

Experiences and lessons in managing water from Cape Town

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Headlines

- Water shortages will become more common in cities around the world during the 21st century due to climate change.
- Cape Town, South Africa experienced an especially severe drought in 2017-2018 after several years of low rainfall. This drought prompted an estimate of Day Zero, when freshwater reservoir levels supplying the city would fall below 13.5% of capacity and the majority of the municipal water network would be shut down.
- In response to this crisis, the City of Cape Town municipal government significantly extended an existing set of rules and regulations, and introduced additional measures, to limit water demand. These actions included restricting available water; new tariffs to penalise excess water usage; water management devices installed in domestic properties; and novel communication strategies.
- The water crisis has had widespread economic and social impacts, with damage to the tourist and agriculture industries; and tensions between sections of society and government.
- Any city under water stress, like Cape Town, needs a long-term strategy for water supply and demand. Such a strategy should include diversity of water sources, equity of service provisions, thoughtful but forceful messaging, early warning systems and co-operation between local, regional and national levels of government.

Introduction

Stress on water supplies caused by drought is a global phenomenon¹. Increasing urbanisation and population growth have impacted existing water supplies that were developed decades ago. Current modelling estimates a significantly increased frequency and severity of drought due to climate change if the rise in average global temperature exceeds 1.5°C above pre-industrial levels or more². With over two thirds of the world projected to live in urban areas by 2050³, solutions to maintaining urban water supply are essential to maintain the health and wellbeing of the global population. Cities and urban populations need to adapt both supply- and demand-side planning, as well as existing infrastructure, to accommodate threats to water supplies.

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Grantham Briefings analyse climate change and environmental research linked to work at Imperial, setting it in the context of national and international policy and the future research agenda. This paper and other publications are available from www.imperial.ac.uk/grantham/publications

Cape Town, a rapidly urbanising coastal city of over 4 million people in the Western Cape region of the Republic of South Africa, has been at risk of water scarcity for many years. Its dry climate and relatively high per capita water consumption are at the heart of the city's water challenges. In early 2018, after three concurrent winters of low rainfall (a one in around 300 year event and the worst in over 100 years)^{4,5}, the City of Cape Town (CoCT) announced that the population would need to take drastic action to avoid running out of water – a situation termed 'Day Zero' (Box 1) – for the first time in the city's history. On Day Zero, the majority of the water distribution system for the city would be shut off, and water would be distributed through communal standpipes to residents and limited to 25 litres (6.6 gallons) per person per day⁶, in line with World Health Organization (WHO) minimum short-term emergency survival recommendations⁷. 60% of the population were regularly using more than 87 litres (23 gallons) at the time of the announcement⁸. The issue has been legally and politically contentious – the Constitution of South Africa guarantees the entire population the right to access 'sufficient water', so the

Government of South Africa is obliged to ensure that water supplies are adequate⁹.

The experiences of Cape Town and its population are directly relevant to many urban environments globally, both those experiencing rapid urbanisation with large differences in the socio-economic status of its residents, and cities in developed countries, where, like Cape Town, finance and other services are the largest contributors to economic growth¹⁰.

Threats to water supplies can also compromise health and sanitation, and have a knock-on effect to several of the United Nations' (UN) Sustainable Development Goals (SDGs), which were created with the target of ending extreme poverty worldwide by 2030. The SDGs most affected by restricted water supplies are SDGs 3 (Good Health), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 15 (Life on Land)^{11,12}. Universal access to safe and affordable drinking water and sanitation is also part of the UN New Urban Agenda¹³.

Box 1: Definitions

Day Zero: The estimated day on which reservoir levels supplying Cape Town fall below 13.5% of capacity⁶. The last 10% of the reservoir levels is difficult to extract²³. It is not a fixed date as it was shifted according to dam levels and projected water consumption in the city⁷⁸. The scenario would lead to Phase 2 of the Disaster Risk Management Centre of Cape Town to protect water supplies⁹². Taps would be turned off, leaving only vital services with access to water. Schools and most businesses would close, unless they fulfilled certain criteria, such as possessing their own bore holes, temporary off-mains toilets and drinking water. The entire population would have to collect water from around 200 collection sites, with a restriction to 25 litres (6.6 gallons) per person per day, in line with World Health Organization (WHO) minimum short-term survival recommendation⁷.

City of Cape Town (CoCT): The municipal government in control of the metropolitan area of Cape Town. The Water and Sanitation department within the CoCT is responsible for, amongst other things, maintaining the water supply system for the city, reading water meters and billing households appropriately, and water demand management⁹³.

The Western Cape Government (WCG): The provincial government in which Cape Town falls geographically and reports into. The WCG provides a support and oversight role in relation to water, and acts as a liaison to escalate requests to national government⁹⁴.

The South African Government: The national government, and the highest level of authority in South Africa. Through the National Water and Sanitation Department it is responsible for producing major water infrastructure within South Africa,

including building dams. It also controls access to critical disaster funding through the National Disaster Management Centre and decides how much water within the Western Cape Water Supply System (WCWSS) to allocate to agriculture vs the city.

Surface water: Water that collects on the surface of the ground, typically in rivers and dams, supplied by rainfall¹⁵.

Groundwater: Water that seeps underground after falling as rain, in between the porous soil, sand and rock, forming bodies of water known as aquifers¹⁵. Water can be extracted from aquifers through the installation of pumps, known as boreholes or well points, that draw the water to the surface. These pumps vary in the volumes of water extracted, ranging from the 22,000 boreholes registered to private households around the city, through to the wide-scale wellfields used for municipal extraction⁹⁵. CoCT has two aquifers that are targeted for use in the future, the Cape Flats and Table Mountain Group Aquifers, and is already providing 2% of the city's water supply through the Atlantis-Silwerstroom Aquifer⁹⁶.

Informal settlements: An unplanned settlement on land that has not been surveyed or proclaimed as residential, consisting mainly of makeshift structures not approved by a local authority and not intended as a permanent dwelling⁹⁷.

Indigent households: Households consisting of residents lacking the necessities of life, including sufficient water and basic sanitation⁹⁸.

Desalination: The method of purifying water with high salinity, typically sea water, to remove the salts so that it can be used for other purposes, such as drinking and cleaning.

In this paper, we will contextualise why Cape Town is experiencing water shortages, what the government and society have been doing, and continue to do, to avoid and mitigate the severity of the water crisis, what effect the water shortage is having on Cape Town, and what lessons can be drawn from Cape Town’s experience for decision makers and stakeholders worldwide.

Why has Cape Town experienced water shortages?

The Western Cape region of South Africa has a Mediterranean climate, with wet, cool winters and warm, dry summers¹⁴. Most rain in Cape Town falls during winter (May-August), with average annual precipitation of 749mm¹⁴. Cape Town’s surface water supplies are stored in six major reservoirs, supplied by rainfall, as well as a small portion from groundwater sources (Box 1)¹⁵. The Western Cape Water Supply System (WCWSS) supplies water from these reservoirs via its distribution networks¹⁶. When water restrictions have not applied, around 70% of the water supplied by WCWSS is allocated to urban and industrial users, with 30% for agricultural use¹⁶.

The recent water shortages have been mainly caused by a lack of rainfall, and exacerbated by other factors, such as high consumption and lack of investment in water supply capacity^{5,17}. Freshwater supply (rainfall and groundwater combined) to the Western Cape region is sensitive to small changes in rainfall. Since 2015, the rainfall has been abnormally low^{5,17}.

As the population of Cape Town has grown (from 1.6 million in 1980 to over 4 million in 2018), the water available per person each year has dramatically decreased, from a high of over 500,000 litres (100,000 gallons) per person in the early 1980s, to around 200,000 litres (50,000 gallons) per person in 2016¹⁸. In the early 1990s, the CoCT put in place extensive water demand management, decoupling water demand from growth in population (Figure 1). However, this has not diminished Cape Town’s vulnerability to water shortages due to lack of diversity in the water supply system. Water usage by urban, industrial, and agricultural users is also changing, putting more

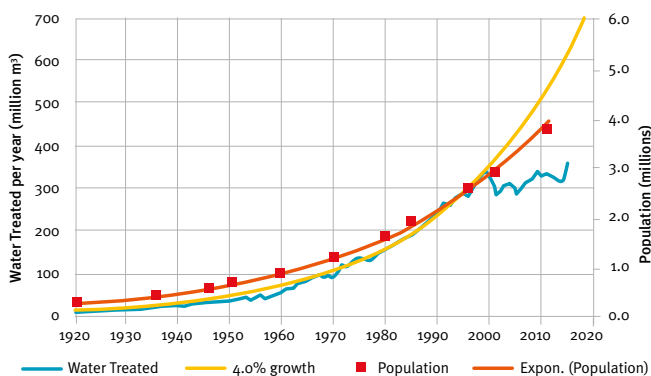


Figure 1: Quantity of water treated per year, and population over time in Cape Town¹⁰⁵

pressure on the water supplies. ‘Virtual water’, water used in the production of a commodity that is then exported out of South Africa, has emerged as a key factor – South Africa is a net exporter of virtual water¹⁹. Increases in agricultural water use has also contributed to recent shortages. The formalisation of previously informal settlements of indigent black communities (Box 1), moving away from drawing water from communal taps, has made a relatively small impact on the water usage¹⁶.

A report issued by the Water Research Commission in 1990 highlighted that the CoCT would face a major water supply crisis in 2007²⁰. Suggestions for action included building new dam capacity, as well as introducing new water conservation and management laws. The report was based on population growth prediction and the available fresh water supplies. The CoCT successfully implemented various initiatives to reduce water demand. However, the limited funding available for investment in water infrastructure from national government did not allow for water augmentation plans to be fulfilled^{20,21}.

What could happen under future climate change scenarios?

Average annual temperature has increased in South Africa at 0.14°C per decade over the past 30 years¹⁴. Estimates of future warming are in the range of 1.4°C to 4.7°C, relative to 1971-2000, by 2100¹⁴. Rainfall may also reduce annually by as much as 9% by 2100, relative to 1971-2000 levels, which is estimated to lead to a 20% reduction in surface water supply²². Projections also suggest changes in distribution of rainfall throughout the year, with more prolonged drought and dry spells along with more intense rainfall events¹⁴.

The increase in overall temperature, reduction in rainfall, and increase in drought is likely to have cascading impacts on water availability in the Western Cape and Cape Town, putting more strain on freshwater supplies.

Managing water demand

The CoCT prioritised reducing demand for water to manage the drought, and then rationed the remaining reservoir water stored within the supply system²³. Projects targeting water demand typically yield faster results with low investment cost when compared with increasing water supply²⁴. The CoCT focused on promoting water-saving behaviour in households, while simultaneously implementing projects that would forcibly curb excessive water use²⁵. Aside from CoCT-led initiatives, citizens, regional Western Cape Government (WCG), private industry and Cape Town’s academic community all played a role in reducing water demand in the city, as outlined below.

Water restrictions

The CoCT introduced increasingly strict water restrictions over the period of the crisis, which evolved and developed over time as the water shortage became progressively more acute (Table 2). Fines of between R1,000 (\$70) and R10,000 (\$700) were used as punishment for transgressive behaviour and high-consumption households²⁶. Water restrictions defined limits on how water could be used, in what quantities and for which purposes. At the most extreme level of restriction implemented, Level 6B, residents were restricted to a maximum of 50 litres (13.2 gallons) of water per person per day. Restrictions were revised on an ad-hoc basis by the CoCT, with some revisions taking place within a month of the previous restriction. Under normal circumstances, further restrictions would have to be sanctioned by the Council of the CoCT. However, under enacted

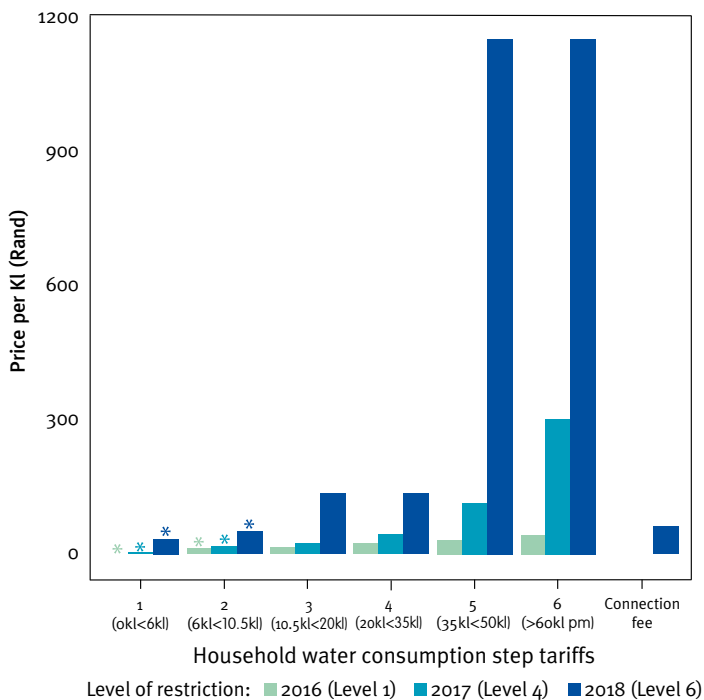


Figure 2: Step tariff charges for water usage during different restriction levels imposed by the City of Cape Town municipal government
Prices marked with a star (*) are free for indigent households

‘state of emergency’ laws, the Council could be bypassed^{26,27}. The expected increase in water shortage events worldwide, like Day Zero in Cape Town, may therefore have implications on the safety of democracy, with autocratic decisions required to maintain sufficient water restrictions.

Tariffs

The CoCT operates on a step tariff payment system for water, in existence before the current water crisis. In the system, each additional unit of water becomes more expensive as greater volumes are used (Figure 2)²⁸. Different rates are applied based on the level of water restrictions currently active²⁹, and households are also subject to a sanitation charge, calculated as a percentage of their water consumption for the month²⁸. Under normal circumstances, the CoCT is limited to a single adjustment of tariffs per year as part of their budget review, which comes into effect annually in July. In response to the water crisis, tariffs were increased significantly from 2016 until late 2018 in order to reduce water demand. Tariffs were not downgraded again until 1 October 2018³⁰.

Prior to the drought crisis, all households in Cape Town received 6,000 litres (1,320 gallons) of free water per month, while indigent households received an additional 4,500 litres (1,189 gallons) free²⁹. In the 2017/2018 budget, the free allocation of water was removed for non-indigent households, while the 2018/2019 budget introduced a new fixed monthly connection charge, unconnected to the consumption volumes and based on the diameter of the supply pipe entering the property (Figure 2)²⁹. This new tariff structure was required to cover the fixed costs incurred in the delivery of water, and attempted to mitigate the loss of income resulting from reduced consumption in the higher tariff blocks (which had previously been used as a buffer for these expenses)²³. The potential conflict of interest here hints at a challenge in retaining commercial viability of water utility companies, public or private, when encouraging reductions in water usage while still wanting to maximise profitability. The challenge of maintaining commercial viability is further laid bare by the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) report from 2017, which found that, in more than half the countries surveyed, water tariffs are already insufficient to recover operations and basic maintenance costs³¹.

Water Management Devices

A Water Management Device (WMD) is equipment that can be installed to a water supply pipe to enforce a set daily limit of water for a property³². After the maximum withdrawal is reached for the day, the water is reduced to a trickle until the following day when service is resumed³³.

Originally used to manage debt and unfixed leaks from indigent houses over many years, the CoCT rolled out WMDs throughout 2017 as part of a voluntary program whereby indigent households could choose to have a WMD installed without charge, combined with a one-off house leakage fix and an agreement to write off historic water debt³².

In a shift of strategy away from targeting only indigent households, as part of Level 4 restrictions (Table 2), the CoCT targeted high-consumption households who refused to voluntarily reduce water use despite having received written warnings. Within the new water restrictions, households with consumption above 10,500 litres (2,773.8 gallons) per month were penalised by having a WMD fitted at their expense. The devices were designed to restrict households to 350 litres (92.5 gallons) per day, or 10,500 litres (2,773.8 gallons) per month³³. Households could apply for increased amounts of water based on the number of people living at the residence³⁴.

City-wide water pressure reductions

From 2017, the CoCT steadily reduced the water pressure in municipal pipes, controlled through localised pump stations²³. Water pressure management provided various overarching benefits – the reduction of water pressure through the city,

compared with pre-crisis levels, reduced overall consumption, decreased water loss through leaks, and resulted in a reduced frequency of pipe bursts and further leaks^{23,35}.

Communication strategies, behavioural nudges and the Cape Town Water Map

In 2016-2017, the CoCT embarked upon an extensive public relations campaign to encourage water saving. Websites were set up to display current dam and consumption levels, and to help households understand their water use. Messages providing tips on how to save household water were published across various channels, from radio adverts, to flyers in water bills, to billboards around Cape Town (Figure 3). These communication campaigns were successful in contributing to changing the social norms around water use in the city, as many of the recommendations were widely adopted by residents³⁶.



Figure 3: Ways to reduce water usage from “Water Saving Checklist to Avoid Day Zero”¹⁰⁶



Figure 4: Screenshot of the Cape Town Water Map website. Dark green dots represent residential properties that are currently using under 6,000 litres (1,585 gallons) of water per month, with light green representing those using 6,000 (1,585 gallons) to 10,500 (2,773.8 gallons) per month¹⁰⁷

As well as these positive messaging campaigns, other aspects of the communications were more forceful and, at times, controversial. The city's press release announcing the city's 'Critical Water Shortages Disaster Plan and Day Zero' outlined the drastic measures that would be required if water savings targets were not met. High-consumption households received strongly worded personalised letters from the mayor, instructing them to reduce their consumption or face severe consequences. The CoCT encouraged citizens to monitor and report any transgressors to toll-free hotlines set up by the city. Citizens who were not adhering to water restrictions were shamed for their behaviour and blamed for bringing about Day Zero, and the road names where the top 100 'water guzzlers' lived were published in local media by the city³⁷.

The CoCT also built on previous behavioural economics research that showed that public recognition for reducing water consumption, and visibility of social norms around consumption, is effective at incentivising households to conserve water³⁸. To do so, the Cape Town Water Map (Figure 4) was developed, a controversial webpage showing a map of Cape Town, with markers per household to indicate which households were achieving reduced consumption targets^{39,40}.

Smart Water Meters

Smart Water Meters (SWMs) have been installed in over 350 schools across the city, alongside an educational campaign to save water⁴¹. The project was run as a partnership between the provincial government of the Western Cape who provided access to schools, private companies that contributed funding, and local universities who monitored the impact.

Mobile applications

A variety of mobile applications were produced during the drought and preceding years to address different aspects of water management, including TapOff and Drop Drop. TapOff focused on gamifying the experience of water saving, by presenting users with leader boards to display low-consumption behaviour⁴². Drop Drop was developed as a research prototype by the University of Cape Town to test the impact of information on a household's water consumption behaviour, and provide them with tools to track and visualise their water use⁴³.

Research on the original prototype of Drop Drop demonstrated that the application aided water savings amongst users⁴⁴.

Reducing water use in the agricultural, commercial and industrial sectors

CoCT initially focused on reducing Cape Town's domestic usage, as this made up the largest portion of water use (69% in 2017) (Figure 5)²³. From September 2017, at Level 5 water restrictions, non-domestic water restrictions were introduced, aiming for a 20% saving compared to the same month in the previous year⁴⁵. This was increased under Level 6 (January 2018) to target a 45% saving for commercial and industrial properties compared to 2015⁴⁶. The CoCT hosted business forums to encourage voluntary water savings and sharing of best practices⁴⁷. There were hard limits on agricultural quotas for water⁴⁸.

Overall impact of water demand initiatives

The net impact of the water saving interventions was highly effective, with daily average water consumption for the city reduced from 1,200 million litres (317 million gallons) in February 2015, to 500 million litres (132 million gallons) in February 2018. From December 2017 to March 2018, the percentage of single-family homes using less than 10,500 litres (2,773.8 gallons) of water per month increased from 64% to 81%, with those using less than 6,000 litres (1,585 gallons) increasing from 31% to 49%³⁹.

Evaluating the individual impacts of interventions on reducing water consumption is challenging due to concurrent, overlapping initiatives. It is also difficult to quantify exactly how much the reduction in municipal water use is due to change in water source, rather than a reduction in water consumption. However, the following factors most certainly contributed towards the overall reduced water usage:

- The announcement of Day Zero and the city's Critical Water Shortages Plan precipitated the most significant drop in consumption, as citizens took to heart the severe consequences of not saving water⁴⁹.

**Potable water consumption by use category
(01.01.2017 – 31.12.2017)**

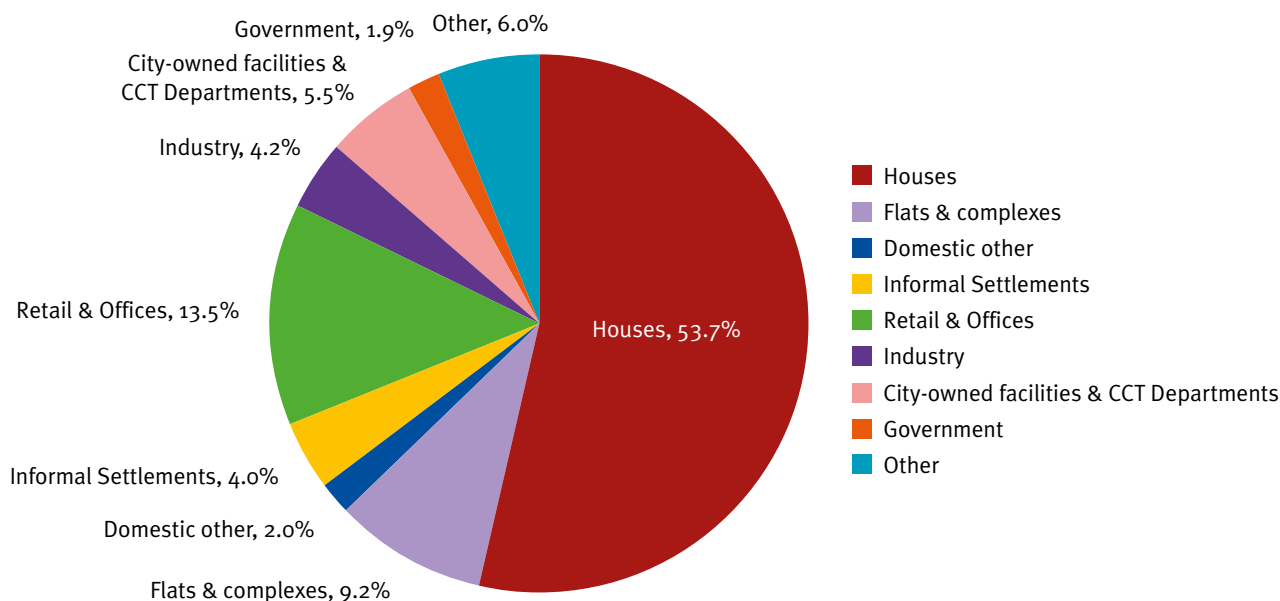


Figure 5: Potable water consumption in Cape Town by use category in 2017

- Levels 1 and 2 of water restrictions (Table 2), introduced before most other interventions, reduced water usage by between 10% and 15.5% compared with pre-restriction levels⁵⁰. In contrast, the introduction of Level 5 restrictions seemed to show hardly any change in consumption⁴⁹.
- At a household level, it became commonplace for citizens to have ‘navy showers’, i.e., stopping water flow while applying soap and shampoo, to conserve water, and for water from showering to be captured in buckets and used to flush toilets. This was also carried through to many public bathrooms, in which citizens were either encouraged to flush toilets only when necessary, or included a ‘permission stall’ in which people were authorised not to flush.
- The net impact of the removal of the free allocation of water (Figure 2), along with the increased tariff charges and the introduction of a fixed monthly charge, have, according to some, resulted in an increased monthly municipal bill for some households⁵¹.
- The CoCT credited their aggressive pressure reduction scheme as saving 55 million litres (14.5 million gallons) of water per day during the drought, though some residents experienced water outages from this measure²³.
- As of March 2018, 46,000 WMDs had been installed in high-consumption households in Cape Town²³. Though effective, WMDs represent one of the more controversial and adversarial drought interventions in terms of societal impact. Most prominent of the concerns raised is the fairness of the limit being applied for high-occupancy households⁵².
- SWMs are saving upwards of 1 million litres (0.3 million gallons) of water per day in local schools, with a saving of over R13 million (\$900,000), and have contributed to over 165 million litres (43.6 million gallons) of water saved for the duration of the initiative.
- The high volume of media coverage and social media commentary around the Cape Town Water Map (Figure 4) suggests that it contributed towards awareness of the importance of reducing household water usage³⁹. It was, however, a controversial intervention as some Capetonians felt that the website violated their privacy and was being used as a tool to shame households that did not appear on the map as being non-compliant^{39,40}.

Managing water supply

Aside from the contingencies introduced to reduce water demand, a complementary stream of interventions was directed towards increasing, or augmenting, the water supply to the city. A continuing challenge to creating or increasing the water supply in Cape Town is that supply infrastructure, such as reservoirs, are financed, planned and administered by the national government, currently run by a separate political party to that of the CoCT.

In June 2017 the CoCT issued a ‘Request for Information or Ideas⁵³’ to source ideas for the production of an additional 500 million litres (132 million gallons) of water per day through a combination of groundwater extraction, water reuse and

desalination (Box 1). These projects were prioritised in two stages: emergency – to provide water immediately to stave off Day Zero; and strategic – to create greater resilience in the water supply system in the long term (Table 1).

Desalination: temporary installations and barges

The CoCT originally planned to install nine temporary desalination plants around the coastal periphery of the city, contributing some 50 million litres (13.2 million gallons) per day to the water supply system, as well as a further 50 million litres (13.2 million gallons) per day through a desalination barge⁵⁴.

However, upon consultation and further analysis of the technologies, the CoCT determined that containerised desalination plants, though quick to roll out, were neither cost-effective or reliable, nor would they produce sufficient volumes of water to have a measurable impact on the immediate drought⁵⁵. Based on this feedback, the projects were scaled down to three temporary plants, yielding a total of 16 million litres (4.2 million gallons) per day²³.

Extracting groundwater from Cape Town’s aquifers

Groundwater extraction was assessed to be the cheapest, quickest large volume water augmentation option, as the operating and capital expenses are lower than alternative projects and it requires less electricity to operate than other options^{23,55}. An advantage of using groundwater as a resource is that there is a significant time delay between the onset of

drought and water availability²³. The CoCT’s Water Resilience Plan released in 2018, a proposal on how to develop Cape Town’s water infrastructure to minimise the impact of future water shortages, includes the intention to produce a further 100 million litres (26.4 million gallons) per day for the municipal water supply system from three groundwater sites around Cape Town, within a total time frame of 12-48 months²³. However, aquifers must be recharged, either naturally through rainfall or artificially through water being pumped into them, if they are to continue to supply water without significant knock-on environmental impacts. For example, the Cape Flats Aquifer supplying Cape Town requires a recharge of water supplies from treated wastewater and stormwater²³. The Atlantis Aquifer, which has been in operation for four decades, is also being refurbished to ensure it is operating efficiently⁵⁶.

Since the drought crisis was classified as a national emergency, the interventions put forward are exempt from having to comply with the National Environmental Management Act⁵⁷. Environmental concerns have been raised relating to groundwater extraction projects, as 141 of the intended 222 drill sites planned fall within protected areas. If the projects proceed, they could cause significant impacts to the biodiversity of these areas⁵⁷. Compared with the alternatives, however, the CoCT asserts that groundwater extraction has the potential to have the smallest environmental impact if managed correctly²³. Nature-based solutions, which use or mimic natural processes to contribute to the improved management of water, may also provide some of the future water supply while minimising environmental impact⁵⁸.

Table 1: CoCT’s water supply augmentation planning^{23,54}

Technology	Water augmentation projects as per Water Resilience Plan (August 2017)		Water augmentation projects as per Water Outlook Report (May 2018)	
	Total Ml (multiples of 1,000,000 l) per day (Short term)	Total Ml per day (Medium-long term)	Total Ml per day (Short term)	Total Ml per day (Medium-long term)
Groundwater extraction	100		57	100
Desalination: temporary (land-based containers and barge)	100		16	0
Water reuse		50	10	70
Desalination: permanent (land based/marine based)		250		120
Surface water (dams)				60
Springs and rivers	7.5		7.5	
Total	207.5	300	90.5	350

Figures in bold indicate **temporary** supply sources that will not contribute to medium-long term water supply.

Aside from the large-scale municipal groundwater extraction projects, many households have begun to make use of localised groundwater sources by installing and sharing boreholes and/or well points at private residences and businesses, and by collecting water from natural springs. This raises issues of equity of availability.

Residential spring water collection

Cape Town has a large network of publicly accessible spring water collection points of varying degrees of formality⁵⁹. During the water crisis, the number of households supplementing their municipal supply with spring water increased dramatically. For example, the number visitors to one small spring increased from 100 to 7,000 per month, while another received over 2,000 visitors per day⁵⁹.

In some cases, the facilities in place at the spring water collection points were not designed to accommodate the increased volumes of people, causing negative impacts on the experience of water collectors as well as the surrounding neighbourhoods⁶⁰. Many individuals reported having to queue for hours to collect water, and a new restriction was put in place to dictate that a maximum of 25 litres (6.6 gallons) could be collected per individual per day in an attempt to reduce queuing times. Tensions heightened, with cases of physical fights breaking out between individuals, leading to the city supplementing existing private security with police. Residents in the areas in which springs were located, such as Kildare Road, complained of increased traffic and noise from crowds visiting the spring^{60,61}. The Kildare Road spring was subsequently closed by the CoCT and water rerouted to Newlands Pool, so that people could park and congregate in a more suitable place⁶¹.

Water recycling

Prior to the drought, around 8% of the city's wastewater was made available to be processed into water suitable for irrigation and industrial purposes, but not of drinking quality⁵⁵. The Water Resilience Plan originally intended to introduce 50 million litres (13.2 million gallons) per day (later upgraded to 70 million litres) of recycled drinkable water to the city's municipal supply⁵⁴. These two different types of wastewater recycling will help to reduce pressure on existing drinking water supplies.

The timeline of constructing wastewater recycling plants depends on the quality of the water being received, and the type of treatment necessary to bring it up to drinking quality⁵⁵. Projects are currently underway to implement the water reuse plants.

Early warning systems for drought

As the water restrictions developed during the drought, specialists, the public and the international community began to question why the response to an apparently predictable crisis had been so slow and so late. This became a contested issue, highlighting the difficulty of prediction and early warning systems, as well as the challenge of responding to a crisis early in a resource-constrained setting.

A reason for the slow response to the prediction of a drought, cited by the academic community as well as the CoCT, was the limited data available, which minimised the ability to forecast with a greater level of certainty⁶². To illustrate this, only four rain gauge stations were available for dams relevant to Cape Town⁶². Since September 2017, several initiatives have been implemented to prepare for water supply and demand issues⁶³. A core focus of these initiatives has also been to provide better communication to the public.

First, accurate monitoring of dam levels provides information which feeds into when and how various plans of action are implemented by the CoCT. The CoCT and the National Department of Water and Sanitation measures and monitors dam levels, providing daily and weekly levels online, as well as a detailed monthly report⁶⁴.

Operational predictions of rainfall are also being developed. Rainfall data visualisation showed that 2017 had been one of the driest years on record, but the main challenge was that low levels of rainfall in 2017 had been preceded by two very dry winters⁶⁵. Recognising the importance of research into early warning systems for drought, the CoCT and local universities are now working more closely on building forecasting and warning capacity^{5,17,62,63}. However, forecasting is always based on a probability, and the assessment of such probability requires decision makers to understand the severity of the situation, as well as the possibility for forecasts to be inaccurate. Even the most trusted seasonal forecasts can be off-target during El Niño and La Niña years⁶⁵. Furthermore, under climate change, weather patterns will become more varied, which could have an impact on weather predictability¹⁴.

As highlighted by specialists in the field, forecasts only help so much. It is also necessary to have a flexible approach to resource management, which requires innovation and collaboration between the city and climate research communities.

Long-term water planning in Cape Town

In 2000, the Integrated Water Resource Planning Report (IWRPR) explored 16 demand and supply-side interventions proposed in Cape Town²⁴. The IWRPR ranked interventions across five metrics – yield, financial, socio-economic, acceptability and environmental – and was used to inform the CoCT water strategy²⁴. Initiatives focusing on demand management were the top-rated projects, with ‘pressure management’, ‘elimination of automatic flushing urinals’, and ‘tariffs, metering and credit control’ as the top three. These became the CoCT’s primary focus of future efforts to match water demand and supply. In addition, in 2007, a report commissioned by a consortium of local and regional governmental partners in the Western Cape projected water supply and demand to 2030⁶⁶.

Since then, the CoCT have recognised the critical importance of medium- to long-term diversification of water sources to include supply systems beyond rainfall²³. Plans are now underway to increase long-term water supply by 350 million litres (92.5 million gallons) per day (Table 1)²³. Non-surface water (such as groundwater) is consistently more expensive compared with rain-fed dams (R12 (\$0.84) per 1000 litres (264.2 gallons) compared with R5 (\$0.35) per 1000 litres (264.2 gallons). Surface water will likely remain the dominant source for Cape Town. Nevertheless, resilience will be increased through augmentation from different sources that are less dependent on rainfall in specific regions²³.

Beyond infrastructure-driven augmentation plans, the CoCT is also investigating measures to ensure that more water reaches the existing supply network by clearing water-hungry foreign vegetation from water catchment areas – an approach that economic models have suggested will produce a better return on investment than desalination projects⁶⁷.

What were the impacts of the water crisis on Cape Town and its residents?

The Cape Town drought has impacted a variety of different aspects of society, from public health, tourism and agriculture, to other parts of the economy and government finances.

Public health risks of drought

Commonly observed health impacts of drought include malnutrition, vector and airborne or dust-related diseases, water-related diseases and mental health aspects⁶⁸. Particularly at risk to drought are children⁶⁸, old⁶⁹, indigent⁷⁰ or chronically-ill people, and young or pregnant women^{68,71}. In Cape Town, drought causes potential disruption to healthcare provision, such as for teenage girls vulnerable to HIV and unwanted pregnancies, and could endanger researchers of sensitive biological material in laboratories due to increased risk of fire and chemical injury at a time when water is limited⁷².

The possibility of these impacts occurring in Cape Town were considered highly likely in the event of Day Zero, particularly in relation to the spread of disease. Under Day Zero conditions, the allocated 25 litres (6.6 gallons) per person per day would likely be insufficient to keep a household hygienic, particularly so given the risk of cross-contamination caused by the widespread practice of using greywater, and misinformation around food hygiene practices, such as encouragement to forego washing fruit and vegetable, which spread through popular media⁷³.

While formal healthcare systems in Cape Town reportedly had plans in place for dealing with water being cut off, they were not shared with the public⁷³. The CoCT did identify sites in Cape Town as being of strategic importance that would continue to receive water directly during Day Zero water cut offs, and further initiatives were put into action to install boreholes and alternative water supplies at hospitals to enable them to operate independent of a municipal water supply.

Drought impacts on agriculture could have also had knock-on effects to health due to reduced yields of crops and livestock, leading to reduced quantity and/or quality of nutrients, making individuals more vulnerable to disease.

Agricultural impacts: reduced yields and job losses

The main commodities produced within the Western Cape are based on horticulture, particularly fruit, vegetables, grape vines, wheat, canola and barley – crops that typically require irrigation during summer⁷⁴. In addition, livestock and dairy are important agricultural products produced in the area. Farmers attempted to mitigate the impact of reduced rainfall on crop and livestock yields by relying more heavily on municipal water for irrigation and moving to alternative water sources. However, due to water restrictions that limited consumption, there was still a significant impact on agriculture⁷⁵.

It has been estimated that production for major crops was 20.4% lower from 2016/2017 to 2017/2018 representing a R5.9 billion (\$415 million) loss in industry⁷⁵. Furthermore, the anticipation of the reduced harvest size led to the unemployment of seasonal farm workers, with over 30,000 jobs lost during the drought. The impacts of this reduced harvest are expected to last 8-10 years. Loss of employment has also increased social unrest in agricultural areas⁷⁴.

Economic impacts

Tourism accounts for 10% of South Africa’s economic output, and provides 1.5 million jobs – around 10% of total employment in the country⁷⁶. During the drought in Cape Town, reports suggest a decrease in visitors over 2017 compared with previous years⁷⁷⁻⁷⁹.

Other specialised commercial businesses were impacted by the drought, with some benefitting and many others suffering depending on their line of work. A decreasing demand for garden plants due to restrictions on using municipal water saw nurseries having to make redundancies, while swimming pool producers reported a 50% decrease in sales, and building companies scaled back development plans^{80,81}. Some isolated examples of businesses that thrived were producers of water tanks, borehole installers and bottled water companies^{82,83}.

Beyond business, the CoCT municipality faces opposing incentives in relation to water demand, as reducing water consumption represents a loss of income, particularly when water use is reduced in households paying a higher tariff. During the drought, the city faced a dramatic reduction in their revenue due to reduced water sales, leading to a shortfall of close to R2 billion (\$14 million). The CoCT budget had to be subsidised by reducing other programmes, reducing other programmes and funnelling money to subsidise provision of services through the water department²³.

Social impacts

South Africa is one of the most unequal countries in the world⁸⁴. While many of the poorest residents live in informal settlements in unplanned quarters of the city without flushing toilets, some exclusive residential properties are worth tens of millions of dollars.

The difference in water usage between the socio-economic groups in Cape Town is also clear, with informal settlements making up 3.6% of total water consumption, compared with formal settlements making up 64.5%. Before the drought, the average daily water usage per person in the Western Cape was 201 litres (compared with 140-150 litres in the United Kingdom (UK)), in part due to significant volumes of water in Cape Town being used for outdoor activities⁸⁵⁻⁸⁷. Despite this, the CoCT have historically targeted poorer households for installation of WMDs. Furthermore, communal water springs, such as those at the base of Table Mountain, are often many miles away from the indigent population⁸⁸. Many wealthier residents managed to stockpile water or develop private access to groundwater via boreholes, which can cost thousands of dollars to install⁸⁸.

The division between the wealthier and indigent members of the population is commonly along racial lines. The water shortage has potential to further exaggerate and exacerbate historical divisions.

Policy recommendations

Cape Town's water crisis and the preparations for Day Zero provides valuable lessons for policymakers. Although water supply and demand issues are highly localised, these lessons are translatable across cities and countries across the world. Long-term water supply augmentation planning reduces the lifetime cost per litre of water used, in comparison with short-term emergency measures²³. While these recommendations are not necessarily exhaustive, they provide a broad strategic template for long-term water security.

1. Long-term supply side augmentation and diversification

Long-term investment in water supply capacity, in harmony with an understanding of population change, is critical to avoid or minimise water crises in the future. The Cape Town water crisis was arguably an avoidable one²¹. Although there had been several low rainfall seasons before the onset of the water shortage, there was also a marked decrease in water reserves, driven by population increase and lack of investment¹⁸. The only major reservoir built to supply Cape Town in the last three and a half decades was the Berg River Dam in 2009¹⁸.

In any scenario, maintaining enough water redundancy in the system to cope with difficult years of low rainfall is essential. There are also other viable options for augmenting the supply of water to Cape Town, such as groundwater extraction, storm water harvesting, water re-use and clearing of foreign vegetation from water catchment areas^{23,67,89}.

2. Permanent changes in water usage

An attitude of water-use conservatism should remain a priority in discussions to educate all ages and backgrounds. The residents of Cape Town demonstrated that they were resilient enough to adapt to a drastically lower level of water usage over a short space of time^{23,50}. However, once water levels in reservoirs return to non-critical levels, water usage must remain thoughtful and conservative. The Day Zero crisis should mark a turning point in how water is valued and used, both domestically and commercially, without taking it for granted. The UN recommends five principles for valuing water to recognise its full direct and indirect benefits, which can be used as guidelines for future education⁹⁰. Educational and informative programmes around water usage, such as the installation of Smart Water Meters in schools, help to engender an appreciation of water as a limited and fragile resource.

3. Positive, but forceful, messaging and communication

Consistent and coherent messaging with significant buy-in from all levels of government is a key requirement of engendering change in the water use of a population. The most effective intervention to shift citizen behaviour was the announcement of the specific details of the CoCT disaster plan, indicating how strong communication can be a powerful driver of change. In contrast, the CoCT frequently changed the level of restrictions for water usage and shifted the nature of the target^{26,27}. Different ways of expressing restrictions, for example, use per person, per household, per day, per month, were used depending on the level of restriction applied. This created confusion among the population of Cape Town. The Cape Town Water Map, while controversial, at least got the conversation going^{39,40}, and may be a template for other cities to provide a live and accessible resource to help improve domestic water usage in times of crisis or otherwise.

4. Actionable early warning system development

Early warning systems need to be developed and upgraded to give as much preparation time as possible for water crises. Early warning systems help to prepare for foreseen issues in water availability. The implementation of early warning systems should be driven by a recognition of their usefulness, not just in times of crisis, but in times of relative water abundance.

5. Co-operation between levels of government

It is essential that different levels of government communicate and co-operate over planning of water supply. The CoCT were responsible for developing initiatives of water-use reduction within Cape Town itself. Supply side development, such as new reservoirs, require major investment and are planned and administered by the national government of South Africa. There are plans to increase reservoir capacity in the Western Cape⁹¹. There is also evidence of co-operation between levels of government to plan for Cape Town's future water challenges⁶⁶. This long-term co-operation and planning between local, provincial, and national government must continue and is essential for successful planning of water supply. Co-operation between levels of government needs to take place at all times, and not simply during crises.

6. Sensitivity to different sections of society

Different parts of society must understand the situation each finds itself in during water crises and show mutual understanding and co-operation. The Day Zero crisis at times led to tensions between different sections of the Cape Town population, with resentment building over lack of accessibility to springs, boreholes and bottled water. Indigent households were also seen as unfairly targeted for installation of WMDs. Drilling boreholes to access freshwater and storing bottled water costs considerable amounts of money, and were only accessible to a relatively small percentage of households. To avoid tensions between sections of population due to water shortages, which could lead to civil unrest, a solution for all members of society must be found.

7. Incentivise water reduction while maintaining financial solvency of water utility providers

Eliminating conflict of interest between water utility providers is necessary to further reduce water usage. Income from providing water as a utility, whether by public or private institutions, is an essential source of revenue for government. Future financial models of income from reduced water usage must allow and account for reduced direct income.

8. Climate change mitigation policy

Curtail human-caused climate change to minimise further impacts on water supply. Extreme weather events like drought are exacerbated by the large-scale, long-term changes in climate caused by human-sourced greenhouse gases. The Cape Town water crisis provides yet another example to decision makers around the world of the potential impacts of a changing climate. To avoid irreconcilable changes in climate, drastic action must be taken to reduce greenhouse gas emissions.

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Table 2: Cape Town Water Restrictions: An overview of key features per level

Level	Date applied	Main features of restriction
1	2005 ⁹⁹	<ul style="list-style-type: none"> • Aimed to promote ‘good water management habits’ by defining appropriate times to water gardens with hosepipes, and other practices
2	Jan 2016 ¹⁰⁰	<ul style="list-style-type: none"> • Increased limits on garden watering restrictions to three days a week for a maximum of one hour • Reduced the use of hosepipes without auto-stoppers fitted • Banned washing pavements/hard surfaces with water
3	Nov 2016 ⁵⁰	<ul style="list-style-type: none"> • Banned hosepipes and irrigation systems for watering; only buckets and watering cans allowed • Banned watering gardens within 24 hours of rainfall • Removed restriction defining set days/times for watering • Banned washing cars/hard services, except with a bucket • All swimming pools must be fitted with a pool cover, and portable play pools banned.
3B	Feb 2017 ¹⁰¹	<ul style="list-style-type: none"> • Reintroduced restriction defining set days/times for watering (two days a week, one hour a day) • Banned watering gardens within 48 hrs of rainfall • Banned washing cars/hard services with municipal water, except for informal car washes
4	June 2017 ¹⁰²	<ul style="list-style-type: none"> • Banned all non-essential uses of municipal water (watering garden, topping up pools, etc.) • Strongly encouraged’ limit of 100 litres (26.4 gallons) per person per day • Provided suggested practices to save water indoors, e.g. flushing toilet with non-potable water • Banned watering seven days after rainfall • Banned washing cars with municipal water for car washes
4B	July 2017 ¹⁰³	<ul style="list-style-type: none"> • Maximum limit of 87 litres (23 gallons) per person per day • Expanded list of suggested practices to save water indoors • Enforced installations of WMDs on high-consumption households
5	Sep 2017 ⁴⁵	<ul style="list-style-type: none"> • Non-residential properties to reduce consumption by 20% compared with Sep 2016 • Agriculture to reduce consumption by 30% compared with Sep 2016 • Maximum household cap of 20,000 litres (5,283.4 gallons) per month
6	Jan 2018 ⁴⁶	<ul style="list-style-type: none"> • Non-residential properties to reduce consumption by 45% compared with 2015 • Agriculture properties to reduce consumption to 60% compared with 2015 • Maximum household cap of 10,500 litres (2,773.8 gallons) per month
6B	Feb 2018 ¹⁰⁴	<ul style="list-style-type: none"> • Maximum limit of 50 litres (13.2 gallons) per person per day • Restricted hours of use for private boreholes for irrigation to one hour, twice a week
5 (amended)	Oct 2018 ³⁰	<ul style="list-style-type: none"> • Return to personal water use limit of 70 litres (15.4 gallons) per person per day (modified from 87 litres per person per day in original Level 5 restrictions)

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