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CASE REPORT

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Towards a water secure future: reflections on Cape Town's Day Zero crisis

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ABSTRACT

Capetonians have relied on dams to meet their needs for over a century. Extremely limited rainfall between 2015–2018, however, forced the City to impose a 50-litres per capita per day water restriction on its four million residents to avoid supply cut-offs. Cape Town's water crisis highlights the importance of moving away from past infrastructural practices. South Africa needs a new water paradigm that embeds water sustainability and resilience in day-to-day practices that, inter alia, protects the natural water systems and ensures a sustainable water supply through reducing the environmental footprint of a growing population and developing alternative supply systems to dam infrastructure. To accomplish this, government, the private sector and consumers need to work together to develop and implement a water sensitive approach that will transform water planning, supply and demand at scale.

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Water crisis; water sensitive design; resilience; South Africa

1. Introduction

Opening a tap and having running water in one's home is a convenience of modern urban life that the 'developed world' considers a basic amenity, a given. In South Africa, this basic amenity is also considered a human right (RSA 1996, 1997). Cape Town has relied on surface water diverted from impounded rivers (*i.e.* dams) for over a century to provide for this basic amenity and right. Extremely limited rainfall over three consecutive years commencing 2015 combined with insufficient drought resilience planning however threatened water supply access by summer 2017, and forced municipal authorities to impose a 50-litres per capita per day (ℓ/c/d) limit on 1 February 2018 to avoid supply cut-offs. Cape Town's crisis speaks to the risk of relying on historical water resource paradigms in changing climatic conditions. There is an urgent need to adopt a new water governance regime that transforms the urban populace's relationship with this essential resource.

Constructive discussion of how best to address Cape Town's future water security can be hindered by sensational coverage that tend to overlook the various nuances and contextual factors that contributed to the water crisis (Ziervogel 2019). Media coverage during the drought represented views that primarily assigned blame to various factors:

(1) 'Manmade' causes primarily associated with local government 'mismanagement' – *e.g.* the City of Cape Town's (the City or CCT) ignorance of national predictions, inadequate planning (Muller 2018; Rodina and Findlater 2018; Poplak 2018; Newkirk II 2018), over-optimistic interpretations of the success of its prior water conservation and demand management efforts (Muller 2017);
(2) Increasing demand from various sectors linked with population growth (WWF-SA 2017);
(3) The national government's overallocation of water to an unchecked agricultural sector during dry weather events (Muller 2018);
(4) Climate change resulting in reduced rainfall (Wolski, Hewitson, and Jack 2017); and
(5) The proliferation of 'thirsty' invasive alien vegetation (Slingsby and Botha 2018; Wild 2018)

The first point highlights the municipal sphere's responsibility for providing water services. It, however, overlooks the critical role national government has as South Africa's water custodian and the need for better intergovernmental coordination between different arms of government responsible for water resources and water services. While the second through fifth points might have contributed to the crisis to varying extents, the water crisis arguably lies at an even deeper level, with the approach to water resource management in Cape Town and the broader Western Cape region.

Wolski (2018) argues that the water shortage occurred primarily due to low rainfall levels between 2015–2017, but the escalation to a water crisis, was largely due to the lack of drought-resilient water resources in Cape Town's catchment. This paper concurs with Wolski's assessment but aims to go a step further by providing context for events before and during the drought, before describing a way of increasing Cape Town's drought resilience through 'Water Sensitive Design (WSD)', a multi-faceted approach that incorporates supply and demand management measures, multidisciplinary expertise and tools, and cooperation and collaboration from all sectors of society. The authors were informed by a review of relevant literature and government documents on Cape Town's water system and services and also drew from the experience of national and municipal government officials

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(current and former), consultants and experts who are actively involved in water resource management and water sensitive design development across South Africa.

2. The Cape Town case: the 2017/18 water crisis

2.1. Cape Town water resources and crisis

In principle, water is considered a 'shared responsibility' in South Africa divided between the three spheres of government: (a) resources and bulk management are the domain of the national Department of Water and Sanitation (DWS), the country's water custodian; (b) supply infrastructure and service delivery are the responsibility of municipal authorities; and (c) provincial governments provide support when needed to municipal authorities and the agricultural sector. Significantly, DWS manages the water resources that the CCT municipality supplies to its citizens with support from Western Cape Province. Cape Town's potable water supply primarily comes from six dams that also meet some of the demands of the province's agricultural sector (approximately 29%) and nearby small towns (approximately 7%). Cape Town households and businesses receive the bulk of the province's water (approximately 64%) (CCT 2018a).

Cape Town's average per capita water use in 2012 was around 223.4 ℓ/c/d (CCT 2012). The City had managed to contain total demand to around 1999 levels despite population growth of 50%, in part due to reducing losses from leakages (Western Cape Government 2017). As a result, Cape Town has one of South Africa's lowest percentages (15%) of 'unaccounted for water' (typically losses due to leakage, meter under reading and theft) (Western Cape Government 2017).

The national government officially plans water resources at a 1 in 50-year level of assurance, which means that there might be inadequate supply to meet demand once every 50 years. As part of short- and long-term planning, the national government assesses the supply status and the probability of future restrictions on an annual basis. If a drought is anticipated, then the national government will proactively implement restrictions based on predetermined levels of assured supply for different users, and will increase said restrictions should drought conditions progressively become more severe. In these circumstances, the three spheres of government are supposed to work together to implement the necessary water restrictions and reduce demand. Although climate risk models show the future potential for significant drying and extreme weather patterns in the Western Cape – translating into both severe droughts and floods (Cullis et al. 2015) – they also indicated that Cape Town would not be significantly impacted until around 2025.

Cape Town, however, experienced well below-average rainfall three consecutive years commencing 2015 – including the two driest recorded by many gauges. Existing rainfall models proved unable to predict the severity, timing or duration of the drought (Wolski, Hewitson, and Jack 2017). Provincial and national government explained that this was in part due to unpredictable climatic change (Saal 2018).

Consequently, in September 2017, DWS instructed the City to reduce water use to 500 Mℓ/d until dam water levels recovered to 85% capacity. Thus, between September 2017 and September 2018, the City's response targeted both demand and supply.

2.2. Demand restriction measures

The City adopted a three-phase disaster plan (CCT 2017a) outlining water distribution during the crisis:

- In Phase 1, the City has adequate supply to service everyone through the existing reticulation system but, to preserve dwindling resources, everyone is required to limit demand – mostly by self-regulation.
- In Phase 2, if the dam levels fell below 13.5% nominal capacity – dubbed 'Day Zero', the water supply to large areas of the City would be cut off and residents would be required to collect their water from some 200 water distribution points. Supply would be limited to 25 litres per person a day in line with World Health Organization (WHO) recommendations for minimum safe potable water supply.
- In Phase 3, if the dam levels fell below approximately 10%, surface supplies are effectively exhausted as what would be left would be mainly sediment. At this point, the City would make limited supplies of drinking water available at distribution points. Most of this water would likely come from outside of the drought region.

Phase 1 of the disaster plan was implemented in October 2017. Residents were informed that the restrictions would be in place until the dam levels recovered to at least 85% full. The extent of the restrictions, however, was adjusted from time to time in accordance with the demand targets set by the Western Cape Water Supply System (WCWSS) team, a DWS-chaired committee representing all major water users in the area and hence is tasked with determining bulk water allocation across the region. Consequently, targeted maximum per capita water use was halved within seven months (Table 1). To reduce demand during Phase 1, the City:

- Limited supply through manual valve closing in reticulation sub-districts and installation of water management devices (WMD) to limit daily water use in households that exceeded restriction levels (CCT 2017a);
- Reduced water pressure wherever possible, especially areas with high leakage (CCT 2017b);
- Sharply increased the existing stepped tariffs (CCT uses a progressive tariff structure to increase charges for water as water use increases up each 'step') to effectively punish households that used more than the targeted maxima and address revenue deficits; and
- Employed an information, education and communications (IEC) campaign to influence consumer behaviour. For example, the City released a web-based water: (a) map on usage based on meter readings (https://citymaps.capetown.gov.za/waterviewer/); (b) dashboard for a weekly updates on dam levels, consumption and augmentation progress (http://coct.co/water-dashboard/); and (c) calculator to educate consumers about how much water they use on a daily basis (http://coct.co/thinkwater/).

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	-	-

The IEC campaign was, in no small measure, driven by the initial inadequate response to water saving calls, such as warnings of intermittent outages if residents used more water than the water restriction level dictated. Municipal messaging and media coverage on the threat of an imminent 'Day Zero' increasingly conveyed a new sense of urgency – warning Capetonians of having to queue for daily rations if water use was not drastically curbed.

The City's various interventions produced tangible results: total use (all sectors including unaccounted-for-water) during the summer dry season pre-drought often exceeded 1200 Mℓ/d. Due to the interventions, collective water use dropped to 523 Mℓ/d by February 2018. More importantly, consumers' relationship with water had clearly changed on a day-to-day basis. Many residents, for instance, were only flushing toilets after defecating and not after urination ('If it's yellow, let it mellow, if it's brown, flush it down'!), and were collecting what rainwater there was in buckets or tanks or using greywater collected from showers and basins to flush toilets.

Despite considerable success, the City failed to reach the 500 Mℓ/d target mandated by the DWS by the end of February 2018, so the target was further reduced to 450 Mℓ/d to account for the increasing shortfall against WCWSS' requirements. This difficulty might have been partly due to the City having already improved system efficiency pre-water crisis. Hence, when the call came to reduce water demand, the City had little option other than to focus on changing water-use behaviour, which resulted in various responses – often simultaneously:

- Anger; many people 'lashed out' at the City for failing to adequately plan for a drought of this severity;
- Panic; large queues formed at various city springs to collect water of often dubious quality while some households stockpiled copious quantities of water in containers in the event of supply failure;
- Disbelief; some accused the City of using 'Day Zero' as a scare tactic to cover up municipal mismanagement (Newkirk II 2018) and justify the privatisation of the water supply for profit and thus deprive the poor – although how this would be to the benefit of the politicians in control of the City was never spelt out; and
- Disregard; some of the most affluent residents installed very expensive groundwater extraction and treatment systems to go 'Off-the-grid' and continued to use large quantities of water to maintain lush green lawns and full swimming pools in defiance of calls from the City to desist from this practice.

While the various restriction and IEC measures succeeded in massively reducing water demand, Cape Town's behavioural change interventions were largely reactive and linked to short-term goals. Media outlets expressed concerns about how long citizens would continue cooperating with the strict regimes, either because (a) they become 'fatigued' after surviving extended periods of time with little water; or (b) complacency setting in once the winter rains start to fall and the City relaxed water restrictions. CCT announced on 10 September 2018 that water restriction levels would be relieved from Level 6B to Level 5 from 1 October 2018 after local dams recovered to 72.7% due to good winter rainfall (CCT 2018b). The daily allowance increased from 50 ℓ/c/d to 70 ℓ/c/d, and thus far daily water usage is still well below pre-drought levels (~55% of pre-drought usage) (CCT 2019); although this is likely related to remaining restrictions. Whether or not the behavioural changes are temporary crisis driven changes or will lead to longer-lasting water use awareness and conservation efforts will take more time to determine.

2.3. Supply augmentation efforts

When it became apparent that the long-term supply was severely constrained, the City called for tenders to provide short-term relief that initially resulted in proposals for nine small-scale desalination plants, three desalination barges/ships, three recycling/reclamation plants, and the abstraction of as much as 150 Mℓ/d groundwater from three local aquifers (de Lille 2018). Eventually, the City awarded tenders for: the implementation of a number of small groundwater abstraction schemes; the construction of three small seawater desalination units; the construction of a temporary wastewater treatment for re-use scheme; and various minor interventions to make better use of various small springs and streams as short-term measures to bridge the City over the immediate crisis and in anticipation of more permanent, larger scale, more cost-effective schemes to follow (CCT 2018c). The unit cost of water from these schemes was not disclosed but was likely to be up to ten times that from the established surface water schemes. This was problematic because, in a curious case of 'if you win, you also lose', the City's success in water demand management had led to a precipitous loss of revenue now desperately required for augmentation projects. Consequently, the City was forced to change the way it billed for water, introducing an additional 'Fixed Basic Charge' related to the size of the connection from 1 July 2018 (CCT 2018d).

Despite the City's various demand restriction and supply augmentation measures, it was only after the release of a 10 Gℓ donation of surplus water from commercial farmers and the cutting of further supply to the agricultural sector when it had reached its prescribed water limit (eNCA 2018) that, combined with all the other measures already described, finally led to the City's announcement on 7 March 2018 that 'Day Zero' had been averted for 2018 at least. Cape Town thus averted disaster in the short-term due to a combination of: the agricultural buffer, substantial water savings, limited augmentation from the City's temporary supply interventions, and, finally, winter rainfall closer to the long-term mean from mid-2018. Averting the immediate crisis, however, should not be the only concern. The drought was likely an early indicator of Cape Town's 'new normal' as a water-scarce region that needs to learn how to cope with climatic shocks and stresses. This water crisis thus hopefully will be the impetus Cape Town needs to become resilient in the face of a growing population, to provide a higher level of service to the large numbers of people currently living in the under-serviced informal settlements, and to transform itself into a 'Water Sensitive City' (WSC), which entails changing stakeholders' relationships concerning how water is planned, sourced and used.

3. Discussion: a 'water sensitive' Cape Town

Water Sensitive Urban Design (WSUD) – or, simply 'Water Sensitive Design' (WSD) in recognition that the approach is not restricted to urban areas – is an integrated land and water planning and management approach that aims to sustainably manage water by transitioning from linear technology-centred and resource-intensive approaches to cyclical human-centred systemic approaches. The WSC framework was developed in Australia as a response to the Millennium Drought (Wong and Brown 2009). University of Cape Town (UCT) researchers adapted it and produced guidelines for a South African context (Armitage et al. 2014). A discussion follows of how water sensitivity should be reflected in water planning, sourcing and use to transition towards more resilient water systems in cities like Cape Town.

3.1. Plan: paradigm shift, guidance & decentralisation

The Cape Town crisis exemplifies the danger of dividing governance and management of water resources from supply. This linear approach breaks down the urban water cycle into institutional compartments or silos (Armitage et al. 2014) in a political landscape where spheres of government are better known for partisan politics than collaboration. To embed WSD in Cape Town policy and practices, advocates from within and outside of government (namely, the private sector and consumers) need to redress the political and institutional barriers that constrain water management to incentivise a paradigm that transforms water planning, supply and demand at scale (Armitage et al. 2014).

At the design level, both government clients and design engineers need to be more receptive to the idea of innovative approaches such as WSD that deviate from conventional engineering design. At present, all three spheres of government rely on private engineering firms to design, build and (occasionally) operate infrastructure. Consulting firms tendering for government projects often undercut each other on prices to win tenders based predominantly on price. Consequently, there is little scope for potentially costly innovations or deviations from the advertised scope of work as the procurement process tends to demand measurement against a preconceived product. This constraint suggests that South Africa's public sector must revisit its procurement processes to put less emphasis on short-term costs and incorporate consideration for long-term benefits and needs.

Official guidance on aspects such as roles and technical specifications are also essential to facilitate WSD implementation. In Cape Town, the local government introduced new provisions in its 2010 *Water By-laws* and 2015 *Amendments* considering changing demographics, water demands and water-wise needs (Western Cape Government 2018). The amendments critically highlight the responsibility of (a) owners (concerning compliance for installation and maintenance); (b) users (wastage or abuse); and (c) plumbers (registration and works). DWS similarly needs to draft policies about non-potable water use and new approaches (*e.g.* dual sewer systems) to try and safeguard public safety. Moreover, WSD criteria need to be entrenched in the standards and guidelines that government officials and design engineers conform to (*e.g.* the 'Red Book' (CSIR 2005)).

Effectively, faced with the consequences of national government inaction, CCT has set a precedent whereby a local government largely shouldered the responsibilities of reducing customer demand and identifying feasible supply augmentation interventions. The City's need to undertake both water servicing and resource roles suggests a failing in the current 'shared responsibility' principle underpinning South Africa's water management. To reduce future risk, contingency plans should be prepared, and funds made available for the development of decentralised water resources.

3.2. Source: diversification and infrastructure adaptations

Diversification of water sources is a significant component of WSD. The City's proposed amendments significantly introduce regulations for installing, storing and using non-municipal or alternative systems (*i.e.* greywater, rainwater, surface water, treated effluent or groundwater) (CCT 2017c), but stormwater harvesting has been overlooked: UCT researchers estimated that stormwater could potentially provide the City with considerable quantities of potable water per annum from just one catchment (Zeekoevlei). The City has experience with stormwater harvesting in the Atlantis area, which it can capitalise on to maximise (a) reduction of flood risks during peak flows and (b) local ecosystem health benefits by protecting natural assets and biodiversity and adding social value as recreational spaces when stored in parks or wetlands (Fisher-Jeffes et al. 2017).

With regards to water reuse, national government has long recognised its potential cost-savings and environmental benefits (DWAF 2007) and Cape Town increasingly sells treated wastewater for irrigation, industrial and construction purposes. For long-term transformation, the City could recycle all its treated wastewater for potable or non-potable reuse. An advantage of this approach is that wastewater reclamation is not as energy-intensive (and hence not as expensive) as desalination. The thirteen largest wastewater treatment works (WWTWs) could supply 161.8 Mℓ/d of effluent for reuse (BVi Consulting Engineers 2007). Currently, the city is considering a scheme to recycle effluent from wastewater treatment works for potable reuse at Faure treatment plant to provide 70 Mℓ/d. Potentially, this scheme could be extended to other wastewater treatment works around the metro as needed (CCT 2018a). The wide-spread WWTW coverage should facilitate a more extensive reuse strategy. A public consultation and education campaign for water reuse – in addition to very careful monitoring – would likely be necessary given potentially negative public perception and public health risks (GreenCape 2018).

Given the difficulty of introducing and sustaining change (Bouton 2014) and challenge of adapting infrastructure, South Africa's three governments' different spheres should work together in their respective roles to facilitate: (a) treatment of wastewater from Cape Town's ~92% of sewered properties for direct or indirect potable reuse and (b) installation of dual reticulation of potable and possibly non-potable water at the outset of new construction works. While this seems largely technological, the widespread introduction of water and sanitation infrastructure has historically been more effective at protecting public health at-scale than hygiene-focused education campaigns when coupled with enabling legal and administrative structures (Mackenbach 2007). The government – at all levels – thus plays a critical role in instituting the technologies, policies and systems that shape residents' behaviours and builds resilience against climatic shocks and stresses.

3.3. Use: behaviour and equity

South African authorities prefer waterborne sanitation systems for densely-settled urban areas (DWAF 2003), because the systems conveniently collect wastewater for transfer to WWTWs for processing and further distribution and are demanded by households of all socioeconomic classes (Taing et al. 2013). Convenience and effectiveness are two behavioural determinants for why waterborne sanitation has remained the preferred sanitation solution (Armitage 2018). However, since flush toilets typically use 6–9 ℓ of potable water per flush, dry (on-site) sanitation is popularly touted as a means of reducing water usage (Times Live 2018). The City has experience with dry sanitation options such as container-based toilets and ecological toilets in informal settlements. Transitioning to a broader dry sanitation application, however, is a complicated people- and resource-intensive exercise that requires careful significant planning to ensure safe containment, emptying, transport, treatment and possible reuse of faecal sludge (Strande, Ronteltap, and Brdjanovic 2014). Current faecal sludge management (FSM) practices would need to significantly improve and increase in scale if dry sanitation becomes more widely used to conserve water. Wider social acceptance is also a key to the successful promotion of dry sanitation (Mkhize et al. 2017).

Given CCT's experience, IEC interventions will likely continue to play a critical role in broadening awareness and support for water sensitive changes in the built and social environment during non-drought events. These campaigns should be coupled with programmes that apply behaviour science concepts of 'settings' (Aunger and Curtis 2016) or 'nudges' (Thaler and Sunstein 2008; Thaler 2018) to influence users' decisions about and adoption of long-term water sensitive habits. Lifestyle changes are especially important for high income households living on large stands with higher water usage, as they are more likely to resort to the installation of wells – thus drawing on the groundwater reserve – than restrict their water demand.

While all residents should be encouraged to use water responsibly, it is important to ensure that the burden of conserving water does not disproportionately affect indigent households and that the government continues to prioritise improvement of the level of services in underserved households living in informal settlements or backyard shacks. Thus, water and sanitation interventions in modern South Africa need to embed equity as a critical principle for building sustainable systems (Pan, Armitage, and Van Ryneveld 2015). The City critically did not reduce basic services to informal settlements or backyard dwellers during the water crisis (albeit people are typically limited by what they can carry from communal taps). Its implementation of the national Free Basic Water policy, cross-subsidised by increasing the price paid by more affluent citizens (CCT 2001), serves as an example of how services are provided at no cost to poor households to meet basic needs.

It is clear from this crisis that Cape Town residents need to rethink their relationship with water. The cost of transforming into a WSC may be initially high and resource-intensive, but – as anxious officials and Capetonians have learned – having a sustainable and resilient water supply is critical for the future of the City.

4. Conclusions

The severity of Cape Town's unforeseen water crisis offers a glimpse of the consequences of climate change in water stressed regions should societies not adapt planning and management practices. In general, cities in these regions should:

- Not solely rely on surface water resources to meet water demand.
- Adopt a water sensitive approach to city planning and redevelopment. This includes shifting water management paradigms – developing new governance mechanisms and guiding diversification of water supplies to provide resilience to potential climate shocks.
- Explore interventions that promote and proactively encourage (rather than restrict) behavioural change and address inequity.

The Cape Town water crisis received worldwide publicity; what many do not realise is that nearly half of South Africa was in a similar predicament at the same time: the national government declared three of its nine provinces drought disaster areas in 2018 (news24 2018), and an additional two are water-stressed. The country's water crisis is proof that previous warnings about climate change's impact on water supply, demographic patterns and operational efficiency are warranted (Deloitte 2016). South Africa needs a new paradigm that embeds water sustainability and resilience in day-to-day practices by protecting water systems and reducing the environmental footprint of growing populations. To accomplish this, government, the private sector and consumers need to work together to realise the development and implementation of new methods and instruments that will transform water planning, supply and demand to ensure water security in times of drought or plenty.

Cape Town's crisis will likely serve as a cautionary tale of what is to come should the world allow climate change to continue unabated: according to Park et al. (2018), more than a quarter of the planet will experience drought and desertification by 2050 if average global temperatures continue to rise. The world can learn from the Cape Town experience and pre-emptively promote public/private sector collaboration for the purpose of transitioning towards a water secure future.

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References

Armitage, N. P. 2018. "To Sewer or Not to Sewer?" In *ACC Urban Conference*. Cape Town: UCT Future Water Institute. http://www.futurewater.uct.ac.za/sites/default/files/image_tool/images/416/Future_Water/Documents/To%20sewer%20-%20ACC%20Conference,%203%20February%202018.pdf

Armitage, N. P., L. Fisher-Jeffes, K. Carden, K. Winter, V. Naidoo, A. Spiegel, and B. Mauck. 2014. *Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines*. Pretoria: Water Research Commission. doi:10.13140/2.1.3042.5922.

Aunger, R., and V. Curtis. 2016. "Behaviour Centred Design: Towards an Applied Science of Behaviour Change." *Health Psychology Review* 10 (4): 425–446. Taylor & Francis. doi:10.1080/17437199.2016.1219673.

Bouton, M. E. 2014. "Why Behavior Change is Difficult to Sustain." *Preventive Medicine* 68 (November): 29–36. Academic Press. doi:10.1016/J.YPMED.2014.06.010.

BVi Consulting Engineers. 2007. *Treated Effluent Re-Use Strategy and Master Planning within the City of Cape Town (Report C1500/1.1)*. Cape Town: BVi Consulting Engineers.

CCT. 2001. *Water Services Development Plan*. Cape Town: City of Cape Town.

CCT. 2012. *Five-Year Plan for Cape Town: The City of Cape Town's Integrated Development Plan (IDP)*. Cape Town: City of Cape Town. https://www.westerncape.gov.za/text/2012/11/city-of-cape-town-idp-2012-2017.pdf

CCT. 2017a. *Critical Water Shortages Disaster Plan - Public Summary*. Cape Town: City of Cape Town. http://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2C%20plans%20and%20frameworks/Critical%20Water%20Shortages%20Disaster%20Plan%20Summary.pdf

CCT. 2017b. *Pressure Reduction - What is it?* Cape Town: City of Cape Town. http://resource.capetown.gov.za/documentcentre/Documents/Procedures,%20guidelines%20and%20regulations/Water%20rationing_how%20it%20works.pdf

CCT. 2017c. *Draft Water Amendment By-Law. Water and Sanitation Regulations*. Cape Town: City of Cape Town.

CCT. 2018a. *Cape Town Water Outlook 2018 (20 July 2018)*. Cape Town: City of Cape Town. http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/Water%20Outlook%202018%20Presentation.pdf

CCT. 2018b. *Amended Level 5 Water Restriction Guidelines*. Cape Town. www.capetown.gov.za/thinkwater

CCT. 2018c. *Cape Town Water Outlook 2018 (20 May 2018)*. Cape Town: City of Cape Town. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/Water%20Outlook%202018%20-%20Summary.pdf

CCT. 2018d. "Fixed Basic Charge for Households." *Residential Water and Sanitation Services*. http://www.capetown.gov.za/Family%20and%20home/residential-utility-services/residential-water-and-sanitation-services/fixed-basic-charge-for-households

CCT. 2019. *City of Cape Town: Dam Levels Report (25 March 2019)*. http://www.capetown.gov.za/Family%20and%20home/residential-utility-services/residential-water-and-sanitation-services/this-weeks-dam-levels#section-docs

CSIR. 2005. *Guidelines for Human Settlement Planning and Design*. Vol. 1. Pretoria: CSIR Building and Construction Technology.

Cullis, J., T. Alton, C. Arndt, A. Cartwright, A. Chang, S. Gabriel, Y. Gebretsadik, et al. 2015. *WIDER Working Paper 2015/045: An Uncertainty Approach to Modelling Climate Change Risk in South Africa*. Helsinki. http://hdl.handle.net/10419/126385

de Lille, P. 2018. *Statement by the City's Executive Mayor: City Starts Drilling for Groundwater from the Cape Flats Aquifer in Mitchells Plain*. Cape Town: City of Cape Town. http://resource.capetown.gov.za/documentcentre/Documents/Speeches%20and%20statements/11%20January%2018-%20City%20starts%20drilling%20for%20groundwater.pdf

Deloitte. 2016. *Water Tight 2.0: The Top Trends in the Global Water Sector*. London: Deloitte Touche Tahmatsu Limited. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-water-tight.pdf

DWAF. 2003. *Strategic Framework for Water Services: Water is Life, Sanitation is Dignity*. Pretoria: Department of Water Affairs and Forestry. http://www.dwaf.gov.za/Documents/Policies/Strategic%20Framework%20approved.pdf

DWAF. 2007. *Overview of Water Re-Use Potential from Wastewater Treatment Plants*. Pretoria: Department of Water Affairs and Forestry.

eNCA. 2018. "Watch: Cape Town Gets 10bn Litres of Water." *ENCA*. https://www.enca.com/south-africa/cape-town-gets-10bn-litres-of-water

Fisher-Jeffes, L., K. Carden, N. P. Armitage, and K. Winter. 2017. "Stormwater Harvesting: Improving Water Security in South Africa's Urban Areas." *South African Journal of Science* 113 (1–2): 2–5. doi:10.17159/sajs.2017/20160153.

GreenCape. 2018. *Water – 2018 Market Intelligence Report*. Cape Town: GreenCape.

Mackenbach, J. P. 2007. "Sanitation: Pragmatism Works." *BMJ* 334 (January): s17. doi:10.1136/bmj.39044.508646.94.

Mkhize, N., M. Taylor, K. M. Udert, T. G. Gounden, and C. A. Buckley. 2017. "Urine Diversion Dry Toilets in EThekwini Municipality, South Africa: Acceptance, Use and Maintenance through Users' Eyes." *Journal of Water Sanitation and Hygiene for Development* 7 (1): 111–120. doi:10.2166/washdev.2017.079.

Muller, M. 2017. "Understanding the Origins of Cape Town's Water Crisis." *Civil Engineering* 25 (5): 11–16.

Muller, M. 2018. "Cape Town's Drought: Don't Blame Climate Change." *Nature* 559 (7713): 174–176. Nature Publishing Group. doi:10.1038/d41586-018-05649-1.

Newkirk II, V. R. 2018. "How Will Climate Change Affect Politics?" *The Atlantic*. https://www.theatlantic.com/science/archive/2018/09/cape-south-south-africa-water-crisis/569317/

news24. 2018. "Drought Crisis: 3 Provinces Declared National Disasters." *News*. https://www.news24.com/SouthAfrica/News/drought-crisis-3-provinces-declared-national-disasters-20180213

Pan, S. M., N. P. Armitage, and M. B. Van Ryneveld. 2015. "Sustainable and Equitable Sanitation in Informal Settlements of Cape Town: A Common Vision?" *Water SA* 41 (2): 222–231. doi:10.4314/wsa.v41i2.07.

Park, C.-E., S.-J. Jeong, M. Joshi, T. J. Osborn, C.-H. Ho, S. Piao, D. Chen, et al. 2018. "Keeping Global Warming within 1.5°C Constrains Emergence of Aridification." *Nature Climate Change* 8 (1): 70–74. Nature Publishing Group. doi:10.1038/s41558-017-0034-4.

Poplak, R. 2018. "What's Actually Behind Cape Town's Water Crisis - The Atlantic." *The Atlantic*. https://www.theatlantic.com/international/archive/2018/02/cape-town-water-crisis/553076/

Rodina, L., and K. M. Findlater. 2018. "What Can Other Cities Learn about Water Shortages from 'Day Zero'?" *The Conversation*.

RSA. 1996. *Constitution of the Republic of South Africa (No. 108 of 1996)*. Pretoria: Republic of South Africa.

RSA. 1997. *Water Services Act (No. 108 of 1997)*. Pretoria: Republic of South Africa.

Saal, P. 2018. "SA Weather Service Tells Zille to Stop Blaming It for the Water Crisis." *Business Day*. https://www.businesslive.co.za/bd/national/2018-01-26-sa-weather-service-tells-zille-to-stop-blaming-it-for-the-water-crisis/

Slingsby, J., and M. Botha. 2018. "Aliens are Greatest Threat to Cape Town's Water Security | GroundUp." https://www.groundup.org.za/article/aliens-are-greatest-threat-cape-towns-water-security/

Strande, L., M. Ronteltap, and D. Brdjanovic. 2014. *Faecal Sludge Management: Systems Approach for Implementation and Operation*. London: IWA Publishing. http://ocw.unesco-ihe.org/pluginfile.php/950/mod_resource/content/1/fsm_book_lr.pdf

Taing, L., N. P. Armitage, N. Ashipala, and A. D. Spiegel. 2013. *TIPS for Sewering Informal Settlements: Technology, Institutions, People and Services (Report No. TT 557/13)*. Pretoria: Water Research Commission.

Thaler, R. H. 2018. "Nudge, Not Sludge." *Science (New York, N.Y.)* 361 (6401): 431. American Association for the Advancement of Science. doi:10.1126/science.aau9241.

Thaler, R. H., and C. R. Sunstein. 2008. *Nudge: Improving Decisions about Health, Wealth, and Happiness*. New Haven and London: Yale University Press.

Times Live. 2018. "Flush with Answers: WWF Offers Day Zero Toilet Training." *Times Live*. https://www.timeslive.co.za/news/south-africa/2018-02-07-flush-with-answers-wwf-offers-day-zero-toilet-training/

Western Cape Government. 2017. "The Cape Water Crisis – FAQs and Honest Answers." *Water Crisis*. https://www.westerncape.gov.za/news/water-crisis

Western Cape Government. 2018. "Comment on the City of Cape Town's Proposed Draft Water Amendment By-Law." *News*. https://www.westerncape.gov.za/110green/news/comment-city-cape-towns-proposed-draft-water-amendment-law

Wild, S. 2018. "South Africa's Invasive Species Guzzle Precious Water and Cost US$450 Million a Year." *Nature* 563 (7730): 164–165. doi:10.1038/d41586-018-07286-0.

Wolski, P. 2018. "Drivers of Cape Town's Water Shortage." *CSAG Blog*. http://www.csag.uct.ac.za/2018/07/18/drivers-of-cape-town-water-shortage/

Wolski, P., B. Hewitson, and C. Jack. 2017. "Why Cape Town's Drought Was so Hard to Forecast." *The Conversation*, 1–4. https://theconversation.com/why-cape-towns-drought-was-so-hard-to-forecast-84735

Wong, T. H. F., and R. R. Brown. 2009. "The Water Sensitive City: Principles for Practice." *Water Science & Technology* 60 (3): 673–682. doi:10.2166/wst.2009.436.

WWF-SA. 2017. *Scenarios for the Future of Water in South Africa*. Cape Town: World Wildlife Fund South Africa. http://awsassets.wwf.org.za/downloads/wwf_scenarios_for_the_future_of_water_in_south_africa.pdf

Ziervogel, G. 2019. *Unpacking the Cape Town Drought: Lessons Learned*. Cape Town: Report for Cities Support Programme by the African Centre for Cities. https://www.africancentreforcities.net/wp-content/uploads/2019/02/Ziervogel-2019-Lessons-from-Cape-Town-Drought_A.pdf