projected to face an "energy crunch" in 2007;[36] and
- **improved integration of climate variability information into decision-making**: a Water Research Commission-funded project, Climate for Water, is exploring ways to enable water resource managers to integrate information about climate variability on an annual timescale, in order to better manage resources given the expected seasonal variation. Adapting to annual variability can be seen as an adaptation to climate change.

b. Stormwater

The damaging floods in March 2003 and April 2005 were due to heavy rainfalls over a short period of time. The extent of the damage in the Western Cape province during this period exceeded R 260 million.[37] Furthermore, stormwater drains in the area are prone to blockages – sand from the Cape Flats is blown into the drains during the dry summer months and then obstructs rainwater drainage during the rainy winter season, and more specifically during times of unpredicted heavy storms and intense rainfall. In the "leafy" suburbs, leaves block the drains, particularly in the autumn, with the same result. These blocked drains cause flooding and damage to property and infrastructure. This is also true in areas where there is no drainage infrastructure, such as informal settlements (mostly on the Cape Flats). Poor drainage also has other adverse impacts on the livelihoods and health of low-income households.

Impacts and vulnerabilities. The intensity of rainfall in the Western Cape can be expected to change due to climate variability. An increase in the number of extreme events will have the effect of substantially increasing the losses to the public and private sectors, as well as increasing personal hardship for the people directly affected.

Adaptation initiatives. The city has an extensive stormwater and flood risk infrastructure and an elaborate hydrological monitoring network.[38]

Further risk reduction initiatives would include:

- ongoing monitoring and warning of impending disaster risks, with the help of the provincial weather and hydrological monitoring stations;
- reducing the impacts of these natural hazards through infrastructural means, such as flood detention ponds and weirs;
- increasing the flood event return period that structures are designed to accommodate;
- the ongoing maintenance of stormwater drains to clear them of sand build-up and rubbish; and
- the development of resilient infrastructure, to include appropriately designed and constructed low-income homes, and stormwater drainage and sewage treatment installations to cope with flash floods.

c. Fires

There are large areas of natural vegetation (mainly *fynbos*) within the city's municipal boundary, including the Table Mountain National Park, which are subject to bushfires. These bushfires normally occur, on average, every 15 years or so, with actual intervals between fires ranging between 4 and 40 years. The prevailing warm, dry summers are conducive to fires, which are common between November and March each year, especially when hot, dry, windy conditions prevail for several days.[39] These fires, while necessary for the regeneration of the *fynbos* and *renosterveld*, sometimes get out of control and cause damage to urban infrastructure.

Impacts and vulnerabilities. Based on modelling, the frequency and intensity of wildfires is expected to increase substantially due to lower rainfall (reducing the moisture content of fuels), lower relative humidity, longer droughts and higher wind speeds. High fire risk conditions are projected to almost triple in the west of the province. This will have a negative effect on biodiversity, soil structure and the spread of fire-adapted alien invasive plants, which would further alter and enhance fuel loads, making wildfires more intense. Plantations and buildings will be subject to increased risk.[40]

The soil erosion caused by winter rains after the summer fires further reduces the chances of indigenous vegetation recovering. For example, a study conducted in the Western Cape revealed that 6 tons of soil per hectare were lost following fires in pine stands, compared to 0.1 tons per hectare following a fire in an adjacent *fynbos* area.[41]

Adaptation initiatives. Since management strategies to influence the frequency and intensity of fires in *fynbos* have been unsuccessful in the past, it may be appropriate to adopt defensive measures as well.

Some adaptation responses to fire risks would include:

- increased training in ecological fire management to improve control of the necessary burning of *fynbos* vegetation;
- increased fire-fighting capabilities, including greater training and investment in capacity for fire-fighting, as well as rapid and effective response to fires using aircraft for example;
- removal of plantations, especially in areas where future climate change might make them less productive;
- control of alien invading plants as a specific focus for managing the risk of damage by wildfire;
- appropriate fire breaks between vegetation and residential areas; and
- erosion protection, to avoid loss of top soil due to post-fire rains.

d. Coastal zones

A change in global surface temperature is likely to be accompanied by worldwide sea-level rise through three main mechanisms: the warming and associated thermal expansion of the oceans, the melting of glaciers and, to a much lesser extent, the polar ice balance (Greenland and the Antarctic).[(42)]

It is suggested that specific locations be evaluated carefully in terms of their vulnerability to the following five potential impacts:[(43)]

- increased exposure to extreme events (which themselves might increase in frequency or intensity);
- increased saltwater intrusion and raised groundwater tables;
- greater tidal influence;
- increased flooding (frequency and extent); and
- increased coastal erosion.

Impacts and vulnerabilities. The city of Cape Town's coastline, for example, has many sandy areas with a high potential for erosion as a result of the high-energy wave regime. In addition, the most significant impacts of sea-level rise are expected in those areas where problems are already being experienced. In most cases, these are areas where development has taken place too close to the high-water line or at too low an elevation above mean sea level.

A case study conducted by Hughes[(44)] in 1992 showed that a one-metre rise in sea level would cause damage to private property in Muizemberg and on Woodbridge Island in the order of tens to hundreds of millions of Rands (property values have since risen sharply).

Adaptation initiatives. Proposed planning and mitigation measures to manage the potential coastal impacts should include:

- the development of a coastal vulnerability map using GIS, where sites are assessed according to the scale of potential impacts with respect to sea-level rise. A point-rating system, whereby the vulnerability of sites can be evaluated objectively, should be developed;
- the development of a shoreline management plan, to include the protection of the ecological water reserve for estuaries. Ribbon development close to the shore should be avoided and buffer zones should be maintained;
- a review of the existing regulations and by-laws, for example, more stringent set-back lines for developments;

- the development of a maintenance and monitoring programme for existing coastal infrastructure;[45] and
- the design of structural mitigation measures, such as coastal protection/developments/structures specifically to compensate for the effects of sea-level rise. These would include breakwaters, revetments and sea walls, which protect infrastructure such as housing, promenades, pavements and parking areas from direct wave action and under-scouring.

The question arises as to when and to what extent coastal protection measures should be implemented to deal with possible future sea-level rise.

V. Conclusion

This paper presents a methodology for municipalities to develop an integrated adaptation plan. However, the MAP should not be seen as a one-off process. It should be used initially to educate planners concerning these potential impacts and to develop both sectorally based and cross-sectoral interventions. With time, the integration of climate-sensitive actions into development planning should become commonplace in all municipal departments and their strategic plans.

An integral part of the MAP is the inclusion of an early warning system, where daily and seasonal weather forecasts are monitored to identify any pending impacts and potential disasters. A communication protocol is required to ensure that early warnings from the relevant entities are effectively communicated to the affected authority and communities so that appropriate interventions can be initiated.

A number of potential barriers to implementing a MAP do, however, exist. Issues such as low local human capacity to undertake this kind of planning, and the limited knowledge and understanding of climate issues at local and municipal level are some of the more obvious obstacles. Limited financial resources and competing priorities often result in medium- to long-term planning being sidelined, and projects that don't fit into the short political life of decision makers are not implemented. It is difficult to convince decision makers to consider the need for a climate strategy when the climate projections cover a longer time horizon than the political and development framework and are associated with high uncertainty. Finally, in the absence of a legislative framework, not all municipalities will undertake comprehensive and consistent adaptation planning.

The case study of the city of Cape Town has shown that although it has no formal adaptation strategy in place, there has been enough momentum to initiate a framework that can then, ideally, be leveraged to implement action. Gaining political support could help provide the necessary resources to ensure the MAP is taken seriously and is implemented. Although there are not many activities in the city that currently are called adaptation actions, there are many ongoing activities that already facilitate adaptation to climate variability in that they reduce the impacts of climate variability, and that could therefore be supported as climate change adaptation actions that contribute to the climate change strategy of the city of Cape Town. Developing a thorough methodology will require integrating the expertise of government stakeholders, researchers, civil society and the private sector. This integration may prove challenging and will depend on the level of support. Yet it is clear that Cape Town is vulnerable to climate change, and finding ways to adapt should be adopted sooner rather than later, when the costs of recovery or change to infrastructure and planning will be even higher.

This paper serves as an initial, broad overview of the problems posed by projected climate change, and requires further attention to detail in many areas before a clear adaptive strategy can be developed. Further focused study is required, both to reduce uncertainties in many areas relating to the climate projections themselves and to improve understanding of the implications of impacts and sectoral and cross-sectoral vulnerabilities. More detailed assessments of the vulnerability of key threatened areas, together with likely timelines of impacts, should be undertaken. Along with this is the need to better understand how institutions might “adapt”, to enable climate-sensitive development to become the norm, not only in order to respond to projected climate impacts but also to ensure resilience to current climate variability.

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