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The potential impacts of climate change on water supply in Johannesburg

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6 POTENTIAL CLIMATE CHANGE IMPACTS FOR JOHANNESBURG

"No-one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks"
(Stern, 2006, i).

Johannesburg is a growing and developing urban city that is presently experiencing climate change and will, without a doubt, continue to do so in the future. Johannesburg has, to a certain extent, taken the necessary steps in acknowledging and responding to the challenges of climate change. This chapter reveals the potential climate change impacts projected for Johannesburg. Chapter six also represents the point of convergence of the entire report, as it combines all the information, knowledge and impacts referred to previously, before applying these findings to the city of Johannesburg, as the case study. Firstly, the potential water supply impacts, which Johannesburg will face due to climate change, are presented. These impacts are drawn from envisaged international and African impacts outlined in Chapter four, while additionally putting forward potential South African and Johannesburg impacts. Secondly, the impacts of climate change on planning in Johannesburg are examined; in addition this section assesses the overall planning consequences of climate change. Thirdly, the need for climate change and water supply planning is outlined. This part of the chapter emphasises and recaps the importance of climate change in planning. Lastly, a conclusion to this chapter is formulated; the identified information from previous chapters is used to help project the possible impacts on water supply that might occur in Johannesburg, in the future. The importance and contribution of this chapter to the whole report is essential, since it draws together and summarises the impacts that Johannesburg might experience and evaluates those impacts from a planning perspective.

6.1 WATER SUPPLY IMPACTS

6.1.1 PRECIPITATION AND TEMPERATURE

In summary, internationally the projected impacts of climate change will result in a rise in temperature and greater irregularity in rainfall. In addition, this trend may be further exacerbated by the deterioration of carbon sinks due to climate change. In semi-arid, subtropical and mid-latitude areas of the world, precipitation is projected to decrease. In Africa, temperatures are expected to increase, and southern Africa is anticipated to receive lower levels of rainfall. As South Africa is situated in one of the world's mid-latitude and semi-arid regions, a rise in temperature and decreased and more irregular rainfall can be projected for the country.

The following projections for South Africa – and Johannesburg in particular – have been recorded. In southern Africa, the standard temperature, by the end of the century, will increase by about 2 – 4°C (Hewitson, date unknown; Du Plessis et al., 2003; DEAT, 2004; Joubert, 2006; Joubert, 2008). Night-time temperatures will escalate more than day-time temperatures, which means the difference in temperatures will decrease. Furthermore, minimum winter temperatures will increase more than the maximum temperatures in summer (Du Plessis et al., 2003). The central region of South Africa will be warmer than the coast, as the sea will mediate temperatures in those regions. Escalating temperatures will bring about stronger floods as well as a rise in the prevalence of floods, droughts and heat-waves (DEAT, 2004; DWAF, 2004; Joubert, 2006; Joubert, 2008).

Precipitation in South Africa is expected to decrease by about 5–10% during the 21st century, because South Africa is situated in a subtropical region (Hewitson, date unknown; Du Plessis et al., 2003; DEAT, 2004; DWAF, 2004). DEAT (2004) emphasises that lengthy dry periods will be followed by periods of severe storms. "A marginal increase in early winter rainfall is predicted for the winter rainfall region of the country" (DEAT, 2004). Due to increased water vapour in the atmosphere, during summer the eastern parts of South Africa are expected to

become wetter. What is more, the storms will bring added rain, will be more powerful and will occur more regularly (Joubert, 2006; Joubert, 2008).

In Johannesburg, the predicted daily minimum and maximum temperatures for the period 2046–2065 are expected to increase. The minimum temperatures for January to March are projected to increase by about 2–2,7°C, and from April to December by about 3,5°C. During the period 2070–2100, the minimum summer temperatures will increase between 1 and 3°C, and in winter between 1 and 2°C. The maximum summer temperatures could potentially increase by as much as 3–4°C, and between 2 and 4°C in winter (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008).

The predicted rainfall for Johannesburg, between the periods 2070 and 2100, for the months December to February, may possibly show an increase of about 20%. Between March and May, rainfall could decrease by 20–30%, and rainfall between June and August could increase by 5–10 mm. During September, rainfall may decrease by 40–80%, but increase by 40% in November (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008).

The temperature in Johannesburg is set to increase, with overall decreases in rainfall and possible precipitation variability in the distant future. Therefore, temperature and precipitation are set to influence water supply in Johannesburg, because due to higher temperatures and decreased rainfall, the demand for water may increase. This stress will add to the already existing large numbers of migrants flowing into the city, and rapid urbanisation which is occurring in areas, and already stressing water reserves. Furthermore, as Johannesburg receives most of its water from the Vaal dam area, and because South Africa is a semi-arid country with rainfall variability, the future supply of water in Johannesburg may be under stress.

6.1.2 DROUGHT

In review, the potential impacts of climate change on global drought would be a predicted rise in the occurrence of droughts. The semi-arid, mid-latitude and subtropical regions of the world will become drier and will experience more frequent droughts. As a result of higher temperatures, decreased levels of precipitation and arid climatic conditions, droughts in southern Africa are expected to occur more frequently.

In South Africa it has been projected that “the west of the country will become hotter and drier, the east will become hotter and possibly wetter, but this will not spare it from the impact of increasing drought stress” (Joubert, 2008, 81). The rise in temperatures will lead to lengthier periods between precipitations, an increase in the incidence of droughts, and stronger drought events, which will inevitably result in drought stress (DWAF, 2004; Joubert, 2006; Joubert, 2008). “Desertification, which is already a problem in South Africa, could be exacerbated by climate change” (DEAT, 2004, 15).

The possible impacts which drought will have on water supply in Johannesburg will be that the frequency of droughts might rise due to a rise in temperatures. Surface water is important in many urban areas, and because of increased incidences of drought, such water levels will most likely decrease. Johannesburg, which is not situated on a watercourse, relies on water from other sources. Therefore, the quantity of water supplied to the city from the Vaal River might be affected by water shortages due to more frequent droughts. As disclosed earlier in the report, South Africa and Johannesburg may experience water shortages within the next sixteen years (until 2025).

6.1.3 FLOODS

To summarise, the international consequences of climate change and global warming will result in greater unpredictability when it comes to weather events, as well as increased flooding. In Africa, due to the predicted higher temperatures,

the variability of rainfall will increase. Therefore, for South Africa there is the prediction that rainfall variability will occur, with possible increases in flooding.

In South Africa, as stated under the temperature and precipitation section, periods of drought will be followed by periods of rainfall, and during certain times of the year rainfall will increase. The eastern side of South Africa may receive more rain. Water is a very important commodity: a warmer atmosphere and higher water vapour levels will result in heavier rainfall. Therefore, due to increased precipitation, South Africa will be especially susceptible to a reduced quantity of water infiltrating the soil, added runoff and increased flooding (Joubert, 2008). Incidences of flooding, which are attributable to rising temperatures, will not only bring more flooding, but will also bring stronger floods (DWAF, 2004; Joubert, 2006; Joubert, 2008). Climate change may influence the location, size and period of the storms, creating flood events (DEAT, 2004).

Johannesburg may experience more inconsistent rainfall, as well as heavier and more frequent flooding. Flooding will affect Johannesburg in that due to increased rainfall, the water supply in the Vaal River may increase, but this will only occur if adequate storage facilities exist. Floods may bring about other related problems, for instance causing damage to settlements and infrastructure. In Johannesburg, owing to the intensification of migration and urbanisation, there is a lack of green spaces, but a prevalence of informal settlements, thus exacerbating the risk of damage, because man-made surfaces influence the speed and directionality of floods. Flooding may affect and damage settlements, and consequently water supply to these areas may be contaminated with sewerage, for example.

6.1.4 THE SUPPLY OF WATER

Water supply worldwide in semi-arid, subtropical and mid-latitude regions, due to decreased rainfall and increased periods of drought, may be affected in that there will be less available water, an increased demand for water, and greater water stress. Furthermore, globally the increase in temperature may bring more frequent periods of droughts and floods, and rainfall will become more

inconsistent. Southern Africa is also expected to experience greater water stress and increased demand for lower reserves of water. South Africa may experience water shortages, as one of a variety of impacts which climate change will have on the region.

Water is the one of the most vulnerable resources in South Africa, because the country's rainfall is so unpredictable, and because its climate is so arid. "Runoff was found to be highly sensitive to changes in precipitation" (DWAF, 2004, 51). As revealed previously, precipitation will decrease, and therefore the runoff may potentially decrease by up to 10% in certain areas – the western parts of South Africa are expected to begin experiencing such decreases by the year 2015. The reduction in runoff will advance from the west coast of the country to the east; potentially the east coast will experience a decrease in rainfall of up to 10% by the year 2060 (DWAF, 2004; Schulze, 2005b).

Joubert (2006) mentions that as the level of runoff decreases, so the quantity of water flowing into rivers, streams and groundwater will be altered. In addition, on account of a possible 2℃ rise in temperature, certain susceptible areas in southern Africa are likely to experience a 20–30% decrease in water availability (Jarman, 2007). "The balance between water coming into the system and water going out of the system will be shifted towards an overall drying trend, as heat stress and changed rainfall will probably result in greater runoff, evaporation and drying out of soils" (Joubert, 2008, 154).

Other factors associated with water stress or water shortage will have overall economic and social impacts. The cost of water might increase per unit, and the quality of that water might be affected, due to limitations on availability of water (DWAF, 2004). Climate change additionally, may bring about socio-economic impacts because as the price of water may increase, this may result in social impacts due to changes in the economy. Subsequently, the quality of life for individuals will be affected given that more money will have to be spent on water, less water will have to be consumed, water will become a valuable resource that will have to be protected and other aspects of life (e.g. food, shelter and clothing) will have to be restricted in order to have the basic shrinking resource that is water (Birdsall and Giddens, 2001).

Water supply in Johannesburg will be affected by climate change because, as droughts occur more frequently, rainfall will decrease and water availability will be compromised, so the demand for and use of groundwater will increase. The effect which climate change has on water supply, will sooner or later have far-reaching effects, including the following: the potential price of water may increase; water shortages and lower-quality water may result in water-related diseases and problems in the disposal of wastewater; informal settlements will bear the brunt of the impact, with leaking pipes and blockages in sanitation services potentially polluting the surface water (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008).

In summary, the potential impacts of climate change on water supply in Johannesburg have been outlined above, along with other impacts that are attributable to changes in temperature, precipitation, drought and floods. Therefore, the impacts for Johannesburg could include:

1. An increase in the demand for water supply;
2. Greater stress on the future supply of water;
3. A decrease in surface water;
4. Water shortages;
5. A possible water supply increase in the Vaal River due to high rainfall;
6. The contamination of water supply through sewerage;
7. A decrease in runoff;
8. An increase in water tariffs; and
9. Water-related health problems.

6.1.5 OTHER WATER SUPPLY-RELATED IMPACTS

Climate change produces countless primary, secondary and tertiary consequences related to water supply. The factors highlighted above are all primary physical impacts on water supply, which are attributable to climate change. In addition to these presented physical impacts, there are other possible water supply-related impacts, which will not only affect the city of Johannesburg, but also South Africa in general. The impacts may include social, economic,

environmental and political factors. These impacts are going to be the secondary and tertiary consequences of climate change on both society and the environment. This is as a result of change in the supply of water to Johannesburg and South Africa. The section below presents and examines certain basic secondary and tertiary consequences from changes in water supply. However numerous other simultaneous and unrelated consequences do exist but due to time and length constraints, could not be examined in detail. Hence, below are a couple of other human-related secondary and tertiary consequences due to changes in the supply of water:

1. Water supply changes may bring about changes in quantity, quality and size of food. This may in turn lead to malnutrition – which may affect mental and bodily development in children and lead to low efficiency in adults. Hence this might cause undernourishment and increase the vulnerability to disease (Bates et al., 2008; Joubert 2008);

2. Diseases are related to human health (food availability) and hygiene. Inadequate infrastructure leads to poor removal of sanitation and water contamination causes diarrhoea. Therefore this increases morbidity and mortality of people (Spence, 2005; Bates et al., 2008);

3. Ecosystems may perhaps be affected by encroachment of alien species, loss or extinction of biodiversity and loss of fauna and flora (Jarman, 2007; Bates et al., 2008);

4. Agriculture could experience lower production of crops that might cause increases in prices. In farming, loss of land may lead to poor performance of cattle or death, hence this might result in less production of food and milk and also lead to price increases (Bates et al., 2008);

5. Lastly, there may be loss of livelihood and displacement for individuals and depletion of open grasslands (Spence, 2005; Godrej 2006; Joubert, 2006; McCaffrey, 2006; Joubert, 2008).

The impacts stated below of social, economic, environmental and political factors relating to a change in the supply of water, will examine both possibilities of increases and decreases in the supply of water. This is based on the reality that in South Africa and in Johannesburg, the unpredictability of climate change and

seasonality may bring about increases or decreases of water supply and demand. The increase in water supply may be due to heavier precipitation and consequently flooding and therefore greater quantity of water available. The decrease in the supply of water may be as a result of higher temperatures, higher evaporation rates and droughts and hence less water being available.

SOCIAL IMPACTS

The social impacts from increases in temperature and drought might bring about an increase in the demand for water and less water supply due to higher evaporation levels. Hence related to this aspect is the point that due to higher water demand and less water supply, this will give rise to stricter management of water. Consequently municipalities will have to impose laws, raise prices and severe penalties in reference to water use, and hence citizens will have to limit and control their use of water. The social impacts, which refer to negative factors such as increased water tariffs, and a lack of and higher demand for water, could result in residents and communities experiencing difficulty in accessing water, not being able to afford water and hence the potential risk of conflict over the commodity. In addition, a lack of water may lead to more migrants coming to Johannesburg from rural areas in search of water, which will lead to further stresses on water.

A further negative impact from a lack of water and heat waves due to higher temperatures, could lead to dehydration of individuals and a possible increase in deaths. Additionally, higher temperatures could result in the spread of diseases. This may arise as a consequence of the fact that in higher temperatures, many insects that may include malaria-carrying mosquitos in South Africa, flourish and spread in warmer environments (Houghton, 2004).

The rise in precipitation and flooding and consequently more water supply may produce physical damage to housing and buildings. This successively will result in increased costs of fixing damages, and in addition, paying for and replacing damaged furniture, appliances and cars. In certain areas, possible relocation of settlements may be required because of the danger in location; hence the owner will have to buy a new house. These aspects may cause additional financial

stresses for flood victims. Flooding may also cause overflowing of the sewer water that will produce health risks and diseases, and therefore the negative impact of water contamination and water scarcity may result in more people becoming ill, and in the worst-case scenario, a rise in the death toll. In addition, the increased availability of water may result in an influx of illegal aliens and immigrants from African countries' who are experiencing water shortages, this too will cause additional stresses on water.

ECONOMIC IMPACTS

The availability of increased water supplies may have an economic impact, in the form of increased tourism due to better environmental care. This will encourage the influx of finance into Johannesburg in particular, and the rest of South Africa in general. Increased water supply can also bring about higher costs for government and individual municipalities, having to spend more funding on flood protection, prevention measures, response and water management. Lastly, the increased availability of water can highlight other uses of this precious commodity, such as hydropower, resulting in more opportunities for the country.

The negative impact of a decrease in water supplies is that it may give rise to an economic crisis, because less water will be available to all sectors (domestic, agricultural, industrial, recreational and environmental). This will curb production in especially the industrial and agricultural sectors. Many sectors will be subject to prioritisation, which means certain sectors may suffer, as socio-economic development may take priority over environmental protection and the provision of water to water-stricken communities. Related to this impact is the possible introduction of penalties for the overuse of water in the various sectors that will inevitably cause social impacts.

In addition more of the country's municipal budgets will be spent on water management and water supply. This will cause shortage and reductions in funding in other sectors of the economy, as water supply will take priority over other aspects that may include providing housing, education, infrastructure upgrade or other sectors. More money will have to be spent on adapting and managing the problem and consequences of climate change. Another impact

flowing from water shortages (from rivers) caused by drought and temperature rise, may be the introduction of other water supply sources, for example, desalination plants to desalinate seawater (however this is not directly relevant to Johannesburg, but predominantly to coastal areas in South Africa).

ENVIRONMENTAL IMPACTS

Environmentally, a change in the country's water supply may impact negatively on biodiversity, ecosystems and animals, and may simultaneously lead to the spread and development of desertification in South Africa, and even in Johannesburg. Water shortages may result in environmental degradation by changing the shapes of rivers, and leading to water shortages for those animals which use river water as their primary water source. The environment will become secondary to human needs, as water will be needed for industrial, domestic and agricultural use. Related to this aspect is the point mentioned in the economic impacts section, namely the fact that the economy uses, is affected by and depends on the environment (for example the use of water in agricultural purposes). The economy draws on environmental resources for production. Therefore, if the environment becomes degraded, the economy will also suffer due to losses in production. Hence these sectors are all inter-related, in that they are reliant on one another. Consequently, a loss in production can cause a loss in finance and a decrease and instability of the economy. A decrease in production may also bring about less food production and therefore, food shortages and cause a crisis in the food market.

The positive side to an increase in water supply as a consequence of more rain and floods, is that it may lead to (as presented earlier) a greater focus on the environment, due to more water being used for the environment and not only for human use. This may result in improved protection and conservation efforts, which may, in turn, boost tourism and consequently bring about more money to the country. However, having access to a greater supply of water may give rise to bigger rivers with greater carrying capacity, thereby creating new river meanders that may lead to loss of fauna and flora in floodplains. In addition, more precipitation and flooding could cause overflow of rivers and seepage of the ground; this will instigate erosion of topsoil, washing away of nutrients and

damage to food sources. Hence, this will cause repercussions for animals and people relying on these food sources.

POLITICAL IMPACTS

The negative political impacts are related to possible water shortages (from higher temperatures and drought) – something that will lead to disarray in South Africa, with water becoming a scarce and very expensive commodity. The government will be forced to heighten its involvement, and will need to prioritise aspects like water supply and climate change, over other planned goals that might include providing housing and employment. Climate change impacts may bring about changes in government's goals and agendas. Another impact of water shortages could be that South Africa may require help from other countries' to access water. This will create additional stress seeing that the country's growth and development will be guided by the amount of imported water, and on its relations with other countries'. On the other hand, increased water supplies may lead to positive impacts as our ability to export water could result in improved relations with our neighbouring countries'.

Consequently related to the above aspect of acquiring assistance from other countries', is the problem of 'water wars'. This notion may arise in the future as a result of the increasing problem with water shortages across the globe. Countries' that possess water will have power and control over the limited resource; hence countries' with a lack of water will have to conform to these countries' regulations. In the worst case, conflicts and fighting may arise over the limited resource. South Africa may be one of those countries' with a water shortage in the future, and subsequently this may lead to a need in acquiring water from other water prosperous countries'. This inevitably will lead to more changes and influences on social and economic impacts, as water will be more expensive for the average person and more of South Africa's finance will be spent on water.

6.2 CLIMATE CHANGE IMPACTS ON PLANNING IN JOHANNESBURG

Increased rainfall and flooding due to climate change can have the worst possible outcomes on planning, which might bring about the most visible changes as far as cities are concerned. The overall impacts influencing planning in Johannesburg may include a strain on Johannesburg's service delivery and, in particular, on its infrastructure. When rainfall and flooding occur, the increased water levels will lead to Stormwater drainage overflow, which will seriously damage infrastructure, such as roads, and this will result in the spread of pollution, while erosion due to flooding may also make some terrains unstable.

A rise in rainfall and flooding may also cause damage to housing, not only residential buildings but also offices, industrial warehouses, and formal and informal settlements in Johannesburg. All of these structures will suffer physical damages to their foundations and walls, windows and electric cables; sewerage blockages may lead to pipes overflowing, which will bring additional repair costs for the owners. The effect of all of these factors on planning will be that the location, altitude, use and size of any new development, settlement or service will have to be considered and planned with the possible effects of climate change in mind.

In addition to the abovementioned impacts, the reality is that due to factors like urbanisation, population growth, changes in land use and the development of settlements in areas at risk of flooding (or in floodplains) will add to the effect of climate change and worsen the potential damages. These urban development and expansion factors will amplify the risk associated with vast man-made surfaces, because of an increase in the number of settlements, roads and developments. In turn, these surfaces will guide and speed up flooding waters, since they act as man-made channels for flooding water. In addition, due to the increased number of people and developments in a city, there will be fewer open or green spaces available to absorb rainfall and excess water. Consequently, in Johannesburg all of these factors will increase the damage to buildings, roads

and houses, there will be a rise in the number of casualties related to floods, and an increase in the number of low-lying settlements which are at risk of flooding. Therefore, planning will have to integrate these additional features and their possible consequences into any future planning.

In Johannesburg, planning will be impacted by climate change in a number of ways. The planning-related impacts projected for the city are that, due to the increasing impacts of climate change and the required focus on the issue, more money will be spent on preventing and adapting to climate change, which will lower people's standard of living, while the cost of living will sky-rocket (City of Johannesburg, 2008c; Golder Associates Africa, 2008). Planning might be forced to adjust its contemporary thinking and priorities from planning for future basic services, settlements and any type of human development, to having to adjust, improve and inspect existing developments. In addition, due to climate change-induced water stress, the number of new developments may be reduced due to an increase in water tariffs, and the limited availability of this commodity.

Due to migration into Johannesburg, the increase in population numbers will bring about an increase in water consumption and air pollution, the number of informal settlements will rise, there will be an increased demand for sanitation and water – all of which may place additional stresses on infrastructure and could lead to health problems (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008). The future of planning will have to incorporate various related aspects in future developments, such as raised pollution levels due to traffic congestion, construction, factories and industries, water use and sewage from informal and formal settlements, and any other kind of human development.

Informal settlements in Johannesburg will be more susceptible to climate change and may become breeding grounds for diseases (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008). As revealed earlier in this chapter, due to urbanisation and migration, the number of people in Johannesburg will increase, meaning informal settlements will mushroom. The impacts these settlements will have on planning include the need to provide

proper housing, with services, in appropriate locations, which are free from the danger of flooding.

The environment is one aspect of planning that has in the past due to a lack of information on the environment and global warming taken a back seat to new development. However, in recent years (in Johannesburg and worldwide) the focus on the environment and the possible future implications of any human developments have started to become priority issues. In addition, global warming and climate change have led to greater public awareness of the importance of any new and existing developments in cities, and their effect on our surroundings. Climate change will change our environment, as human expansion, urbanisation and migration to the city continue to take place. Therefore, any local planning must incorporate environmental aspects, but the aspects that should receive priority include the number of open or green spaces, the planting of trees and, where necessary, the protection of plant and animal species.

Schulze (2005b, 14) identifies an important point, namely that "in water resources one needs to evaluate both: impacts of water availability on land use . . . and impacts of land use on water availability". This statement reiterates the aforementioned point, namely that planning should not only focus on the physical location and size of any existing or future developments, but should also integrate other related aspects, such as costs, health implications, social aspects, economic and political aspects and the impact on the environment.

All the presented sections in this chapter will have an affect on planning, as they will all be affected by climate change, and will therefore alter the composition of the city. Therefore planning in the face of climate change will affect the city of Johannesburg by having an influence on services, the location and spread of any existing or new developments, the priorities and goals of planning and on the population numbers in the city. Planners will be needed not only to predict the possible future impacts, but also to plan for those impacts becoming a reality.

6.3 PLANNING IN THE FACE OF CLIMATE CHANGE

While climate change is an existing issue, it is also essential to be aware of possible future consequences, and of our contributions to climate change, since climate change and global warming have the ability to alter and intensify existing weather patterns. Climate change influences the quantity and availability of a region's water supply, which is what makes planning such a significant aspect. Planning considers the quantity of water that will be required for any development, it shapes the development and growth of a city, and makes provision for the storage of surplus water.

Climate change will not only add to a country's existing problems, but will also create additional problems. Therefore, in order to limit and prevent possible environmental risks, planners need to be familiar with and comprehend the consequences of climate change as it impacts on water supply, infrastructure and human settlements. Planning formulates ideas and anticipates the future by providing workable scenarios to counteract the impact of climate change.

Changes and the subsequent future consequences for people, animals and the environment will occur as a result of climate change, and for that reason planners need to be able to design and plan future developments and cities accordingly. Planning has to be used to try to predict, prepare and limit the future consequences of climate change; to plan and design future settlements; to envisage current and future developments by taking into account possible altered climatic conditions; to mitigate and adapt to climate change; to adapt to the existing limitations of countries'; to prepare for possible increases in urban populations and to ensure the availability of adequate supplies of water. Therefore, planning for climate change and making allowances for climate change in planning are not only necessary, but also vital.

To conclude, the location and topography of Johannesburg and the aridity, variability of rainfall and weather events, along with the rise in temperature will

influence water supply in the city. A rise in temperature, lower precipitation, and increased drought and floods across South Africa and Johannesburg will shape the supply of water to the city. The features of water supply that may be affected by climate change include the demand, stress on and supply of water, the quantity and quality of surface water, water shortages, run-off, higher water tariffs and water-related health problems. The other water supply-related impacts on Johannesburg and the rest of South Africa will relate to secondary and tertiary social, economic, environmental and political factors, which may have positive as well as negative spin-offs. Overall, humans and animals will have to adjust to the changes from climate change, as the changes may be an increase or decease in water supply.

In Johannesburg, planning as a consequence of climate change will be altered and subjected to a number of influencing factors. The overall aspects of planning that might be influenced include damage to existing informal settlements, developments, formal settlements, infrastructure and services. Furthermore, any future developments, informal settlements and changes in land use will place additional stresses on water supply services and heighten the risk of damage to any development. The other impacts that might affect Johannesburg include increased water use and air pollution, finance being spent on prevention and adapting to climate change, health-related problems in informal settlements and the effect on the environment. Hence the above impacts of climate change will emphasise the need to consider and include aspects of climate change and their possible effect in any type of urban planning.

Climate change and global warming have a variety of impacts on humans, animals and the environment. Climate change shapes water supply, in addition to worsening existing problems in countries' and altering weather events. Planning shapes the future design of cities and relies on scenarios to limit future risks, while planning for adequate and effective water supply to cities. Climate change factors will need to be incorporated into any planning, so as to limit the future impacts on people, animals and the environment. To limit the effect of climate change, all possible consequences have to be considered and provided for in future plans.