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Surviving the Drought: A Comparative Study of Water Security in Israel and Cape Town

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Abstract

Securing water on national and municipal levels is becoming more challenging all around the globe, due mainly to climate change and population growth. In 2018, the City of Cape Town – following its worst drought in a century – nearly became the first city of its size to run out of water. At the same time, Israel – a country with a climate similar to that of Cape Town – was also experiencing severe drought. In contrast, Israel showed the exact opposite trend, achieving water security despite these adverse conditions. This paper therefore aims to understand why the water security outcomes for these two regions were so different, given the similar circumstances. The method used for conducting the research is a comparative analysis, examining the threats to water security that both regions face, and how water security is approached. Findings showed that there are several reasons for the differing outcomes. Cape Town faced several challenges that Israel did not, such as the Apartheid and severe poverty; however, it seems that the challenges Israel did face -- such as large immigration waves and settling the desert made Israel's water sector more resilient overall. This was thanks to the development of management practices such as supply augmentation via large-scale seawater desalination, utilizing treated wastewater, developing efficient agriculture technologies. Cape Town's water management practices are far less comprehensive and developed. Additional findings show that Israel has prepared for climate change better than CoCT, a practice that may have influenced preparedness for surviving the drought.

Keywords: Water security, Water scarcity, Water stress, Climate Change, Israel, Cape Town, Water policy, Water management, Comparative water studies, Drought.

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1.Introduction

1.1 Background

Water security is an increasingly important topic in a world where climate change and population growth are significantly impacting freshwater resources (Falkenmark and Lundqvist 1998; Parks *et al.* 2019). In the last decades, securing water on national and municipal levels has become a burdensome task for countless regions. As we approach the year 2020, "with coming decades projected to be even hotter and most likely drier" (Enqvist and Ziervogel 2019), with the world's population growing fast, the challenge is increasing. In 2019, Byker *et al.* stated that, "whether acknowledged by world leaders or not, the next decade may be known for when the major cities of the world ran out of water." In just the previous year, 2018, the City of Cape Town (CoCT), South Africa's famous coastal city and capital of the Western Cape province, nearly became the first big city to align with that prediction (Enqvist and Ziervogel 2019). This was the first global case for a city of its size (The Nature Conservancy 2018). After experiencing its worst drought in a century from 2015-2018, CoCT was facing the fear of its taps running dry in a just a matter of months (Enqvist and Ziervogel 2019). The city went into a state of emergency, exercising extreme efforts to conserve the remaining water to last as long as possible (Parks *et al.* 2019). Water consumption was restricted to 50L per day per person, garden watering was banned, and several other restrictions were put into place as the city neared 'day zero', which was the day all the taps in the municipal region of CoCT would be shut off (Enqvist and Ziervogel 2019). Cape Town's water emergency received a great deal of attention from all around the globe. What was the city going to do as its dams were drying up? The crisis was eventually averted thanks to the coming of the winter rains, and the city's ability to reduce consumption enough until they arrived (Enqvist and Ziervogel 2019).

In the same year, 2018, Israel, a small Middle Eastern country, was facing its fifth year of consecutive drought, which was also the worst one it had seen in the last century. The level of the Sea of Galilee, the country's only freshwater lake, was declining rapidly, nearing a historical low. Springs were going dry and the Sea of Galilee was approaching its lowest level ever on record, almost reaching the black line. This was despite the fact that no water was pumped from the lake in recent years. The mountain and coastal aquifers were also reaching extremely low levels, with the former lacking 18 MCM and the latter coming extremely near its red line. They were both down ~50 MCM compared to the previous year (Avgar 2018).

Yet water in the taps continued to flow, and the country was facing no apparent threat to its water security. In fact, it was quite the opposite. In 2017, in the midst of the drought, a report by the World Bank Group stated that, despite its extreme conditions of water scarcity, Israel has shown to achieve water security (Marin *et al.* 2017). International attention was pointed at Israel's water sector for the opposite reasons as CoCT. News titles discussing Israel's water success appeared such as 'How Israel Became a Water Superpower' (The Times of Israel 2015), 'Israel, the Water Superpower' (Triple Pundit 2016), 'How Israel Became a Water Surplus Nation' (The JC 2016) and there was even a book published titled 'Let there be water: Israel's solution for a water starved world' (Siegel 2015).

Israel and Cape Town have several similarities. Firstly, both regions lay in areas of Mediterranean climate. Although Israel also has a large area of desert climate, most of the population is settled in the Mediterranean area (and although CoCT is not on the Mediterranean, is it considered to have a Mediterranean-like climate). Second, both regions have a history of water scarcity; on a national level Both Israel and South Africa are considered 'physically water scarce' regions by the IWMI. Thirdly, both regions have had their fair share of political issues, facing much criticism from the world, as noted by Mctague (1985) in a comparison of their political history. And lastly, as mentioned, between 2015-2018, both regions were experiencing their worst drought in a century.

1.2 Project Aims and Objectives

Noting the similarities of these two regions, the question arises why following the drought in each region, water security conditions were so different. This thesis therefore aspires to explore these two cases, compare them, and achieve the following aims and objectives:

- To gain insight on the reasoning for the contrasting water security conditions in Israel and Cape Town.
- To contribute general understanding of which water policies and management strategies help to achieve water security in water stressed areas.
- To draw lessons (the ones applicable) from Israel's water policy and management strategies for the future of Cape Town's water security.

1.3 Research Questions

The research questions are the following:

- What accounts for the contrasting outcomes in water security in Cape Town and Israel in 2018, considering both regions were experiencing their worst drought in a century?
- What can Cape Town learn from Israel about effective water policy and management?
- What general water policy and management lessons can be applied to other water stressed areas?

1.4 Review of Thesis

The thesis will begin with a review of literature on water security in chapter two. This chapter discusses why water security is so important and what the current global state of water security looks like. It additionally discusses the main threats to water security and how they can be tackled, creating the structural base for the case studies. Chapter three explains the thesis methodology, discussing the research design, framework, what data was used and how it was analyzed. Chapter four and five present the results of the case studies; chapter four discusses water security in Israel, and chapter five discusses water security in CoCT. Each case study provides a comprehensive picture of the threats to water security and how water is managed in each region. Chapter six is the comparative analysis of the cases; this chapter compares and contrasts findings of chapters four and five, while simultaneously attempting to answer the research questions. Finally, chapter seven concludes the thesis.

2. Literature Review

2.1 Introduction to Water Security

2.1.1 Water Security Definitions

Water security as a concept is “complex, contested and dynamic” (Allan *et al.* 2013). The complexity of water security derives from its interdisciplinary nature (Bakker 2012) and its multidimensional influence at “local, national, regional, and global scales.” (Moumen *et al.* 2019). These dimensions include “hydrologic, geographic, economic, environmental, social, political, legal, financial” and more (Moumen *et al.* 2019).

While the definition of water security is still evolving (Lautze and Manthrithilake 2012), multiple interpretations of the concept are available. A rather comprehensive definition given by Bakker (2012) describes water security as “the availability of water of sufficient quantity and quality to support livelihoods, national security, human health, and ecosystem services.” While this definition resonates with several general definitions of water security, there are additional factors found in alternative definitions of the concept.

The first factor is the protection from threats caused by water. Water is unique because its presence can be just as threatening as its absence, when it comes in undesirable circumstances. (Grey and Sadoff 2007) This factor is included in the definition of water security when defined by Eekhout and colleagues (2018) as “a condition in which the population has access to adequate quantities of clean water to sustain livelihoods *and is protected against water-related disasters*” (Eekhout *et al.* 2018). These disasters can come in several forms such as floods, water pollution, and water borne diseases (Eekhout *et al.* 2018).

An additional factor is water use for development and economic purposes such as defined by Grey and Sadoff (2007) as: “the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems *and production*, coupled with an acceptable level of water-related risks to people, environments and *economies*”. They acknowledge the importance of water for the economic development and production.

There is also the factor of cost. Availability of water does not necessitate affordability, or the access to enough water at the given cost, which is why Kujinga *et al.* (2014) define water security as “access to enough safe water *at affordable cost* to lead a clean, healthy and productive life while ensuring that the natural environment is protected and enhanced” (Kujinga *et al.* 2014).

The last additional factor is water for political stability. This idea can be found in the definition given by UN Water (2013) which defines water security as *“*the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems *in a climate of peace and political stability*.” (UN Water 2013) This definition is unique because it is very broad and includes almost all factors covered in the literature.

The concept of water security originates from the general concept of security which refers to “freedom or protection from serious risk and threats to *human* well-being.” (Kujinga *et al.* 2014) Since the concept of security concerns humans, a no less anthropocentric definition is expected from that of water security (Kujinga *et al.* 2014). Although the idea of ecosystem and environmental health is mentioned in several definitions of water security, these factors are considered mainly for human interests. It can therefore be concluded that the general idea of water security is mainly aimed at sustaining human life (Kujinga *et al.* 2014). For this reason, human water security is often prioritized over the environmental aspects, which results in harm caused to ecosystems (Pahl-Wostl *et al.* 2013).

2.1.2 The Importance of Water Security

According to Grey and Sadoff (2007), “water is a source of life, livelihoods and prosperity”. Water as a resource is crucial for “socio-economic development, energy, and food production, healthy ecosystems and human survival” (Moumen et al. 2019). In addition, availability of water is “one of the main drivers of the quality of social and ecological systems on which we depend” (Gain *et al*.2016). Bogardi *et al.* (2012) point out that water is a resource that cannot be replaced or substituted. This is due to its unique qualities as a “universal solvent and, hence, is a vector of compounds and transport medium, a climate regulator, a carrier of energy, and cooling and heating agent” (Bogardi *et al.* 2012). For these reasons, attaining water security has always been a central goal of human societies, and continues to be so today (Grey and Sadoff 2007). As stated by Kujinga *et al.* (2014): “The goal of all nations in both the developed and developing world is to achieve water security for their citizens”.

A lack of achieving water security can results in several challenges for a nation or region such as the struggle for economic growth, development and alleviating poverty. (Grey and Sadoff 2007). Grey and Sadoff (2007) find a connection between water security and the economic state of a nation; the most developed countries were able to achieve water security in early stages of their growth, while those that could not, it seems, remain poor. (Grey and Sadoff 2007)

Water insecurity can also result in social and political conflict. For example, long lasting droughts in the Sahel region have caused water shortages that intensified social conflicts (Sadoff and Muller 2009).

Water security is also a key ingredient in food security (Falkenmark and Lundqvist 1998), a core component of national security (Zeitoun 2011) and is interconnected with several other types of security as can be seen in Fig. 1 (Zeitoun 2011).

Zeitoun (2011) identifies this as a *'security web'* where all these types of security are linked to each other, and most importantly reliant on water.

Water security is also critical for the sustainable development of countries (Lautze and Manthrithilake 2012). In 2016, the United Nation's posed 17 sustainable development goals (SDGs) (Gain *et al.* 2016). Goal number 6 (out of 17) is to "ensure availability and sustainable management of water and sanitation for all" (United Nations 2019). In other words, ensuring the human aspects of water security everywhere. Although only explicitly mentioned in goal 6, several of the SDGs rely on water security according to Zeitoun's (2011) security web such as goal 2: Zero Hunger (food security), goal 3: Good Health and Well-being (human/ community security), goal 11: Sustainable Cities and Communities (human/ community security) and goal 16: Peace Justice and Strong Institutions (national security). Hence, water security is clearly an important factor in achieving the SDGs, making it a high priority issue on the sustainable development agenda (Moumen *et al.* 2019).

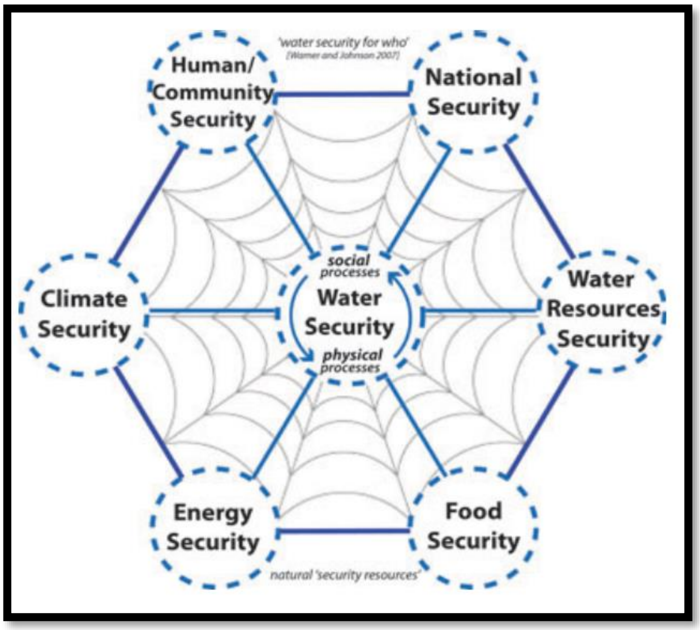

Figure 1: The Water Security Web
Source: (Zeitoun 2011)

However, despite its importance, achieving water security is not a simple goal. It is seen to be one of the biggest global challenges of the 21st century (Gain *et al.* 2016). Sadoff and Muller (2009) emphasize that that challenge is not only about achieving water security, it is also about sustaining it (Sadoff and Muller 2009).

2.1.3 Evaluating Water Security

It is quite complex to assess a country's water situation for several reasons. First, the criteria chosen for the evaluation may be political in addition to scientific (Brown and Matlock 2011). Second, it is difficult to include all factors into the calculation, resulting in indicators that often assess only part of the picture (Brown and Matlock 2011). Third, there is also complexity that derives from the definition of water security, since one well performing component may "adversely affect the performance of other components and vice versa" (Lautze and Manthrithilake 2012).

Nonetheless, there were several indicators developed to measure water scarcity and water security, usually on the national level. Water *scarcity* indicators measure the water scarcity a region experiences, and water *security* indicators measure the level of water security a given region has achieved. Both are important for assessing the level of water security a region has or hasn't achieved, and how challenging it may be to achieve it (Gain *et al.* 2016).

<u>Assessing Water Scarcity</u>

Several indicators are available for measuring the water scarcity of countries or regions. Falkenmark created the most commonly used water scarcity indicator on the national level (Brown and Matlock 2011). The Flakenmark indicator is used to determine levels of national water scarcity for different countries (Brown and Matlock 2011). According to this index, countries with renewable water resources of more than 1,700 m^3 per capita annually experience no water stress, countries with less than 1,700 m^3 per capita annually experience water stress, countries with less than 1000 m^3 per capita annually suffer from water scarcity, and those with less than 500 cubic meters per capita annually suffer from absolute water scarcity (Brown and Matlock 2011). This indicator places water abundant countries like Brazil (with 27,919 m^3 per capita annually) and Canada (with 80,423 m^3 per capita annually) in the 'no stress' category, relatively wet countries like Germany (with 1,321 m^3 per capita annually) and Poland (with

1,410 m^3 per capita annually) in the 'stress' category, drier countries like South Africa (with 821 m^3 per capita annually) or highly populated countries like Bangladesh (with 680 m^3 per capita annually) in the 'water scarcity' category, and low rainfall countries like Syria (with 381 m^3 per capita annually) and Algeria (with 289 m^3 per capita annually) in the category of 'absolute water scarcity' (water statistics from The World Bank 2020). It is important to note that the Falkenmark indicator is very simplified and lacks the consideration of several factors such as water demand and water distribution (Brown and Matlock 2011).

An additional and more complex indicator is one developed by The International Water Management Institute (IWMI). This indicator divides water demand by water supply, multiplying each factor by either historic or future water supply and/or demand from environmental and anthropogenic sectors (Brown and Matlock 2011). The analysis labels countries as 'physically water scarce' when more than 75% of river flows are withdrawn for

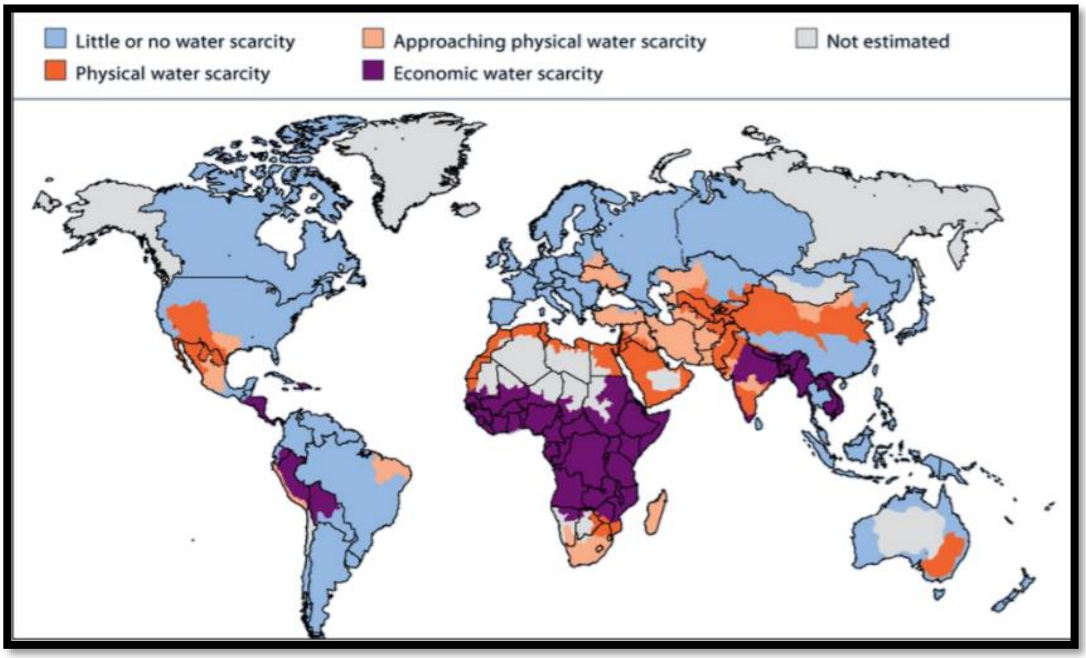

Figure 2: The IWMI Water Scarcity Indicator Map
Source: (Brown and Matlock 2011)

agriculture, industry, and domestic purposes, or 'economically water scarce' when significant improvements are needed in water infrastructure, even if only 25% of water from rivers is being withdrawn (Brown and Matlock 2011). This indicator puts several African countries in the category of ‘economic water scarcity’, several desert areas such as the middle east in ‘physical water scarcity’ and most of Europe, the United States, South America and several Asian countries in ‘little or no water scarcity’, as can be seen in Fig. 2.

Several other indexes are available such as the ‘the social water stress index’, ‘water resource vulnerability indices’, the watershed sustainability index and more (Brown and Matlock 2011), but I find the two presented above satisfactory for the purposes of this research.

Assessing Water Security

Several indicators exist for measuring water security on a regional scale. Among them are the national water security index (NWSI) and the water insecurity index (WII) (Moumen *et al.* 2019). The NSWI was developed by the Asian Development Bank for the purpose of assessing water security of countries in the Asian and Pacific region. The NWSI considers five dimensions: urban, economic, household, environmental security, and resilience to water related risks (Shrestha et al. 2018). The WII was developed by Aggarwal, Punhani and Kher in 2014, and applied on a broad scale in India. This index takes into account water resources, water access, water consumption, water capacity, water for the environment, and climatic stress (Shrestha et al. 2018).

However, Moumen and colleagues (2019) find these indicators to be limited due to their lack of considering the interactions between humans and the natural water systems. According to Gain *et al.* (2016): “The integration of both physical and human pressures on water resources (e.g., growing global population, changing climate, and increasing urbanization), is a fundamental requisite for a comprehensive understanding of human-water systems.” (Gain *et al.* 2016). For this reason, Gain and colleagues (2016) created The Global Water Security Index (GWSI) which takes into account the socio-economic and physical aspects of water security on a global scale.

According to Gain and colleagues (2016), there are four stages of water security assessment. They state: “first, we should emphasize whether a sufficient quantity of water resources is available or not. Second, we need to focus whether available water resources are accessible or affordable to society and ecosystem. Third, we need to consider whether available and accessible water is of good quality and whether the area is free from flood risk. Finally, consideration of governance and management aspect are central to implementing a sustainable approach to water security.” (Gain *et al.* 2016). Their research method therefore has four indicators that are calculated in order to measure global water security: availability, accessibility, safety and quality, and management. *Availability* is assessed by the amount of water of acceptable quality at hand. *Accessibility* is a calculation of the percentages of

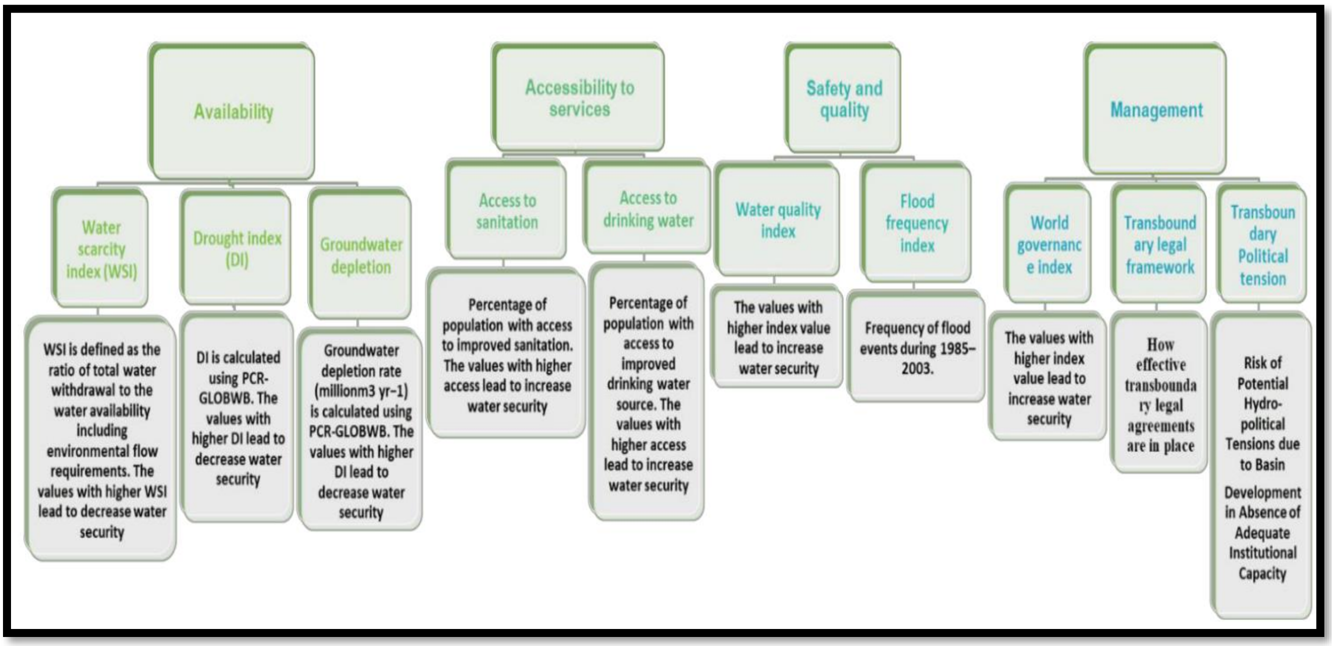

Figure 3: Global Indicators of Water Security According to Gain *et al.* (2016)
Source: (Moumen et al. 2019)

population who have adequate access to drinking water and sanitation. *Quality and safety* were measured by the water quality index, and assessment of flood risk. *Management* was assessed by the world governance index which measures factors such as political stability, corruption, and the effectiveness of government on a national level (further details can be found in Fig. 3) (Gain *et al.* 2016).

The results of the GWSI showed that *Availability* issues are mainly located in India, China, parts of The United States, parts of Australia, and several Northern African countries (as can be seen in Fig. 4). Gain *et al.* (2016) take note that 90% or more of global irrigated areas are in these regions. *Accessibility* issues are mostly in African countries (Fig. 5), while

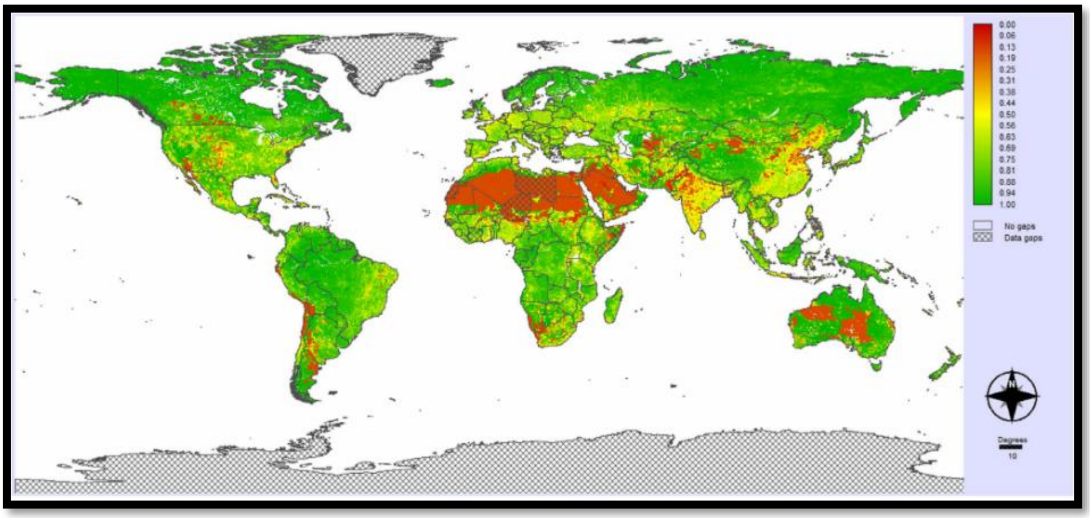

Figure 4: Global Water Availability
Source: (Gain *et al.* 2016)

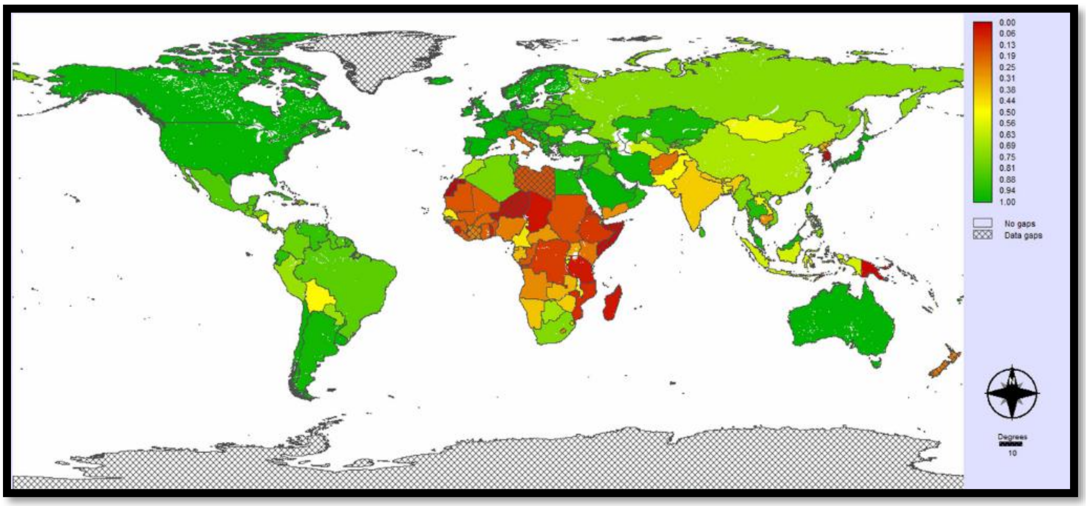

Figure 5: Global Water Accessibility
Source: (Gain *et al.* 2016)

most people in developed countries (United States, Europe, Australia, Canada) have access to improved sanitation and safe drinking water (Gain *et al.* 2016). As for *quality and safety*, it is interesting to see that risk of flood is a global concern, fore developed and developing countries

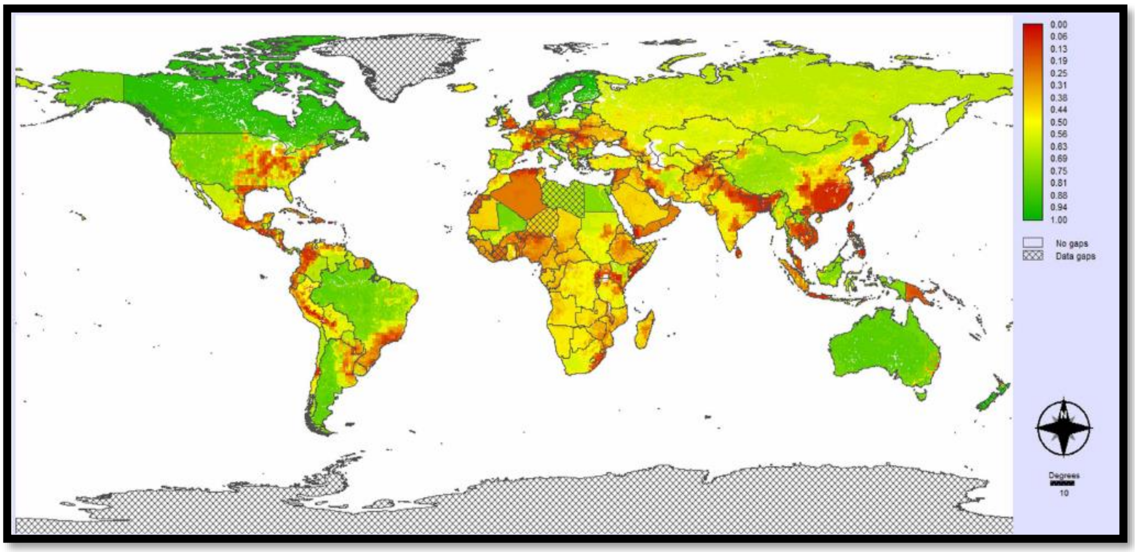

Figure 6: Global Water Quality and Safety
Source: (Gain *et al.* 2016)

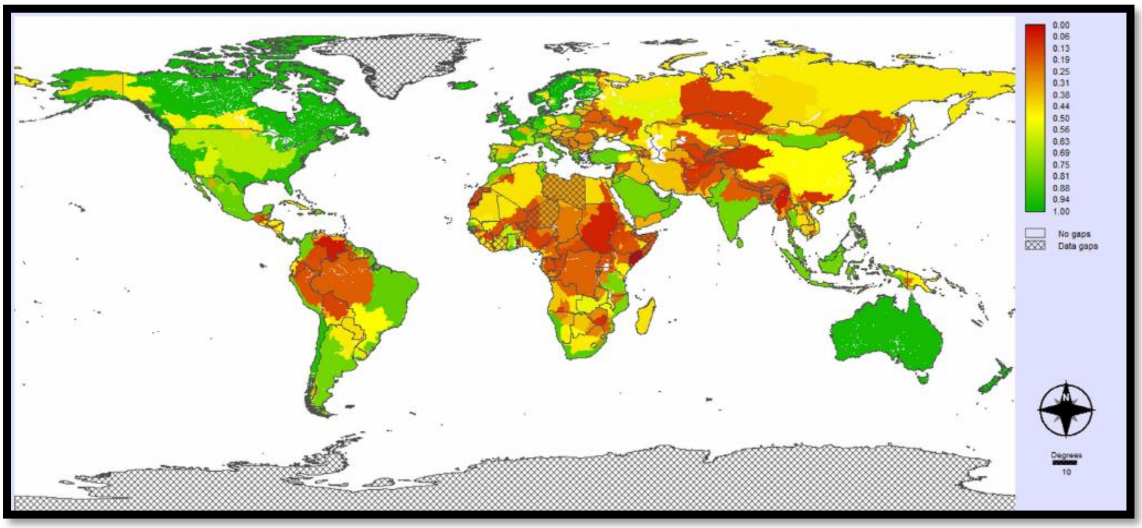

Figure 7: Global Water Management
Source: (Gain *et al.* 2016)

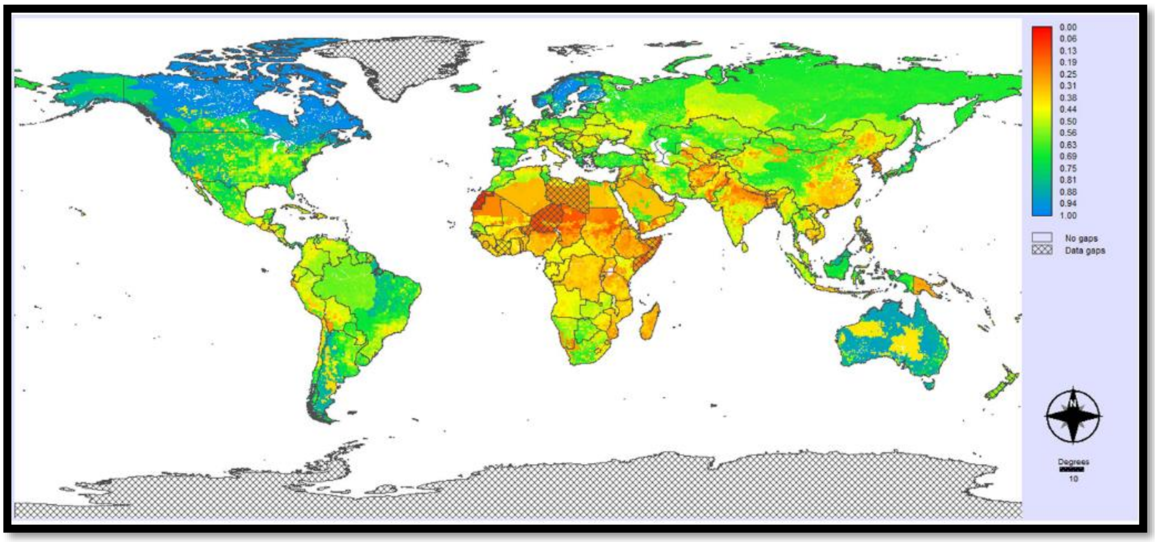

Figure 8: Aggregated Global Water Security Index
Source: (Gain *et al.* 2016)

(Fig. 6). Water quality was found to be best in Scandinavian countries, New Zealand and Canada, while the lowest quality was found in the Middle East and African countries (Figure 6). And finally, management was found to be of poor quality in Africa countries, most Asian countries, and parts of South America (Fig. 7).

As for the Global Water Security which took all these factors into account (Fig. 8) it was found that "water security is low in many countries in Africa and Asia, whereas the criteria for water security is met in Scandinavian countries, New Zealand, Australia, Canada, Japan, and throughout Western Europe" (Gain *et al.* 2016).

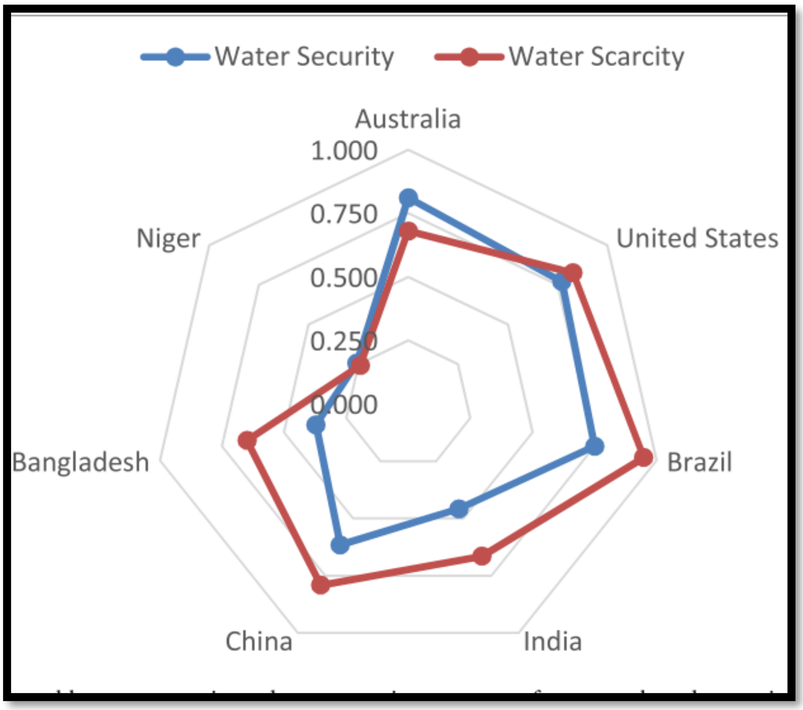

Figure 9: Water Scarcity Vs. Water Security
Source: (Gain *et al.* 2016)

An interesting finding by Gain et al. (2016) shows that when comparing water scarcity with water security, countries such as Australia (followed closely by the USA) have achieved higher levels of water security despite elevated levels of water scarcity (Fig. 9), and countries like Bangladesh, with similar water scarcity levels have very low water security (Gain *et al.* 2016) This has been found to be a result of good management of water resources, which emphasizes the exceedingly important role of managing and governing water when it comes to securing it (Gain *et al.* 2016).

2.2 Threats to Water Security

According to Bakker (2012), it is estimated the 80% of the global population faces a threat to water security. More than a billion people do not have access to adequate drinking water, and approx. two billion lack access to sanitation (Bogardi *et al.* 2012). It is often the case that countries with unpredictable climates that suffer from floods and droughts face water insecurity issues. (Moumen *et al.* 2019). However, the human intervention in the hydrological cycle is straightforwardly endangering freshwater resources (Vörösmarty *et al.* 2010), meaning that threats to water security are made up of both man made and natural causes (Kujinga *et al.* 2014).

Based on Gain and colleague's assessment, my review of the literature, and Pahl-Wostl and colleagues (2013) statement that: "the science decides how much water there is and where it is, and the social and political bodies decide where it's going", I have divided the threats to water security into environmental threats, socio-economic threats, and political threats, which will be described in the following section.

2.2.1 Environmental Threats

Environmental threats are threats to water security caused by environmental conditions or harm caused to the natural environment. These threats usually affect the categories of availability, or quality and safety given it Gain and colleagues (2016) assessment. Examples of such threats are the following:

<u>Water Scarcity</u>

Several regions suffer from natural water scarcity due to "low average precipitation, high seasonality of rainfall and high inter-annual variability" (Jones 2009). Currently, approx. 1.3 billion people reside in regions that suffer from water scarcity. (Kundzewicz and Matczak 2015). The areas found to be most vulnerable are ones of semi-arid climate, because the climatic patters are most unpredictable; some years bring floods and other droughts. (Jones

2009). In certain regions water scarcity is also caused by population growth and the demand for water exceeding the available supply. This is especially true for regions "where water resources are already stretched" (Jones 2009). Hence water scarcity is a combination of climatic condition and the water demand of the population. The indicators mentioned in chapter 2.1.3 can be used to assess the water scarcity of a region.

Hydrological Extremes (Droughts and Floods)

Hydrological extremes are seen to impact human security, livelihood and welfare (Kundzewicz and Matczak 2015).

Floods are caused by unusually heavy precipitation events, and can cause deaths, property damage, economic losses, water pollution, crop destruction and more. According to Kundzewicz and Matczak (2015) "Since the dawn of civilization, destructive floods have jeopardized settlements located near rivers." They additionally state that "despite developments in technology and extensive investment in flood protection and preparedness, flood occurrences as well as material damages are not decreasing" (Kundzewicz and Matczak 2015). Currently there are approx. 800 million people residing in areas with flood risk, and approx. 70 million of those actually experience floods on an annual basis (Kundzewicz and Matczak 2015).

Billions of people globally are exposed to droughts. As noted by Kundzewicz and Matczak (2015), there are several types of droughts: "meteorological drought (precipitation deficit), agricultural drought (soil moisture deficit), hydrological drought (surface water and groundwater deficit), and environmental drought (a combination of the above)." Droughts impact agricultural crops that rely on rainfall, domestic, industrial, and agricultural water supply as well as aquatic ecosystems.

It shall be noted that the risk posed by extreme hydrological conditions may vary based on the combination of hazard (how hazardous the particular event is), exposure (the presence of subjects in the affected area) and vulnerability (how resilient the present subjects and systems are) (Kundzewicz and Matczak 2015).

Climate Change

According to a report published by Global Water Partnership (GWP) in 2009: "Many of the anticipated impacts of climate change will operate through water" (Sadoff and Muller 2009). The increase in atmospheric CO_2 causing temperatures to rise, will change the stores of water and fluxes between them in the hydrological cycle (Fig.10 shows the average of stores and fluxes for the end of the 20th century) (Bogardi *et al*. 2012). These changes will affect the availability and distribution of freshwater (Allan *et al.* 2013). As states by Bogardi *et al.* (2012): "future water demands will need to be satisfied from a resource with an increasingly uncertain and variable distribution in space and time" (Bogardi *et al.* 2012)

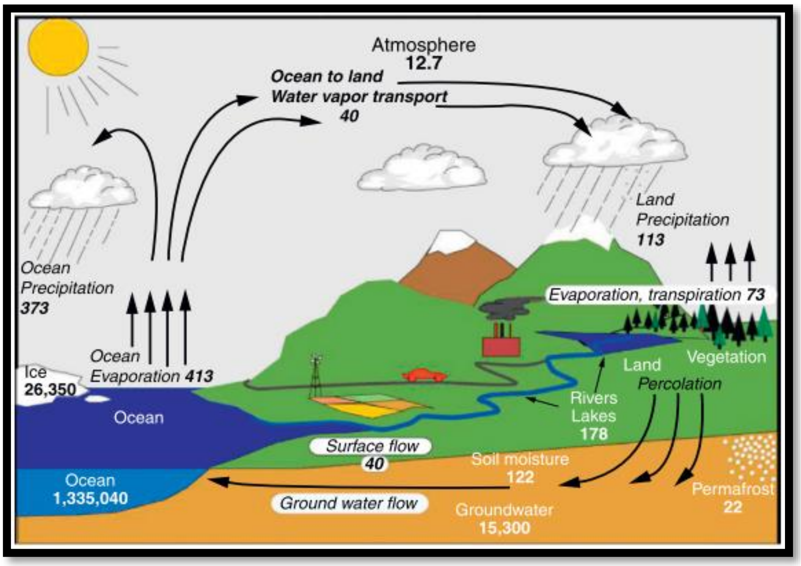

Figure 10: Water Flux and Storage in the Hydrological Cycle (1979-2000)
Source: (Bogardi *et al.* 2012)

Additionally, climate change is likely to cause an increase in water borne diseases, change in precipitation and river flow (increase in some and decrease in others), and periods of flood and drought will grow more intense (Sadoff and Muller 2009). Over the last half a century, the area of land affected by droughts has grown from 1% to 3% (Jones 2009). Studies show that that by the end of the 21st century, almost one third of all land will be susceptible to droughts (Jones 2009). The increasing frequency of extreme events such as hurricanes, earthquakes and tsunamis due to climate change risk the water security of millions of people and the scale of these events far exceeds the capacity of emergency services to provide basic water and sanitation (Jones 2009). Sea level rising is also impacting the availability and quality of freshwater resources: "sea-level rise extends areas of salinization of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas." (Kundzewicz and Matczak 2015).

According to Huntjens and colleagues (2011): "it is increasingly recognized that we need to adapt to the challenges and opportunities that a changing climate will bring" (Huntjens *et al.* 2011). Such adaptation is already necessary in several developing countries, especially in sub Saharan Africa, and will be necessary globally to ensure the future of water security (Grey and Sadoff 2007). Hence climate change is a growing threat to water security; it is expected to further exacerbate the situation in countries which already suffer from water insecurity, and introduce new uncertainties in countries which are yet to face this challenge (Grey and Sadoff 2007).

Water Pollution

Freshwater is a delicate resource that is highly susceptible to pollution and contamination (Musingafi and Tom 2014). When water is polluted, it poses a threat to the entire ecosystem (Musingafi and Tom 2014). Water pollution is defined as any unwanted change in the "physical, chemical and biological properties of water that has a harmful effect on living things" (WHO 1997). According to Jones (2009) "At least 50% of the world population currently suffers from water pollution, most of it directly or indirectly man-made." These man-made causes include agriculture, use of pesticides, mining, industrialization, and waste disposal (Musingafi and Tom 2014).

Water pollution is a serious threat to water security (Vörösmarty *et al.* 2010). Bogardi et al. (2012) state that: "widespread pollution has made good-quality freshwater scarce, posing threats to human health and biodiversity." In several countries, human and industrial waste are reducing the amount of usable water due to pollution. (Sadoff and Muller 2009)

Water pollution is especially threatening since it knows no boundaries; almost all rivers flow through multiple countries, carrying the pollution with them (Boos-Hersberger 1997). For example, a spill of chemicals into the Rhine river in 1986 in Switzerland, resulted in a toxic red coloured trail along the river, 70 kilometers long, that flowed downstream, all the way through France, Germany and Netherlands, and into the North Sea (Schwabach 1989).

Even countries with abundant supplies of water are threatened by water pollution, as the water quality may be easily compromised by human activities (Bogardi et al. 2012). Bogardi and colleagues (2012) state that: "this is evident from the presence of nutrients, agrichemicals, industrial wastes and persistent organic pollutants in many water bodies, high nitrate levels in groundwaters, heavy metals in river and lake sediments, and algal blooms and depleted oxygen that causes fish kills."

2.2.2 Socio-economic Threats

Socio-economic threats to water security are threats caused by social factors, economic factors, or the interaction between them. These factors mainly affect accessibility to water but may also affect factors of availability and management from Gain and colleagues (2016) assessment. Examples of such threats are the following:

<u>Population Growth</u>

World population growth has added huge pressure on the freshwater resources. According to Jones (2009) population growth is the most significant factor influencing the global water crisis. Bogardi et al. (2012) state that: "The threefold increase of the global population during the 20th century has triggered a simultaneous six fold increase in water use" (Bogardi et al. 2012).

Moreover, the expected growth is due to take place mostly in regions that are already water scarce such as Sub-Saharan Africa and the Middle East, and parts of India, where some areas already use over 100% of their freshwater resources (Jones 2009).

Fig. 11 and Fig. 12 show the growth in world population alongside the decline in freshwater available per capita (globally). This growth is surely a threat to water security everywhere (Allan *et al.* 2013).

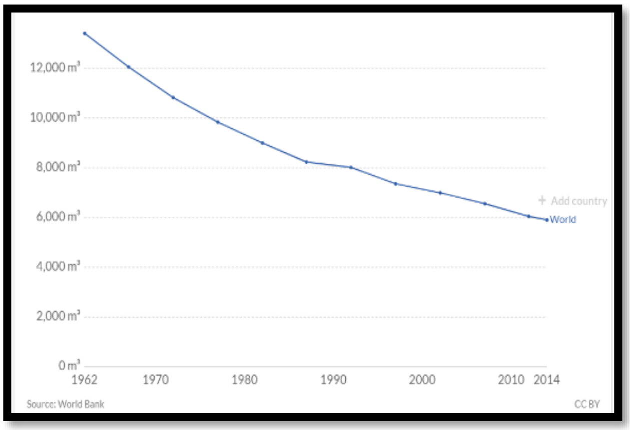

Figure 11: Renewable Internal Freshwater Resources per Capita (m^3) Source: (Our World in Data 2018)

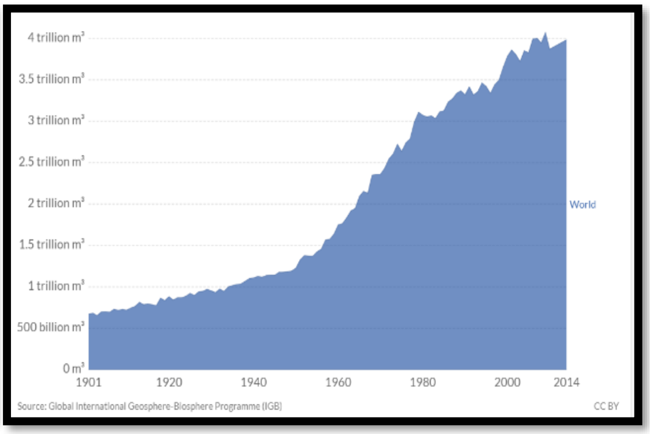

Figure 12: Global Freshwater Use Source: (Our World in Data 2018)

Infrastructure and Investment

Ensuring accessibility to water resources, especially in cities, requires proper infrastructure. According to Grey and Sadoff (2007): “water infrastructure is needed to access, store, regulate, move and conserve the resource.” It is also needed to “treat and reuse wastewater” (Sadoff and Muller 2009) and mitigate flood risk (Grey and Sadoff 2007). When a country is unable to/does not provide proper infrastructure for sufficient water access, this can be a threat to their water security (Grey and Sadoff 2007).

Providing proper infrastructure requires fiscal investments: “financial resources are required for the purchasing and installation of infrastructure as well as its operation and maintenance” (Kujinga *et al.* 2014). Grey and Sadoff (2007) mention that billions of dollars of investment in flood mitigation (e.g. dams, reservoirs) in the US has significantly reduced risk of flooding and curbed the potential economic damage from such events. Once infrastructure is in place, maintenance is also needed; maintaining the infrastructure can help reduce losses to water supply from leaky pipes as well as reduce water contamination (Kujinga et al. 2014). Failure to maintain and renew infrastructure is also a significant threat to water security. As stated by Jones (2009): "leakage from ageing pipes, even in Developed Economies, can be in excess of 25%, despite government drives to reduce them." For example, in London in 2006, the city was losing 1000L of water per day just from pipe leakages (Jones 2009).

Sadoff and Muler (2009) state that: "to achieve water security, investments will be needed in infrastructure." If a country or region cannot/ do not for various reasons make the investments needed in infrastructure, this can be a threat to their water security.

Urbanization

It seems that the rapid urbanization trend the world has experienced is also a threat to water security. According to Jones (2009), It is expected that by 2050, 75% of the world population will live in cities, several in megacities. Jones (2009) also points out that urban inhabitants tend to use far more water than rural inhabitants; approx. four to six times as much (Jones 2009). Additionally, Kujinga *et al.* (2014) state that: "Infrastructure i.e. shopping centers, lodges, hotels, hospitals, houses, are associated with urbanization and require substantial amounts of water. This leads to the reduction of water availability for households in an area where water resources are already limited." However, there is also another aspect to this issue; most of the urbanization taking place today is in developing countries where inhabitants are moving into informal housing around the cities. This on the one hand risks the exposure to water borne diseases due to lack of proper water supply, but also increases the risk of exposure to floods due to lack of proper infrastructure (Jones 2009).

Privatization and Commercialization of Water

According to Bakker (2007), the increasing privatization of water around the world has been raising fiery debates. Many are opposing the "increasing involvement of private, for-profit multinational water corporations in running networked water supply systems" (Bakker 2007). An important question being raised in the debate is whether the privatization of water is compatible with water as a human right. On the one hand, if water is priced too low, it results in water wastage and losses (which is a threat to water security) (Bakker 2007) (If water is not priced at all – tragedy of the commons (Mitchell 1984)). On the other hand, treating water as a commodity, a market good, threatens access to water of indigenous people, poor people and tribes that relied on access to natural water resources (Bakker 2007) (making it a threat to water security from another perspective). For example, the 1981 Water Code in Chile, established with a neo-liberal perspective, considered water to be a commodity which can be freely leased and sold. This code was found to be deeply flawed when it resulted in negative impacts for the poor, the farmers, and the environment (Andreen 2011).

The commercialization and privatization of water began with companies utilizing water resources for a profit, which gave them control of the resources (Jones 2009). Jones (2009) points out that this action is supported by the World Trade Organization (WTO) who "long ago declared water a "commercial good" and supports foreign takeover of water services under international trade rules with specific enforcement procedures." These companies taking control of water resources often leads to corruption as well, in maintenance and infrastructure and even contracts, threatening water security in several communities, especially in Africa (Jones 2009). Dr. Peter Gleick, President of the Pacific Institute states that "Water is far too important to human health and the health of our natural world to be placed entirely in the private sector" (Jones 2009).

Poverty

Poverty and low income can also be a threat to water security, as stated by Kujinga *et al.* (2014): "Household income has a bearing on equitable access to water as households with more disposable income can afford private connections and to pay for consumption while those with less disposable income cannot do the same."

2.2.3 Political Threats

Political threats are threats to water security caused by political bodies, decisions, or conflicts. These threats may affect all the factors given in Gain and colleagues (2016) assessment. Examples for such threats are the following:

Transboundary Waters

According to Jones (2009), "Worldwide, one third of river basins, amounting to some 261 systems, pass through more than one country." Additionally, "Nearly all major aquifers are transboundary" (Jones 2009). Transboundary waters place a huge burden on the task of achieving water security by adding legal and political aspects to the issue as well as tensions between nations (Grey and Sadoff 2007). Several wars are even fought over access to water resources (Jones 2009).

For example, several conflicts exist over the water in the Nile Basin, which passes through ten countries in north and east Africa. Egypt which is the last country the Nile flows through before reaching the sea, has taken military action against upstream countries to ensure their supply of water from the river. Ethiopia, an upstream country on the Nile was threatened by Egypt after they declared they would capture a portion of the Nile water for their own use (Wiebe 2013). Another example is the La Plata Basin shared between Argentina, Bolivia, Brazil, Paraguay and Uruguay which remains conflicted despite the an established framework for cooperation between the nations (Espíndola and Ribeiro 2020). Several transboundary water conflicts also exists in the Middle East (Baumgarten 2010).

Jones (2009) notes that while there have been many successful transboundary agreements made in Europe and North America, there is a lack of such agreements in Asia and Africa, and "there is still a need for more binding legislation and a strong means of enforcement based on the UN International Court of Justice system for transboundary waters, both surface and subsurface" (Jones 2009).

Terrorism and War

Jones (2009) notes that "withholding or poisoning water supplies was a military tactic often used in the ancient world." Yet this tactic seems to still be at use today by military forces and terrorist organizations (Jones 2009). In 2001, following 9/11, the US Environmental Protection Agency (EPA) felt it was necessary to establish a special task force for the protection of water from terrorist attacks. Following this realization, several security measures were taken to protect water resources by countries all across the globe (Jones 2009).

However, it is not just individual attacks but ongoing wars that are also threatening water supplies. Much damage has been done to water resources due to war in Iraq (Jones 2009). In the 1990's the Balkans conflict resulted in bombing of dams and other damages to water resources (Jones 2009). Moreover, Jones (2009) points that "pollution of soils and groundwater by the products of weaponry, like depleted uranium, and the various chemicals released directly from damaged industrial plants or resulting from combustion can persist for decades." Hence, the aftermath of wars can threaten water security for years after they're over.

Water Equity

Water equity is a serious consideration on the path towards water security *(Kujinga et al.* 2014). This threat is considered political, because it is often an issue caused by poor governance (Kujinga *et al.* 2014). Water equity can be defined as "the absence of systematic disparities in water allocation and distribution between social groups who have different levels of underlying social advantage/disadvantage, that is, different positions in a social hierarchy" (Kujinga *et al.* 2014). One example for issues of water equity is socio-economic: "The inequity arises because the wealthy are able to bring public water services to their neighbourhoods while those less fortunate have to rely on private vendors." (Brooks and Linton 2009). However, water equity can also be affected by political power or status of societal groups. For example, in Botswana, water equity is affected by the category of a settlement. Settlements in the category of “gazetted” are recognized by the government and provided necessary water supplies and services. Settlements which are considered “ungazetted” are not recognized by the government and are not eligible to receive water services. The government can determine which settlements are recognized and which are not based on certain factors such as population size and economic potential (Kujinga *et al.* 2014). This leaves many settlements without sufficient access to water because of their political status. A similar issue can be found in Israel, where Bedouin settlements in the desert are not recognized by the government and therefore not eligible for official water services. (see chapter 5). The societal groups left without access to water are often the ones with less financial and political power (e.g. minority groups (like in the case of the Bedouins)). Zeitoun (2011) points out that “Policy makers would do well to consider the effects of the fact that water security for the powerful does not mean water security for the rest, and question how tenable and ‘secure’ their policies are in the long term.”

<u>Improper Governance & Management</u>

Improper governance and management of water resources can also be a threat to water security. As a result of poor governance, millions of people lack access to safe water, and are forced to turn to contaminated water sources for their basic needs (Kujinga *et al.* 2014). In many regions, “the prevailing management of water resources has resulted in waste, abuse and low efficiency and productivity” (Falkenmark and Lundqvist 1998). For example, the use of flood irrigation in agriculture is responsible for the use of up to 70% of agricultural water worldwide, despite the availability of water saving systems such as spray or drip irrigation (Jones 2009).

Zeitoun (2011) expresses very harsh feedback about the steps taken to achieve water security: “the largely uncoordinated approach taken to regional and global water security issues lags far behind the emerging global policy regime for climate change, and attempts to achieve water security fall well short of their mark." He additionally points out the insufficient quality of policymaking for water security: "water security policy is at best incoherent; at worst, it creates situations of insecurity for other natural resources that people and states have come to depend upon, or for the communities and nations themselves" (Zeitoun 2011). He then provides examples of the UK importing virtual water from Peru, and aggravating a water conflict in the Ica Valley, as well as bad policy choices made by the Egyptian government, farther provoking the conflicts over the Nile water (Zeitoun 2011).

Kujinga *et al.* (2014) point out that there are several outdated water policies negatively impacting water security. For example, in Botswana the main water legislations are the water act of 1968, the Borehole Act of 1956, and the Waterworks Act of 1962, and the Water Utilities Corporation Act of 1970. Such outdated policies that do not allow integrated water resource management, since they fall under separate ministries which are not in coordination (Kujinga *et al.* 2014).

Bogardi et al. (2012) go as far as to state that: "In short, the global 'water crisis' is ultimately a 'governance crisis' extending from the local to the planetary Scale."

On the positive side, Allan *et al.* (2013) state that Exploring better management of water is a trend worldwide (Allan *et al.* 2013), which may mean better hope for the future.

2.3 Steps Towards Water Security

2.3.1 Water Laws

According to Mager (2015), "Water Law is indispensable although not sufficient to assure a rational use of water." Additionally, Mager (2015) points out that, "Water Law is evolving more and more into a part of environmental law under the leading principle of sustainability." Water law exists on international, and national scales. International Water Law: "comprises customary law, framework treaties with a universal scope of application, regional framework treaties and regional or bi-national water law treaties for specific water resources." However, an issue with international water law, like all international laws is that "there is no institution with undisputed power to enforce its rules." (Mager 2015). International law in mainly necessary due to the transboundary nature of countless watersheds, but also to ensure water as a human right for all citizens of the world. There are several examples of international water laws and treaties.

One example is **The Helsinki rules of 1966** on the uses of water of international rivers, established by the international law association (ILA). This was one of the first international treaties that addressed transboundary groundwater. The rules, in short, establish that the riparian states shall engage in reasonable and equitable utilization of the shared water resources "as the basic principle of international water law". The rules also specify a number of factors that explain what reasonable and equitable means for every state such as climate, economic needs, population and more. There are separate chapters which discuss issues of pollution and other harms that can be caused. (Salman 2008).

Another example is **The United Nations Watercourse Convention**, adopted by the general assembly in 1997. This convention is "a framework convention that aims at ensuring the utilization, development, conservation, management and protection of international watercourses[1], and promoting optimal and sustainable utilization thereof for present and future generations" (Salman 2008). Similar to The Helsinki Rules, the convention also adopts the ideas of equitable and reasonable utilization of water resources, which is determined according to similar factors. Unfortunately, as of the year 2006, only 16 states had ratified the convention, which is not enough to enable it to take force and effect.

Later on, also established by the ILA are **The Berlin Rules on Water Resources of 2004** (Salman 2008). This set of rules includes 73 articles divided into 14 chapters and is more

[1] While watercourse refers to surface and groundwater (Salman 2008).

comprehensive than the Helsinki Rules and the UN Watercourse Convention. These rules address "various issues related to all waters, ranging from participation of persons likely to be affected by decisions concerning the management of waters; the conjunctive management of surface waters, groundwater and other waters in a unified and comprehensive manner; and integration of the management of waters with the management of other resources, as well as the sustainable management of water and the prevention or minimization of environmental harm" (Salman 2008). Additionally, these rules refer to both international and national waters (Salman 2008).

There are two more important notes on international water law. One, it pointed out by Salman (2008) that there still lacks a satisfactory treaty on transboundary waters: "given that water is the most precious resource that humanity shares, and given the ever-increasing challenges facing shared water resources, it is indeed quite unfortunate that the task of sharing and protecting water resources still lacks a universally agreed upon treaty." And two, Wouters (2000) notes that "it is important to know that the rules of international law apply to sovereign States, and it is primarily for States themselves to ensure compliance with international commitments."

National water law, "regulates the legal status of water resources, the right to use water, priorities between the uses, water services, water quality and pollution control including wastewater management, control and protection of waterworks and structures, protected zones or areas, data collection and planning, fees, penalties and sanctions, administration and administrative procedures of water resources" (Mager 2015).

Wouters (2000) states that in the national context, "water is generally the property of the State held in trust for its citizens with overall responsibility for resource-related activities vested in the State." However, this may vary between nations. For example, in the Eastern states of the USA, water is treated as common property under the riparian water rights, however several Western states have rejected this system for one that sees water as private property, and in some places private permits are given only for large-scale water projects (Andreen 2011). Another example is in the United Kingdom; while England and Wales have privatized all their water, Scotland's water remains public (Wouters 2000).

Additionally, every country has their own set of water laws. For example, in the USA, the **1972 Clean Water Act** establishes quality standards for surface water, and how pollution will be controlled and regulated (EPA 2020). The **1974 Safe Drinking Water Act** sets standards for the quality of drinking water and requires operators to comply with these standards (EPA 2020). Some legislations concern water access and water as a human right such as South Africa's new constitution which established the right of access to water for all (Colvin *et al*. 2016).

The overall goal of water laws, according to Wouters (2000) is to promote proper management of water resources through "through a system of regulatory and institutional measures and mechanisms." Moreover, the lack of proper water legislation can be a serious obstacle to achieving effective water resource management" (Wouters 2000).

2.3.2 Water Governance

Water governance according to the latest definition of the UNDP: "refers to the political, social, economic and administrative systems in place that influence water's use and management. Essentially, who gets what water, when and how, and who has the right to water and related services, and their benefits" (United Nations Development Program 2020).

Throughout the 20th century, water was generally governed on a local scale, by local or national governments. However, as noted by Cooley *et al.* (2013): "There is growing recognition that the scope and complexity of water-related challenges extend beyond national and regional boundaries and therefore cannot be adequately addressed solely by national or regional policies." For this reason, global water governance has also emerged in the last decades (Cooley *et al*. 2013). On the global scale, there are several bodies of various types engaged in water governance: there are International Professional Societies such as The International Water Association (IWA), Intergovernmental Organizations such as the United Nations Development Program (UNDP) and the World Health Organizations (WHO), Global Research Organizations such as the Global Water Systems Project (GWSP), Donor Agencies such as The World Bank, Non-Governmental Organizations such as the International Water Management Institute (IWMI) and Global Action Networks such as Global Water Partnership (GWP) (Cooley *et al.* 2013). A particularly important body is UN-Water, which was established in 2003, to be a platform of coordination between all the UN bodies on issues of water (Baumgartner and Pahl-Wostl 2013).

Some of the main actions these bodies engage in are establishing water laws and treaties, financing water management and service delivery, establishing the best water management practices, transferring technology and knowledge through education programs, collected data and conducting research (Cooley *et al.* 2013).

Water governance is extremely important. Enqvist and Ziervogel (2019) state that, "water governance is necessary because as a resource, water connects people, places and different sectors of society; it is of both local and global concern and involves public, private and nonprofit actors; and it often requires high capital investments and is critical for development needs." Additionally, Pahl-Wostl and colleagues (2013) point out that "enhancing water security is first of all a governance challenge", which emphasized the importance of water governance for achieving water security.

2.3.3 Water Policies and Management Strategies

Managing water involves all the activities that aim to keep water resources in a desirable state (Özerol *et al.* 2018). Water management typically has two approaches: supply management and demand management (Katz 2016). Supply management focuses mainly on enlarging the amount of available water resources, while demand management focuses on reducing consumption and using the resources more efficiently (Katz 2016).

Water demand management in a rather broad sense includes all actions taken to reduce water consumption and water withdrawals (Brooks and Linton 2009). The goal is to maximize efficiency at all stages starting from water extraction and until it reaches the consumer side, while using economic incentives and water efficient technologies (Brooks and Linton 2009). Water demand management involves several actors since it "involves literally every household or firm or activity that uses water in a given location" (Brooks and Linton 2009). The involvement of managers and consumers at all levels is crucial for the process, especially farmers, when it comes to water efficient irrigation methods (Brooks and Linton 2009). Strategies include water pricing and block tariffs (Brooks and Linton 2009), water education and conservation campaigns, setting water quotas, investing in water efficient technologies (Katz 2016), controlling pressure in pipes, repairing leaks, restricting water use (Joubert *et al.* 2003), and any other actions that reduce the overall water consumption.

Water supply management generally includes any actions that enlarge the supply of water to a given area (Katz 2016). This can mean building [new] dams and reservoirs, tapping into new groundwater sources (Joubert *et al.* 2003), investing in additional infrastructure, increasing the use of recycled wastewater and investing in artificial supply augmentation sources such as seawater desalination (Katz 2016).

Katz (2016) believes that, "most water managers use a mixture of both supply side and demand side policies, seeking to capitalize on the relative advantages of both." Naturally, each option has its advantages and disadvantages; supply management may increase economic potential and provide more available water to populations, but it is also often costlier than demand management, which is more economically and environmentally efficient (Katz 2016). Brooks and Linton (2009) argue that reducing demand, rather than augmenting water supply, is a better and cheaper option in the long term: “Strategies to reduce water use can provide more easily implemented ways to improve water security” (Brooks and Linton 2009). However, countries that are still in economic development, typically focus on supply side developments such as building proper infrastructure to access the water resources, while more developed countries, who already have the necessary infrastructure in place focus more on demand management (Katz 2016). It is also important to note that demand management is a more efficient strategy in immediate short-term situations such as droughts, where supply management options would take too long to implement (Katz 2016).

There are several challenges that water managers face. For example, investing in technological efficiencies may reduce the cost of water supply, which will then unwantedly boost water consumption (Katz 2016). Another example is that following efforts to augment supply, consumers may perceive water as a less scarce resource and therefore increase consumption (Katz 2016). This is especially problematic in water stressed countries. An additional concern for water managers is that “a balance must be found and maintained between water used to meet human needs and the needs of aquatic ecosystems.” (Andreen 2011). Water managers must therefore carefully choose the best strategies to use to achieve the most sustainable and efficient management of the water resources.

2.4 What Works Best?

As discussed in this chapter, there are several different ways to govern water, manage it and establish legislations around its use. It was also noted that some regions have done better achieving water security and other less so. In practice, water governors and managers must make the choice of which strategies to adopt. When attempting to make such choices, with all the existing strategies for resolving water security, the question arises, which strategies work best? This can of course be learned, like anything else from experience, trial, and error.

However, with water being such an essential part of sustaining human life, it is ideal to reduce the risk of these decisions as much as possible.

Özerol *et al*. (2018) point out that an excellent tool to assess water governance strategies (in which they include water management) is comparative studies. They state that "Comparisons of water governance serve several purposes. These include identifying the ways in which water governance is shaped across varied settings, assessing performance, and drawing out lessons on what works in which context and why." Hence, studying and comparing the water systems of different regions can contribute valuable knowledge on the topic of water security. Studying a region that has done well with water security with one that has been less successful can contribute specific knowledge for the less successful region in the comparison, if this region has enough similarities (in the area of water) to the more successful area.

While conducting a comparative water study is not new, and comparative studies have been done between Israel and South Africa (e.g. Mctague 1985), no study has yet been conducted between Israel and Cape Town on the topic of water security. Israel and Cape Town have several similarities relevant to the water sector (as pointed out in chapter 1), yet a study comparing the contrasting outcomes of water security after both experiencing a severe drought in the same consecutive years, has yet to be conducted. This study can contribute general knowledge about securing water, in addition to specific knowledge for Cape Town from Israel, and vice versa, which is exactly the research gap that this thesis aims to fill.

3. Methodology

3.1 Research Design

The design of this research is a comparative study based on the comparative method. According to Rihoux and Ragin (2008), “comparison lies at the heart of human reasoning and is always there in the observation of the world”. There is a long line of academics and philosophers who have reflected on this idea and applied in empirically beginning all the way back with Aristotle (Collier 1993). Collier (1993) also refers to the importance of comparison stating that, “Comparison sharpens our power of description and plays a central role in concept formation by bringing into focus suggestive similarities and contrasts among cases.” Collier (1993) additionally points out that comparison is an excellent tool for forming new hypotheses, and building theories, emphasizing its importance as a research tool.

The comparative method in its modern form can be traced back to John Stuart Mill, explained as the “method of discovering empirical relationships among variables” (Lijphart 1971). This method is one among two other types of methods: the experimental method[2] and the statistical method[3]. The comparative method is considered to be an alternative of experimentation, but instead of observing empirical phenomena, it uses cases (Rihoux and Ragin 2008). More specifically, the method observes a small number of cases, referred to as ‘small N’ research (Collier 1993). Conducting such a study aims to collect in depth insights about specific cases and simultaneously produce knowledge that can be applied generally (Rihoux and Ragin 2008). ‘Small N’ research has gained more legitimacy over time, as some analysts have seen that certain phenomena are best understood through a small selection of cases (Collier 1993).

[2] The experimental method uses two groups, while one is exposed to a stimulus and the other (the control group) is not. The groups are than compared, and any contrasting findings are explained by the stimulus. (Lijphart 1971)
[3] The statistical method involves the “conceptual (mathematical) manipulation of empirically observed data… in order to discover controlled relationships among variables.” (Lijphart 1971)

Berg-Schlosser and De Meur (2009) present two models for comparative research design: the most similar different outcome (MSDO) and most different similar outcome (MDSO) model. The MSDO model selects similar cases with contrasting outcomes, while aiming to find the differences in the similar cases and use them to explain the outcomes. The MDSO strategy compares different cases with similar outcomes. This model seeks to maximize heterogeneity in the cases selected, (while assuming that small similarities still exist), in order to eliminate factors that are not influential and find more universal explanations for phenomena (Berg-Schlosser and De Meur 2009).

This research uses the MSDO model; it compares two cases (Water security in Israel and Cape Town) which appear to have several similar factors but show contrasting outcomes (Israel was water secure while CoCT almost ran out of water). These similarities include a Mediterranean climate, water scarcity, political issues, and both being hit by their worst drought in a century in overlapping consecutive years.

The comparative method usually studies cases on the national or the sub national level. Sub-national analysis has two strategies of comparison: *within nations* and *between nations* (Snyder 2001). The *within nations* strategy focuses on a number of cases within the same country, while the *between nations* strategy focuses on cases across separate countries. Snyder (2001) points out that it is also possible to use a combination of these two strategies. The method adopted for this research is a combination of the national and sub national analysis. The country of Israel on the national level was compared to the City of Cape Town metropolitan region on the sub national level. This comparison is justified by parks *et al.* (2019) who state that, "Although water supply and demand issues are highly localized, these lessons are translatable across cities and countries across the world." In other words, it is possible to transfer lessons in managing water between the national and sub national scales. Additionally, The combination of intra and inter-nation comparison is perceived as a promising and fruitful combination according to several analysts (Lijphart 1971).

The timeline for the comparison is between the years 1948 and 2018. The year 1948 is significant for both Israel and South Africa; for Israel, it was the year that the state was founded, and for South Africa it was the year the Nationalist party was first elected, creating Afrikaner dominance, and bringing the famous apartheid policies to the country (Mctague 1985). Both these historical events hold significance in shaping the future of water security for the regions.

According to Rihoux and Ragin (2008), In order to conduct a comparative study, the cases need to be converted into configurations, defined as “a specific combination of factors that produces a given outcome of interest” (Rihoux and Ragin 2008). The factors compared in this study were carefully selected based on the findings of the literature review. In order to gain understanding of what accounts for the differences in the two cases, the threats to water security were assessed, divided into the categories of environmental threats, socio-economic threats and political threats. The strategies for tackling water security were then explored and for each region including water laws, governance structure, management and policy strategies and technological innovation.

For Israel, the factors were all considered on the national level. However, for CoCT, factors were considered on the municipal level and on the national level when this information was relevant or provided a deeper understanding of the case. Also, some factors such as water laws and governance could not be considered solely on the municipal level, since national levels are also involved. Hence, although the comparison is between Israel and CoCT, the CoCT is still a municipal region within a country that is influenced by higher levels of governance.

3.2 Data Sources

This research comprises of several data sources. Firstly, there are peer reviewed articles which make up the literature review, provide some information for the results, and the base for the theoretical framework. These articles were carefully selected based on their quality and relevance to the topic. Second, several books and book chapters were used to collect information about water security, water policy and water management. These are mostly edited books providing chapters by several authors, but also books published by one author. Third, there are government documents, reports and information provided by governmental bodies on official websites. These are documents such as master plans for the water sector, water policy documents, water management strategies, water laws, assessment of water issues, environmental reports, usually published by municipalities, government bodies governing the water sector and environmental ministries. The selection of these documents was done with most effort to ensure they are most relevant to the years of the case, or the most recent of their kind to that time period. Additionally, most effort was made to rely on documents published by the state or city themselves, if available. The Fourth source is reports published by NGOs such as Global Water Partnership (GWP) and World Wildlife Foundation (WWF). Such reports are often similar to government documents about the water sector but provide a more objective assessment and additional information which is found helpful to the research. Finally, there were also some official websites used such as The World Bank data, Water SA, and other official governmental and municipal websites.

3.3 Data Analysis

After the data was collected and organized in the framework, it was analysed through comparative analysis. In other words, each factor was set aside the comparable factor in the opposite region, and the differences were pointed out. First the climate and freshwater resources were compared and contrasted, and the differences were identified. Next, the threats to water security were compared, each factor in its own section, and the differences were analysed in attempt to understand why the water security outcomes were different between the regions. Finally, the steps taken towards water security in each region were compared and contrasted in order to understand additional reasons for the different outcomes, but also to conclude what the regions can learn from each other about managing water (predominantly but not limited to what CoCT can learn from Israel's success). For factors that were unique to each region (e.g a threat to water security that does not exist in the other region), a direct comparison was not done. Instead, a discussion took place to understand how this factor impacted the regions' water security, and if its uniqueness to the region could be included in the explanation of the contrasting outcomes in water security. Throughout the analyses chapter the research questions were indirectly answered, and the project's aims, and objectives were achieved.

3.4 Research Limitations

There were several limitations faced in this research. Firstly, are the limitation that exist in the nature of the research design. The comparative method uses a small number of cases, which limits the scope of the research. This is considered to be a limitation of the method in general according to Lijphart (1971).

Secondly, not all factors could be considered in the comparison. This is for two main reasons. One: a comparative study must be conducted in some sort of framework. The framework is used to focus on a specific set of factors, in order to narrow down the scope and maximize the details of the findings. Hence it is impossible for such research to consider all the factors influencing the case simply because not all can be fit into a specific framework. Two: there are surely factors that are unknown to the public or to the researcher, which also cannot be considered (e.g. government corruption, political incentives, bribes, mafia etc.). This is especially relevant to corruption in the government of SA, which is knows to exist, but naturally information on how it affects water security is not available. Moreover, the factors themselves could not be completely considered or researched to their fullest extent. For example, when presenting legislations or water policies, it is impossible to include every single law or policy established by a country or municipality, considering the scale of the project. Therefore, the focus was on the ones found to be most important and most mentioned in the data sources. The same goes for threats to water security; there may be several small or local threats that were not considered because I was aiming to consider the ones which had most impact or burden on the water sector.

Thirdly, while conducting the research I found that more comprehensive information was available on Israel's water sector than on CoCT's. It seems that far more research has been done on issues of water in Israel. Although following CoCT's water crisis in 2018, the city's water sector began to receive more academic attention, the information available about the past is far more limited than Israel. This is possibly because Israel's water struggle has been around for longer, and received much attention over the years, but naturally this limited the research in a way.

Fourth, water security is an extremely broad topic which includes the intersection of several disciplines, as can be seen in the definitions presented in chapter 2.1. It is impossible to consider all of these aspects in a project limited in time and space, which also had to be narrowed down into a framework. While most effort was made to incorporate as many aspects as possible, the issues most considered were those of access to sufficient water and sanitation for human populations. This was also because that was the issues most threatened by the drought. However, it limited the space for other issues such as the quality and quantity of water in nature and aquatic ecosystems which were discussed in a very limited form.

Finally, this research had some circumstantial limitations. Unfortunately, the timeframe for this research was in the middle of the outbreak of the COVID19 pandemic. This affected the original plan for the research which was to collect additional data from policy makers, authority figures in the water sectors, and experts via semi structured interviews. I believe these subjects could have enriched my findings by providing information and analysis that is not available in a published format. However, the circumstances of this time significantly limited the access to these persons, which eventually led to a change in the research plan and structure. I still believe this research has been valuable and provided useful insight to the academic world, nonetheless I acknowledge that involving these additional sources could have made the research even more valuable.

3.5 Research Ethics

The CEU research ethics were carefully reviewed and followed in this research. Before conducting the research, the ethical implications of the project were considered, and no potential risks to the nations involved or minority groups mentioned were identified. All the information collected and analysed in this project was found in documents, books, articles or websites made available to the public. No information was used or collected without consent. Most effort was made to show respect for both the nations being discussed in the research. A full commitment to principles of integrity, openness and intellectual honesty was followed in this project. The research was designed to maximize social benefits and minimize social harm. No conflicts with the individual ethics of the researcher were found. No funding was collected form external sources.

4. Water Security in Israel

4.1 Climate and Freshwater Resources

Israel is a small country in the Middle East (22,072 km^2), located on the eastern coast of the Mediterranean Sea. It lies between 29-33ºN, which is categorized as a subtropical region, between the temperate and tropical zones (Israel Science and Technology Directory 2020). Israel's landmass can be divided into two main climate zones; the northern and coastal regions, characterized by Mediterranean climate (hot and dry summers and cool and rainy winters), and the southern and eastern regions, characterized by arid desert climate (hot dry summers and less than 200 mm of rain per year) (Feitelson 2013). The desert areas cover about 60% of the country's landmass (Feitelson 2013), but most of country's population is gathered in the Mediterranean areas.

The rainy season generally begins in October and ends in early May, while the peak of rainfall is December through February (Feitelson 2013). Rainfall amounts are between 1000 mm/year in small areas of the north, and 100 mm/year or less in the southern, desert parts of the country (Israel Science and Technology Directory 2020). There is very high variance in the annual rainfall, resulting in some years receiving twice the average and some years just half (Avgar 2018). The average annual rainfall throughout the country from 1981-2010 can be seen in Fig, 13. Fig. 13 emphasizes how precipitation levels decrease from the north to the south of the country (Avgar 2018).

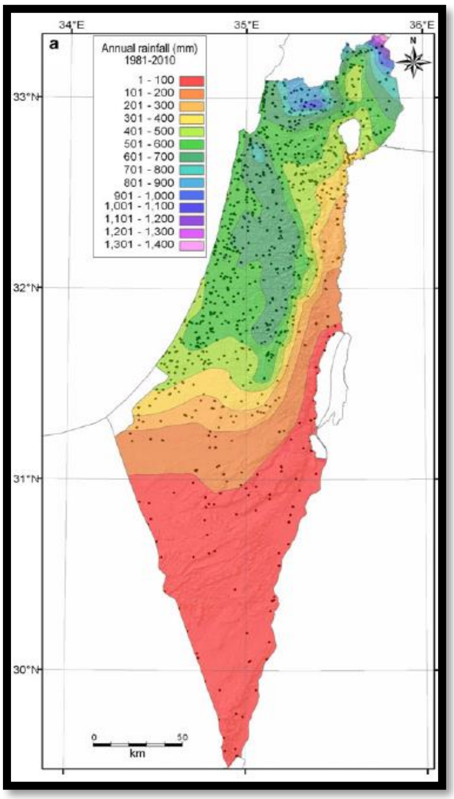

Figure 13: Average Annual Rainfall in Israel
Source: (Ziv *et al.* 2013)

The main freshwater resources in Israel are The Sea of Galilee, located in the northern west part of the country, the coastal aquifer, located along the coastal plain of the Mediterranean, the mountain aquifer, located under the central north to south mountain range, and additional regional springs scattered throughout the country (Fig. 14) (Israel Ministry of Foreign affairs 2013).

In addition to the natural freshwater resources, Israel is also heavily reliant on artificial water sources, mainly seawater desalination and treated wastewater (Avgar 2018).

Figure 14: Israel's Freshwater Resources Source: (Friends of the Earth Middle East 2005)

Seawater desalination is a significant source of water for the Israeli water sector. Israel has five main seawater desalination facilities located along the Mediterranean shore (Ashkelon, Palmahim, Hadera, Sorek, and Ashdod), which produce high quality freshwater. In 2016 these facilities produced 604 MCM, and are expected to produce 750 MCM by the end of 2020 (Avgar 2018).

Treated wastewater is an important source of water for agriculture in Israel. 93% of sewage produced in Israel is treated to some level (primary, secondary or tertiary) in facilities adjacent to the cities. 87% of the treated wastewater is used for irrigation, making Israel one of the top wastewater reclaimers in the world (Avgar 2018). The following table summarizes

Israel's water resources including the artificial sources. Note that these numbers change yearly and therefore the estimated total does not equal to the adding up of all these numbers.

Table 1: A Summary of Israel's freshwater Resources

Freshwater Resources	**Replenishable Quantities (MCM)**
The Sea of Galilee	700
The Coastal Aquifer	320
The Mountain Aquifer	370
Additional Regional Resources	410
Desalination	660, (750 by 2020)
Recycled wastewater	530
Total	¬2663

Source of information: (Avgar 2018; Israel Water Authority 2020)

4.2 Threats to Water Security

4.2.1 Environmental Threats

Water Scarcity

Due to its semi-arid climate and low rainfall, Israel has always struggled with freshwater resources (Feitelson 2013). According to Marin (2017) "Israel is one of the most water-scarce countries in the world." Israel's natural freshwater resources provide approx. 150 m^3 per capita annually, and when artificial sources are added, the number rises to approx. 310 m^3 per capita annually. According to these numbers, The Falkenmark Index (see chapter two) places Israel in the category of 'absolute water scarcity' (under 500 m^3 per capita annually), even with the added artificial sources.

The IWMI index (see chapter two) places Israel in the category of 'physical water scarcity' which means that when all factors are considered including water demand, Israel is in a state of chronic water scarcity. It must be emphasized therefore that Israel's efforts to augment water supply did not lift the country out of water scarcity and are unlikely to do so in the future (Katz 2016). Avgar (2018) emphasizes this in a report published by the Knesset:

“In 2020, supply is expected to reach 2,663 MCM a year, which, when compared with the projected use, will result in a shortage of 9 MCM a year; in 2030, supply is expected to reach 2,715 MCM a year, which, when compared with the projected use, will result in a shortage of 50 MCM a year; and in 2050, supply is expected to reach 2,900 MCM a year, which, when compared with the projected use, will result in a shortage of 671 MCM a year. According to the plan, closing the gap between supply and demand requires supplements from artificial water resources (desalination of brackish water, seawater, and imports) of some 750 MCM a year in 2020, and twice that by 2050.”

This means Israel’s chronic water scarcity is not expected to be resolved anytime in the near future.

Climate Change

In 2014, the Israel Ministry of Environmental Protection (2014) stated that “Israel’s water sector is expected to be highly affected by climate change.” The IPCC report of 2007, foresees that the eastern Mediterranean will see a downhill trend in precipitation, making the region significantly drier (Black 2009). The Israeli water authority predicts a 10% reduction in the country’s precipitation by the end of the 21st century (Israel Ministry of Environmental Protection 2020). Since the year 2000, changes in rainfall distribution have been observed, as well as a change in the volume and intensity of winter storms (Israel Ministry of Environmental Protection 2020). Distribution trends show a decrease in rainfall in the northern areas, and an increase in the southern areas of the country (Israel Ministry of Environmental Protection 2020). The northern Jordan river, which is the main source feeding the Sea of Galilee, is expected to see a 22% decrease in its flow in the coming decades, due to precipitation trends, which will be a significant threat

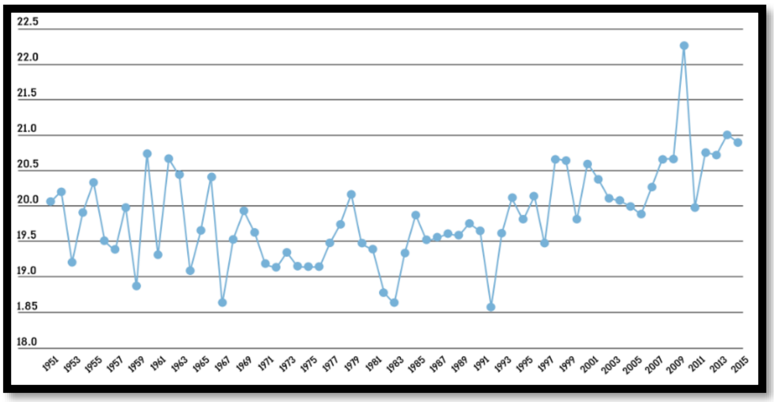

Figure 15: Average Annual Temperature 1951-2015 Source: (Israel Ministry of Environmental Protection 2017)

to the Sea of Galilee, Israel's only freshwater lake (Israel Ministry of Environmental Protection 2020).

Due to Climate Change, temperatures have been warming significantly throughout the entire country (Fig.15). Since the turn of the century, there has been an increase in heat waves that are at least six degrees above average temperatures, lasting for three consecutive days or more (Israel Ministry of Environmental Protection 2020). The warming is most noticeable along the coastal plain, the mountain regions, the northern desert, and the lowlands. Warming temperatures cause an increase in evaporation which will "cause an increase in the salinity of water, an increase in nutrient concentrations, and a decrease in water quality" (Israel Ministry of Environmental Protection 2020).

Hence, changing temperatures and reduced precipitation will reduce the availability of freshwater of good quality. This change is likely to result in further damage to freshwater habitats due to the human needs for water, and threaten food security, as crop yields and quality may be lower (Israel Ministry of Environmental Protection 2020).

Climate change induced sea level rising has been observed to be approx. 10mm per year on the Israeli coast (Fig. 16). This is a serious threat to the coastal aquifer, which may be infiltrated by saltwater, significantly harming the groundwater quality (Israel Ministry of Environmental Protection 2020). Katz (2016) mentions that "each 50 cm rise

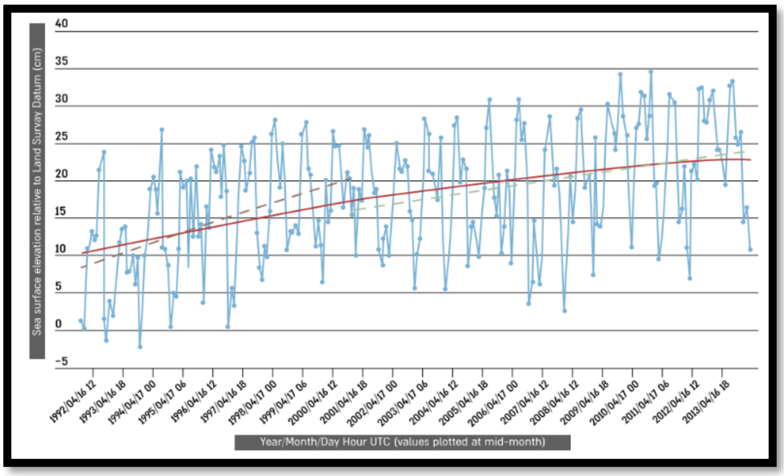

Figure 16: Sea Surface Elevation Relative to Land 1992-2013
Source: (Israel Ministry of Environmental Protection 2017)

in sea level would reduce the storage capacity of the coastal aquifer by 16.3 MCM per kilometer of coast."

There is also an expected increase in extreme weather events such as floods and droughts. The flood risk is mostly in cities, where the lack of exposed ground leaves the water with nowhere to be absorbed (Israel Ministry of Environmental Protection 2014). The drought threat is far more serious. The 2014-2018 drought has been attributed to climate change by several climate professionals (Mekorot 2018). The reduced rainfall led Israel into a rare drought that hadn't been experienced since the 1920's (Mekorot 2018). The shortage throughout those years came to approx. 2.5 billion cubic meters of water, which is equal to three years of consumption. According to Mekorot (2018) "There is consensus among climate professionals and scientists regarding the climate changes that different regions of the world are experiencing. In the Middle East, the drought phenomenon is intensifying with extreme dry conditions, and there is a danger of water sources drying up" suggesting that due to climate change, the intensity of droughts is only likely to worsen in the future, posing a great threat to water security in the region.

Water Pollution

Water pollution is a serious concern for Israel. According to Haran *et al.* (2002): " The deteriorating quality of the water poses a more immediate risk than the depletion of the volume of available water."

Surface Water Pollution

Israel has twelve rivers that flow west into the Mediterranean, and fifteen that flow east into the Jordan River and Sea of Galilee. However, due to Israel's climate, the flow in most of the rivers is very low and highly seasonal, resulting in most of the rivers running dry for most of the year. In the 1950's and 60's these rivers and river channels became dumping grounds for sewage and agricultural drainage causing them to be highly polluted. This human action caused all of Israel’s rivers to be polluted, (aside from the upper Jordan River that flows in the Sea of Galilee) aquatic life to be exterminated, and several groundwater sources to be contaminated. However, Israel has made it a goal to rehabilitate several of its rivers including all of the coastal rivers, and two of the rivers flowing into the Jordan. (Haran *et al.* 2002)

The Sea of Galilee is Israel’s only surface freshwater resource that is of drinking quality. Since the mid 1990’s, the lake’s water quality has been deteriorating. Levels of Cyanobacteria, Peridinium Algae, and Chlorophyll have been rising, causing the lake to have a greenish colour, due to agricultural discharge and over-pumping of the lake’s water. Deterioration of quality can also be attributed to the drying up of the Hula Pond which was a natural filter for the water entering the Sea of Galilee. Pumping of the lakes water has halted in recent years thanks to Israel’s desalination plants, and attempts are being made to restore the lake’s water quality and ecosystem (Israel Ministry of Environmental Protection 2017).

Groundwater Depletion and Salinization

Groundwater is an extremely important resource for the Israeli water supply, and it faces several contamination threats (Haran *et al.* 2002). Until the 1980’s, no precautions were taken to prevent contamination of the groundwater, allowing sewage, pesticides, industrial chemicals, oils and discharge from animal agriculture to seep into the groundwater (Israel Ministry of Environmental Protection 2017). Additionally, salt content (mainly of the coastal aquifer) has increased due to decades of over-

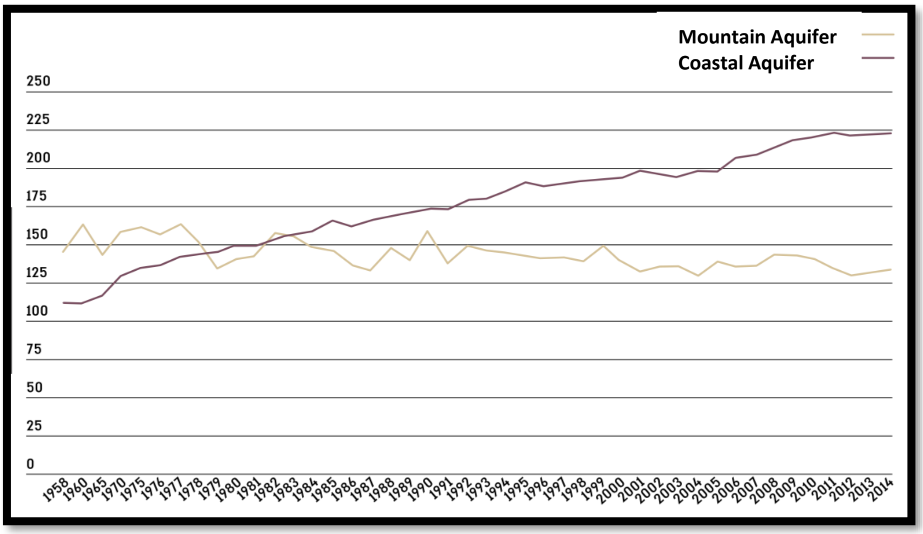

Figure 17: Chloride levels (mg/L) of Israel’s Aquifers 1958-2014
Source: (Israel Ministry of Environmental Protection 2017)

pumping and low rainfall. (Haran *et al.* 2002) This increase threatens the quality of drinking and irrigation water, in addition to harming soil and crops. The threat of salinization is largest for the Coastal Aquifer. This is due to the potential for seawater infiltration when the water table is lowered by groundwater pumping (Haran *et al.* 2002). The chloride content of the coastal aquifer is increasing at a rate of 2.3 mg/L per year (Fig. 17). The Mountain Aquifer is far less threatened due to its structure[4], and its distance from the sea. Additionally, several wells have been closed, with the leading cause being Nitrate pollution. Sources of Nitrate pollution are mainly fertilizers, untreated sewage, animal agriculture, solid waste and irrigating with treated wastewater (Israel Ministry of Environmental Protection 2017).

4.2.2 Socio-economic Threats

<u>Population Growth</u>

Israel is a small country, with a very fast-growing population. Today, Israel's population is just over nine million and continues to grow at a high growth rate of 1.9%, (The World Bank 2018). However, the struggle with a fast-growing population is not new to Israel and has been a challenge since the founding of the state due to large immigration waves. Following the deceleration of independence in 1948, Israel was very quickly faced with large waves of migration into the country. The first three years (1948-1951) saw the immigration of over one million people (from Muslim countries, Western countries and several holocaust survivors from Eastern Europe) (Jewish Virtual Library 2020). The 1960's and early 1970's saw additional immigration waves from Yemen, Iran and other Arab countries that the Jews were expelled from, keeping the growth rate high, until dropping in the 1980's (Jewish Virtual Library 2020). But the 1990's brought the largest peak in growth rate with the large Russian

[4] The Mountain Aquifer is comprised of several bodies of different sizes as a result of the geological structure (limestone and gypsum), while the coastal aquifer is one large connected body (in sandstone), making it more susceptible to contamination.

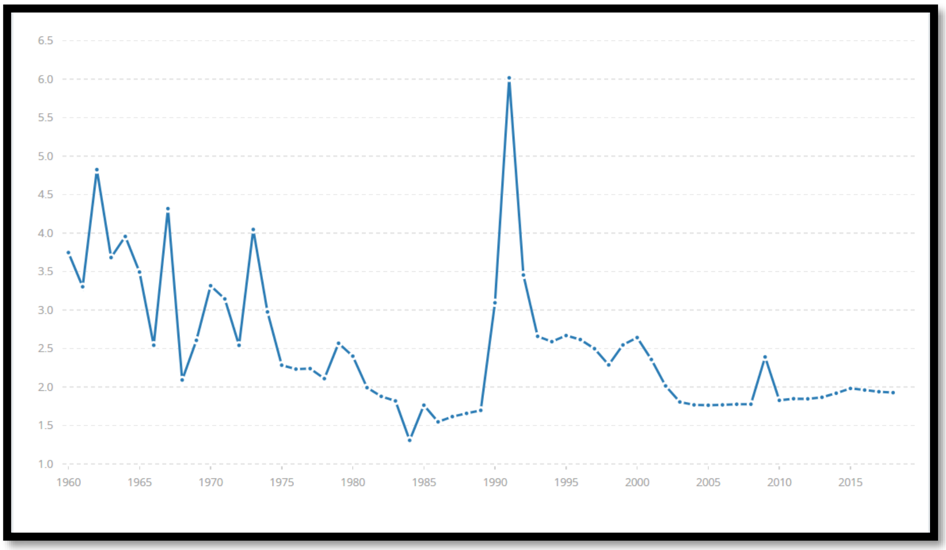

Figure 18: Annual Growth Rate in Israel 1960-2019
Source: (The World Bank 2018)

immigration after the collapse of the Soviet Union (Jewish Virtual Library 2020). Additional immigration in the 1990's from France, Latin America and North America, kept the growth rate high (Jewish Virtual Library 2020), but it eventually stabilized around 2% right after the turn of the century, and was down to 1.9% in 2018 (The World Bank 2018). Fig. 18 shows annual growth rates from 1960-2019. It is important to note that 2% is still a very high growth rate which can be attributed to the high birth rate, which is slightly over three children per woman. This is more than double the birth rate of most European countries (as can be seen in statistics from The World Bank 2018). Providing water and food for the constantly growing population was a huge challenge for the country's water security, and it was a heavily contributing factor to the eventual overexploitation of nearly all the country's natural water resources (Feitelson 2013).

<u>Water Losses</u>

Water is conveyed throughout the country via a national pipe grid, from point of extraction to the consumers. It has been observed that this type of water conveyance loses 10-12% of the water that enters the pipes. This is due to several causes, among them theft, leakages, and faulty metering. Identifying locations of pipe leakages and repairing pipes is a difficult and costly task that comes to $570 million per year (Israel Water Authority 2011).

Agriculture

From the very beginning of the country's founding, agriculture was highly valued in Israeli culture. It was important for producing food for the growing population, creating jobs and settling the land with a stable presence. But most importantly, the significance was emphasized by the ideologies of the Zionist movement which believed in the Jews resettling their homeland through working the land. (Feitelson 2013). But the use of water in agriculture was not being properly managed. The water sector was managed completely by the Ministry of Agriculture until 1996 (Marin 2017). This meant the decisions made about water were prioritized to match those of the agricultural sector, while protection of the water sources and ecosystems was completely ignored (Laster and Livney 2009). The importance of agriculture and agricultural settlements created the attitude in the early years of the state that all water resources must be used and developed, and the water must be conveyed to where it is needed for this purpose. This led to the state investing in large scale water supply projects, that resulted in all water resources being tapped by the 1960's and several being overexploited (Feitelson 2013). Water for agriculture was also heavily subsidized by the government and continues to be today, costing less than half the price per cubic meter (Israel Water Authority 2011). The threat to the natural water resources posed by agriculture was eventually mitigated by Israel's technological innovations, especially drip irrigation and the use of recycled wastewater as a primary source in agriculture (Feitelson 2013). Israel also encourages the use of effluents in agriculture by making the water a fraction of the price of potable water (Israel Water Authority 2011). Additionally, Israel replaced crops that used large amounts of water (e.g. cotton), with crops that could grow with less water (e.g. dates), and began to rely more on virtual water, through crops such as wheat that were imported (Feitelson 2013), which were all significant steps to reduce the water security threat posed by agriculture. Agriculture remains the top consumer of water among all sectors, but thanks to the use of treated effluent, the burden on the water resources has been significantly eased (Avgar 2018).

4.2.3 Political Threats

Transboundary Water Conflicts

Almost all of Israel's freshwater resources are transboundary, bordering with the Palestinian authority, Jordan, Syria and Lebanon (Katz 2016). Feitelson (2013) states that "Israel has been embroiled in some of the most widely discussed international water conflicts in the world." He suggests that the number of words written about the Israeli-Arab water conflicts, when weighed against the amount of said water, is higher than any other water conflict in the world.

Israel and Syria: the conflict over the Upper Jordan River and Sea of Galilee.

In 1967 Israel captured the Golan Heights, a mountain range that lies between Israel and Syria. Prior to the capture, Israel and Syria were fighting over the water resources that lied beneath the valley. Syria had attempted several projects to divert the Jordan river away from Israel, and Israel had been piping the water from the Sea of Galilee all the way to the Negev desert through the National Water Carrier. This conflict was essentially one of the triggers of the 1967 war. Israel has retained control over these water resources ever since, however, Israel and Syria are still at war, and the conflict over water is a threat to the water security and national security of both countries. (Baumgarten 2010)

Israel and Jordan: the conflict over The Jordan River Basin.

The Jordan River flows from the Sea of Galilee to the Dead Sea, and acts as a border between Israel and Jordan. There were several disputes between Israel and Jordan over the water usage after the founding of the state. In 1953, The United States attempted to mediate a negotiation (Referred to as The Johnston Allocations) between Israel, Jordan and Syria to settle the water distribution of the river between the countries. In this plan: “Israel was allocated 400 MCM per year, Jordan 720 MCM per year, and Syria 132 MCM per year.” The plan was accepted but was never ratified by Israeli or Arab sides. In the 1960’s both countries were trying to divert the water from the river in their favor, despite that said agreement. This was a trigger between Israel and Jordan for the 1967 war. In the war, Israel gained territory that included three headwaters of the Jordan river and access to the mountain aquifer. In 1994, a peace treaty was signed between Israel and Jordan that includes an entire chapter about shared water resources. In this treaty both parties recognize the other’s rights to the Jordan and Yarmouk rivers, and the Arava Groundwater, while agreeing on the amounts each country may pump in every season. They additionally agree to protect the quality of the water from pollution and contamination and share technological innovations with one another. This peace treaty remains a positive step towards the water security of both countries. (Baumgarten 2010)

Israel and the Palestinians: The Conflict over the Mountain Aquifer

The water conflict between the Israelis and Palestinians is mainly over the Mountain Aquifer, which lies under the West Bank, but also extends east into Jordan and West towards the Mediterranean. The Mountain Aquifer has three sub aquifers: The Western (362 MCM), Eastern (172 MCM) and North Eastern (145 MCM) aquifers. Israel utilizes most of the Western and North Easter aquifers, while the Palestinians use the remaining amounts. The Eastern aquifer has almost 100 MCM that have not been utilized. The Palestinians argue their right to utilize the aquifer freely and drill wells as needed, which is mostly refused by Israel. There is a lot of international pressure on Israel to provide the Palestinians with the additional water they need (70-80 MCM). According to the Oslo B agreement (1995), Israel will supply additional water to the Palestinians from the Eastern and North Eastern aquifers (Feitelson 2013). However newer evidence suggests that Israel will provide the Palestinians with desalinated water from a new plant that will be piped directly to the west bank (Baumgarten

2010). The situation continues to be extremely complicated as agreements fail to be settled between the two sides who remain in conflict over the land (and water).

As Israel relies more and more on desalinated water, these conflicts become less of a threat to the country’s water security.

Unrecognized Settlements

The Israeli water law rules that water will be provided only to houses that obtain legal building permits. Several settlements of Bedouins[5] exist in the Negev desert, but are considered illegal under Israeli law. Because these settlements are not legal, water or water infrastructure is not provided by the government. The Bedouins must therefore acquire water by purchasing water from a so called ‘water center’ which provides water to a legal settlement (which may be several kilometers away) or get permission to create private water access points, usually from a roadside pipe, which may also be several kilometers from their home. They must then get the water from these points to their homes, which is often led through low quality pipes, significantly reducing the water quality. The Bedouins sued the government for the right to water access, in a famous case *Abu Massad* which reached the supreme court. The court ruled that the Bedouins must receive access to water according to Israeli and International laws, despite their unrecognized living conditions. However, the court also recognized the state’s rights to enforce its laws and planned development. This resulted in a complex situation where although recognized as a right, the implementation options remain small, and the situation remains mostly unchanged, leaving a minority group struggling daily for sufficient water access (Murthy *et al.* 2013).

[5] An indigenous group made up of several Arab tribes who live a nomadic lifestyle in the Israeli Negev Desert.

4.3 Steps Towards Water Security

4.3.1 Water Laws

Israel inherited the core of its water law from the Ottoman Empire and the British mandate, which had previously ruled in Israel (Laster and Livney 2009). The *Mejelle* (the civil code of the ottoman empire) declared water as a free good that is owned by the public and cannot be privately acquired. The 1922 British Mandate declared water as a government-controlled resource, with the Water Commissioner having the power to allow or restrict water use. This legal inheritance allowed the State of Israel, established in 1948, to "set water policy without the encumbrance of private rights in water" (Laster and Livney 2009). There were four main legislations made after the founding of the state, following the path of its heritage, which shaped the governance of water in Israel.

1. **The 1955 Water Measuring Law** – rules that water may not be distributed without being metered, and amounts must be reported monthly to the water commission (Laster and Livney 2009).
2. **The 1955 Water Drilling Control Law** – declares that government permits are needed for drilling wells, and license may be refused by the water commissioner if groundwater or household consumption is threatened (Laster and Livney 2009).
3. **The 1957 Drainage and Flood Control Law** – creates national and regional drainage boards. This law appoints the ministry of agriculture to approve regional drainage plans, local and national government representatives to ensure proper drainage, and the water commissioner and minister of agriculture to declare protective zones around water resources (Laster and Livney 2009).
4. The most important is the **1959 Water Law**, considered to be the "most comprehensive legal arrangement for the Israeli water sector" (Avgar 2018). This law nationalizes the country's water and rules that the state's water resources are "state-run public

property" meaning there is no private ownership of the water resources, which are meant for the use of Israel's citizens and the country's development (Avgar 2018). The law also established the framework for the country's water governance; the Water Commission, inside the Ministry of Agriculture was the government appointed body to govern the system, with the Water Commissioner in charge of managing it (Feitleson 2013). The law rules that "all decision-making and management of the water supply in the State of Israel is accomplished at the national level" (Israel Water Authority 2011).

Over the years, a number of important amendments were made to the water law:

In 1971, following the US's clean water act, the water law was amended to include water pollution. The amendment defines water pollution and the water polluter and appoints the minister of agriculture (and later the minister of environment) to take action in preventing water pollution. The amendment however failed to deal with the sewage disposal of local authorities, leaving several issues unresolved (Laster and Livney 2009)

In 2004, the law was amended to recognize nature as a legitimate consumer of water (Laster and Livney 2009) However this amendment also failed to mention important issues such as habitat protection and biodiversity or define the criteria for environmental flows.

Later legislation modified the water governance structure to be more fragmented. The 2001 Water and Sewage Companies Act Law required local authorities to appoint or create a municipal or private company to operate their water system. In 2005, following the state comptroller's criticism that the drainage authorities failed to properly manage streams and flood plains, the government created 26 local drainage authorities in charge of 11 catchment basins. Different responsibilities were also handed over to different ministries over the years such as control of drinking water quality to the Ministry of Health, pollution control to the Ministry of Environmental Protection and drainage and flood control to the Ministry of

Agriculture. In fact the system became so fragmented over time, that in 2006-2008 the government attempted to reunite it, eventually creating the Water Authority, which holds similar responsibilities to the original Water Commission (Laster and Livney 2009).

4.3.2 Main Governing Bodies

The Governmental Authority for Water and Sewage (The Water Authority), founded in 2007, is the state's main authority for water and sewage services. The Water Authority was created in order to bring together all responsibilities of the water sector that had been previously scattered between several entities. This body was entrusted with "efficient and professional management, regularization, and supervision of the Israeli water sector." (Avgar 2018) Responsibilities include: "regulating, managing, operating and developing the water sector; preserving and rehabilitating natural water resources; developing new water resources and setting prices for the various sectors; setting standards for services the water corporations are required to provide; ensuring the corporations' conduct meets said standards; setting rules for calculating the cost of services offered by the corporations; and setting rules that govern payments and fees." (Avgar 2018) The Water Authority is overseen by the Ministry of Infrastructure (Laster and Livney 2009).

The Water Authority Council forum is a board responsible for all policy making made by the water authority. The council is made up of eight members who are leading representatives from the ministries of Infrastructure, Environmental Protection, Finance, Interior, Health, the Water Authority, and two public interest representatives. This council works together with the water authority to make the best policies for the Israeli water sector. (Israel Water Authority 2011)

Mekorot Israel National Water Company Co. (Mekorot) is a government owned infrastructure company, defined as the national water company under the water law. Mekorot has a monopoly on water transportation and supply, making them the provider of most of the water consumed in Israel. Mekorot's main operation is producing or acquiring freshwater and transporting it to the pipelines. The company also takes part in seawater desalination, wastewater treatment and brackish water supply (Avgar 2018).

Water Corporations. Until 2001, the local authorities provided water and sewage services. The Water and Sewage Companies Act law of 2001resulted in the creation of 55 water and sewage corporations, which serve 155 local authorities, accounting for 94% of Israeli citizens. The Water Authority sees the shift to water corporations as a huge success for the water sector, resulting in better infrastructure, less water losses, and increased investment in water recycling facilities. The corporations are overseen by the water authority, and plans are in place to merge the corporations into just 15 or 11 bodies, for financial and efficiency reasons (Avgar 2018).

The Ministry of Agriculture is in charge of water usage in agriculture, drainage, runoff and soil conservation (Laster and Livney 2009).

The Ministry of Environmental Protection is responsible for the state of the water in nature, the quality and quantity of water in the streams, groundwater and floodwater (Laster and Livney 2009).

4.3.3 Water Policies and Management Strategies

The main elements that shape Israel's water policy and management strategies are as follows:

<u>Strong Demand Management</u>

Israel began using demand management in the 1990's when the government realized it was in desperate need to reduce water consumption to avoid a severe water crisis (Feitelson 2013). These efforts have successfully reduced per capita water consumption to 90 cubic meters annually (Fig. 19) (Marin 2017). Several policies were implemented to reduce domestic consumption:

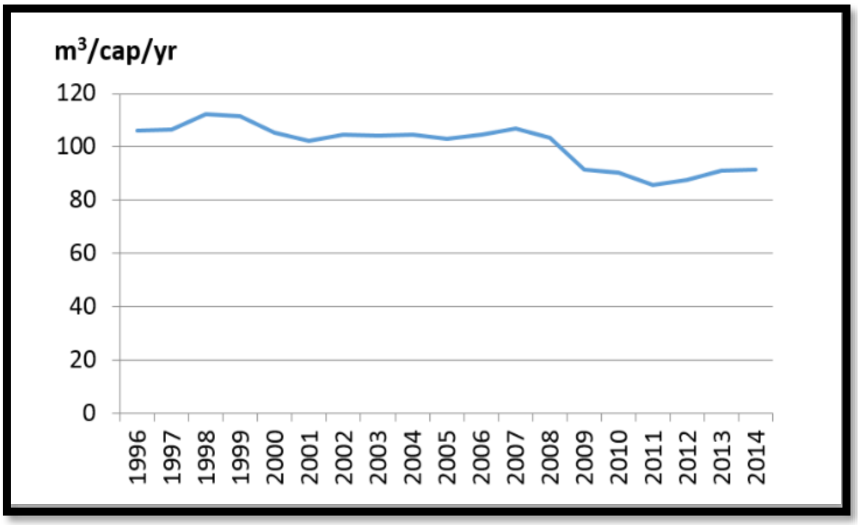

Figure 19: Domestic Per Capita Consumption 1996-2014
Source: (Katz 2016)

1. **Water pressure and conservation devices** - from 2009, water pressure in municipal taps was reduced, lowering consumption by more than 5%. This was especially effective in the mountain regions where water pressure in the pipes is very high Additionally, water conservation devices were installed on household taps, to further reduce consumption (Israel Water Authority 2011).

2. **Water pricing** – firstly, the price of water in the domestic sector *is equal to the cost of production and conveyance*, meaning there are no subsidies. Second, consumers pay according to the volume of their consumption, while heavier consumers pay more than lighter consumers. Consumption of over 2.5 m^3 a month means paying approx. $3 per cubic meter instead of $2 (Israel Water Authority 2011). Third, from 2010, a 40% increase was made in water tariffs (which was actually to pay for the new desalination facilities but ended up reducing water consumption as well).

3. **Conservation campaigns** – In order to encourage individuals to reduce their water consumption, multi-media water conservation campaigns were conducted. These campaigns warned the public of a coming water crisis and requested they reduce their water consumption. In addition to their success, these campaigns were also found to be extremely

cost efficient. In 2009, the state invested $7.5 million but managed to reduce consumption by 10% (!) this made the cost effectiveness of the campaign $0.10 per m^3 of water (considered to be extremely high cost efficiency) (Israel Water Authority 2011). It was also found that the conservation mentality of the citizens was effective beyond the running of the campaign, with water consumption remaining at the low level even months after it was terminated (Israel Water Authority 2011).

4. **Metering instalments for municipal garden watering** – This policy required consumers to report how much garden space they were watering, and what type of garden it was, trees and bushes, flowers, or grass. This was enforced very strictly, to the point of shutting off garden water supply to municipalities who failed to fill out the reports. After collecting the information on garden surface area per garden type, the country established a quota of 20 MCM annually for this purpose. The garden water in previous years was estimated at 45 MCM, meaning they cut the usage in half (Israel Water Authority 2011).

5. Another strategy was the installation of tap systems in public places that require continuous pressure to keep the water flowing, to reduce water losses in parks, public bathrooms and other public places (Israel Water Authority 2011).

In addition to the domestic sector, water conservation is encouraged in the industrial sector and water conveyance system:

Reducing losses in water conveyance – In order to minimize losses in conveyance which were found to be around 12%, the state started charging companies for conveyance losses above 8%. Additionally, they allowed the reduction of pipe pressure to 3 or 3.5 atm which reduced leakages by more than 5% (Israel Water Authority 2011).

Industrial Sector – The industrial sector uses roughly 120 MCM annually. In order to reduce consumption, the industrial sector was given strictly limited quotas for water use by the government. Additionally, like in the domestic sector, the price of water in the industrial sector is equal to the cost of production and conveyance (no subsidies) (Israel Water Authority 2011).

Using Treated Wastewater for Irrigation:

Israel treats 95% of its wastewater, and 84% is reclaimed for irrigation. The policy for effluent reuse was established in 1990, and by 1993, 25% of the water for irrigation was coming from effluents and 38% in 2011 (Fig. 20). Israel made several policies to encourage the use of effluents and brackish water in agriculture. Firstly, the tariffs for reclaimed wastewater are half the price of potable water ($0.26/ $0.28 compared to $0.44 per m³). Second, the amounts of potable water per farmer are restricted. There is also a reward system in place, allowing the farmer to receive for free an amount of reclaimed wastewater equal to the amount of potable water not utilized in his quota. The state is also willing to provide up to 60% of the cost for installing pipes that convey brackish or effluent water to the necessary locations for the farmers. Thirdly, the government invests in research and technological development in order to increase irrigation efficiency and educates the farmers on these new technologies for free. (Israel Water Authority 2011)

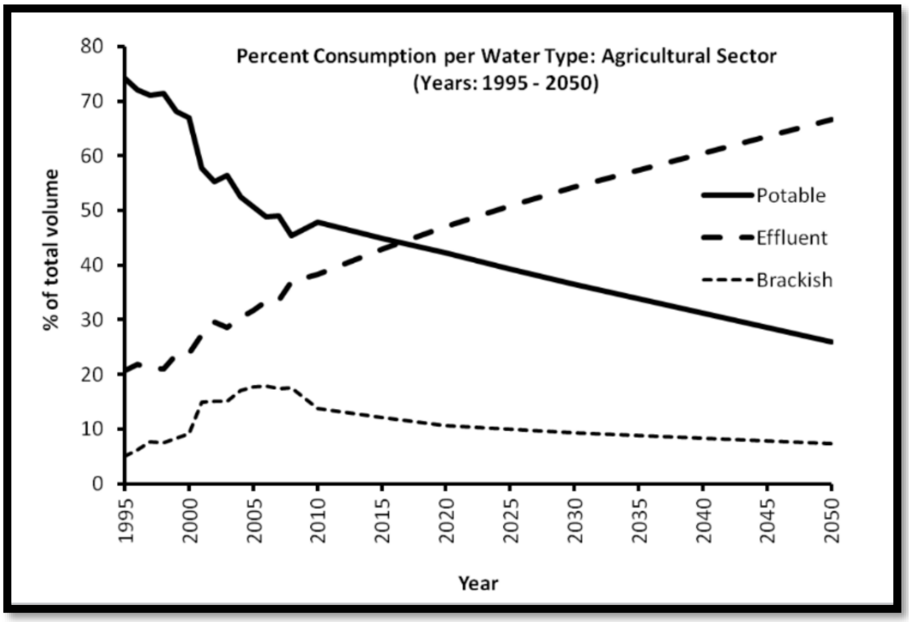

Figure 20: Percentage of Consumption per Water Type in Agriculture (1995-2050)
Source: (Israel Water Authority 2011)

Israel plans to maximize quantity and quality of effluents by upgrading all of its treatment facilities to tertiary level treatment by the end of 2020 in addition to constructing new facilities. The state also plans to make the process more cost efficient and reduce the costs to $0.23/m^3 which is expected to increase the demand for effluent water while reducing demand for potable water (Israel Water Authority 2011).

The industrial sector also utilizes reclaimed wastewater which together with brackish water accounts for 30% of consumption in the sector. This is mainly due to lower tariff ($0.3/m^3 compared to $1.3/m^3). The government also offers industries grants for internal wastewater treatment plants (Israel Water Authority 2011).

Supply Augmentation via Large-Scale Seawater Desalination.

Israel began large-scale seawater desalination in 2005, following the realization that the state's chronic water scarcity would remain unresolved without a source of supply augmentation. The goal was to supply most of the municipal water demands with desalinated water, in order to ensure the state's water security. Over the course of a decade, five largescale

Project	Year of operation	O&M duration	Concessionaires	Business model	Price per m³ (US$)	Production capacity (million m³)	Estimated capex (US$ billion)
Ashkelon	2005	25 years	IDE (50%) Oaktree (50%)	BOT	0.78	119	0.27
Palmachim	2007	25 years	Derech HaYam (100%)	BOO	0.86	90	0.16
Hadera	2010	25 years	IDE (50%), Shikun U'Binui (50%)	BOT	0.72	127	0.43
Sorek	2013	25 years	IDE (50%), Veolia (50%)	BOT	0.54	150	0.41–0.54
Ashdod	2016	25 years	Mekorot (100%)	BOT	0.65	100	0.41–0.54

Figure 21: Major Seawater Desalination Plants in Israel
Source: (Marin 2017)

desalination plants, using reverse osmosis technology, were built along the coast of the Mediterranean, with a total capacity of 585 MCM annually (Fig. 21). Desalinated water now accounts for 85% of the urban water supply and 40% of the country's total supply (Marin 2017).

It is important to note that Israel's desalination plants are among the most energy efficient and cost efficient in the world (Marin 2017). This is due to several factors. Firstly, the plants use natural gas instead of coal, making the energy cheaper, and use technologies that reuse energy in the desalination process. Second, the plants were built through build-operate-transfer (BOT) or build-operate-own schemes (BOO), which divide the financial risk between the government and private sector. In these schemes, the private companies finance the entire investment, and are responsible for operation of the plant for 25 years, after which the plants are transferred to the government. During the time of operation, the companies have full responsibility for financial overrun, giving them incentive to minimize the costs and maximize efficiency as much as possible. This allowed the cost of the desalinated water to be relatively low (see Fig. 22). Thirdly, the existence of national infrastructure allowed a small number of large plants to be constructed, making the operation and maintenance cost cheaper (since it is cheaper to run larger plants). several other technological, mechanical, architectural,

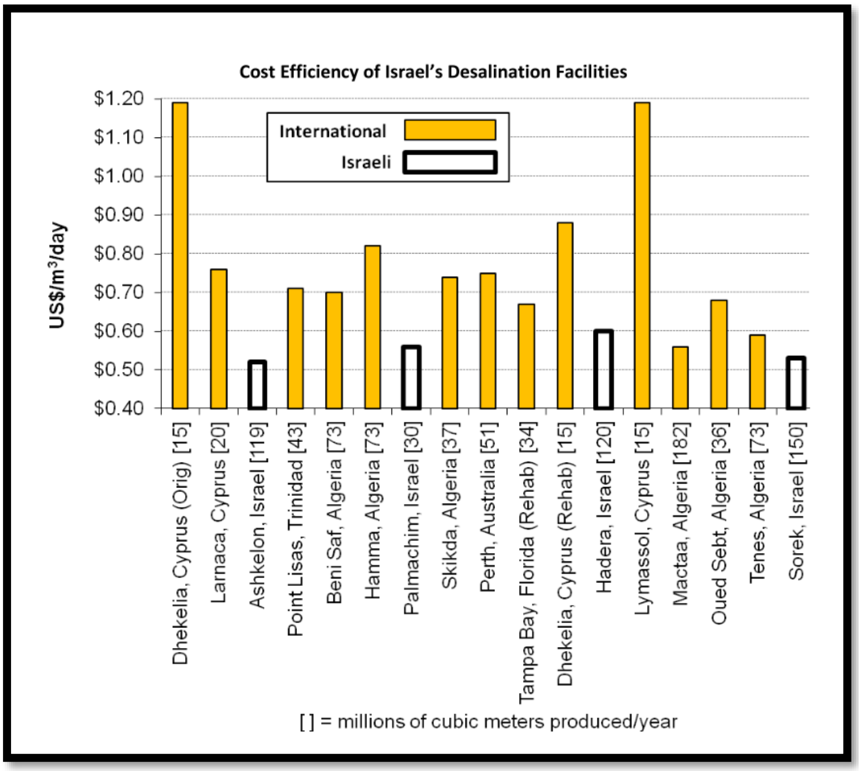

Figure 22: The Cost Efficiency of Israel's Desalination Facilities
Source: (Israel Water Authority 2011)

and managerial factors. Additionally, water tariffs are raised with the completion of each desalination plant which is expected to cause a reduce in water demand (Israel Water Authority 2011).

The Construction of a National Conveyance Infrastructure

In 1964, Israel completed its first piece of national conveyance infrastructure – the national water carrier (NWC). The NWC is essentially a giant pipeline that was built to bring water from the Sea of Galilee, to the center and desert areas of the country where it was needed for domestic and agricultural use. It also integrates groundwater, other surface water and desalinated water. Additional infrastructure was added after the NWC, built mainly by Mekorot that include 3,000 installations that come up to 12,000 kilometers of pipelines, controlled by ten command centers throughout the state. This system is now connected to all five of Israel's desalination plants. This system has the advantage of enabling the state to control which water source is being used. In wetter winters, more natural water can be integrated, and in dry periods, more desalinated water, as needed. The biggest advantage though is having water easily connected to areas where it is naturally scarce, such as populated areas of the Negev desert, overcoming a climatic limitation of settling the land. (Marin 2017)

Using Aquifers as Reservoirs

In the first few decades after the founding of the state, the aquifers came to be extremely overexploited. However, the state's innovation to use aquifers as storage reservoirs has changed the condition of several of the aquifers. The aquifers now serve as buffers – during dry years more water can be pumped from them into the NWC, and during water can be pumped into them. The water being pumped in is desalinated water and tertiary level treated reclaimed wastewater. Storing water in the aquifers also reduces evaporation**.** (Marin 2017).

Technological Innovation

Israel has invented and used several innovative technologies that have made an impact not only on the country's water management but also on a global water management practices. Examples of these technologies are, drip irrigation (an irrigation system set up to maximize water efficiency, where drops of water are fed directly to the roots of the plants) micro sprinklers (sprinklers that release micro amounts of water to keep plants moist), ultra-small drip irrigation with computerized control systems (basically drip irrigation and micro sprinklers controlled by computers), crop strains that require minimal water supplies/ thrive on brackish water (such as dates), tertiary wastewater treatment such as the aquifer recharge method (a type of tertiary wastewater treatment where secondary level treated effluent is naturally filtrated by being pumped into the aquifer) and more. Israel has also provided support to farmers in adopting the more efficient technologies by teaching them how to use them (Marin 2017).

Marin (2017) also notes that "Israel has made a special effort to promote innovations in the water sector, with the establishment of a unique industry–utility–university ecosystem to support the development of innovative water technologies." It is not by chance that Israel's water sector has managed to be so innovative; the country has set up an environment that allows and supports forward thinking technologies to be invented, tested and brought into use.

4.4 Case Summary

Israel is an extremely water scarce country. With its Mediterranean climate only bringing a few rainy months every year, and its vast desert area, the country has very limited freshwater resources. For this reason, Israel has come to rely on artificial water sources such as desalinated seawater and treated wastewater in addition to natural water resources. In addition to its natural water scarcity the country has faced, and still faces several threats to its water security over time. In the past, the fast-growing population fed by large waves of immigration, using large amounts of water for agriculture and transboundary water conflicts with Israel's neighbours, led the country to overexploit and pollute all of its natural water resources. Many of these issues were solved later on by implementing strict demand management policies, investing in supply augmentation and water efficiency technologies, and using treated wastewater for irrigation. Today, with the threats of climate change reducing precipitation, increasing temperatures and making droughts more frequent, along with the very fast-growing population and still ongoing political conflicts, Israel still faces threats to its water security. However, thanks to its solid water governance and sound water management practices Israel is said to have achieved water security despite its severe scarcity.

5. Water Security in Cape Town

5.1 Climate and Freshwater Resources

Figure 23: Cape Town Metropolitan Municipality
Source: (Nhamo and Aygepong 2019)

The City of Cape Town metropolitan municipality or City of Cape Town (CoCT) (Fig. 23), named as the legislative capital of South Africa (SA), and the capital of the Western Cape Province, was founded in 1913. Prior to 1997, Cape Town had 25 separate municipalities that were first merged into six, and finally in the year 2000 they were merged into one metropolitan municipality (Enqvist and Ziervogel 2019). The CoCT is located between 33.9° South and 18.4° East, which is on SA's Southwest coast, on a peninsula[6] that lies beneath a unique flat-topped mountain called 'Table Mountain'. CoCT is the most Southern city on the African continent and is also located at the point where the warm Indian ocean meets the cold Atlantic. The municipal area of CoCT is about 2,500 SQKM in size, with over 300 km of coastline, and approx. four million residents (Dippenaar 2016).

SA has multiple climate zones (Fig. 24). The CoCT's climate is shaped by two main atmospheric systems. In the winter, mid-latitude cyclones come from the west, which bring rain, winds and cooler temperatures. In the summer, the city is dominated by the South Atlantic

[6] A peninsula is "a piece of land specifically bordered by water on three sides but remaining connected to the mainland." (Dippenaar 2016)

high-pressure system, which brings warmer and drier weather. The trade-off between these two systems creates a Mediterranean like climate (Fig. 24), with hot and dry summers, and cold and wet winters (Tadross *et al.* 2012).

The rainy season is generally May through August (winter in the Southern hemisphere). Rainfall amounts vary highly based on topography, while in the valleys and coastal plains the average is about 500mm/year and on the mountains, it can reach 1500mm/year (City of Cape Town 2013).

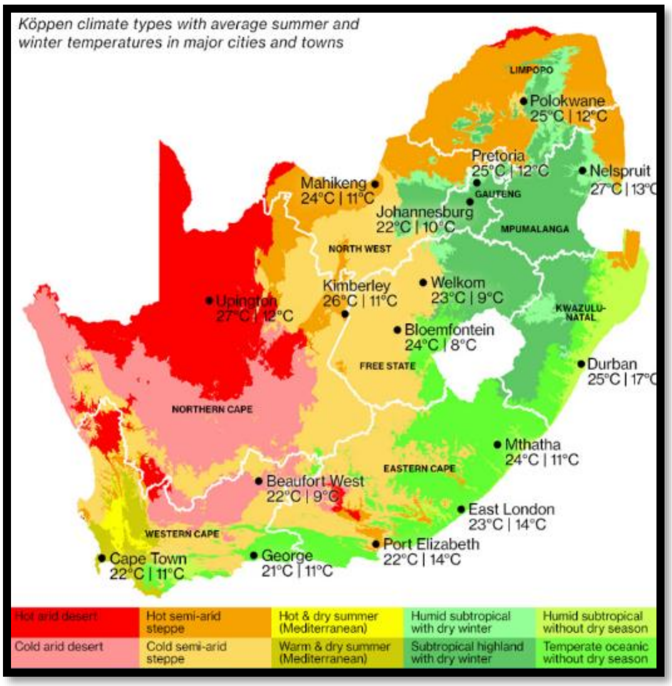

Figure 24: South Africa's Climate Zones
Source: (South Africa Gateway 2018)

The main freshwater resources for CoCT are river basins, aquifers and wetlands. The peninsula has four main river basins that provide surface drainage towards the ocean: Peninsula, Eastern Pluton, Diep and Cape Flats. The rivers create several wetlands on their way to the ocean due to sediment build up (Dippenaar 2016). The main aquifers are the Table Mountain Group aquifer, the Cape Flats aquifer, and the Atlantis aquifer. While groundwater plays an important role in the CoCT's water supply, it only provides 1.5% of CoCT's water, on a very localized level (Luker and Harris 2019). The main water source feeding the municipal supply is surface water stored in dams (Dippenaar 2016). Since 1850, the city's water supply came from several dams and reservoirs that were constructed to store runoff and rainfall (City of Cape Town 2018). Most of the dams are actually located outside of the municipal areas (Fig. 25). These dams are part of the Western Cape Water Supply System (WCWSS), which is managed by the national Department of water and sanitation (DWS) in collaboration with the municipalities (City of Cape Town 2018). Water levels in these dams are especially critical in the dry summer months, and in years of drought. The city's dams have a capacity of approx. 900 MCM annually (City of Cape Town 2018).

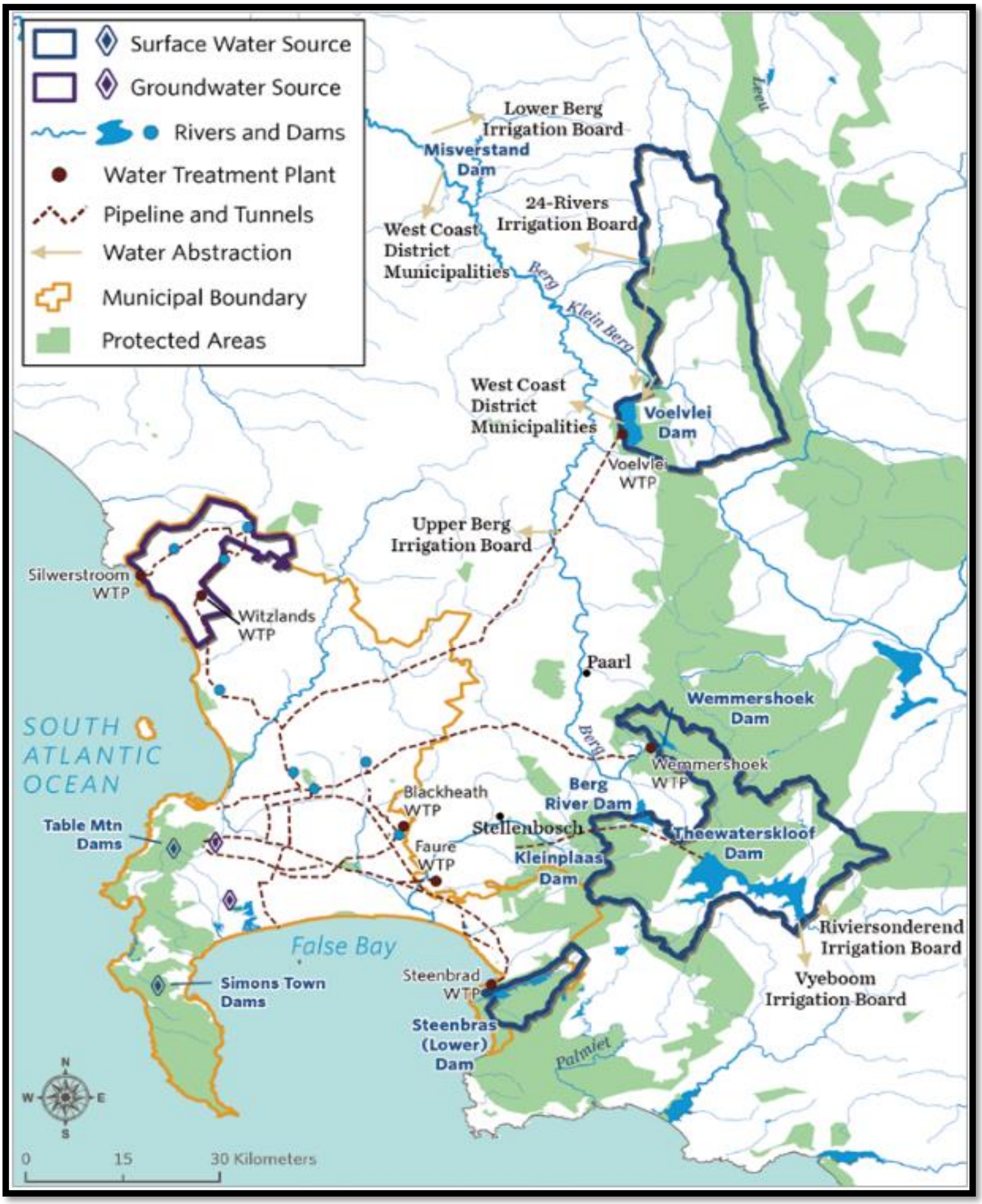

Figure 25: The Western Cape Water Supply System
Source: (The Nature Conservancy 2018)

5.2 Threats to Water Security

5.2.1 Environmental Threats

Water Scarcity

South Africa, on the national level, is a water scarce country. According to The World Bank, SA has 821 m^3 per capita annually, a value which has been declining every year (The World Bank 2020). This number places SA in the category of ‘water scarcity’ according to Falkenmark (see chapter 2.1.3). CoCT is no exception to the water scarce nature of the country. According to a report by the City of Cape Town (2007), “The limited nature of the available water resources and the shortage of raw water storage capacity have markedly increased the risk of water shortages occurring in the Cape Metropolitan Area from the year 2001 onwards.” Additionally, stated by Mukheibir and Ziervogel (2007): “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*.” With four million residents and approx. 2,500 MCM of total freshwater (including surface and groundwater) CoCT has 625 m^3 per capita annually in total (Department of Water and Sanitation 2018). However, CoCT’s water supply relies primarily on surface water stored in dams (Dippenaar 2016) which contain approx. 900 MCM (Department of Water and Sanitation 2018). In this case, the city has approx. 225 m^3 per capita annually, placing it in the category of ‘absolute water scarcity’ according to Falkenmark.

The fact that the city has potential untapped water may indicate economic water scarcity according to the IWMI indicator (see chapter 2.1.3). Most of Africa is placed in this category due to lack of proper infrastructure. However, this indicator places SA in the category of ‘approaching physical water scarcity’, which indicates a true lack of water resources unrelated to economic struggles.

Climate Change

Climate change is a significant concern for South Africa. On the country level, extreme rainfall events have become more frequent, especially in the coastal areas, and temperatures have increased by at least 1.5 times more than the global average of 0.65℃. Warming is expected to reach between 3-6℃ by the end of the 21^{st} century, and precipitation patterns are becoming more and more uncertain. Additionally, floods and droughts are expected to further increase in frequency in the coming decades. These changes in the climate are a major concern for the South African water sector. (Ziervogel et al. 2014)

As for the Western Cape, the climate models predict a decrease in rainfall, which is likely to cause an approximate 15% decline in runoff, resulting in a loss of at least 60 MCM annually by 2050 (Department of Water and Sanitation 2018). The decline in precipitation seems to be caused by changes in the atmospheric circulation. The low-pressure systems that come in the early winter are decreasing in frequency, and the high-pressure systems that come in late winter/ springtime seem to be increasing. The low-pressure systems are associated with the winter rains, and their decline means lower rainfall. The high-pressure systems brings hot and dry winds, which further decrease the chance of rainfall, and increase the chances of wildfires (City of Cape Town 2006).

Temperatures in the Western Cape also seem to be increasing, in addition to the frequency of intense heat waves (City of Cape Town 2018a). The very warm days seem to be getting warmer, and the minimum and maximum temperatures seem to be rising (City of Cape Town 2006). The intensity of the storms is also increasing, bringing short periods of extreme rainfall. (City of Cape Town 2018a). These storms along with Sea levels rising increase the frequency and intensity of floods. Rising sea levels also risk the intrusion of salt water into the aquifers (Dippenaar 2016).

However, one of the biggest threats to the Western Cape's water sector is the increasing frequency and intensity of droughts. The 2015-2018 drought, which brought significant threat to the regions water security, is likely to have been caused by climate change (as well as an El Nino event). According to Enqvist and Ziervogel (2019), "climate change is estimated to have tripled the likelihood for the drought to occur." Mukheibir and Ziervogel (2007) found that in the decades prior to their research, South Africa had experienced several climate change induced droughts, most lasting one or two years. But the 2015-2018 drought was a drought as rare as once in 400 years (City of Cape Town 2006).

Water Pollution

In 1989, Thornton *et al.* stated that "Water scientists and engineers have long maintained that water pollution is a major problem facing South Africa" (Thornton *et al.* 1989). Almost all of SA's surface water was found to be inadequate for human consumption without undergoing proper treatment. (Musingafi and Tom 2014). The main sources of water pollution in SA are untreated or poorly treated sewage, acid mine drainage, industrial processes, agricultural runoff contaminated with pesticides, and inadequate sanitation in informal settlements (Colvin *et al*. 2016).

Acid mine drainage is especially an issue of concern. SA has "the world's largest reserves of platinum-group metal ores including manganese, chromium, vanadium, gold and alumino-silicates" (Musingafi and Tom 2014). Mining processes discharge contaminated water (referred to as acid mine drainage) that, if not properly managed, is later discharged into surface and groundwater, soils and other aquatic habitats. Several water borne diseases such as cholera, diarrhea and dysentery are found to be transmitted in SA due to such contamination (Musingafi and Tom 2014).

Several South African rivers have been found to be threatened by fecal contamination, including the Plankenberg and Eersre rivers of the Western Cape. Both of these rivers provide water for irrigation of fresh produce in the region. A study conducted by Britz et al. (2013) indicated high levels of microbial pollution in these rivers, finding a high presence of *E. coli* and other pathogens which indicated fecal pollution. This indicated that the water from these rivers in not suitable for irrigation according to WHO guidelines.

Additionally, the urban water supply of CoCT faces several contamination threats such as bacterial contamination from improperly treated wastewater, raw sewage spillage into the water resources, unlawful disposal of industrial waste into the storm water pipes or natural water resources, agricultural runoff contaminated with fertilizers and animal waste, illegal waste dumping into waters and destruction of wetlands that provide natural filtration for the water (City of Cape Town 2018a). Fig. 26 shows cape town's rivers and their levels of compliance with the DWS guidelines for water quality. only four rivers are above the 80% line which was set as a goal for the city.

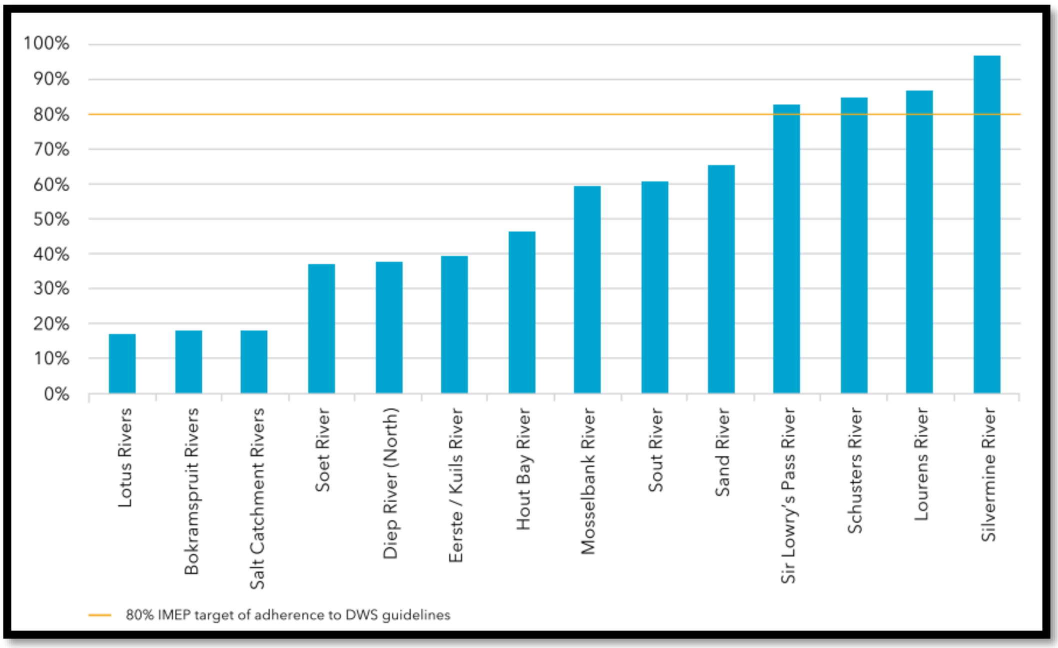

Figure 26: Percentage of Compliance with DWS Water Quality Standards
Source: (City of Cape Town 2018a)

Fig. 27 displays levels of trophic tendency in Cape Town’s rivers. The higher levels indicate poor ecosystem health, while the lower levels are a sign of good ecosystem health. Most of Cape Town’s rivers, as can be seen in the graph are in a poor state of ecosystem health which has impacts on water quality, plants, and biodiversity. According to The Nature

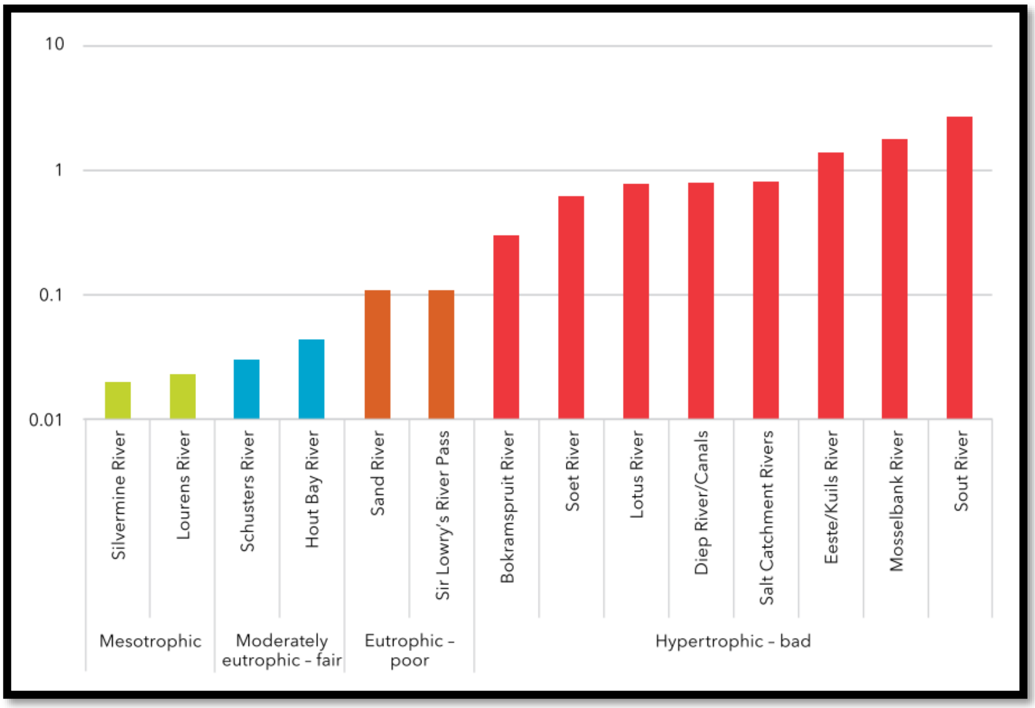

Figure 27: Levels of Trophic Tendency in Cape Town’s Rivers
Source: (City of Cape Town 2018a)

Conservancy (2018): “in catchments where the minimum water quality and quantity necessary for sustaining aquatic ecosystems is not met, the health consequences for people and nature can be disastrous.” This indicates that pollution and contamination of water resources remains a threat to water security in Cape Town and South Africa (City of Cape Town 2018a).

<u>Alien Plant Invasion</u>

Several of the catchment areas that feed water into the WCWSS, have been found to have altered ecosystems. These areas have been invaded by non-native plants such as pines, Australian acacias, and eucalyptus trees. The presence of these non-native species is a threat to the soil ecology, the increase of wildfires and has significant impact on the river flow and recharge of aquifers. These invasive species have arrived mainly due to commercial forestry and the easily spreading nature of the seeds. Over two thirds of the sub-catchments for the WCWSS have been invaded by these alien species (Fig. 28) (The Nature Conservancy 2018).

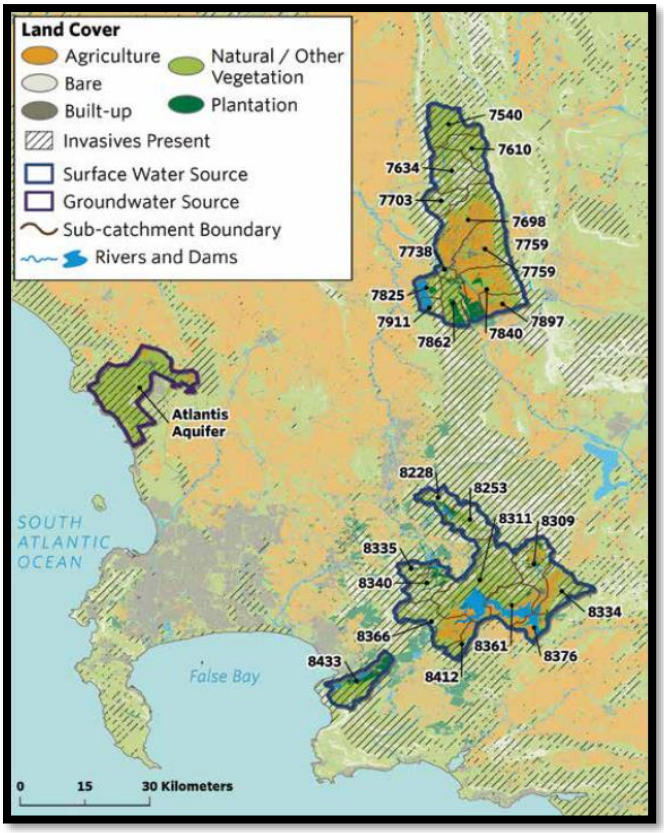

Figure 28: Land Cover Invaded by Alien Plants
Source: (The Nature Conservancy 2018)

The impacts of invasive species vary depending on the density and type of alien plant invasion. In this case, the invasion is by woody plant species (pines, Australian acacias, and eucalyptus trees) which have several impacts on the hydrology. Firstly, these plants have “higher evapotranspiration rates and use up to 20% more water than the native fynbos vegetation” (The Nature Conservancy 2018). This results in a decrease in surface runoff as well as water seeping into the aquifers. Second, these plants have deeper roots, which allow them to access more groundwater (The Nature Conservancy 2018).

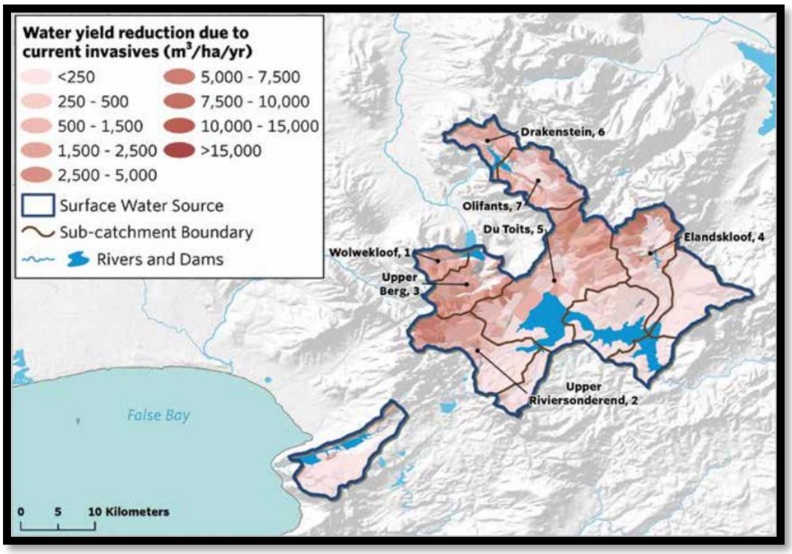

Figure 29: Current Water Yield Reduction due to Alien Plant Invasion
Source: (The Nature Conservancy 2018)

Removal of these non-native species could immediately increase the surface runoff in the catchments. Attempts have been made to compel landowners to remove and control invasive species on their land, but the invasion of alien plants continues to be a serious problem for the WCWSS Fig. 29 & Fig. 30). Unless dealt with in a satisfactory manner such as ecological infrastructure projects, these plants will remain a threat to the region's unique biodiversity and water security. (The Nature Conservancy 2018)

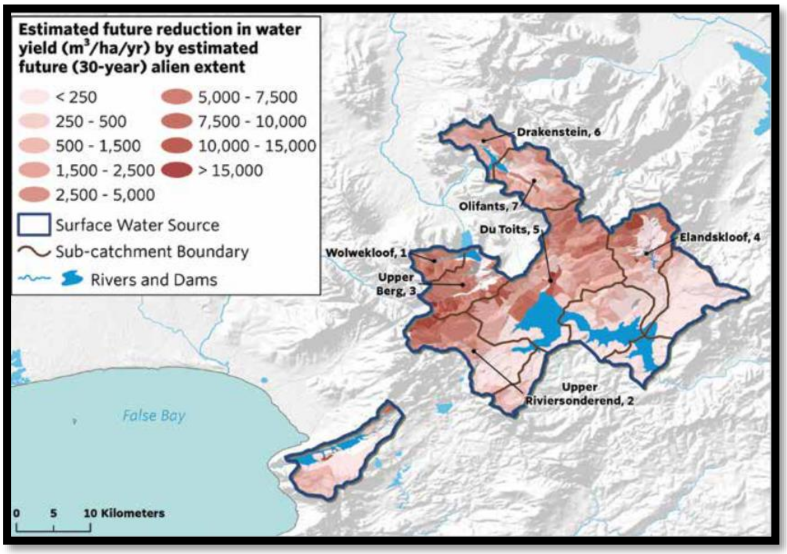

Figure 30: Estimated Future Water Yield Reduction due to Alien Plant Invasion
Source: (The Nature Conservancy 2018)

5.2.2 Socio-economic Threats

<u>Population Growth</u>

The City of Cape Town is the second largest city in SA and currently faces rapid population growth of 2.6% (The Nature Conservancy 2018). According to (Dippenaar 2016), "the Cape Town population has grown steadily since the early 1900s, after which significant growth followed." Following the year 2000, in just 10 years the population increased by 29% (Dippenaar 2016) (Fig. 31). From 1996 to 2017 the population increased by 67% (from 2.4 million to 4 million) (Nhamo and Agyepong 2019). The rapid growth of CoCT's population is both from natural births and

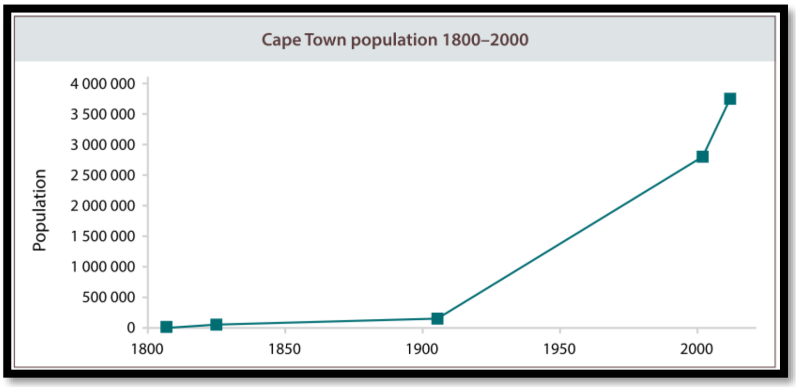

Figure 31: Cape Town's Population 1800-2000
Source: (Dippenaar 2016)

immigration. During the apartheid (1948-1994) many non-whites who were expelled from various areas, found themselves settling in the outskirts of the CoCT called the Cape Flats (Enqvist and Ziervogel 2019). Additional black migration to this area was due to the promising employment opportunities of the city (Enqvist and Ziervogel 2019).

The growth of the population significantly increased water demands for the region. Additionally, several wetlands were bulldozed to make room for housing projects in the informal settlements around Cape Town, causing damage to water resources (Enqvist and Ziervogel 2019). Figure 32 shows water supply relative to population growth, clearly indicating the threat of the growing population to the city's water security (The Nature Conservancy 2018).

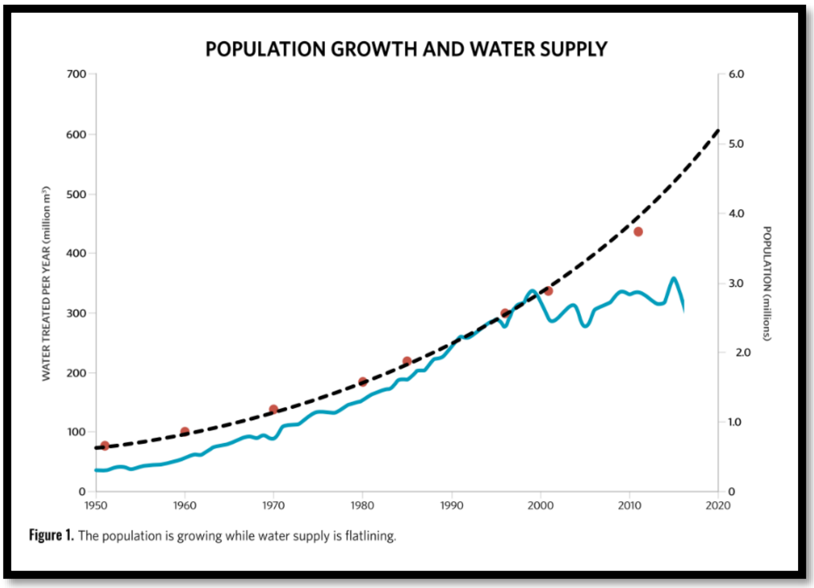

Figure 32: Population Growth and Water Supply in CoCT 1950-2020
Source: (The Nature Conservancy 2018)

The city's population will continue to grow; it is expected to reach over five million within just a decade (City of Cape Town 2013). Water demand is therefore expected to increase 3% per year, and the city will need an additional 128 MCM annually by 2028 in order to avoid demand exceeding supply (The Nature Conservancy 2018).

<u>Poverty and Inequality</u>

Poverty and inequality are significant issues in CoCT. Poverty is caused mainly by unemployment (where the rates are highest among blacks), diseases such as HIV/AIDS, Tuberculosis, and the high population growth amongst the already poor (Smith 2005). The inequality between the races is rooted in SA's past and was severely aggravated by the apartheid policies (Smith and Hanson 2003).

According to City of Cape Town (2013), in 2010 35% of households in CoCT were living in poverty, and that was an improvement compared to 2009 where it was 38% (Fig. 33). Fig. 34 presents the average income by division of race. This table clearly indicates that most of the poor are black and people of colour, while the wealthiest are the whites.

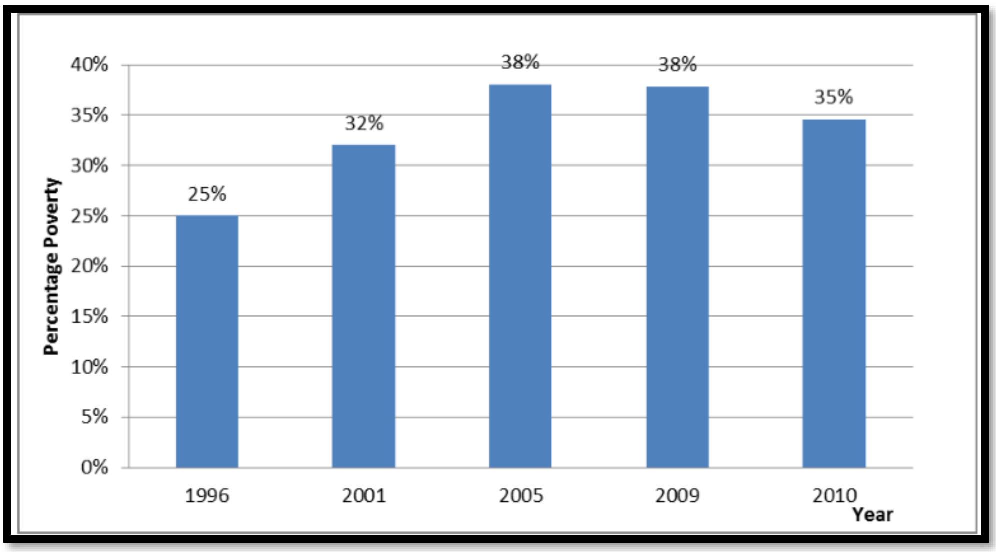

Figure 33: Percentage of poverty by year in CoCT
Source: (City of Cape Town 2013)

Population Group	Average Monthly Household Income
African	R 2 144
Coloured	R 5 630
Indian	R11 312
White	R16 147
Total	R 7 389

Figure 34: Average Household Income by Population Group (2001)
Source: (Smith 2005)

The elevated levels of poverty result in issues of service delivery in the city (Smith and Hanson 2003). Several Capetonians have to retrieve water from a collection point or communal tap that may be more than 200 meters from their home (Dippenaar 2016). Additionally, several issues arise with water tariffs, which have been shaped to discriminate against the poor (Ziervogel *et al.* 2010). For example, the 1998 Water Act in South Africa introduced new water conservation strategies. One of the measures taken was to install water meters on households for the purpose of demand management. However, the low-income neighborhoods usually have poorly maintained infrastructure with breaks and leaks in the pipes. This resulted in extreme levels of water usage being registered in these neighborhoods, putting several poor homes in debt, and having their water shut off. Some black and colored neighborhoods had water cut off in 90% of the households (Enqvist and Ziervogel 2019).

Another example is the adoption of 'block tariffs', which means there is a division into water usage categories, and high-volume users pay more than low-volume users. This was theoretically meant to benefit the poor, who usually used less water, but ended up working against them. This was because several low-income households are living in informal settlements with additional family members in backyard shacks, which results in the appearance of higher water usage per household member (despite the presence of more members) and larger water bills (Enqvist and Ziervogel 2019).

During the drought, in 2017, the city dropped the block tariffs which actually caused further issues for the poor. The city was trying to encourage a decrease in water demand, but due to the low income households already using minimal amounts of water, they were unable to reduce their consumption further, and had to pay more for the basic amounts of water they consumed (Enqvist and Ziervogel 2019).

Severe inequality also exists in infrastructure. Fig. 35 presents the available water infrastructure to households by division of race. While 95% of whites and 96% of Indians and 87% of colored people have a flushing toilet in the house, only 24% of blacks have access to such infrastructure. The percentages of access to drinking water are also astounding among

	African	Coloured	Indian	White	CMA—all races
Shack housing	51	4	0	0	12
Drinkable water in the house	34	89	100	99	82
Flush toilet in house	24	87	96	95	78

Source: CMC (1995).

Figure 35: Available Infrastructure According to Race in CoCT (%)
Source: (Smith and Hanson 2003)

blacks – only 34% (!). These numbers clearly indicate the threat to water security posed by issues of poverty and inequality.

Infrastructure and Investment

Issues with infrastructure are predominantly occurring, but not limited to the informal settlements (or 'dwellings'). According to City of Cape Town (2013) "an informal dwelling is defined as a makeshift structure not erected according to approved architectural plans, for example shacks or shanties in informal settlements or in backyards." Over 100,000 of these exist in the CoCT which are mostly homes to blacks and people of colour (Fig. 36).

DISTRICT	Informal Settlements: No. Dwellings
D1 – South Peninsula	7 992
D2 - Tygerberg	4 105
D3 – Khayelitsha	38 700
D4 - Helderberg	12 371
D5 – Mitchells Plain	26 019
D6A – North East	3 645
D6B – Blaauberg	10 108
Total	**102 940**

Figure 36: Number of Dwellers in Informal Settlements in CoCT
Source: (City of Cape Town 2013)

In these informal dwellings, In 2011, "75% of the population has access to piped water inside a dwelling, 12.3% have access inside their yard, 9.3% within 200 m of their dwellings, 2.7% beyond 200 m, and 0.7% has no access to piped water." (Dippenaar 2016) Additionally, several households lack access to flushing toilets and proper sanitation. Moreover, the infrastructure that does exist in these neighborhoods is old, poorly maintained and often leaking (Enqvist and Ziervogel 2019).

The lack of sufficient infrastructure and the fast growth of the informal dwellings is a serious challenge for Cape Town's water sector. During the recent drought, when the approaching 'day zero' was raising the fear of having to collect water from a communal tap, several residents of the informal dwellings started to speak up and share that collecting water 200m from their home would be no different for them, and that they had been living this 'day zero' for decades (e.g. BBC news 2018).

In addition to supplying adequate water infrastructure to the informal settlements, other infrastructural issues in Cape Town include:

- A lack of preventative maintenance to replace leaky pipes and avoid serious water losses (City of Cape Town 2007).
- Infiltration of storm/ground water into sewers causing stress on the pipes (City of Cape Town 2007).
- A lack of wastewater treatment infrastructure: "there is also a crisis in the wastewater sector resulting from overloaded wastewater treatment plants, substandard effluent discharge and years of underinvestment in infrastructure" (Ziervogel *et al.* 2010) Serious financial investments are needed to overcome this issue (City of Cape Town 2007).
- Inadequate stormwater infrastructure in the Cape Flats (Enqvist and Ziervogel 2019).

5.2.3 Political Threats

Apartheid

In 1948, elections in South Africa were won by The National Party, who established the *apartheid* policies (Enqvist and Ziervogel 2019). The Apartheid policies, as briefly mentioned earlier, treated the White South Africans as superior to all other races. As a result, the policies during 1948-1994 were made primarily to serve the whites (Sinanovic *et al.* 2005). During the apartheid, while whites had access to excellent health services, well-kept infrastructure and the best water and sanitation, the black South Africans, (which make up most of the population of SA), had access to inferior health care, and mostly lived in poorly kept areas without access to water and sanitation services (Sinanovic *et al*. 2005). In Cape Town, the services the White population received 1970's and 80's were equivalent to those available to most people in Europe and North America (Smith and Hanson 2003). These services were also at a very low cost and highly subsidized for the White population. The Coloured population, making up a high percantage of the working class, had access to relatively adequate water and sanitation as well. Meanwhile, the Blacks suffered the from the poorest services. In Cape Town, the aparthied brought over 150,000 Blacks and people of color to settle in townships: "the Black majority lived in townships that were built as dormitory suburbs with rudimentary rental housing, infrastructure and facilities. A shortage of accommodation led to high levels of subletting rooms and to the construction of backyard shacks… Over-crowding in the housing sector was mirrored through overuse of eroding water and sanitation infrastructures and other public services" (Smith and Hanson 2003). Most of these tonwnships were in the Cape Flats; a low elevated area east of Table Mountain, whith sandy soils and high flood risk. This was an additional water security risk next to the lack of access to water supply and sanitation (Enqvist and Ziervogel 2019).

As a result of these discrimanatory policies, in 1994, 40% of the populaiton in South Africa lacked access to basic water supply infrastructure, and 51% lacked access to basic sanitation. 80% of low-income households lacked access to piped water, with 21% of them having to walk more than 500 meters to access a water tap (Sinanovic *et al.* 2005). This indicates a threat to the water security for over 50% of the population of South Africa (!) caused by the aparthid policies.

While the democratic government elected in 1994 did their best to reverse these policies, the inequalities in service today are still influenced by the aparthied: "the service delivery challenges facing elected local authorities in Cape Town are rooted in inequities inherited from decades of apartheid urban planning policies. Cape Town's fragmented system of service delivery was essential to enforcing the National Party government's pursuit of 'total apartheid'." (Smith and Hanson 2003)

Political Tensions/ lack of coordination between levels of government

Water in South Africa today is regulated by "all levels of government from municipal to national levels." (Enqvist and Ziervogel 2019). This structure of governance can cause issues of mismanagement due to political tensions and lack of coordination between levels of governance. At the time of the drought, governance at the national level and municipal level were ruled by two different parties. The African National Congress governing the parliament and the Democratic Alliance governing the CoCT were in competition (Enqvist and Ziervogel 2019). This situation led the city to take on full responsibility for solving the water crisis, despite lack of full authority over the water resources. The city in fact announced in 2017 that they would rather take full responsibility for solving the crisis rather then relying on the national government for help (Enqvist and Ziervogel 2019). While this may seem remarkable, options for combating the water crisis were limited due to lack of the city's authority over the water resources (Parks *et al.* 2019). These tensions also create lack of coordination between the responsible bodies. Taking and colleagues (2019) state that there is a "need for better intergovernmental coordination between different arms of government responsible for water resources and water services." (Taing *et al.* 2019). It seems that these political issues may have further complicated the water crisis.

5.3 Steps Towards Water Security

5.3.1 Water Laws

Cape town's water policies were rooted in segregation back from the 17th century when the building of the city was based on a racial-based conflict over water. The policies established in the following centuries were systematically made to serve the whites and marginalize blacks and people of colour. The apartheid policies following the 1948 election further aggravated the segregation issues. However, after 1994, during the democratic transition, lawmakers did their best to redress the racially unjust policies (Enqvist and Ziervogel 2019).

The first step was the new constitution (1996) which declared every individual's right to sufficient water and sanitation: **The Constitution of South Africa section 27(1) (b)** states that all people have the right to access to sufficient food and water (Colvin *et al.* 2016), and section 24 establishes every individuals right to an environment that protects their health and well-being (Sinanovic et al. 2005).

The next important legislation was the **Water Services Act of 1997.** This act defines basic water supply, and establishes that everyone has the right to receive access to water and sanitation, in formal and informal settlements (Sinanovic et al. 2005). It additionally states that the water services institutions and water services authorities must plan for and make it possible for this to be achieved (Colvin *et al.* 2016).

Next, **The National Water Act of (1998)** establishes the framework for governing and protecting the country's water resources (Sinanovic *et al.* 2005). The act also recognizes the importance of water for social and economic development, and its need to be protected as a resource (Colvin *et al.* 2016) . Additionally, it states that water “belongs to the whole nation for the benefit of all people” and allows a person to use any water source they have lawful access to for domestic purposes such as gardening and watering animals. (Colvin *et al.* 2016)

In 2001, **The White Paper on Basic Household Sanitation** sets standards for minimum levels of sanitation which include ensuring “(1) appropriate health and hygiene awareness and behaviour; (2) a system for disposing of human excreta, household waste water and refuse, which is acceptable and affordable to the users, safe, hygienic and easily accessible and which does not have an unacceptable impact on the environment; and (3) a toilet facility for each household.” (Sinanovic *et al.* 2005)

Another important policy established in 2001 is **The Basic Free Water Policy**. This policy establishes that every household gets the first 25 litres per day per person for free (6000 litres per month for a household of eight). However, “municipalities can decide if free basic water is made available only to the poor, and how the poor will be defined and identified.” This resulted in (out of 169 water service providers) 29 provide free water to all, 136 to some defined as poor, and four small areas to none. Water used over the given amount is to be paid for. (Colvin *et al.* 2016) The CoCT added its own minimum standards to the policy: the tap providing the free basic water should be within 100 meters of a household, and there should be no more than 25 households per tap (City of Cape Town 2013). In 2007, the policy was revised to encourage that the amount of free basic water be raised to 50 litres per person per day, and accentuate the importance of providing proper infrastructure to the poor (Beck *et al.* 2016).

In 2003**, The Strategic Framework for Water Services** provides the implementation of the free basic water policy. This framework also reaffirms the rights of access to water stated in the constitution, and mentions the responsibility on the municipalities to do so (Beck *et al.* 2016).

The Water Allocation Reform Strategy of 2008 established the goal that by 2024 60% of all the water resources are being distributed to Black people, while half of that goes to black women (Beck *et al.* 2016)

And finally, the 2013 **National Water Resource Strategy** aims to ensure full protection and conservation of water resources for the future, while simultaneously utilizing them to achieve the country's social and economic goals (Beck *et al*. 2016).

4.3.2 Main Governing Bodies

Water in South Africa is governed on the national level, catchment level and municipal level (Beck *et al.* 2016).

On the national level is **The Department of Water and Sanitation (DWS)** (previously the Department of Water Affairs and Forestry**).** The department is in charge of "policy development, implementation, regulation, monitoring, enforcement, and administration" (Enqvist and Ziervogel 2019). Their mission is to "ensure that the country's water resources are protected, managed, used, developed, conserved and controlled in a sustainable manner for the benefit of all people and the environment" (South African Government 2020). The DWS is the legal custodian of the country's water resources. For CoCT this means that although the main dams are owned by the city, the DWS holds full control, ownership, and rights to allocate the water within them (Enqvist and Ziervogel 2019).

Several bodies manage water on the catchment level. First, the **Catchment Management Agencies** are in charge of managing water on regional scales and catchment levels. Where such agencies are not established, the DWS takes charge of management through regional offices. Next the **Water Boards**, which are essentially regional water utility companies, are in charge of managing bulk water and wastewater and providing water services on the regional scale. **Regional Water Utilities** manage regional water and wastewater infrastructure (Beck *et al.* 2016).

On the municipal level is **The City of Cape Town's Water and Sanitation Department** (which is not affiliated with the national DWS). The city is the designated service provider, they receive the water from the WCWSS, treat it and distribute it to the consumers. The department has several branches, including "Bulk Water, Reticulation, Wastewater Treatment Works, Water Demand Management and Strategy, Catchment, Stormwater, and River Management" and more (Enqvist and Ziervogel 2019). The city is required by national law to ensure proper water management and encourage conservation, in order to ensure the future water supply. When dam levels are running low, the DWS can issues requirements for the city to reduce water consumption, and the city then has the power to dictate water allocations for reducing consumption (Enqvist and Ziervogel 2019).

There are also private water service companies that provide water and sanitation on local levels, and water user associations, which are individuals working together to improve water and sanitation for their own benefit (Beck *et al.* 2016).

Beck and colleagues (2016) also point out that there are several bodies working with all levels of government to improve water and sanitation in south Africa such as NGO's, various stakeholders, private companies, and donor organizations such as the European Union who are providing funding to SA to improve its water and sanitation. Fig. 37 provides an overview of the main water governing bodies in South Africa:

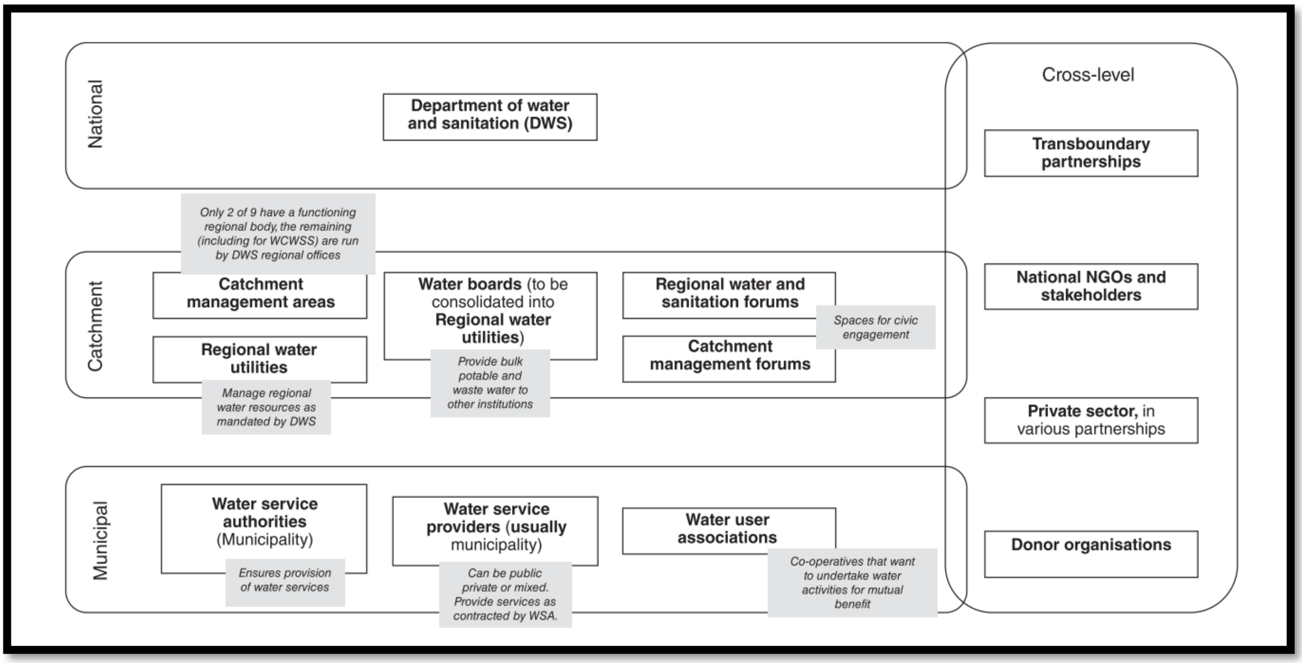

Figure 37: Key Agencies and Organizations Governing Water in SA
Source: (City of Cape Town 2013)

5.3.3 Water Management Strategies and Policies

Cape Town's water is managed through the Western Cape Water Supply System (WCWSS), an integrated system which includes dams, pumping stations, pipelines and tunnels which together supply water to the urban and agricultural demands of the region. This system is collectively managed by CoCT and the national Department of Water and Sanitation (Sinclair-Smith and Winter 2019). Key factors for water management in CoCT are the following:

<u>Demand Management</u>

Cape Town has limited options to augment supply and is already a water scarce region (City of Cape Town 2013). Various demand management and water conservation strategies are therefore the best option for the city to meet its growing water demands (Sinclair-Smith and Winter 2019). In 1995, Cape Town established a goal to reduce its water demand by 10% in the coming decade, and in 2001 the city developed a water demand management strategy. In 2007, an official long term water conservation and demand management strategy was published by the city (City of Cape Town 2007). The main strategies CoCT has used to manage demand and conserve water are the following:

- **Pressure management**: reducing water pressure can significantly minimize bursts and leaks in pipes, in addition to lower household consumption. Reducing water pressure in Cape Town is done by “installing pressure-reducing valves in the water supply to discrete water supply zones that are isolated from the rest of system. The valves are usually linked to an electronic controller that allows for substantial pressure reductions in off-peak (night-time) periods when pressure is normally highest due to lower water use.” (Sinclair-Smith and Winter 2019). Using this system, CoCT has managed to save 3.73 MCM per year (City of Cape Town 2013). Pressure management has been very successful for CoCT, and is now a key factor of their water demand management program (Sinclair-Smith and Winter 2019).
- **Pipe replacements**: The city replaces approx. 40 km of old and leaking pipes every year, in order to improve the infrastructure, that has lacked investment over the years. Due to pipe replacement, the city has manged to reduce pipe bursts from over 6,000 in 2008, to 2,656 in 2018 (Sinclair-Smith and Winter 2019).
- **Minimizing leaks through leak detection technology:** the city created leak detection teams, that use a combination of listening devices, Geographic Information Systems (GIS), and other mapping platforms to detect and locate underground leaks. This system is said to have saved 2 MCM of water annually (Sinclair-Smith and Winter 2019).
- **Water restrictions:** The city has a system of water restriction levels, which are used according to the amount of available water in the dams. Each level restricts the city’s water usage to a certain amount (Fig. 38) and increases the price of water per

block (Fig. 39). Figure 38 shows the implementation of these restrictions during the drought: (Taing *et al.* 2019).

- **Block Tariffs**: since 1997 the CoCT has used a water tariff system where prices increase the more water one uses. This results in high water users paying significantly larger water bills than low water users. The tariffs for each block change according to the city's current water restriction level (Fig. 39). This encourages water users to reduce consumption further during periods of low rainfall (Sinclair-Smith and Winter 2019).

Table 1. Timeline of Cape Town water restrictions, from June 2017. Collated from various weekly CCT reports and GreenCape (2018).

Water restriction level	Disaster plan phase (from 1 October 2017)	Dam levels	Target water use volumes (litres): Daily per capita usage (ℓ)	Target water use volumes (litres): Daily collective usage (Mℓ, inc. businesses & critical services)	Implementation date
Level 3	-	61%	User dependent (50–1000)	800	1 November 2016
Level 3B	-	40%		700	1 February 2017
Level 4	-	20.3%	100	600	1 June 2017
Level 4B	-	24.3%	87	500	1 July 2017
Level 5	Phase 1	34.1%	87	500	3 September 2017
Level 6	Phase 1	30.9%	87	500	1 January 2018
Level 6B	Phase 1	26.2	50	450	1 February 2018
Day Zero	Phase 2	13.5%	25	-	-

Figure 38: Water Restriction Levels in CoCT during 2016-2018
Source: (Taing *et al.* 2019)

Tariff blocks	Level 1 tariff	Level 2 tariff	Level 3 tariff	Level 4 tariff	Level 5 tariff	Level 6 tariff
Step 1 ** (0 ≤ 6 kl)	R14.78	R15.25	R15.73	R16,25	R24.37	R33.24
Step 2 ** (> 6 kl ≤ 10,5 kl)	R19.70	R20.95	R22.38	R25.90	R39.59	R52.90
Step 3 (> 10,5 kl ≤ 35 kl)	R26.20	R28.47	R31.77	R39.16	R60.25	R138.31
Step 4 (> 35 kl)	R45.30	R52.54	R69.76	R97.39	R345.00	R1,150.0

Figure 39: Block Tariffs According to Levels of Water Restriction in CoCT (price per m^3)
Source: (Sinclair-Smith and Winter 2019)

- **Replacing potable water with recycled water**: the city is using treated effluent instead of freshwater for industrial purposes, agriculture, watering golf courses, sports clubs, irrigation and more. The city attempts to increase the use of recycled water by promoting the cause and financially invested in upgrading wastewater recycling systems (Sinclair-Smith and Winter 2019).
- **Installing Water Management Devices:** these devices can be installed on supply pipes in order to enforce daily limits of water consumption. After reaching the limit, the water pressure is reduced to a trickle until the following day. The city worked on installing a significant amount of these devices during the drought in order to control water consumption (Parks et al. 2019).
- **Water metering**: in order to increase the efficient use of water, the city aims to have all water use metered and recorded on a monthly basis. In order to achieve this, the city is working on installing meters for all consumers, and replacing old and defective ones with functional ones (Sinclair-Smith and Winter 2019).
- **Education and campaigns:** in 2005, the city launched a long lasting 'keep saving water program' which aimed to raise awareness and influence the behaviour of water consumers. This program was launched through various media outlets, in addition to creating workshops and other community engagements to teach residents about the importance of water conservation. The program was successful even through years of high rainfall. Through the period of the 2015-2018 drought the city significantly increased educational efforts in desperate attempt to reduce water consumption (Sinclair-Smith and Winter 2019).

Fig. 40 shows how demand management efforts since the turn of the century have managed to reduce total water demand in CoCT. The years circled in red show the significant drop in consumption during the drought (City of Cape Town 2019).

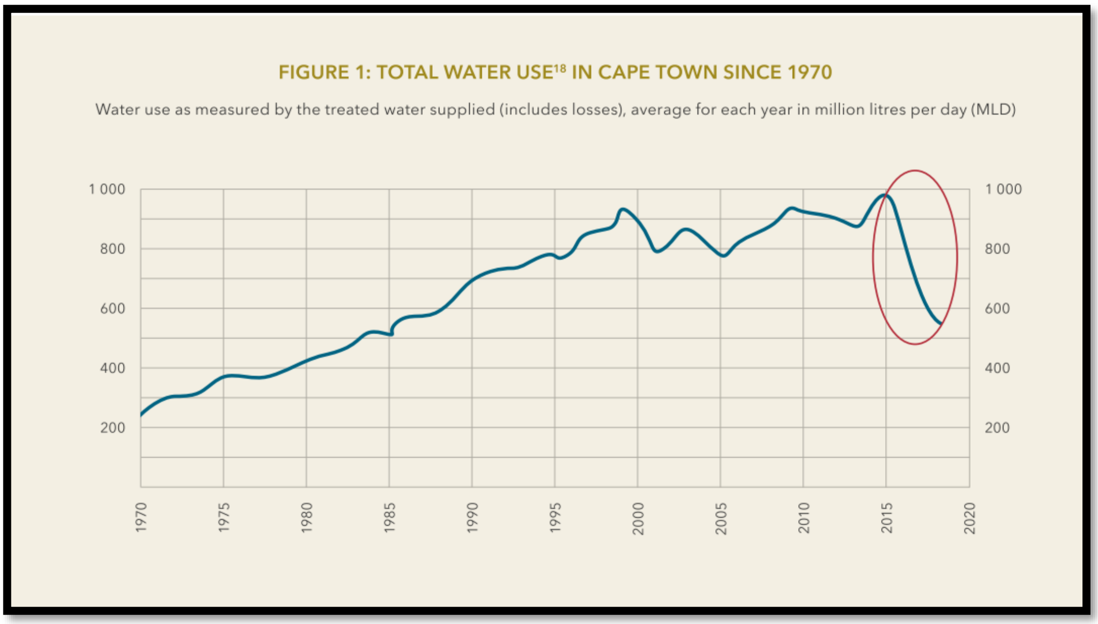

Figure 40: Total Water Use in Cape Town 1970-2019
Source: (City of Cape Town 2019)

The city also has an emergency demand management plan that was used during the drought…

<u>Supply Augmentation</u>

Planning for supply augmentation is collectively managed by the city and the DWS. The recent construction of the Berg river dam provided an additional 81 MCM to the WCWSS (Sinclair-Smith and Winter 2019). Following the 2018 water crisis, it became clear that the city can no longer rely solely on rainwater (City of Cape Town 2019). Therefore, the city's new water strategy report of 2019 declares that it will begin to augment its water supply from the following sources:

1. Groundwater from The Cape Flats Aquifer, The Table Mountain Group Aquifer and The Atlantis Aquifer. The water from the aquifers will be abstracted and added to the dams where it will become part of the city's water supply. The aquifers will also undergo artificial recharge of treated effluent (City of Cape Town 2019).

2. Desalination – the city plans to build a desalination plant with a capacity of 150 million litres per day. However this plant is still in the first stages of planning. (City of Cape Town 2019)

Other options in plan are eliminating alien vegetation from water basins (The Nature Conservancy 2018)and increasing use of recycled water (Sinclair-Smith and Winter 2019)

Addressing Racial and Socio-economic Inequality

With racial inequality resulting in insufficient access to water and sanitation and/ or infrastructural issues and water being shut off due to debt for many non-whites, the city has several programs aimed at tackling these issues.

The integrated water leak repair project – the city gathered over 200 unemployed individuals from the disadvantaged communities and trained them in household plumbing. They then provided over 4,500 households in these communities with repairs to plumbing issues with the costs covered. This simultaneously created employment opportunities and allowed plumbing repairs in several households (Sinclair-Smith and Winter 2019).

The Schools Project – the city brought technical teams to schools who repaired leaky pipes and taught the school staff members to repair plumbing issues, while also conducting water awareness and education campaigns to the students (Sinclair-Smith and Winter 2019).

Debt forgiveness and free water for low income households – most of the leaks in the city are in low-income households with old and faulty infrastructure. Several of these households have been burdened with heavy debts caused by leaks which appear to increase water consumption. The city has implemented a program to forgive the debt and repair the plumbing in these households free of charge and provide them with 10,500 litters of water on a monthly basis. Water management devices are installed to meter the water amounts, and additionally help the city track water consumption (Sinclair-Smith and Winter 2019).

Raw Water Treatment

Cape Town has 12 water treatment plants that purify approx. 1.6 MCM per day to provide clean water to the municipal area (Colvin *et al.* 2016). Treating water is a very costly process; the yearly water purification from the Voelvlei dam alone was approx. $300,000. This is a cost that could have been spared if pollution of the surface water was prevented *(Colvin et al.* 2016). However, the water provided after treatment was found to be of very high quality in CoCT. Fig. 41 shows the percentage of compliance with regulation for chemical and micro-biological pollution. The water seems to be in compliance with regulation except for in the informal settlements, where the annual average for micro-biological pollution was only 95% compliance. (City of Cape Town 2013)

Water Supply Outlets	Sample Points Per Water Supply Outlet	Sample Points Sampled	Number of Samples taken for July		% Compliance SANS 241			
					July Month		12 Month Rolling Average	
			Chemical	Micro-biological	Chemical	Micro-biological	Chemical	Micro-biological
Water Treatment Plants	10	10	45	45	99	98	99	100
Reservoir	24	23	104	114	100	100	100	99
Distribution	126	116	562	576	100	100	100	100
Informal Settlements	43	37	76	82	100	93	100	95
Total	**203**	**186**	**787**	**817**	**99.8**	**97.8**	**99.8**	**98.5**

Figure 41: Level of Compliance with DWS Regulations for Water Quality
Source: (City of Cape Town 2013)

Still, the city aims to improve water quality. Cape town is taking steps to tackle water pollution together with the national government, and the western cape government (City of Cape Town 2018a). "the City has a number of ongoing projects in place to improve water quality. These include an increase in maintenance for clearing litter and dumped material from storm water systems, improving aquatic weed and algae management measures, improving informal settlement servicing and managing databases to include downstream water-quality criteria, and eliminating sewer-to-storm-water cross connections, to name a few." (City of Cape Town 2018a)

Wastewater Treatment & Effluent Reuse

The processing of wastewater is required by 1998 the National Water Act (City of Cape Town 2018). The city has 26 wastewater treatment plants which are linked to 20,000 km of pipes and sewer reticulation network (City of Cape Town 2018). The wastewater arrives at the facilities and is treated in five stages: screening (removing large objects), filtration (removing small particles such as grit, sand and glass), primary sedimentation (remove solids, greases and oils), secondary treatment (biological processes such as activated sludge and bio filtration) and disinfection (killing bacteria and other pathogens with chemicals or other technologies). The treated effluent is monitored and then safely discharged into rivers, aquifers, or into the sea through deep sea marine outfall pipes.

Some of the treated effluent is used for agricultural and industrial purposes. There are 160 effluent consumers in the city, who use 50,000 cubic meters daily, which in total recycles 8% of CoCT's water. These consumers include "schools, sports clubs, golf courses, farms, industry and commercial developments with large water features" and more (City of Cape Town 2018).

The city is also investing in expanding and improving their wastewater treatment facilities in order to treat more water and ensure higher quality effluent (City of Cape Town 2018).

5.4 Case Summary

The City of Cape Town, capital of South Africa's Western Cape province, has several struggles with water security. A highly variable climate, dry summers and population growth make the area naturally water scarce. The effects of the changing climate further exacerbate the water stress in the area. In addition, industrial activities and other man-made causes such as invasive on non-native plant species negatively affect water quality as well as quantity. On top of threats to the availability of water, the city suffers from inequality between the races, which results in lack of proper infrastructure and water services for many people of colour. Racial segregation was caused by the Apartheid policies established by the government from 1948-1994. Since the Democratic Era began in 1994, the National Government has implemented several laws and policies in attempt to achieve water security for all and reverse the inequality of the Apartheid era. On the municipal level, the CoCT is making an effort to address issues of inequality, faulty infrastructure, and water quality, as well as attempting to both conserve water and augment supply in order to prepare for future water struggles.

6. Comparative Analysis of Israel and Cape Town's Water Security

6.1 Climate and Freshwater Resources

Israel and CoCT are both located in regions of Mediterranean climate, with cool and rainy winters and hot and dry summers. Both regions also have high rainfall variability between localities; Israel's rainfall decreases (more or less) from north to south, and CoCT's rainfall decreases from the mountains to the valleys and coasts. However, one thing Israel has that CoCT does not is a large desert area. Although SA does have some desert areas, CoCT is not located in them. In Israel, the desert area covers approx. 60% of the landmass, meaning over half the country receives less then 200mm of rainfall annually. There are areas of CoCT which also receive relatively lower rainfall, but not to that extent. Also, since CoCT is a metropolitan area, areas with lower rainfall can still be easily connected to the water supply system. For Israel, having this desert area and wanting to accommodate life in it, definitely gave a significant push towards learning how to manage water. In fact, one of the reasons for building the National Water Carrier (NWC) (completed in 1964) was to supply water to agricultural settlements in the desert areas, from the Sea of Galilee. Being able to settle life in the desert was and still remains a huge advantage for Israel, especially with the fast-growing population, and this could not have been achieved without supplying sufficient water access to these areas. This specific climatic factor was something Israel had to deal with early on in its days which COCT did not face, which may be one factor putting Israel ahead of CoCT in its journey towards water security.

Another significant difference between the regions is the type of water resources they rely on for supplying water to populations. While CoCT relies mainly on surface water stored in dams, Israel incorporates large amounts of desalinated water and recycled wastewater into their water system. CoCT's entire surface water supply is approx. 900 MCM, and Israel gets approx. 750 MCM just from desalination. What this means in practice, is that Israel's water supply is less reliant on climatic factors while CoCT's is completely reliant on them, especially rainfall amounts. Being fully reliant on surface water is very risky, especially with climate change reducing rainfall amounts in both regions. This factor definitely played a significant role during the droughts in both regions; while Israel already had an alternative way to supply freshwater when rainfall was low, CoCT had only the remaining water in their dams, leaving them with few options (that could be implemented quickly[7]), mainly to reduce consumption as much as possible.

Still, it should be noted that although Israel had sources of supply augmentation, the country was not water abundant during the years of drought. As Katz (2016) points out, the fact that Israel had desalinated water may have rescued it from five years of drought, but it did not make the country have water surpluses, and even created a false perception that Israel had more water than it really did. Israel had utilized all of its natural freshwater resources, unlike CoCT, which meant desalinated water was their *only* backup, and the capacity Israel was able to meet in these plants would determine how much water the country had.

6.2 Threats to Water Security

6.2.1 Environmental Threats

Water Scarcity

It is clear that both Israel and South Africa are water scarce countries. On the national level SA is in a slightly less scarce category then Israel according to the Falkenmark index ('water scarcity' vs. 'absolute water scarcity'). Additionally, the IWMI index places SA in 'approaching physical water scarcity' while Israel has already reached 'physical water scarcity'. However, on the regional level, CoCT has even less water per capita (approx. 625 m^3/c/y vs. 821m^3/c/y). CoCT still technically has more water per capita then Israel (which only

[7] They had the option to begin supply augmentation projects, but they were not ready when the crisis hit like they were in Israel.

has approx. 310 m^3/c/y), but with CoCT only using their surface water (900 MCM stored in dams) they actually only have approx. 225 m^3/c/y making them even more water scarce than Israel in practice.

While this may be another explanatory factor for the contrasting water security situations, it also raises the question—why did CoCT have to face day zero if they had so much untapped groundwater? Interestingly enough, Luker and Harris (2019) conducted research that answers this exact question. Their research, conducted during the drought period, explores the challenges Cape Town faces with utilizing groundwater. They found several reasons for this phenomenon. Firstly, one of the main issues found was lack of proper infrastructure for integrating groundwater into the supply system. It seems that since CoCT already has numerous infrastructural issues, they did not want to invest in additional infrastructure to connect the groundwater to the supply system, which created the lack of investment in proper infrastructure. The next hindering factor is the city's concern that groundwater requires different types of management than surface water, which they did not yet have experience with. Surface water management is perceived as an easier task for the city, especially since it has been designed that way for centuries, and groundwater has several unknowns and uncertainties. Another issue was public perception; part of developing the groundwater was going to be usage of the aquifer recharge method, which pumps stormwater and treated wastewater into the aquifers to refill them. The public was opposed to this system, due to fear for the water quality, after stormwater and treated wastewater were added into the water system. Lastly, the city generally saw groundwater as a resource that shall only be used in times of extreme scarcity, which is why they had not yet utilized it in the past. There was also the attitude that drought is temporary, and not wanting to invest in new infrastructure which will no longer be needed after the drought is over.

All of these issues mentioned by Luker and Harris (2019) must be considered in the comparison, since these are troubles Israel did have to tackle. It was clearly more convenient for CoCT to rely mainly on surface water over the years, but this convenience turned into a serious inconvenience as the city approached day zero in 2018. It does seem though that these challenges could have been overcome – new ways of managing water can be learned and adopted—but having the same system in use for so long definitely makes it difficult to adjust to changes. For Israel, everything was changing all the time, and adapting to new water management strategies was what they were accustomed to, as is described by Feitelson (2013) in his article about Israel's different eras of water policy. It seems therefore that Israel's ability to adapt versus CoCT's desire to keep their old ways is another factor which can be attributed to the water security situation of the regions.

Climate Change

In addition to the already existing water scarcity, climate change is further exacerbating the water shortage in both regions. It seems that the impacts they are suffering are quite similar. Both are threatened by a decrease in precipitation, rising temperatures, an increase in heatwaves, sea level rising, and an increase in frequency of droughts and floods. It appears that droughts are a particularly significant threat to both regions (although Israel's water sector was more resilient then CoCT's in the last drought). One threat that seems to be more dangerous to Israel though is sea level rising. This is due to the importance of Israel's coastal aquifer, and the salinization of the groundwater. For CoCT this is a lesser threat since they do not currently rely on groundwater, but for Israel, the coastal aquifer provides 320 MCM annually. This may be another reason Israel pushed for seawater desalination; the fear of losing the water from the coastal aquifer.

However, there is also a big difference between the regions in their preparedness for climate change. Luker and Harris (2019) found that several water managers in CoCT are not incorporating climate change into the water models, and therefore its impacts are not being considered in the city's planning for future water supply. This may have seriously impacted Cape Town's level of preparedness for the 2015-2018 drought and limited the capacity they had for dealing with it. The managers reasoning for not considering climate change was that the impacts are still uncertain. But when it comes to water, that is a source of life, I would think it makes more sense to prepare for the worst, than assume the best. When researching about Israel, I found issues of climate change being discussed in almost every report. In fact, the amount of information and graphs available about climate change in Israel was far more than what could be found about CoCT. The fact the Israel appears to be taking more steps to prepare for climate change than CoCT could be another factor explaining the contrasting outcomes of the droughts.

<u>Surface Water Pollution</u>

Water pollution is a serious issue in Israel and Cape Town. Both regions suffer from surface water pollution, especially sewage and other types of waste being discharged into rivers and other water bodies. This type of pollution seems to be a larger threat for CoCT's water security though, since surface water is their only source of water supply. The city provides clean water to its residents thanks to its raw water treatment facilities. For Israel, surface water pollution is less of a threat to urban water supply, especially since they have substituted the water from the Sea of Galilee with desalinated water. This has also given a chance for the lake's water quality to improve (after years of being polluted and over-pumped), since less water is being pumped.

Nonetheless, when considering the environmental aspects of water security (as defined in chapter two) such pollution is a threat to the aquatic ecosystems of both regions. Contaminated water is also dangerous because it can carry diseases, so even if both regions are providing clean water to their consumers, *if the water is sitting in nature polluted this remains* *a constraint to achieving water security according to several definitions.* Also due to the water cycle, these pollutants eventually get into the clean water as well. Still, it seems that this factor was not significant for either region during the drought, since CoCT purifies water before distribution, and Israel is desalinating water. It certainly cannot be ignored when assessing water security on a holistic scale, but it also cannot be used to explain the outcomes of the droughts.

Groundwater Salinization and Contamination

The contamination and salinization caused to aquifers is also a threat to Israel's water security which CoCT is not facing. Israel spent decades over-pumping the aquifers, and now with sea level rising, levels of salinity in the coastal groundwater continue to increase (as mentioned previously). It is unclear how serious this threat is considering Israel's desalination capacity; however, it may be an issues in the future if Israel's population grows faster than its desalination plants. Desalinating water has been an advantage for Israel's aquifers though, since water surpluses can be pumped into them to lower groundwater salinity. This is also being done with treated effluent via the aquifer recharge method. There are also technical solutions available to keep the seawater from mixing with the freshwater, but they are highly complicated and expensive. Israel can surely also desalinate the aquifer water if needed, but this of course comes additional costs and investment in infrastructure. Regardless of how Israel will solve this issue, I would like to point out, as mentioned previously, that the threat to the water quality in the coastal aquifer may also have been an additional push for Israel to invest in seawater desalination—one that CoCT did not have.

Alien Plant Invasion

The last environmental threat is one only found to significantly impact CoCT. The invasion of alien plants is impacting quantity and quality of Cape Town's surface and groundwater. This specific issue does not seem to be one that Israel is facing. Although Israel does suffer from alien species invasion, I have not found any evidence that it is impacting the water sector. For CoCT though this seems to be a big problem left untreated. There was a report published by The Nature Conservancy in 2018 called 'The Greater Cape Town Water Fund' which suggests that the investment in ecological infrastructure (dealing with alien plant invasion) has the highest cost benefit among other options for Cape Town increasing water supply. While this may be a great solution in the future, the results of this project are unknown to me at the time of my research.

6.2.2 Socio-economic Threats

Population Growth

High rates of population growth are increasing pressure on the water sector for both regions. Israel's growth rate stands at 2%, while CoCT's is 2.6%. These are both relatively high growth rates for developed countries. An interesting point here is that Israel's current growth rate is low relative to the past, and CoCT's has increased since 2000. Israel experienced extremely high growth rates in the past, such as 4.9% in the 1960's and 6% in the 1990's. For Israel, this meant it had to make enormous efforts to augment water supply for the fast-growing population. This did result in over exploitation of the country's resources, but it may have also influenced the efficient manner in which Israel has learned to manage water. CoCT has seen a significant increase in population growth since the turn of the century (67% growth since 1996 (!)). This may therefore be a relatively new constraint on CoCT's water sector, which has yet to be properly managed. Moreover, a large amount of this growth is in the informal settlements where people use relatively lower amounts of water, or lack access to water, making it less noticeable. I have two points to make here. One, that Israel has experienced rapid population growth in the past, and therefore learned to accommodate such changes. Two, CoCT's population has grown extremely fast in the last decades prior to the drought, which may mean that they still have not had a chance to augment supply accordingly. The drought may have put the issues caused by population growth in the spotlight, making cape town finally have to face them. Israel had to accommodate sudden population increases several times in the past, meaning this was a much bigger challenge for CoCT, and the drought reducing available water did not make it any easier.

Poverty & Inequality

Cape town faces very high levels of poverty which seem to be impacting access to water for several of its residents. However, Israel's poverty level is also not low; in 2018, it was 18.6%, the highest poverty rate among OECD countries (OECD 2018), yet it does not seem to be a factor threatening Israel's water security. CoCT's poverty levels are clearly higher than Israel's, but with that said, how come Israel's poor still have access to water?[8]

While I cannot confidently answer this question, I can only assume that in Israel, the subsidies and unemployment payments available to low income families (or other systems I am unaware of) can help pay the water bill. As for Cape Town, issues of poverty are deeply rooted in racial segregation and inequality. During the apartheid, providing water and sanitation to non-whites was simply not a priority for the government. It has only been since 1994, that Cape Town has begun tackling the water issues caused by segregation. Meanwhile, Israel has been working on providing water and sanitation to its citizens since the founding of the state. However, SA does now have the free basic water policy established in 2001, which provides 25L of free water per person per day. This policy on the one hand is a positive step towards providing water to the poor, but on the other hand raises issues of undervaluing water. Israel charges consumers the full price for water in order to make consumers value it as a scarce resource. Providing free water may encourage water wastage in CoCT, especially for wealthier families (since the policy provides free basic water to ALL). However, if properly implemented, the free basic water policy is an excellent tool for tackling threats to water

[8] I will note that I am not referring to issues in the West Bank and Gaza in this Paper.

security caused by poverty and inequality. Still, there is just another issue in the way, which is the lack of infrastructure.

Infrastructural Issues

Cape Town's informal settlements, with over 100,000 residing in them, have serious infrastructural issues. Where infrastructure does exist it is old, leaky and often poorly maintained. And in several places, it lacks; almost 13% of residents have to leave their house to access water, and flushing toilets and sewer pipes are a luxury. The attention received by this issue around day zero, showing how these dwellers already lived 'day zero', really emphasizes how serious it is. Surely anyone living an average life in a developed country could not imagine walking even five meters from their home to access water. And surely neither can Cape Town's wealthy (and white) who have benefited from excellent water and sanitation services for years.

Although Israel does have issues with leaky pipes causing water losses, besides for some unique cases such as the Bedouin settlements, all Israeli households have access to piped water. This may be another reason why it is easier in Israel to provide water for the poor – because the infrastructure is there, it is more of a matter of paying the bills, or living in subsidized housing, but there is still water easily accessed within the home.

Agriculture

For Israel, the importance of agriculture was a threat to water security in the first few decades of the country's standing, resulting in overexploitation of all the country's water resources. However, Israel later became known for some of the most sustainable and water efficient agricultural practices in the world. While the (not so small) damage to natural resources and ecosystems still remains (such as the draining of the Hula valley – a wetland that naturally filtered the water entering the sea of galilee), the technologies Israel has developed such as drip irrigation have allowed the country to save huge amounts of water, and sustain agricultural crops. Moreover, the importance of water for agriculture was definitely a push towards Israel's technological innovations; they had to find ways to irrigate more efficiently if they wished to sustain the rural living and agricultural settlements. The high importance of the issue may have also made room for the making of the policies needed to support the efficient use of water in agriculture, especially the investment in technological innovation and the use of treated effluent for irrigation. For the Zionists, the belief in working the land was ideological, making it especially strong. They were willing to work especially hard and go far to achieve their ideal way of life. This kind of strong ideological belief, that really impacted the perception towards water and shaped its value, was definitely something unique Israel experienced that pushed it towards water efficient practices, something CoCT did not have.

Levels of Wealth (GDP)

It must be acknowledged that Israel is a wealthier country than South Africa. Its GDP per capita is quite higher and has been on an almost constant rise since the 1960's (figure 42).

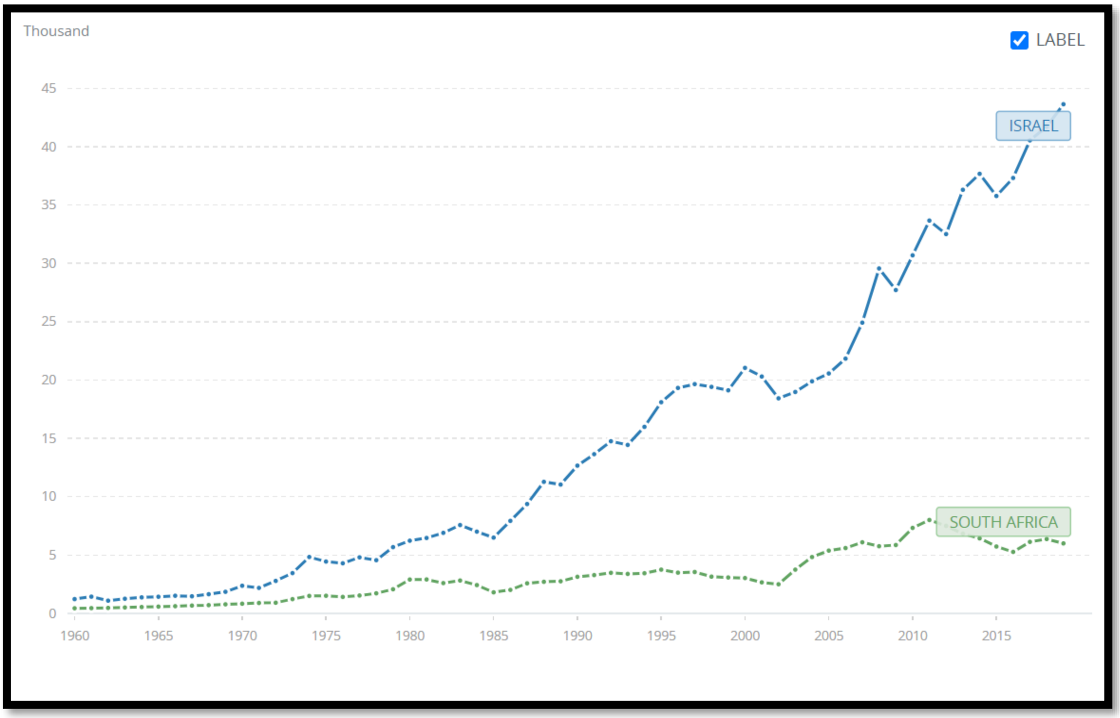

Figure 42: Annual GDP per Capita from 1960-2019 (in thousand USD)
Source: (The World Bank 2020a)

While on the one hand this would generally be associated with higher water demand, it is also a factor which allowed Israel to invest in expensive desalination. Also, interestingly enough, Israel's water demand shows no correlation of increase as the GDP increases. It is in fact the opposite – since the 1990's Israel's water demand has generally seen a downward trend thanks to the demand management efforts made. I will not discuss this in depth, but I see it necessary to point out when attempting to understand the differences in water security. Israel's higher financial capabilities are a factor that cannot be ignored when comparing it with CoCT, and the results of their water management practices.

6.2.3 Political Threats

Israel and Cape Town face very different political threats; they are not only different in their category, but also in their nature. Cape Town's political threats are mainly caused by the government itself, meaning directly from the political structure or government in power. Israel's political threats are more related to tensions with other nations or societal groups which result in conflicts over land and water resources. These threats can be divided into three categories: 1. Government vs. external government, 2. Government vs. internal government, 3. Government vs. the people.

<u>Government vs. External government</u>

In this category are Israel's transboundary water conflicts. Almost all of Israel's water resources are transboundary, which means this is an issues they had to tackle early on which influenced the development of several water management practices. Such conflicts can be extremely burdensome on a nation, which is why Israel made numerous efforts to allocate water for resolving them. Israel's decision to provide water to Jordan and the Palestinians meant additional stress on an already water scarce nation. This was definitely a factor contributing to Israel's decision to invest in augmentation of its water supply; Israel now needed water to keep the peace as well as for basic human needs. Additionally, the conflict over water and the fear of not having enough pushed Israel to aim for water independence, another factor contributing to the decision to augment supply. The CoCT did not face this particular threat to peace or such a battle over its water resources while this was a factor significantly influencing Israel's water management decisions.

Government vs. Internal Government

In this category are the tensions and lack of coordination between CoCT and the national government. There are two issues here. One is that water in SA's water sector is being governed by several levels of government which are often not in coordination. Two, is that at the time of the drought, political tensions between the parties governing the national government and the CoCT further exacerbated this lack of coordination and unwillingness to work together. Several papers have pointed out this issues as having a significant role in the mismanagement of the drought (e.g. Enqvist and Ziervogel 2019; Parks et al. 2019). The city, not wanting to work with the national government decided to tackle the situation themselves, which was extremely challenging considering their lack of authority. to This particular issue was definitely one that Israel did not face thanks to its centralized water governance. Feitelson (2013) even states that Israel has one of the worlds most centralized water governance systems. While this type of governance naturally has its disadvantages, it also makes it easier to make decisions and implement them. If Cape Town's water governance had been more centralized, results of the drought may have looked different, but this I can only assume. It does seem though that in the case of water management, having a centralized management system has been a major advantage for Israel, and a disadvantage for CoCT, allowing political tensions between governmental parties to sacrifice the proper management of water.

Government vs. the people

In this category are the issues of apartheid in SA and Israel's case of water access to the unrecognized settlements. The apartheid was a very serious threat to SA's water security;

in 1994, 40% of the population in SA lacked access to adequate water and sanitation. For SA and CoCT, the government itself was causing its citizens not to have access to water, simply on the basis of racial discrimination. Although Israel faces a challenge with the Bedouins, it is on a much smaller scale, and mixed with the lack of cooperation on the Bedouins part to reside in legal settlements. The lack of water and sanitation access for non-whites in South Africa was based solely on what color one was born. My point here, is that this was a severe threat to water security that CoCT was dealing with unlike Israel.

I think it is fair to say that it is far more difficult to tackle a governance threat caused by the government itself, then it is to tackle a threat between governments. Governments have more power to make changes in a system (although it is not always easy), and to face other governments, while in the case of SA it was the people against the government. And not just people – the poorest people with the least political power. How could they have possibly tackled the apartheid issues on their own? And once the apartheid was finally over, the challenge was not; reversing political harm, segregation and inequality is extremely hard, especially in a country where finances are limited. I think it is therefore fair to assume that Israel's political threats to water security were easier to tackle than CoCT's, simply because they could be tackled by a body that had power and authority. Moreover, tackling these threats gave Israel incentive to learn and implement the most efficient water management policies and strive for water independence, while it CoCT, these threats were a constraint and extra challenge for achieving water security, which still remain today.

6.3 Steps Towards Water Security

6.3.1 Water Laws

When comparing the main legislation made around water, there is a major difference that stands out between Israel and SA. While Israel's water laws focus mainly on how water will be managed and who will manage it, South Africa's laws following the democratic era are mainly about water rights and equality. Israel's laws and policies allowed the state to take full control of water resources and easily implement demand management strategies. The early legislation regarding water metering and abstraction make it far easier for the state to manage water efficiently. Additionally, nationalizing and taking full control of the water resources in the 1959 water law, was also an advantage for controlling water usage. South Africa's laws declare water as belonging to the people and managed by the government but gives people the right to use any water source they have lawful access to. This indicates that South Africans have freer access to water and water usage than Israeli's, which, whether seen as a good thing or not, means the government has less control over the resource. Additionally, water demand management only began in 2001 in South Africa, and water conservation was only acknowledged legally in 2013. Israel had quite the head start over South Africa with controlling water consumption and managing demand. This was definitely an advantage for Israel when the drought hit— they already had so many tools in place to work with for managing and controlling demand. For CoCT, they had to use new tools and work in ways they had not before in order to learn to aggressively control water consumption during the drought. This was not a small task for the city; authorities went around installing water management devices in almost every household in attempt to control water usage. This is an interesting difference reflected in the countries water laws that may have had some kind of impact on water security during the drought. While this is the main point I find in the comparison of legislations, there are a few other small things I'd like to point out.

After 1994, access to sufficient water and sanitation became a constitutional right for South Africa. Israel to date, does not have a constitution. This is interesting because the constitution is supposed to be the strongest form of legislation, and this shows that declaring access to water and sanitation as a constitutional right may not be enough to ensure water security. It may not even be much if the steps to implement this constitutional right are not taken. Seeing that Israel achieved water security without a constitution at all, says something about the importance of working towards implementation beyond just making the law itself.

Another small point I'd like to acknowledge is the importance of the free basic water policy established by the South African government. Providing basic water and sanitation to all, especially those who cannot afford it is essential. This is a policy that not only Israel should learn from, but all nations around the globe aiming to achieve water security. If implemented properly, this kind of policy could save many disadvantaged communities and households from lack of water and sanitation.

6.3.2 Main Governing Bodies

The main difference in governance is that in South Africa, water is governed on the national level, catchment level and municipal level, while in Israel water is governed only on the national level. Mekorot, the infrastructure company is government owned, and the corporations only provide services. On the municipal level, CoCT is a service provider but is also responsible for some local policymaking. The city has its own water and sanitation department and is given some responsibility in properly managing water. Israel's centralized governance versus SA's fragmented governance has already been discussed, and it is clear that this structure had many advantages for Israel and many disadvantages for SA and CoCT in managing water in general, and particularly during the drought.

Another advantage I find for Israel is the establishment of the water authority council. This board, including representatives from several ministries, is a space created to ensure collaboration between government bodies. This may have been much easier to implement in Israel considering it is a far smaller country than SA, and the government is structured in a very centralized way. However, SA clearly lacked a space where collaboration could take place during the water crisis in CoCT, and instead, the lack of coordination between bodies responsible for water governance ended up heightening the crisis.

6.3.3 Water Management Strategies and Policies

There are several similarities and differences in the water management strategies used in each region. Some are comparable like demand management, supply augmentation and wastewater treatment and reuse, while other are unique such as Israel's national infrastructure and technological innovation and CoCT's raw water treatment and efforts to address inequality. The comparable strategies will be discussed first.

Demand Management

Both Israel and CoCT have implemented various demand management strategies in attempt to reduce water consumption. Israel started using demand management strategies in the 1990's, while CoCT completed its first demand management strategy a decade later, in 2001. Israel's demand management effort managed to successfully reduce water consumption by 10%. CoCT's efforts since the turn of the century also managed to reduce total water demand, with the most significant decrease in consumption being during the drought.

As for their strategies, both Israel and CoCT used pressure reduction in pipes as a first step to reduce water consumption. This strategy showed successful results for both regions.

Water tariffs and pricing strategies have differences and similarities. In Israel, consumers must pay the full cost of water, and if they consume more than their water quota (2.5 m^3 per person in one month) they must pay even more. In CoCT, the block tariff system gives four water consumption categories (the more consume the more you pay) which is similar to Israel's system except there are different levels of consumption and no quota (so you could be a medium consumer, and also you can consume as much as you want). Also, Israel's quota is per person and CoCT's is per household. CoCT also has the free basic water though, which means several Capetonians get their first 25L a day for free. So, who pays more for water? Israelis are paying $2 per cubic meter and $3 per cubic meter if they cross the quota. Capetonians are paying approx. $0.84 per cubic meter in the lowest block and $2.59 in the highest block. However, in the highest block a household has consumed over 35 m^3 in one month (!), and still it is cheaper per cubic meter than using more than 2.5 m^3 per person per month in Israel. Hence, I think it is safe to conclude that Israeli's are definitely paying more for water than Capetonians, which may have played and continue to play a role in water consumption levels in the country. However, one thing CoCT also has is water restriction levels, where the price per block is raised as restrictions grow. This gave Capetonians serious incentive to reduce consumption during the drought. At the highest level of water restrictions prices in the lowest block are $1.9 per m^3 and in the highest block $65.70 (!) per m^3. If you could afford to be a top consumer before the restrictions, you definitely had incentive not to be once they were put in place. These high prices certainly influenced the drop in water consumption during the drought – no one wants to pay their entire salary on the water bill. It can be learned from here that water tariffs and restrictions are both very effective strategies when aiming to reduce demand, and both played an important role in demand management in Israel and CoCT. However, it seems that in time where water levels are not restricted in CoCT, Israelis are paying higher prices for water, which may have an impact on consumption.

Both Israel and CoCT have used education strategies and conservation campaigns as a demand management tool. In Israel the use of campaigns began in the 1990's and is still used today from time to time to remind Israelis to conserve water. These campaigns appeared all over the media, making them hard to miss if you were an Israeli citizen. These multimedia campaigns along with water conservation education were seen to be extremely successful and cost-efficient strategies. In CoCT the use of education and conservation campaigns began in 2005. These campaigns were said to be successful, even though total water consumption increased after 2005, but this could of course be attributed to population growth and other factors.

In order to minimize leaks in pipes and water losses, Israel mainly relied on charging companies for water losses and pressure reduction. However, in CoCT they sent out teams to detect leaky pipes and repair them. They also invested in pipe replacement which was probably far more necessary than in Israel considering the age of the infrastructure. For CoCT these efforts saved 2 MCM annually, and for Israel they reduced total leakages by 5%.

One strategy used in CoCT which was not used in Israel is the installment of water management devices. These devices can actually control the amount of water a household consumes in a day. While Israel does have a quota on monthly water use per person, they cannot prevent additional water consumption, only charge more for it. Israel also installed water conservation devices, but they only reduce water flow and pressure without limiting the amount of usage. These water management devices give CoCT a strategy of control over water usage which came to be very useful during the drought and may also play an important role in conserving water for the city’s future. This may be a strategy Israel can learn from CoCT if the country finds itself in a water crisis in the future.

While both regions implemented several demand management strategies, it seems that Israel’s were overall more developed and more aggressive compared to CoCT’s. It is clear though that Israel had a head start with demand management; while campaigns and education only started in the 1990’s, metering and controlling water extraction began already back in the 1960’s, giving them several decades to develop these strategies. For CoCT demand management is a relatively new tool that they were required to learn very fast and very urgently during the drought. Although they did use some strategies even before 2015, the scale does not compare to the ones they used to combat the 2018 water crisis. If CoCT had the demand management tools that Israel has prior to the drought, things may have turned out differently. Still, there are some strategies them Israel can definitely adopt from Cape Town such as water management devices.

Supply Augmentation

Israel's investment in supply augmentation is certainly a significant factor to be considered in this comparison. Israel has managed to supply 85% of its municipal water supply from desalination—a water source that does not rely on climate, rainfall, or the state of the freshwater resources. And here I cannot emphasize enough how significant it is for a water scarce country like Israel to have an artificial source of freshwater during a severe drought. In CoCT, augmenting supply has been much more limited and has so far meant building more dams (which is an additional reliance on surface water), and tapping into the unutilized aquifers, with possible options of desalinating water in the future. It may be assumed that Israel was able to invest in large scale desalination plants thanks to its finances. However, that may not be the only reason, considering how Israel has managed to produce extremely cost efficient (in addition to energy efficient) desalination technologies. In addition to technologies, Israel used a smart financial model for building the plants, which allowed them to be even more cost efficient. Water tariffs were also raised to help cover desalination costs, which takes some of the financial burden off the government. It may have also been policies, laws and the priorities of policymakers which enabled Israel to invest in seawater desalination. Hence, there are several things CoCT can learn from Israel about supply augmentation and specifically about constructing desalination plants. This difference in the scale and source of supply augmentation was definitely a factor influencing the contrasting outcomes of the droughts.

Wastewater Treatment and Reuse

Both Israel and CoCT treat a significant amount of their wastewater. They also use mostly similar treatment processes, except Israel provides tertiary treatment at most of its facilities while CoCT provides mostly secondary. The main difference here though is what they do with the wastewater. Israel uses 87% of the effluent for irrigation, and other agricultural purposes, and the rest is pumped into aquifers or discharged into rivers or the sea. While CoCT is increasing its effluent reuse, it still only accounts for about 8% of the city's water supply and is used mainly on a small scale. Most of the effluent is treated as waste and discharged into various water bodies, mainly the sea. Israel's greater utilization of effluent is mainly due to several policies encouraging farmers to replace potable water with treated wastewater. Lower prices, support and infrastructure in addition to setting quotas for potable water usage are just some of these encouraging policies. Reusing treated effluent is essentially a source of supply augmentation which can hugely benefit water scarce regions like Israel and Cape Town. Why CoCT does not utilize more of its wastewater is unclear to me at this time, but the city did state in 2018 that they aim to increase effluent reuse. Hence this is another lesson CoCT can take form Israel's water management – incentivizing the use of treated effluent in agriculture in order to free up a large amount of potable water for domestic use (especially when water is scarce). This is surely also another reason Israel's water sector was more resilient to the drought; especially considering that agriculture is the highest water consuming sector in the country.

The strategies unique to each region, while not comparable, can still be acknowledged as impactful on the water security of Israel and CoCT.

Addressing Racial and Socio-economic Inequality

The CoCT continues to make several efforts to ensure access to water and sanitation for disadvantaged households and communities. These efforts have especially increased in the last decade as the issue receives more attention. Having to manage the lack of water security for so many residents in the city is surely a task that requires extensive resources. Devoting resources to one cause often means less investment in another. The fact that Israel did not have to fight so hard for its citizens to have equal access to water means they had the resources to devote to other management practices.

Raw Water Treatment

Due to elevated levels of water pollution, CoCT must treat its freshwater before distributing it for any type of usage. In Israel, mainly due to the use of desalinated water (which is basically treated in the process of desalination) such expensive treatment is not needed. This is just an example of another factor burdening CoCT's water sector that Israel did not have to deal with.

Technological Innovation

Encouraging the invention and use of new technologies in the water sector allowed Israel to develop several ways of managing water more efficiently. Over the years, Israel has worked up a world-wide reputation for its technological innovation and water management practices which many nations are learning from. These innovations have certainly been a critical step towards the country's water security, especially the agriculture related technologies and cost-efficient seawater desalination.

Additional practices that were advantageous to Israel: pumping water into aquifers minimizes evaporation and the national infrastructure allowed the country to easily incorporate desalinated water into the urban water supply.

6.4 Lessons for Cape Town from Israel

This chapter exhibited how several of Israel's water management practices can be a lesson for CoCT. However, it seems that there are some things Israel can learn from Cape Town as well. The main lessons CoCT can learn from Israel are the following:

- Relying solely on surface water in an area of highly variable climate is very risky. It would be very useful for CoCT to have a source of artificial supply, specifically cost-efficient desalination plants such as the ones Israel has constructed.

- Preparing for climate change is extremely important. Preparing for lower rainfall and periods of drought is essential for CoCT in the next decades. Water managers must consider these impacts in order to ensure future water security.
- Israel’s centralized water governance has had numerous advantages for its water security. This is a lesson for South Africa and CoCT. If governance structure cannot be changed, at the least a council where collaboration between levels of government can take place should be established, just as Israel has done with the different ministries governing water. Such a council can be established by the national government or the municipality or both, whatever it takes to increase collaboration.
- Charing the full price for water can be a very effective tool for reducing water demand. CoCT could establish higher water tariffs, which not only show the value of water but also encourage its conservation.
- Recycled wastewater is a source of water supply which should not be taken for granted. Several agricultural crops can be safely irrigated with this water, and the amount of potable water used in agriculture can be reduced. CoCT should maximize its use of treated effluent in order to save potable water. It is important to encourage and give incentive to farmers to use this water by making it cheaper, setting quotas on potable water and providing the needed infrastructure and education.
- A water system must have the ability to adapt to new needs. Israel’s water management strategies changed constantly over the years. The CoCT can learn to be more flexible in making changes in the system, which might allow new practices such as groundwater utilization to be easier.
- Creating an environment where innovation is encouraged can be very helpful for the creation of new and efficient ways to manage water. CoCT can certainly benefit from such innovations, especially in the area of infrastructure and reducing inequality.

Here are a few points where Israel can learn from CoCT:

- When Israel has a constitution, establishing access to water as a constitutional right to all, regardless of the status of your settlement (formal or informal) would be a positive step towards water security.
- Israel could create a policy similar to SA's Free Basic Water policy that provides free water to disadvantaged households.
- Installing water management devices that limit daily water usage can be very useful in a water crisis. Israel could use this as an additional demand management tool so when and if they are facing a crisis they can control and not only suggest and encourage lower water consumption.

6.5 Lessons for Water Management in Water Scarce Regions

These lessons are not only relevant for Israel and Cape Town but can be helpful to water scarce regions all around the globe, especially with the changing climate. Specifically, the lessons that can be applied generally are:

- Relying solely on surface water is very risky for areas of highly variable climate.
- Water scarce regions should over prepare for climate change; better safe than sorry.
- Maximize the use of treated wastewater – this is an excellent source of water supply for all regions, especially water scarce ones, and should not be perceived as a waste.
- Storing water in aquifers filters the water and prevents evaporation.
- Water should be presented as a valuable resource – water should not be too cheap so that consumers use it wastefully. Set high water tariffs.
- Setting water quotas or installing water management devices are excellent demand management tools, which are especially useful for controlling consumption in years of drought.
- Before augmenting water supply, maximize demand management.

- Collaboration between all bodies governing water is critical for achieving water security.
- Use water efficient technologies and encourage innovation in the water sector so more of such technologies become available.
- Seawater desalination is an excellent source of water supply augmentation (for coastal regions) if constructed in cost efficient and energy efficient ways.

7. Conclusion

This thesis aimed to understand the reasoning for the different states of water security in Israel and Cape Town after both regions experienced their worst drought in a century. Using the comparative method, the threats to water security, and water governance and management strategies for each region were compared and contrasted.

The comparison of the threats suggested that CoCT faces several risks due to its reliance on surface water, while Israel relies mainly on desalinated water. This factor makes Cape Town's water supply more vulnerable to climatic factors as well as water pollution and alien plant invasion. Additionally, CoCT experiences more severe water scarcity than Israel (when the amount of available and accessible water is considered) along with issues of poverty, inequality and lack of infrastructure, all threats that Israel was not experiencing. Water governance has also been poor due to apartheid policies and the tensions between levels of government. Meanwhile, the threats Israel faced, it seems, turned into lessons instead of constraints. Having a vast desert area with little to no water led Israel to develop national infrastructure that connected the desert areas to water supply from the wetter parts of the country. A fast growing population, accommodating large waves of immigration as well as the ideological will to develop agricultural settlements at first led Israel to over extract and pollute all their water resources, but later resulted in the development of efficient irrigation technologies, learning how to utilize treated wastewater and investing in seawater desalination. Israel also had several threats to political stability caused by transboundary water resources which added additional pressure on the country to augment supply. Reliance on water resources independent of climatic factors such as desalinated seawater and treated wastewater made Israel's water sector far more resilient to the drought. Moreover, Israel managed to develop some of the most cost-efficient seawater desalination plants in the world, helping overcome financial constraints.

The comparison of governance and management strategies suggest that Israel's centralized governance has been an advantage over South Africa's fragmented Water governance, which raised additional challenges during the drought. Additionally, South Africa's water legislation was mainly focused on ensuring water access for those who were deprived of it by the apartheid policies, while Israel's water legislation was more focused on controlling and managing water resources. It also seems that Israel's demand management strategies, which have been in use for nearly three decades, are far more developed than CoCT's, which really only came into use after the turn of the century.

Overall, it seems that the main reasons Israel's water sector was more resilient than CoCT's was thanks to supply augmentation sources independent of climatic factors, efficient demand management strategies, technological innovation which led to high efficiency in water use and maximizing the use of recycled wastewater. However, it should be noted that this paper provided more of a general assessment of each region, and further research must be conducted to gain a deeper understanding of the cases, especially further analysis of policies and management strategies, alongside interviews with experts and policy makers.

On a final note, there are two more very important findings, which are possibly the most important lessons from this paper for water managers. One, it seems that another reason Israel's water sector was more resilient to the drought, was because the water managers have been preparing for climate change. In contrast, CoCT's water managers were using water models that did not take climate change into account. It is no surprise then, that when a climate change induced drought hit the region, they were far from prepared to face it. Two, it seems that CoCT's water managers were having trouble adapting to new ways of managing water, specifically to integrating new sources of water supply. On the other hand, Israel's water sector has been constantly changing its management styles and adapting to new and better ways since the country was founded. The ability to adapt certainly makes a region more resilient. With climate change coming and the future of water being so unpredictable; the ability to adapt is essential for water managers all around the globe.

Water security is critical for sustaining human life, and it is now more important than ever to start managing the world's fragile freshwater resources in the most efficient and sustainable way. For centuries people have taken freshwater for granted, believing there was an endless supply. What happened in Cape Town is a wake-up call to nations all around the globe, especially those that are already water scarce. The sustainable management of water and making it accessible for all people must be a priority. It is also essential to address the changes in the atmosphere that climate change is bringing and adapt water management practices accordingly. That is the only way water security will be achieved and sustained.

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