4 EXISTING CLIMATE CHANGES AND POTENTIAL CLIMATE CHANGE IMPACTS

"If we continue as we are, we might push the system into overdrive, bringing on irreversible and catastrophic climate change"
(Joubert, 2008, 147).

Climate change has a variety of impacts, because it is a consequence of global warming and the concomitant increase in global temperature. The impacts of climate change are experienced across the planet: the sea, water levels, the land, people and animals are all affected. The impacts will vary from country to country, depending on their environment and location. This chapter provides a general overview of worldwide existing and potential water supply problems, which can be attributed to climate change. Chapter four offers a summary of the climate change that has already occurred, and this may accordingly be used in predicting its effect on the city of Johannesburg. Firstly, existing international and African climate change impacts on water supply are presented. Secondly, the potential climate change impacts on water supply internationally and on Africa are put forward. Lastly, the concluding points of this chapter are revealed. This chapter also provides justification for using the selected research and information on water supply. The reason underlying this chapter is to put together a framework of the essential, universally experienced climate change impacts on water supply.

4.1 EXISTING CLIMATE CHANGES

Climate change has led to numerous unusual changes in weather and climate worldwide – such changes include irregular rain and snowfall; global temperatures; ocean acidification; rising sea levels; a worldwide rise in ocean temperatures; changes in the extent of the Arctic sea ice, and intense climatic events (Spence, 2005; Alcamo et al., 2009). In the past 50 years there has been

a decrease in the ability of carbon sinks to eliminate human-induced carbon dioxide emissions (Alcamo et al., 2009).

The single occurrence of natural disasters, for example floods, droughts, heat waves and extreme storms (that occur in Africa and around the world), cannot be classified as climate change. However, the fact that these disasters are occurring more frequently, and on a global scale, is a good warning that change in usual climate trends is brewing (Joubert, 2008). Therefore this reiterates the reality that climate change is occurring worldwide and in South Africa.

Since climate change adds to existing problems in a country, it is important to note that existing stresses and vulnerabilities, such as poor infrastructure, poverty and excessive population density are the facts that climate change will "play out against", as Depledge and Yamin (2004, 21) suggest.

Johansen (2006), Parks and Roberts (2007) and Alcamo et al. (2009) stress that Latin America, Africa and Asia (mainly developing countries') are subjected to more severe and experience many additional floods, droughts and storms than developed countries'. These continents also boast fast-expanding populations and have lost more livelihood and encountered higher fatality rates. Furthermore Fields (2005, 106) adds, "Africa can easily be said to contribute the least of any continent to global warming". The continent of Africa is made up of developing countries' that have fewer numbers of human produced emissions from industries, factories and other aspects.

4.1.1 INTERNATIONAL EXPERIENCES

PRECIPITATION AND TEMPERATURE

> "The two most important factors determining the climate of an area are temperature and precipitation" (Miller, 1996, 129).

The observed outcomes of climate change include: changes in precipitation patterns; an increase in evapotranspiration (surface water evaporation, together

with the evaporation of water vapour from leaves); an increase in the inconsistency of interannual precipitation; more powerful and more frequent severe events; and an accelerated water cycle (Bates et al., 2008).

Spence (2005) points to the fact that over the past century the average temperature has risen by about 0.6℃ – a trend that became particularly noticeable in the 1970s. “The temperature increase is widespread over the globe and is greater at higher northern latitudes” (IPCC, 2007, 30).

As indicated in Chapters two and three, Joubert (2008) declares that the strength and rate of repetition of normal weather patterns or behaviour have grown, due to rising temperatures. Furthermore “we’ve seen fewer cold snaps (days and nights) and frost events, but more hot spells and heat waves, with an increasing tendency towards temperature extremes” (Joubert, 2008, 150).

Globally, an escalation in the occurrence of severe precipitation in the late twentieth century has predominantly been attributed to human interventions (Bates et al., 2008). Since the 1980s, the level of water vapour in the atmosphere has escalated due to an increase in atmospheric temperature. Heightened evaporation occurs due to those warmer temperatures, and consequently more water vapour signifies more precipitation (Joubert, 2008). Therefore, an increase in precipitation has been the result of a rise in atmospheric water vapour and global warming (Godrej, 2006; Bates et al., 2008).

In the Mediterranean, parts of southern Asia, the Sahel and southern Africa precipitation has declined, causing these areas to become increasingly dry. By contrast, extensively increased precipitation has occurred in the eastern parts of North and South America, Northern Europe, and central and northern Asia (IPCC, 2007; Joubert, 2008).

FLOODS

“The observed increase in precipitation intensity and other observed climate changes . . . indicate that climate might already have had an impact on floods” (Kundzewicz et al., 2007, 177). Throughout the twentieth century there has been

an increase in the occurrence of severe flooding, and this trend will probably keep repeating itself (Johansen, 2006). In the course of ten years, between 1996 and 2005, the number of inland flood disasters was double that of the period between 1950 and 1980. On average, 140 million people annually are hampered by the natural disaster of flooding, since globally it has been the most reported natural disaster (Bates et al., 2008).

From a planning perspective, the increased damage due to natural disasters (e.g. floods) linked to climate change can be attributed to changes in land use, population explosion, economic development and the infiltration of human settlements into flood plains (Bates et al., 2008). All these factors are somehow either controlled by planning or will affect planning. Therefore, as these factors increase or change, they will contribute to the effect of climate change and therefore planning will, in some way, influence or be influenced by climate change.

DROUGHTS

For the most part, droughts can be attributed to global warming due to human-induced carbon emissions (Bates et al., 2008). Since the 1970s, droughts – particularly in the sub-tropics and tropics – have become more frequent and have occurred in more areas globally (IPCC, 2007; Bates et al., 2008; Joubert, 2008). Globally, "droughts were also estimated to be slightly more frequent and of much longer duration by the second half of the 21st century relative to the present day" (Boko et al., 2007, 444).

Contributing to the escalation of areas experiencing drought, are an increase in temperatures and a decrease in land precipitation. These features reduce soil moisture and intensify evapotranspiration, thus resulting in droughts. Globally, areas that have experienced more frequent droughts include Eurasia, Canada and Alaska, Europe, Australia and northern Africa (Bates et al., 2008; Joubert, 2008).

WATER AVAILABILITY

Bates et al. (2008, 38) declare that "the most dominant climate drivers for water availability are precipitation, temperature and evaporative demand". Globally "there is evidence of a broadly coherent pattern of change in annual runoff" (Bates et al., 2008, 35). In higher latitudes, areas in Finland, China and the USA have encountered an increase in annual runoff. By contrast, a decrease in annual runoff has occurred in southern Europe, parts of West Africa and southern Latin America (Bates et al., 2008).

In lakes and rivers the temperature of the surface water in North America, Europe and Asia has warmed by 0.2–2.0℃ since the 1960s. In east African lakes, in addition to the surface water warming, the deep-water temperatures have warmed by 0.2–0.7℃ since the 1900s (Bates et al., 2008).

"Groundwater flow in shallow aquifers is part of the hydrological cycle and is affected by climate variability and change through recharge processes, as well as by human interventions in many locations" (Bates et al., 2008, 36). In south-western Australia, due to a decrease in surface water recharge supplies on account of climate change and due to an increase in the demand for water, groundwater withdrawals have increased (Bates et al., 2008).

Globally, impacts on water systems from climate change are visible in many countries'. In addition, water supply strains around the world have intensified – this can be attributed to changes, brought about by climate change, in respect of water availability, changes in rainfall patterns and by the migration of people into cities from water-stressed neighbouring areas (Alcamo et al., 2009).

In reference to Chapter three, the above-mentioned factors will affect the quantity of water available for consumption, be it for human, agricultural or other needs. However, as has been established, these factors ought to be considered in conjunction with the existing storage infrastructure and means of preserving water.

PLANNING

Internationally, planning (to a certain degree) has been controlled by climate change, seeing as the location and size of settlements are influenced by this phenomenon. The IPCC (2007, 48) states that settlements in river flood plains and those in coastal plains are most susceptible to climate change, and are "in areas prone to extreme weather events, especially where rapid urbanisation is occurring". As revealed earlier, disadvantaged communities are more susceptible to such changes, and to make matters worse, they do not have the ability to adjust to climate change (IPCC, 2007; Alcamo et al., 2009).

It is primarily the disadvantaged and developing countries' that suffer most from climate change. For starters, these countries' already have limited infrastructure, response measures and finance than rich, developed countries'. In addition, developing countries' are home to more informal settlements located on the outskirts of cities and in derelict and unsafe urban areas. Hence, the number of people suffering or at risk is increased, due to the impacts of floods and forced migration (caused by climate change). Developing countries' also experience more severe weather events, which merely add to their existing problems. Therefore, while more people suffer the effects of climate change in developing countries', these countries' do not have the necessary response measures, the ability, money or the experience needed to adapt and change rapidly.

4.1.2 AFRICAN EXPERIENCES

PRECIPITATION AND TEMPERATURE

"The continent of Africa is warmer than it was 100 years ago" (Doherty et al., 2005, 30). Since the 1960s, temperatures in Africa have generally become warmer, but inconsistencies and varying patterns emerge when one investigates these transformations. In western and southern Africa, between 1961 and 2000, the number of particularly cold days decreased, while the number of warm days increased (Boko et al., 2007). Inconsistency in the west of Africa is a result of a change in the temperature patterns of the tropical sea surfaces and changes in atmospheric circulation (Bates et al., 2008).

"In South Africa and Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures" (Boko et al., 2007, 436), while in eastern Africa, area temperatures near internal lakes or the coast have decreased (Boko et al., 2007).

In Africa there are immense inconsistencies in the inter-annual rainfall (Doherty et al., 2005; Boko et al., 2007). Furthermore, unpredictability in multi-decadal rainfall is characteristic of western Africa's Sahel region (Doherty et al., 2005; Boko et al., 2007; Bates et al., 2008). In the 1950s and 1960s the West of the continent experienced a wet phase, but from the 1970s until the 1990s it suffered an extremely dry phase. Since the end of the 1960s, the annual rainfall has been decreasing. Between 1968 and 1990 a decrease of 20–40% in annual rainfall was noted, compared to the period 1931 to 1960. The deficit in rainfall, mainly during the dry spells, was associated with a decrease in the normal rainfall during the monsoon seasons (Boko et al., 2007; Bates et al., 2008).

"In the tropical rain-forest zone, declines in mean annual precipitation of around 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960 to 1998 have been noted" (Boko et al., 2007, 436). Since the 1970s southern Africa's inter-annual inconsistency has increased, resulting in more extensive and severe droughts and higher precipitation irregularity. In Malawi, Namibia, Angola, Mozambique and Zambia, changes in seasonality, a rise in intense rainfall and extremes in weather have been recorded (Boko et al., 2007).

FLOODS

In the past two decades, southern Africa has been subjected to severe flooding, which has resulted in extensive and extremely costly damage to livestock and produce as well as physical infrastructure. It has also caused fatalities and water-borne diseases, as well as a number of health risks (Hirji et al., 2002).

DROUGHTS

Over the past couple of years, droughts have hit Africa harder than other parts of the world. Countries' that have suffered as a result are: South Africa, Botswana,

the Sudan, Mozambique, Ethiopia, Zimbabwe and Eritrea (Spence, 2005). “The recurrent droughts experienced in southern Africa highlight the sensitivity of the region’s water resources to climate variability” (Hirji et al., 2002, 40).

Since the end of the 1960s, droughts have primarily occurred in southern Africa, in the Sahel and the Horn of Africa (Boko et al., 2007; Bates et al., 2008). The droughts or drying trends prevalent in the southern hemisphere from 1974 to 1998 can be attributed to global warming and the decease in land precipitation. Sadly, such droughts result in a lack of food security and the spread of famine (Bates et al., 2008).

As shown in the precipitation and temperature section, the inconsistency and decrease in monsoon rainfall in the Sahel region ultimately resulted in a drought: “The decreasing rainfall and devastating droughts in the Sahel region during the last three decades of the 20th century are among the largest climate changes anywhere” (Bates et al., 2008, 80).

WATER AVAILABILITY

Rivers, rainfall and lakes are very important suppliers of water; the quantity of water that they supply is directly linked to unsustainable water use, and on the irregular physical distribution and accessibility of water. Climate change places additional stresses on water accessibly and availability (Bates et al., 2008).

Presently, in Africa, “water resources are becoming increasingly scarce” (Spence, 2005, 82) and it is clear that many water sources are already reacting to and being transformed by shifts in rainfall. This may be a sign of the likely future climate change-induced stress that may impact on water sources (Spence, 2005). Countries’ that have been altered by changes in hydrology and runoff include Kenya, Tanzania, South Africa, Ethiopia and other states on the continent (Boko et al., 2007). (See Figure A1 in Appendix A).

“In some parts of Africa access to water has become highly unreliable, with floods and droughts occurring within months of each other” (Jarman, 2007, 36). In the east of Africa, many lakes have recorded unstable annual water levels. On top of

this, as a result of warmer conditions, the temperature of the water in the lakes has increased (Bates et al., 2008).

PLANNING

Earlier in this chapter, it was stated that developing countries' – and Africa in particular – make only a limited contribution to global warming, but are set to bear the brunt of extreme events. Brunner et al. (2005) argue that it is useless for Africa to try to halt climate change, and state the only thing left to do is to take action.

Many countries' in Africa and sub-Saharan Africa are "ill prepared to deal effectively with the adverse impacts of climate change" (Brunner et al., 2005, 176), since Africa has only a limited capacity to adjust to change (Spence, 2005). Also, many Africans live in areas that are susceptible to flooding and drought (Brunner et al., 2005). "Preexisting environmental vulnerabilities often exacerbate already bad situations and lead to higher than usual levels of climate-related risk . . . Preexisting environmental vulnerabilities can therefore transform an extreme weather event into a human disaster" (Parks and Roberts, 2007, 118). Climate change makes weather harder to forecast, in addition to making weather patterns more severe (Depledge and Yamin, 2004; Brunner et al., 2005).

The people of Africa are already exposed to weather events, therefore climate change will only serve to exacerbate their existing problems and worsen the impacts of this phenomenon. If Africa lacks the necessary and proper response measures to cope with climate change, planning is vital: planning formulates and anticipates for the future and consequently provides different possible scenarios. Since climate change is a global phenomenon that seems set to stay, planning needs to work towards limiting the risks and vulnerabilities to humans, animals and nature. Planning can be used to plan cities and towns so as to reduce the effects of severe weather, and to reduce the number of fatalities associated with climate change.

4.2 POTENTIAL CLIMATE CHANGE IMPACTS

> "While the experts know climate change is happening, it is not always easy to predict precisely how fast it will happen, and how bad the problem will become" (Spence, 2005, 18).

> "It is changing, but predicting by how much is tricky" (Joubert, 2008, 152), and therefore "reliable prediction is impossible", according to Lawson (2008, 91).

Provided that emissions continue to be produced, countless changes in climate around the world that include droughts, floods, storms and heat waves are expected to increase, and hence may give rise to unpredictable and permanent climatic changes (Joubert, 2008; Alcamo et al., 2009).

The majority of future predictions tend to be negative, and as research has developed and become increasingly accurate, so the predictions have tended to become gloomier (Godrej, 2006). Spence (2005) stresses that predicting climate change globally is much easier than predicting climate change for a specific country or town, due to a lack of accurate weather records. The IPCC states that predicting future climate change is an extremely risky process. The IPCC further asserts that it does not provide predictions but projections of future climate scenarios, based on the notion: "what if" (Lawson, 2008, 26). This point reiterates the links that were made (see Chapter two) between climate change and planning – both planning and climate change are based on uncertainty, and use the concept of scenarios for forecasting the future.

In the climate change section, it was stated that climate change exacerbates existing problems in a country, and that developing countries' experience more severe weather extremes. On top of this, informal settlements (predominantly in developing countries') experience the impact of climate change more intensely owing to their poor location, lack of services and facilities, and their lack of knowledge of climate change.

4.2.1 POTENTIAL INTERNATIONAL IMPACTS

PRECIPITATION AND TEMPERATURE

Warming per decade of about 0.2℃ is anticipated for the next two decades. Temperatures are expected to keep rising, but the actual figure depends on the level of carbon emissions we humans generate. If the emissions remain constant at year 2000 levels, an additional increase of about 0.1℃ would occur (IPCC, 2007; Joubert, 2008). By the last two decades of this century, the projections for temperature increase range from the smallest increment of 1.1℃ to the greatest of 6.4℃ (Joubert, 2008). As temperatures increase, so evaporation levels from sea and land will also rise (Godrej, 2006). "Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean (near Antarctica) and northern North Atlantic, continuing recent observed trends" (IPCC, 2007, 46).

Spence (2005) draws our attention to the projection that several parts of the world, including South Asia, Australia, North America, southern Africa and the South Pacific will be affected by more powerful storms and lower rainfall. By 2100 there may possibly be a decrease in precipitation in subtropical, mid-latitude and semi-arid regions, hence these areas are projected to become drier and to experience increased stress on their water reserves, while some equatorial regions and places situated at high latitudes might experience an increase in precipitation, and so become wetter (Fields, 2005; Joubert, 2006; Joubert, 2008).

"Precipitation variability is very likely to increase, and more frequent floods and droughts are anticipated" (Bates et al., 2008, 44). But the negative outcome of a rise in precipitation may cause nutrients to rise to the surface water, and heralding a growth in periods of turbidity (Bates et al., 2008).

A decrease in the efficiency of and absorption by carbon sinks (of high carbon dioxide emissions) are very likely to occur, and will subsequently produce additional human-induced carbon dioxide in the atmosphere, with a concomitant increase in changes in global climate (Alcamo et al., 2009). Therefore the failing of carbon sinks, may result in increased global temperatures and unpredictable

precipitation, which may be in addition to the above projected increases in temperature and precipitation.

FLOODS

As a result of global warming, an increase in the discharge of a river may cause increased rainfall-associated events, flooding and, in major river basins, an increase in the risk of rivers flooding (Meehl, 2007). “More frequent heavy rainfall events could threaten regions already prone to flooding” (Depledge and Yamin, 2004, 22). During the 21st century, extreme rainfall events are anticipated to become more common worldwide, which will increase the possibility of urban and flash flooding (Bates et al., 2008). Irregular weather events, including freak floods, are expected to increase and may be longer in duration (Godrej, 2006).

Research has shown that an escalation in heavy precipitation is linked to an escalation in flooding. In Asia, in the monsoon region in summer, and in the high, northern latitude areas in winter, it is projected that due to heavier rainfall increased flooding might occur. In Europe there is also a projection of increased flooding in summer and/or winter, due to increased precipitation (Meehl, 2007).

DROUGHTS

Future projections estimate that globally there will be an increase in the number of areas affected by droughts (Bates et al., 2008). High latitudes will experience a reduced number of summer droughts (Hardy, 2003). In the mid-continental areas, there is a trend for these regions to become dry during summer, which may possibly herald the onset of a period of drought (Hardy, 2003; Depledge and Yamin, 2004; Godrej, 2006; Bates et al., 2008).

Bates et al. (2008) put forward a projection of the global occurrence of droughts, until the year 2090:

1. Severe drought events will increase two-fold;
2. The average length of a drought will increase six-fold; and
3. The percentage of land encountering harsh drought at the same time will increase ten- to thirty-fold.

WATER AVAILABILITY

Hardy (2003) predicts that the combination of evaporation, increased temperature and a decrease in rainfall will cause water shortages. ”Water supplies are expected to decrease as weather patterns become more extreme” (Jarman, 2007, 36). This scenario may be prevalent in the mid-latitude, sub-tropical and semi-arid areas of the world.

Bates et al. (2008) indicate that water availability may be reduced by a decline in the levels of groundwater; a reduction in summer rainfall leading to a decrease in stored reservoir water; seasonal changes in streamflow and unpredictability of interannual rainfall, as well as high temperatures and an increase in evaporation (surface water and water from leaves).

According to Bates et al. (2008), climate change alters the depth of groundwater tables and the resources feeding that groundwater. Changes in surface water flows (e.g. due to precipitation, flood and drought) will impact the levels of groundwater: “Increased precipitation variability may decrease groundwater recharge in humid areas because more frequent heavy precipitation events may result in the infiltration capacity of the soil being exceeded more often” (Bates et al., 2008, 38).

Annual river runoff is projected to escalate in the northern hemisphere (Hardy, 2003). This escalation needs to be taken advantage of by having sufficient capacity and infrastructure to secure and accumulate the surplus water. Future changes in water supply may produce both negative and positive outcomes. The positive outcome of an increase in annual runoff may be just that – an increase in the quantity of water available to consumers. The negative outcomes may be an escalation in flooding and greater destruction in areas with low water tables (Bates et al., 2008). “In addition, an increase in annual runoff may not lead to a beneficial increase in readily available water resources, if that additional runoff is concentrated during the high-flow season“ (Bates et al., 2008, 44).

WATER DEMAND

The demands for water are predicted to modify due to changes in:

1. Wealth;
2. Population;
3. Industrial activity;
4. Settlement patterns; and
5. Technology. (Kundzewicz et al., 2007)

Urbanisation, according to Kundzewicz et al. (2007) may bring about an escalation in the demand for water – a demand that will peak in arid areas. "Climate change will probably alter the desired uses of water (demands) as well as actual uses (demands in each sector that are actually met)" (Kundzewicz et al., 2007, 191). The demand for irrigation water is expected to increase because of greater inconsistency in precipitation levels, and temperature increases (Bates et al., 2008).

WATER STRESS

As indicated by Kundzewicz et al. (2007), until the 2050s the projected percentage of global land area influenced by water stress will be as follows:

1. On 62–76% of global land area, water stress is projected to escalate;
2. On 20–29% of global land area, water stress is expected to decline.

This 2050 projection indicates that the number of individuals living in the floodplains of water-stressed rivers is likely to increase, and climate change would be one of the reasons for this stress (Bates et al., 2008). This estimate shows that on account of climate change, river floodplains will probably become more vulnerable, heightening the risk to settlements and communities located in floodplains.

"The principal cause of decreasing water stress is the greater availability of water due to increased precipitation, while the principal cause of increasing water stress is growing water withdrawals" (Kundzewicz et al., 2007, 194).

PLANNING

"Human settlements have been, and continue to be, linked closely to the availability of freshwater" (Hardy, 2003, 77). Climate change will influence not only the infrastructure that supports nations, but also the design of human settlements (Hardy, 2003). The outcomes of climate change that are assumed to impact future infrastructure and human settlements include the possibility and severity of flooding, and changes in water quality, precipitation patterns and water availability (Bates et al., 2008).

Globally, countless human settlements do not have access to secure and ample water supplies. In view of the fact that water supply quality and the availability of water will be impacted by climate change, this phenomenon will, in all probability, intensify the challenges, which need to be overcome, and increase the focus on water provision. The areas that are expected to experience the greatest disruption will be places with growing populations and reduced runoff, i.e. water stress (Bates et al., 2008).

Hardy (2003), in discussing the design of human settlements, refers in particular to the potential relocation of people and extensive human migrations on account of climate change. Therefore, urbanisation may also speed up thanks to climate change, as the impacts of droughts and floods on the outskirts of a city and in rural areas could be the push factors causing individuals to migrate to the city to seek additional water or protection against climate change. In addition to climate change-induced urbanisation, increased rainfall and flooding may possibly produce landslides and slope instability (Hardy, 2003).

Planners need to know and understand the consequences of climate change in respect of its impacts on water supply, infrastructure and human settlements. Given that climate change will add to our existing problems and will most certainly create additional difficulties, knowing the potential future scenarios will limit those possible impacts and prepare us for a number of likely scenarios. Planning for water supply, planning when designing cities and preparing for the envisaged population growth may at best prevent and at worst limit certain risks.

4.2.2 POTENTIAL IMPACTS ON AFRICA

PRECIPITATION AND TEMPERATURE

The future projections of precipitation and temperature for sub-Saharan Africa are uncertain and differ widely, as some researchers and weather forecasters envision decreases while others project increases (Kulindwa et al., 2006; Bates et al., 2008).

Southern Africa, as a result of climate change, will face consistent warming. Thus, future water availability will decrease and evapotranspiration rates will increase, thanks to a rise in temperatures (Hirji et al., 2002). The entire African continent is projected to become 1.5 times warmer than the rest of the world. Temperatures across the continent are set to escalate between 3 and 4°C by the end of the century, with the arid subtropics (e.g. central southern Africa and the Sahara) warming more than the wet tropical areas (Doherty et al., 2005; Joubert, 2006; Kulindwa et al., 2006; Boko et al., 2007; Joubert, 2008).

In the northern Sahara, North Africa and along the west coast, yearly rainfall is projected to decrease, and in southern Africa winter rainfall will most likely decrease. In east and tropical Africa, the average annual rainfall will presumably rise (Kulindwa et al., 2006; Boko et al., 2007).

In semi-arid and arid sections of Africa (Sahel and Southern Sahara) it is extremely difficult to predict future runoff (Kulindwa et al., 2006; Boko et al., 2007) seeing that runoff can be altered by the smallest change in precipitation (Boko et al., 2007). “However, increased precipitation variability may increase groundwater recharge, because only high-intensity rainfalls are able to infiltrate fast enough before evaporating, and alluvial aquifers are recharged mainly by inundations due to floods” (Bates et al., 2008, 40). (See Figure A2 in Appendix A).

FLOODS

“A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts” (Kundzewicz et al., 2007, 186). Unfortunately “there

has been relatively little work published on future climate change scenarios for Africa" (Doherty et al., 2005, 32).

Rural and urban settlements that are located in floodplains and wetlands on account of their fertile soil and their proximity to fish resources may encounter flooding. Consequently, due to the flooding of rivers, the settlements will suffer physical damage to buildings, structures and infrastructure such as roads (Magadza, 2000). "Human encroachment into flood plains and lack of flood response plans increase the damage potential" (Kundzewicz et al., 2007, 186). "Floods invariably lead to disease, destruction of food reserves, and habitations" (Magadza, 2000, 194).

DROUGHTS

Hardy (2003) states that summer droughts will be more frequent in low latitudes. As argued above, there is also a lack of data on African drought predictions. However, for the 21st century, drought projections indicate that central Africa could experience increased rainfall, while northern Africa may suffer under drier conditions (Boko et al., 2007).

WATER AVAILABILITY

Climate change will have an affect on water assets, the flow of rivers, irrigation and the use of water (Hirji et al., 2002). Boko et al. (2007, 446) offer projections, stating that in southern Africa "almost all countries except South Africa will probably experience a significant reduction in streamflow". Although future projections for Africa, in respect of river-runoff differ considerably, a common forecast includes an increase in eastern Africa and a decrease in northern Africa's river-runoff (Bates et al., 2008).

By 2025, the availability of water in many countries' in southern Africa is assumed to decrease. Several SADC countries' (according to Hirji et al., 2002) will either experience water stress (Lesotho, Mauritius, Tanzania and Zimbabwe), water scarcity (Malawi and South Africa) or water fluctuations during the dry season (Angola, Botswana, DRC, Mozambique, Swaziland and Zambia). By 2055,

western and eastern Africa could see a decline in water stress, whereas southern and northern African areas may well be subjected to increased water stress (Boko et al., 2007). (See Figure A1 in Appendix A).

In Africa, "by 2020, between 75 and 250 million people are projected to be exposed to increased water stress due to climate change" (IPCC, 2007, 50). However, excluding climate change impacts, up to 460 million people, primarily in the west of Africa, are expected to be at risk of water stress (Bates et al., 2008). What's more, there is a possibility of "the proportion of the African population at risk of water stress and scarcity increasing from 47% in 2000 to 65% in 2025" (Bates et al., 2008, 79).

WATER DEMAND

In view of the fact that runoff and rainfall will decrease in the southern hemisphere, the demand for water will also increase (Hardy, 2003). In Africa, factors like climate change, increased desertification and drought, and fast-growing populations may cause "increased competition for the scarce resources and heightened resource scarcity " (Kulindwa et al., 2006, 36).

WATER STRESS

"The impact of climate change on water resources across the continent is not uniform" (Bates et al., 2008, 81). In Africa, by the year 2025, increased water demand is projected to aggravate water stress for numerous population groups. This situation will be worsened by climate change (Bates et al., 2008). Arnell, in Bates et al. (2008), projects the number of people to be faced with water stress as:

1. 2020s: 75–250 million;
2. 2050s: 350–600 million.

The main source of drinking water in Africa is groundwater, but as precipitation and runoff decrease this will reduce the levels of groundwater. Likewise, it will

place additional stresses on water for domestic and agricultural use (Bates et al., 2008).

PLANNING

"Human settlements will be affected by climate change through several processes, among them water resources, sea level changes and changes in frequency of extreme factors such as droughts, hurricanes and extreme temperatures causing heat waves" (Magadza, 2000, 194). In developing countries' in semi-arid areas, fast-growing mainly impoverished settlements of people are particularly susceptible to the reduced availability of water, because they have restricted adaptive capabilities. In addition, this problem will increase the costs associated with acquiring water supplies (Bates et al., 2008).

Hirji et al. (2002) reveal that in order to safeguard the security of its citizens and the economy, water-resources planning in any region needs to allow for climatic inconsistency and incorporate the capability to observe and predict climatic changes. "Management for sustainable water supplies will require new policy approaches that plan ahead to accommodate climate change" (Hardy, 2003, 93). In addition, Hardy (2003, 93) emphasises that future plans and designs need to incorporate "a wider range of climatic conditions than traditionally used". These aspects highlight the requirement that planning for both the present and the future have to take cognisance of climate change.

The above point and the ones stated previously in the section on existing changes and that of potential impacts re-emphasise the facts presented in Chapters two and three, of the link between planning and climate change. Climate change will result in numerous changes, which will have dire consequences for people, animals and the environment. Climate change will affect water supply in the future, as well as the location of human settlements. Planning – and more specifically environmental planning – endeavours to envision the future and, accordingly, through the use of scenarios, tries to minimise the effect of development, while optimally benefiting humans and protecting the environment. Planning relies on existing knowledge to reduce future environmental risks and hazards. In review, climate change will have a

number of future impacts on human settlements and infrastructure. Therefore, planners need to be aware of these impacts and must be able to design and plan future developments and cities accordingly.

Bridgman (1998) illustrates an important point in support of the above, namely that any kind of prediction of future climate will always be based on some degree of uncertainty or assumption. He emphasises that future decision making needs to incorporate climate change for the reason that it is an important factor, and there are enough accurate and dependable scenarios to warrant the issue. In addition, there is the fact that the impact of current human carbon dioxide emissions may possibly be recorded for the next 50–100 years. Therefore he stresses "this makes the inclusion of climatic change impacts in planning processes all the more critical" (Bridgman, 1998, 265).

In short, existing global climate changes include an overall rise in the global temperature. In certain parts of the world, rainfall has increased due to increased evaporation, which has brought about more frequent flooding and resulted in greater runoff. In other areas, precipitation has decreased, which has led to more instances of drought and less runoff (caused by a reduction in rainfall and a rise in temperatures). Globally, the speed of the hydrological cycle has increased, making predicting the weather even more difficult. Furthermore, the increases in the supply of water have to be considered in conjunction with the aspects of storage.

The climate changes, which Africa is currently experiencing, include warmer temperatures, inconsistent rainfall and extreme weather events. In Africa there has been an overall decrease in rainfall, which has resulted in longer dry spells, and has intensified droughts. Hence the availability of water has decreased, and many countries' on the continent are experiencing water scarcity. The rise in temperatures has also made rainfall unpredictable in certain areas in southern Africa, which has resulted in flooding.

Existing climate change planning problems are that settlements worldwide have already been affected by climate change. While many informal settlements in

developing countries' and in floodplains or low-lying areas in particular are already at risk of extreme weather, they have also become more vulnerable to the effects of climate change. Africa's increased vulnerability is already burdened by climatic inconsistencies, and the continent may not be capable of dealing with further problems.

The international potential impacts of climate change are similar to existing climate changes in Africa. Internationally, temperatures are expected to increase, with greater inconsistency in rainfall, and a greater prevalence of droughts and floods. In the mid-latitude, semi-arid and subtropical areas, rainfall is expected to decrease; hence conditions will become drier, with more frequent droughts and greater stress and demand on water resources. Less water will be available. In the equatorial and high-latitude regions, rainfall will increase and the areas will become wetter, have more runoff and may experience stronger, unpredictable flooding. In addition, surplus water from such instances of increased rainfall will only add to the availability of water – if it is stored.

In relation to the potential African impacts, some inconsistencies remain. Also, there is a lack of data on expected future impacts in Africa, but what is certain is that there will be a general rise in temperature. As with the above-mentioned forecast international impacts, in the eastern and tropical areas of Africa, precipitation will increase. In the north, west and south, which are mainly arid areas, there will be a decrease in rainfall. This will lead to the decreased availability of water, an increase in the demand for water, and increased water stress.

The potential planning impacts will be that all the stated aspects of temperature, precipitation, floods, droughts and water availability will affect planning when it comes to the location and size of future settlements. Hence, planning needs to take cognisance of potential climate changes in order to plan effectively.

The information used in this chapter is appropriate for this report, seeing that the aforementioned factors of rainfall, temperature, drought and floods are all relevant to issues of water supply. The predicted water supply and planning impacts are both relevant to this report, since they are the two main areas of

focus. All the stated existing and potential impacts of climate change provide a good general explanation of the various factors related to water supply, and the limitations hampering the supply of water. Planning has been the driving force behind this report, therefore the impacts of planning need to be highlighted and examined.

Chapter four has provided an overall summary of existing changes and the potential impacts of climate change in the world and in Africa, in particular, with a focus on water supply and planning perspectives. This chapter is important because it shows the actual physical changes which climate change can and do bring about, and therefore these impacts are used in the following chapters to ultimately investigate the potential impacts of climate change on water supply in Johannesburg.