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Sustainable Water Governance

An Incremental approach towards a decentralised, hybrid water system

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It takes a village to raise a child. And similarly, it takes a team to support a student through a thesis.

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Thank you.

Declaration

I, Tamsin Faragher know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own. This thesis/thesis has been submitted to the Turnitin module (or equivalent similarity and originality checking software) and I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.

Signed by candidate

Tamsin Faragher

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ABSTRACT

Cape Town is experiencing its worst drought in recorded history. Notwithstanding that the Western Cape has always been a water scarce region, it is this current drought that has brought home the area's inherent vulnerability and highlighted the governance issues.

The world wherein South Africa's water governance was created is very different to the world we find ourselves in today. It is a world of uncertainty and unpredictability not contemplated in water governance comprised of legislation, policy, guidelines and practice. The current water governance constructs a conventional approach based upon predictability and certainty and is no longer appropriate to meet today's new challenges.

Consistent with this conventional approach, Cape Town's municipal water supply is almost completely dependent upon surface water which makes it even more vulnerable to drought than if its supply was comprised of a variety of water supply options. With surface water sources fully exploited and storage opportunities within the urban edge limited alternative water supply options must be more seriously considered and the water governance reformed to accommodate its use.

Water governance is the focus of reform because it is the framework for infrastructure planning and therefore controls the resultant system, infrastructure and management. This thesis interrogates the current water governance as the starting point before firstly discussing the proposed incremental approach towards a decentralised, hybrid system for water infrastructure and secondly, identifying specific areas where intervention is necessary for implementation.

1 INTRODUCTION

Water is at the centre of the Climate-Energy-Food-Water Nexus within a complex set of interrelationships and dependencies that create 'wicked problems'[1], described by Jared Diamond as fundamental threats to civilisation (Bazilian, 2011). These wicked problems are derived from the impacts of population growth, climate change and unsustainable resource use which limits the availability of scarce, non-renewable resources, such as water (The Global Commission on the Economy and Climate Change, 2014). Because of water's scarcity and central role in the Climate-Energy-Food-Water Nexus, how it is managed is one of the most pressing challenges of the 21st century (Pahl-Wostl *et al*., 2010). Recognition of this and of the associated challenges is gaining greater prominence globally. There is also an acceptance that the current approach to water management as outlined in the prevailing governance and policy cannot respond to the enormous complexities (Pahl-Wostl *et al*., 2010) posed within the prevailing context. Within this context, the ominous prediction Serageldin made that "if the wars of this century were fought over oil, the wars of the next century will be fought over water - unless we change our approach to managing this precious and vital resource" is not too outlandish at this time (Serageldin, 2017).

Consistent with global trends, South Africa is also prone to the wicked problems posed by water insecurity. Droughts have been a part of South African life for over the last three years, forcing it to come to terms with climate change and water scarcity. The Minister of Water and Sanitation Nomvula Mokonyane's (WWF B. C., 2017) rallying cry in 2015 for revolution to reclaim and better manage our water resources has evaporated into nothingness. Her attempt may not have been necessary had the 2010 Integrated Water Resources Plan for South Africa's warnings been heeded and the augmentation schemes brought forward monitoring systems improved to be better informed about the threat lying ahead. According to its warnings, which predate the preparation of the National Infrastructure Plan (2012), the Western Cape is extremely exposed to the threat of climate change. Consequently, it would have expected that augmentation projects would have been identified. Yet, very little has changed in the last seven years, which exposed Cape Town to the current meteorological drought, which is the worst in recorded history (Figure 1).

[1] "A wicked problem is a social or cultural problem that is difficult or impossible to solve for as many as four reasons: incomplete or contradictory knowledge, the number of people and opinions involved, the large economic burden, and the interconnected nature of these problems with other problems. Poverty is linked with education, nutrition with poverty, the economy with nutrition, and so on. These problems are typically offloaded to policy makers, or are written off as being too cumbersome to handle *en masse*. Yet these are the problems—poverty, sustainability, equality, and health and wellness—that plague our cities and our world and that touch each and every one of us." Stanford Social Innovation Review (https://ssir.org/articles/entry/wicked_problems_problems_worth_solving)

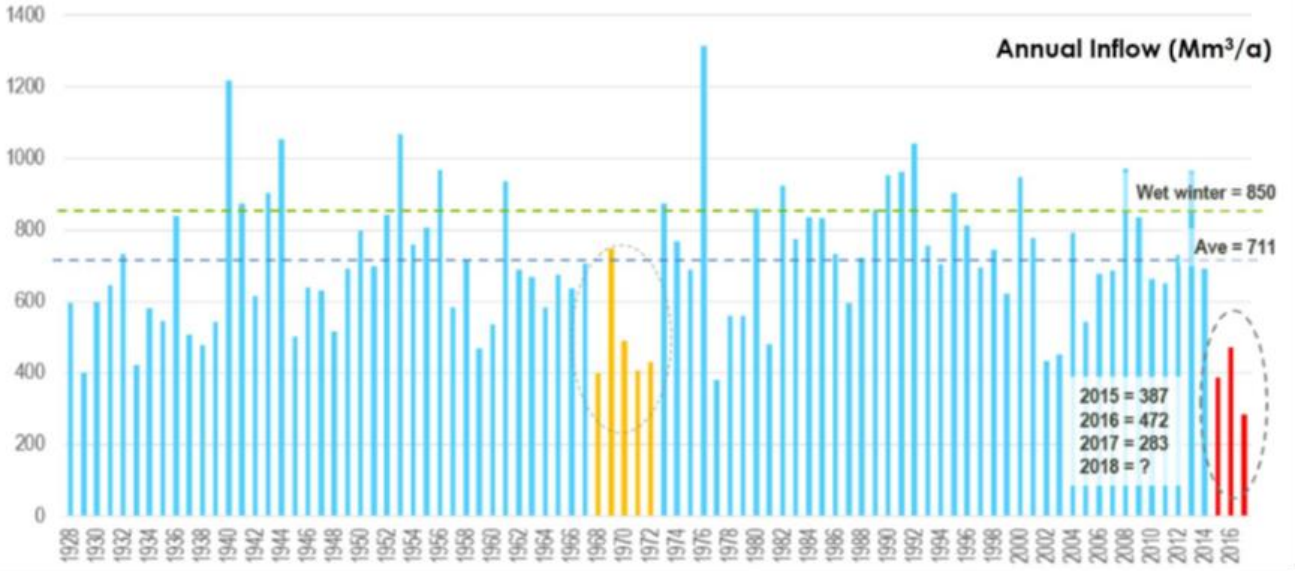

Figure 1: Historical annual inflow into WCWSS dams (Department of Water and Sanitation, 2018)

The governance decision-makers who make the decisions around project priorities and budgets are national (the owner) and local government (the supplier) as mandated by the Constitution. These mandates deliver on citizens' rights as enshrined in the Constitution's Bill of Rights. It includes the right to life which is dependent on another right, the right to access to water. Water availability is however contingent upon rainfall, which government has no control over, but is yet responsible as the custodian and supplier of water. The dependency of the right to life on water illustrates one of the wicked problems. These irreconcilable tensions between roles and responsibilities places government in a very vulnerable position particularly now, as the warnings to the City of Cape Town (CoCT) have become reality and the number of days of remaining water drip ever closer to "day zero"[2].

Too little water, or even too much has devastating effects. As the water restrictions have increased in severity and the crisis has deepened, it has become apparent that the crisis' root causes are nuanced. These range from the un-scientific assumption that dams will be filled from winter rains because to systemic issues related to the complete reliance on surface water and a conventional approach to infrastructure. The CoCT's Executive Mayor, Patricia de Lille herself concluded in May 2017 that it is not possible to predict rain because we are not *sangomas*[3] (De Lille, 2017).

The CoCT's Water Bylaw, which notwithstanding the National Water Services Act's requirements for a water services authority to consider alternative ways of providing access to water services (Department of Water and Forestry, 1997), does not allow the connection to any water source other than the CoCT's and the use of water from any other water source. This limits alternative water usage to non-domestic purposes, unless special permission has been granted by the Director of Water and Sanitation. The reasons for this are understood to be concerns over the potential public health risk related to households treating and using water and the potential impact to the CoCT's water tariff revenue.

[2] "Day zero" CoCT reference to the day when water runs out
[3] Sangoma – witch doctor or traditional healer capable of predicting the future

I believe that forcing the public to use a limited and rapidly depleting source whilst preventing the use of alternatives, is irresponsible in the context of the crisis and future resilience. Through my work in development facilitation, an apparent resistance to alternative water was noticed. Upon enquiry, they responded with three issues, firstly with the Water Bylaw, secondly, the guideline used by engineers, the Guideline for the Development of Settlements, commonly referred to as the Red Book (CSIR, 2000) and lastly, because a rainwater tank cannot store sufficient water for dry, summer months. Unsatisfied with the responses, I engaged in research and this thesis is my response. Through the research of these issues, it has transpired that whilst they are the fundamental inhibitors to systemic re-imagining and an incremental approach, there are others that are not governance-related. These include the need for greater storage opportunities to optimise rainfall to augment bulk supply[4]; the lack of the spatial integration (refer Section 2.7) and implementation of water planning; and the inadequacies of the conventional approach to infrastructure systems (refer Section 2.2).

Whilst it is not suggested that rainwater tanks will supply sufficient water throughout the year, they can certainly reduce the demand on bulk storage during winter months which allows for the banking of water for summer. Research published by Lloyd Fisher-Jeffes (2015) and Coulson (2014) supports this hypothesis. Their modelling, though to different but similar ends, suggests that harvested rainwater can supply a large proportion of domestic water demand throughout the year for homes within his study area, the Liesbeek River Catchment. The stumbling blocks to implementation were however identified by Fisher-Jeffes (2015) and Coulson (2014) as the policy, lack of institutions to manage and operationalise a decentralised system, and the cheap cost of water that renders rainwater harvesting currently financially unfeasible.

As much as augmenting bulk supply is an important part of an incremental approach, it forms part of a larger approach to water management that relies not only on increasing supply, but also reducing demand. Because a conventional approach relies entirely on potable water it is inefficient and is made more so by its linear system that does not allow for optimal use or re-use, or a fit-for-purpose approach. Research by Coulson (2014), also in the Liesbeek River Catchment, focussed on modelling the potential potable water savings achievable using water efficient devices and a fit-for-purpose.

Global research highlights the need to re-imagine water governance as a system where citizens and government share responsibility towards a common goal of resilience (Pahl-Wostl, Karstens, & Knieper, 2010). As Winston Churchill stated – “never waste a good crisis” and so it is suggested that the terrifying, visceral fear of running out of water that makes for popular culture, apocalyptic movies should be exploited and used to effect change.

This change, I propose, is to a different approach that focuses on incremental water interventions that optimise the existing, conventional system and augment it with smaller, decentralised interventions to create a hybrid system. This approach holds opportunities to address supply and storage limitations in several ways. These include rain and stormwater harvesting, greywater re-use which are all implementable on a household and precinct scale and the greater supply and use of treated wastewater. The challenges to

[4] Bulk supply refers to large scale infrastructure projects that store water collected from rivers.

the implementation of this approach lie in water governance, the financial implications for the CoCT and the potential public health risks.

An incremental approach empowers individuals to co-operate within a larger system, in this case government, in a decentralised way by creating multiple sources and storage options on a variety of scales. Supply thus moves away from the current bulk surface water dependence to alternative water sources such as those derived from desalination, groundwater abstraction, spring water, greywater and rain- and stormwater harvesting. These are smaller interventions that do not necessarily rely on bulk storage that is limited by the unavailability of space within the CoCT's largely developed metropolitan area.

Cape Town's surface water storage limitations eliminate the option of conventional, large, expensive infrastructure solutions. Locating storage for large volumes in urban areas where there are unexploited water resources is difficult, particularly when the majority of the CoCT's urban footprint has been developed or has unexercised development rights (Official, 2017).

By disaggregating and decentralising the system, the infrastructure can conceptually become smaller and more compact like sponges that structure storage into small pockets secreted into the urban environment, as proposed in Hanon (China) (Biswat & Hartley, 2017). An application of Water Sensitive Urban Design, these cities are popularly referred to as "sponge cities" and China is aiming to have 80% of urban areas able to absorb and re-use at least 70% of rainwater by 2020 (Hartley & Bizwas, 2017).

The advantage of this incremental approach is that the infrastructure at the domestic, simplest scale is non-technical and does not rely upon specialist skills to operate. Rainwater tanks are discrete units that operate alone, but that have the flexibility to be expanded and modified over time. The advantage of this incremental approach is that the infrastructure at the domestic, simplest scale is non-technical and does not rely upon specialist skills to operate. Rainwater tanks are discrete units that operate alone, but that have the flexibility to be expanded and modified over time. This approach and the resultant hybrid system may not be appropriate across all income groups due to cost and space limitations, but would assist the high water users who typically have large properties and gardens wherein storage can be located. Given that South African cities are expanding in a variety of ways both via densification and development on the periphery, a range of decentralised systems using a range of technologies would be recommended.

This approach and the resultant hybrid system may not be appropriate across all income groups, due to cost and space limitations, but would target the high water users who typically have large properties and gardens wherein storage can be located.

In perpetuating the current approach to water infrastructure, the problem is getting bigger, not smaller. It would be naïve, however, to suggest that an incremental approach will single-handedly resolve all water security problems. It will however, by offering a few possible interventions, make the problem smaller. This thesis concludes with recommendations for governance reform to enable the shift to a different approach to water infrastructure.

2 THESIS STRUCTURE AND METHODOLOGY

This thesis is in three parts (Figure 2). The first part reflects the initial research that I conducted into water governance around rain and stormwater harvesting. The methodology used in this section was to undertake a wider critique of governance, urban water planning, infrastructure systems, revenue and practice and to compare and contrast them against the current literature and international best practice. This part sketches the water crisis and describes how the 'system', urban water cycle, legislation and policy, planning and guidelines have contributed to the crisis. The lens through which each element is analysed relates to the role of the system in structuring the governance and the inclusion of alternative water.

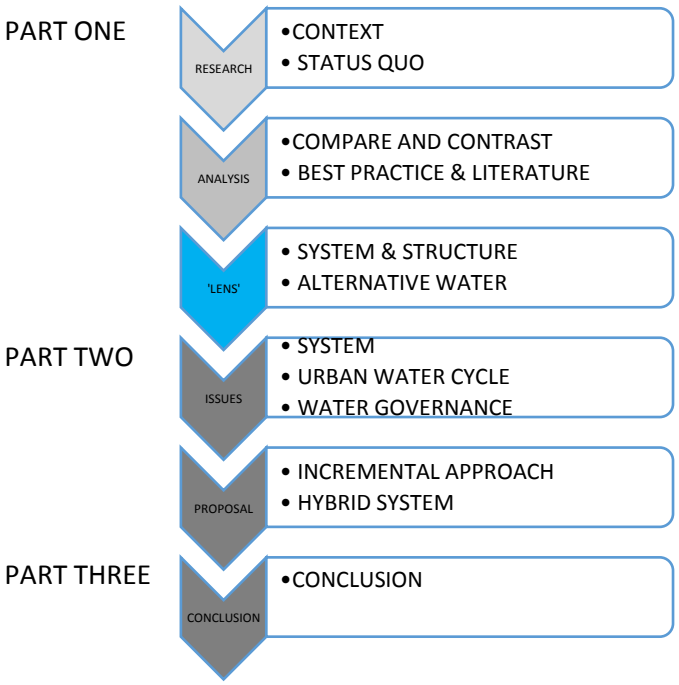

Figure 2: Methodology

Through this process, two issues emerged - the need for greater storage opportunities to optimise the rainfall collection and the need for water governance reform to enable and embed the use of alternative water sources therein.

All relevant issues that have the potential to inform the proposal are summarised in Section 3 Part One- Summary with recommendations in Part Two – Proposal.

The proposal is contextualized against the status quo and responds to the current challenges particularly those relating to alternative water use with a view towards implementation. To this end, current water governance is analysed, potential implementation blockages are identified and recommendations are made. The findings of this research is summarised in Annexure C. The analysis was based on literature, the current water governance and my own professional experience.

The third and last part of this thesis is the conclusion where the argument is summarised.

PART ONE - STATUS QUO OF WATER GOVERNANCE

Water is present in either the natural water cycle or the urban water cycle. The natural water cycle is composed of mountain and valley catchments transports the water either across the surface by gravity to a dam, a lake, the sea or by or infiltration to an aquifer. The urban water cycle overlaps in areas with the natural system, but it collects and transports water using infrastructure that depends on both gravity and pumps from the storage to the user. The design of this infrastructure is subject to and responds to the prescripts outlined in water governance. The World Economic Forum defines governance as either the structures and decision-making processes that allow a sate, organisation or group of people to conduct affairs; or the laws and standards that pertain to the global community, and the ways in which transnational bodies, governments and corporations implement them (World Economic Forum, 2016). Similarly, it is "the range of political, social, economic and administrative systems that are in place to regulate development and the management of water resources and provisions of water services at different levels of society" (Pahl-Wostl, 2010) through which decision-makers are held accountable. For the purpose of this dissertation, governance relates to the legislation, policy, strategies, guidelines including the institutions and processes.

Establishing an understanding of water governance is therefore key towards unpacking the *status quo* systems and structures that underpin water service delivery.

This Part One is divided into two sections. In the first section I will describe the *status quo* that includes the global context and a description of the systems approach upon which the infrastructure is designed. This section acts as an introduction to the *status quo's* second section which outlines water governance.

Water governance[5] is influenced by how water is valued. These values inform the concept for the institutional arrangements and water system including the legislation (laws and policy) devised to control it and the body of practice that underpins the built environment profession that designs the infrastructure systems. Water governance is informed by how water is valued by the society. These values inform the concept for the institutional arrangements and water system including the legislation (laws and policy) devised to control it and the body of practice that underpins the built environment profession that designs the infrastructure systems.

The Cambridge dictionary describes water "a clear liquid, without colour or taste, that falls from the sky as rain and is necessary for animal and plant life" (Cambridge University, 2018). In South Africa water is something more, it is a basic human right, the origin of all things - the giver of life because; "from water is born all peoples of the earth" - Mazisi Kunene (Department of Water Affairs, 1995).

The values in the water legislation include an understanding that water is a scarce resource within a water cycle that must be managed in an integrated way. The legislation acknowledges the critical importance of water to the environment and allows a reserve for its health and functioning. It includes the right of people

[5] Water Governance is my term for all the institutions, legislation, regulations, guidelines and practice that determine how water services are delivered.

to access adequate water and the need for the redress of historical imbalances and the participation of people in water management.

Analysis of South African water governance holistically across government spheres and professional practice in relation to outcomes does not appear to reflect these values. For example, analysis of the intuitional arrangements contemplated in the Water Services Act (1997) that would allow for the participation of the people in water management do not appear to have not been implemented. Water management at a catchment and metropolitan scale does not include public participation much beyond the statutory processes required for documents such as the Integrated Development Plan (IDP). Furthermore, the lack of the requirement to harvest rain and stormwater does not speak to "scarcity".

South African water governance described in this section, mirrors global practice and creates what I refer to as a "conventional system". Sections 2.3 to 2.7 describe water governance via a number of sub-sections that commence with a description of the water system structure and institutions, before dropping down into the detail of the urban water cycle, legislation, policy, planning and guidelines. The purpose of describing the status quo is to illustrate how the current system is structured and to explain why I believe that it is not suitable for meeting future sustainability challenges. These reasons include the limitations of a conventional system that is reliant upon municipal potable water obtained from storing surface water.

2.1 GLOBAL CONTEXT

The actualisation of plausible, though fictional apocalyptic scenarios depicted in the movies Tank Girl and Dune illustrate the visceral fear of running out of water. The Cape Town water crisis featured prominently in news reports, but according to a BBC article, there are 11 other cities that may follow suit, with Sao Paolo, Bangalore and Beijing topping the list (BBC, 2018). As early as 2011, 41 countries experienced water stress with 10 almost depleting their renewable freshwater supplies necessitating a shift to and reliance on alternative water sources (United Nations, 2015). Increasing drought and desertification is worsening these trends and by 2050, it is projected that recurring water shortages will affect one in four people (United Nations, 2015). In 2015 it was estimated that 40% of people around the world are affected by water scarcity and projections indicate that this will increase with the rise of global temperatures that result from climate change (United Nations, 2015).

As the effects of climate change increase and natural resource availability, including water decreases, so the pressures on natural resources will escalate. These ever-increasing pressures, including changing structures of global production, trade, demographics and technological advances (The Global Commission on the Economy and Climate Change, 2014) are altering cities' growth paths.

In Africa and Asia where populations are forecast to increase and where, for example in Africa by 2050, 60% will live, new cities will emerge (Parnell & Pieterse, 2014). Global economic power is expected to move from cities of the developed world to those of the emerging economies within the next 15 years and 80% of economic activity will occur in cities where economic consumption and production will be concentrated (Hodson, 2012). This trend is reinforced by the statistics that indicate that municipalities are responsible for the largest portion of the GDP (Figure 3) (Nditwani, 2018). Responding to global development issues proactively is necessary to protect municipalities and thereby the economy. Cities will have a pivotal role in the future economy and their planning must include resource planning for sustainability because without

resources, including water, the economy is unsustainable (Hodson, 2012). The lack of adequate planning could result in environmental degradation which could in turn damage the economy which impacts on the ability for developing countries, including South Africa, to grow their economies becomes limited.

Economic growth impacts on the availability of scarce resources for current and future demand. Understanding the role of resources and the processes that influence their use is therefore important to establish a more sustainable global growth path, to plan for cities of the future.

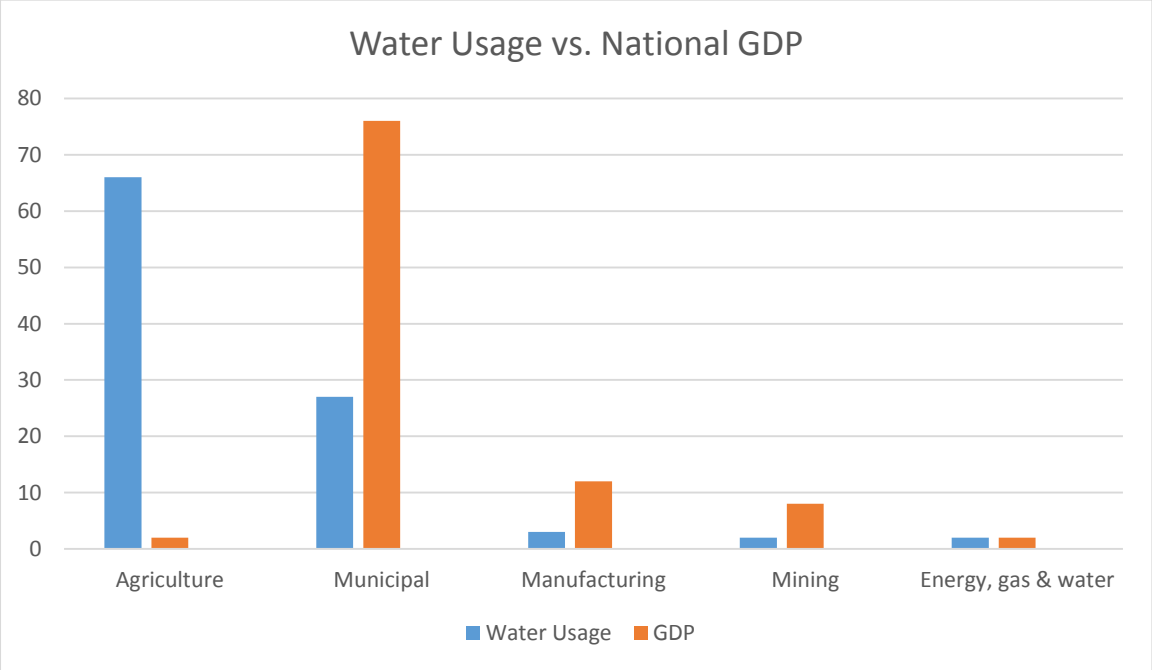

Figure 3: Water Usage vs. GDP (Source: Nditwani, adapted by the Author)

Against this context, the need for Cape Town, an urbanizing African city to manage water resources for sustainable economic growth and poverty alleviation has never been greater. Recognition of these challenges is reflected in the 2015 UN Sustainability Goals that seek to achieve a better and more sustainable future. Goal 6 Water, focuses specifically on water and sanitation and aims to ensure universal access to both by 2030 (United Nations, 2015) and includes that by 2030 the following will be achieved:

a) Universal and equitable access to safe and affordable drinking water for all;
b) Access to adequate and equitable sanitation and hygiene for all and an end to open defecation, paying special attention to the needs of women and girls and those in vulnerable situations;
c) Improvement of water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally;
d) Substantial increase of water-use efficiency across all sectors and ensuring sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity;
e) Implementation of integrated water resources management at all levels, including through transboundary cooperation as appropriate;
f) Protection and restoration of water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes;

g) Expansion of international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies; and
h) Support and strengthening of the participation of local communities in improving water and sanitation management (United Nations, 2015).

2.2 SYSTEM – CONVENTIONAL VS. DECENTRALISED APPROACH

The CoCT's conventional bulk water system structure (conventional approach), referred to as Hughsian large-scale technical systems (Egyedi & Mehos, 2012) offers a degree of assurance of distribution, assuming there is water to supply. It is also enormously useful in managing demand through pressure management. It is overly reliant on a centrally managed, linear system (Figure 4) and dependent on abundant surface water that is stored in large dams. Water moves from the source through the system in a sequential manner to be discharged into a water body/sea. There is little recycling or re-use in this linear system. The system relies heavily on large dams that are capable of storing large quantities of water under average meteorological conditions, but that are vulnerable to evaporation from high temperatures and wind over the summer.

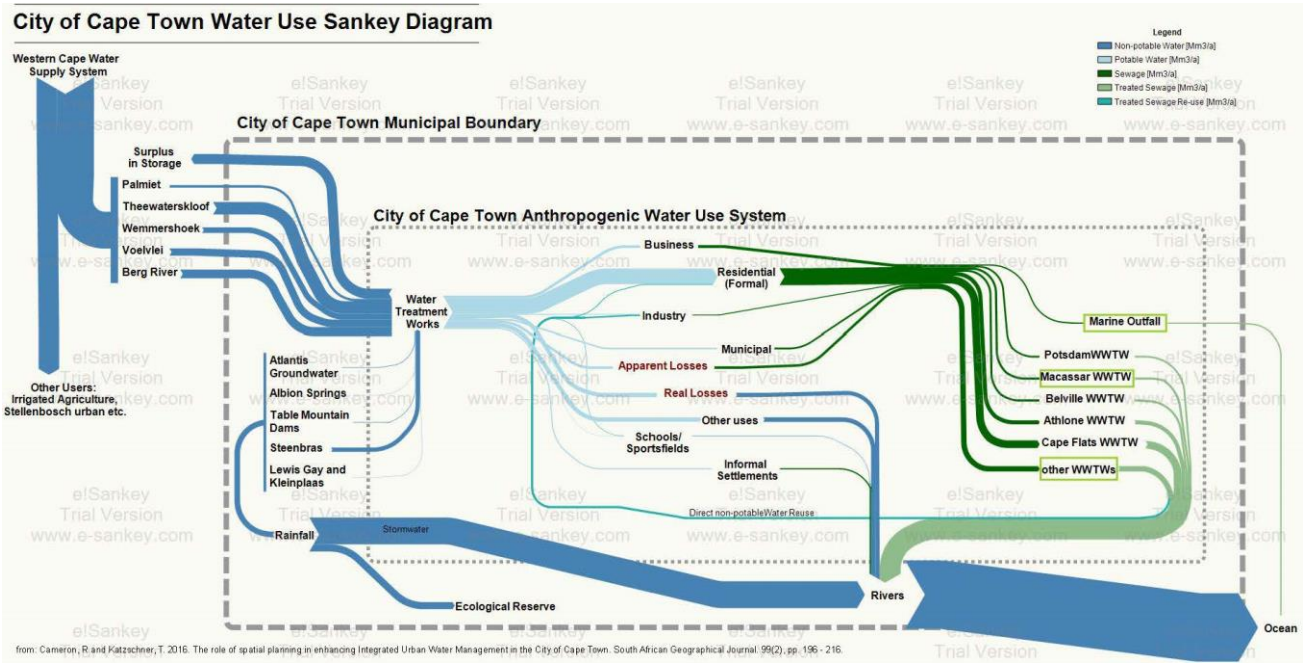

Figure 4: CoCT Water Flow Diagram illustrating the linear system (Source: Rebecca Cameron)

These impacts are exacerbated by large dams that are inefficient because of the enormous surface areas exposed to wind and heat. Poor catchment management and farming techniques further result in the loss of vegetation and topsoil which is deposited by surface runoff into dams. The loss of vegetation and trees remove valuable shade that manages surface temperatures. The sequence of cause and effect that results from reduced shade and increased temperatures further contributes towards and exacerbates the rate of climate change (Roux, 2017). This negatively impacts on vegetation growth which negatively impacts on biodiversity and eco-systems (made vulnerable by water-intensive alien invasive species) whilst also

contributing towards desertification and reducing the availability of water resources for environmental and human needs.

Because of the linear system's structure and approach to infrastructure planning, water demand increases have typically been resolved by building more bulk infrastructure such as dams. Unlike in California, for example, where expanding bulk water storage capacity can be considered (O'Hara, 2008), the Western Cape's options are limited by insufficient surface water availability amidst concerns that this resource is already over-exploited (Heddon & Cilliers, 2014).

The conventional, linear system's hierarchical structure[6] limits its adaptiveness and makes it less able to respond to the high levels of uncertainty created by climate change. The CoCT has experienced these limitations whilst planning the drought augmentation projects. For example, locating sites for desalination plants has been complex because of the system structure which connects parts in a particular sequence that limits does not allow for universal connectivity due to differing pressures throughout the system, difficult topography, protected natural environment and energy costs.

"Universal" connectivity in this context refers to the ability of systems to inter-connect in ways that allow for smaller scaled networks and the use of smaller water resources. Climate-resilience research in Copenhagen focussed on stormwater management found that there are multiple benefits from disconnecting from the main network. These include improved flood protection under a 100-year storm, reduced surcharge to terrain under a 10-year storm; and an improved yearly water balance (Lerer, Righetti, Rozario, & Mikkelsen, 2017). It therefore appears that there is value in adapting the model used in this research so as to apply it to Cape Town to determine if there are similar outcomes. Further research that evaluates Cape Town's water balance across catchments and infrastructure is also necessary to determine what opportunities are available to create smaller, district-scaled water supply systems based on diverse water sources. The intention of an incremental approach, is not to create the need for new infrastructure. It proposes to augment the existing infrastructure by making connections and adding as necessary, whilst focussing on the possibilities within rain and stormwater harvesting. The complexity of integrating the conventional and incremental components is however a challenge experienced globally.

In comparison, a decentralised system as per the systems approach is consistent with the principles of resilience planning. A systems approach refers to holistic analysis focussed on the way that a system's parts interrelate and how the system operates within the context of larger systems and over time. Conceptually, it is a collection of small, self-sustaining units that create many centres and therefore, multiple intervention opportunities (Figure 5)(b) (Coombes & Kuczera, 2002). At an advanced stage a hybrid water system would diagrammatically resemble (Figure 5)(c). Applied to a water system, a decentralised system seeks to optimise resources by "closing" loops so that resources are recycled and re-used within the system to limit waste.

Resilience planning refers to creating entities that are more agile and capable of rapid adjustments necessary to adapt and recover from short-term shock. The multiple centres distribute roles and

[6] A hierarchical system is s system where every entity in the organisation, except one, is subordinate to a single other entity.

responsibilities more equally strengthening the system and its ability to self-organise so that it is responsive not only short-term shock, but to long term stress too (ICLEI, 2015) (refer to Section 3.1)

A decentralised system is consistent with resilience planning as it allows for input into the larger system at many points because it is not linear and hierarchical and thereby allows for access to a variety of sources, unavailable to a conventional system. It can adapt to the context and maximise the opportunities therein, whilst also using the most appropriate infrastructure. A decentralised system is comprised of not only the conventional system but incremental interventions too which when combined, create the hybrid system (Domenech, 2011), referred to in (Figure 5). Significantly, incremental interventions are not reliant on the larger system and can operate either within it, or independently which limits the impact of possible failure on the larger system because the impacts are localised provided that the systems are separate and there are no cross-connections and the necessary valves are in place to prevent contamination. Anecdotally, Dr Kevin Winter, a respected academic commented that Cape Town will not run out of water because it is surrounded by extensive water resources (2017). The problem, he noted however – is how to feed the water into the conventional system which does not typically accommodate universal connectivity. It is apparent that the habitual default to finding big solutions has overshadowed the opportunity lying dormant in smaller opportunities, which may offer equal, if not greater economies of scale than conventional interventions.

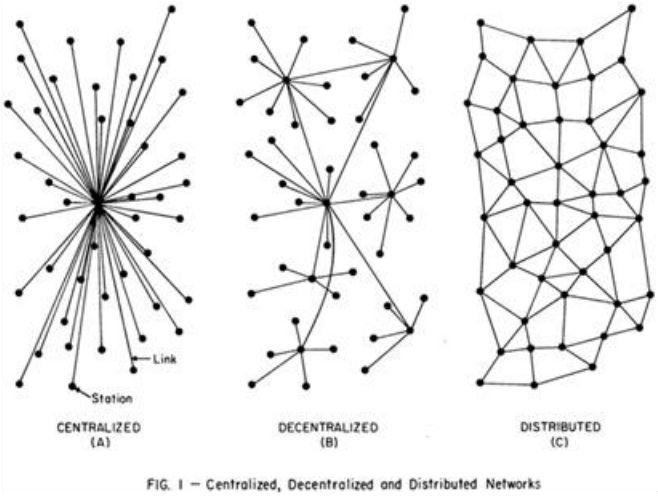

Figure 5: Systems Description – (A) Centralised, (B) Decentralised and (C) Distributed

Whilst the conventional approach and topography has largely shaped the water system, it is apparent that it is also defined by the city's form and the physical manifestations of the infrastructure. South African cities typically have low densities which impacts on how water and other materials/services are transported and used in what Swilling (2016) refers to as the urban metabolism. He contends that by carefully configuring the infrastructure, it is possible to optimise resource efficiencies, which has the greatest potential in cities because it is here that resources (such as water) are used, consumed and disposed of. He goes further and suggests that restructuring infrastructure to optimise resource efficiencies is a means towards resolving the global economic crisis (Swilling, 2011). Applied to a water scenario, interventions could include wastewater treatment for reuse at a local scale, rather than a household scale which could include potential health risks.

For example, dams are most often located on the urban periphery thereby necessitating long pipe runs to provide services. This is inefficient and increases the probability of pipeline contamination, leaks and water quality issues associated with disinfecting lengthy pipe networks (Coombes & Kuczera, 2002). It is also

inefficient because it erroneously assumes unlimited water, materials and energy for the manufacturing and operating of infrastructure components (Swilling, 2017). The concealment of the infrastructure has the unintended consequence of creating distance between the users and the supply. This disincentivises conservation because the supply and use are not seen in direct relation to each other, limiting the user's sense of responsibility (Coulson, 2014).

Used as a tool, infrastructure can be a powerful stimulator of urban growth, referred to as "infrastructure-led planning" (Todes, 2009). It works on the premise that if infrastructure is provided, the market follows with development. In practice, infrastructure-led planning does not always have the intended outcome because the South African development sector is largely driven by land costs that are cheaper on the periphery, and less so by access to infrastructure. This perpetuates urban sprawl. As such, infrastructure roll-out is still largely determined by the market whose penchant for cheap land ignores the infrastructure and environmental costs required to supply services (Coombes & Kuczera, 2002). I argue that a decentralised system builds on Swilling's idea that infrastructure layout determines resource efficiency because it greatly reduces the need for extensive infrastructure and optimises whatever water is provided at source (Swilling, 2011).

These issues underline the need for planning and development controls that assume a resource-limited future and enable a radical paradigm shift, as discussed in more detail in Section 5. A decentralised, incremental approach towards a hybrid system, will require changes to water governance, including infrastructure systems, municipal roles, responsibilities, and delivery methods so that they can respond to the disruptions of new requirements, new technology and new ways of doing things (ICLEI, 2015). This is all necessary because a conventional approach is perpetuating the *status quo* which is inadequate to meeting climate change challenges (Western Cape Government, 2013).

The status quo water system is not equipped to engage with the challenges of climate change and the uncertainty that it embodies. The role of water in alleviating poverty and improving poor people's lives makes navigating a way through these challenges to a sensible solution, even more urgent, particularly in South Africa.

2.3 WATER GOVERNANCE

The Constitution's Bill of Rights enshrines the right to sufficient access to water and .. These rights are embedded in legislation and policies that give effect to the water governance structures and procedures necessary to manage and plan water services. South African cities' water service delivery is informed by national legislation, but the by-laws are specific to cities. Cape Town has been selected as an example in order to establish an understanding across the various scales of legislation (Table 1).

Table 1: Legal Framework and Hydrological Cycle including the Urban Water Cycle (Source: compiled by author)

	RIVER CATCHMENTS	**WATER SERVICES (URBAN WATER CYCLE)**		
	WATER RESOURCES (NATURAL)	**WATER SUPPLY SERVICES**	**STORMWATER**	**WASTEWATER**
Legislation	The Constitution			
	National Water Act	National Water Act	Water Services Act	Water Services Act
		Water Services Act	Stormwater Management By-Law (2005)	Water By-law
Policy/ Strategy/Plan	Catchment Management Strategy	National Water Resource Strategy	Urban Stormwater Impacts Policy	National Water Resource Strategy
		Water Services Development Plan	River and Floodplain Management Policy	Water Service Development Plan
Responsibility	Department of Water and Sanitation	Municipality	Municipality*	Municipality
	Catchment Authority	Not defined	Detention ponds, stormwater	Industrial, recreational facilities, residential, commercial, government
Item	Water Supply and Storage: Watercourses, surface water, estuary or aquifer and abstraction	Water Distribution Dam/reservoir, Water Treatment Works, distribution network, pumpstations	Stormwater Drainage Collection Network and pumpstations**	Wastewater Treatment Works pumphouse, pumping installation
Compliance and Monitoring	Catchment Management	Blue Drop	None	Green Drop

Legend

	National Government
	National Government/Municipality
	Municipality

Notes:

*A Water Institution could be a Water Authority, Water Service Provider, Water Board, Water Services Committee or Joint Venture, but is most commonly and for Cape Town, the Municipality (DWAF, 1997).

** The legislation does not specifically describe or discuss stormwater in either the NWA or the WSA and there is an overlap between municipalities and catchments.

This section is comprised of a description of how water values pertaining to human, environmental and economic needs reflect in the legislation(followed by the water system structure and institutions. These structures relate to the urban water cycle which I discuss before linking it to the legislation and policy that describes government's response to its obligations as outlined in Table 1. The following section lays out the built environment sector's response in the planning and guidelines sections.

South Africa's Constitution (1996) includes not only the Bill of Rights, but the values that guide water management and use too. In so doing, it rationalise a number of previously unjust laws including those pertaining to water. It states that water is owned by all people and identifies government as the people's custodian responsible for the management and allocations of all water resources on behalf of the nation. The National Water Act (NWA) (1998) builds on the Constitutional rights and values and recognizes that; "water is a scarce and unevenly distributed national resource which occurs in many forms which are all part of a unitary, inter-dependent cycle" (Water Affairs, 1998). These humanist and nature-based values underpin water governance informing water governance which at a granular scale determines how it is managed and allocated.

The Red Book Guideline for Human Settlement Planning and Design (2000) (the Red Book) is a guideline widely used by engineers and other built environment professionals. It illustrates an approach to infrastructure planning based on human- and nature-centred that promotes design that is *sympathetic* to the natural environment as opposed to (and preferably) seeing it as a central part of infrastructure and the provider of critical services, such as water, upon which all life depends. Not only does the environment provide services, but it acts as a "sink" to the urban metabolism by processing outputs, such as wastewater, amongst many others (Swilling, 2011). Supporting and enhancing the functioning of the natural systems, including the water cycle, is consequently a key informant to spatial design and or is an underlying prerequisite for water security.

2.4 WATER SYSTEM STRUCTURE AND INSTITUTIONS

South Africa's water management as outlined in the NWA (DWA; 1998) is consistent with flawed, global practice. It assumes a command and control approach centred on technological solutions and regulations (Pahl-Wostl *et al*., 2010) based upon large-scale infrastructural investments using predictive planning (Segrave, *et al*., 2006).

Whilst the NWA purports to promote integrated management the legislation, institutional arrangements and mandates separate water resources and water services. This fragmentation manifests geographically, sectorally, administratively, institutionally, and across disciplinary boundaries within national and local government. The resulting system and governance is consequently less adaptive and therefore more prone to impacts from failure and political manipulation (Pahl-Wostl *et al*., 2010), as already evidenced in various articles recently published wherein the CoCT is criticised for their management of the drought (Diko, 2017).

Water resources are described in the NWA at a catchment scale and their management is delegated to the National Department of Water and Sanitation (DWS) with the local authority, as per the Constitution (1996), responsible for water services. These water services include potable water, domestic wastewater and sewage disposal services and stormwater management in built-up areas (RSA; 1996) (Figure 6).

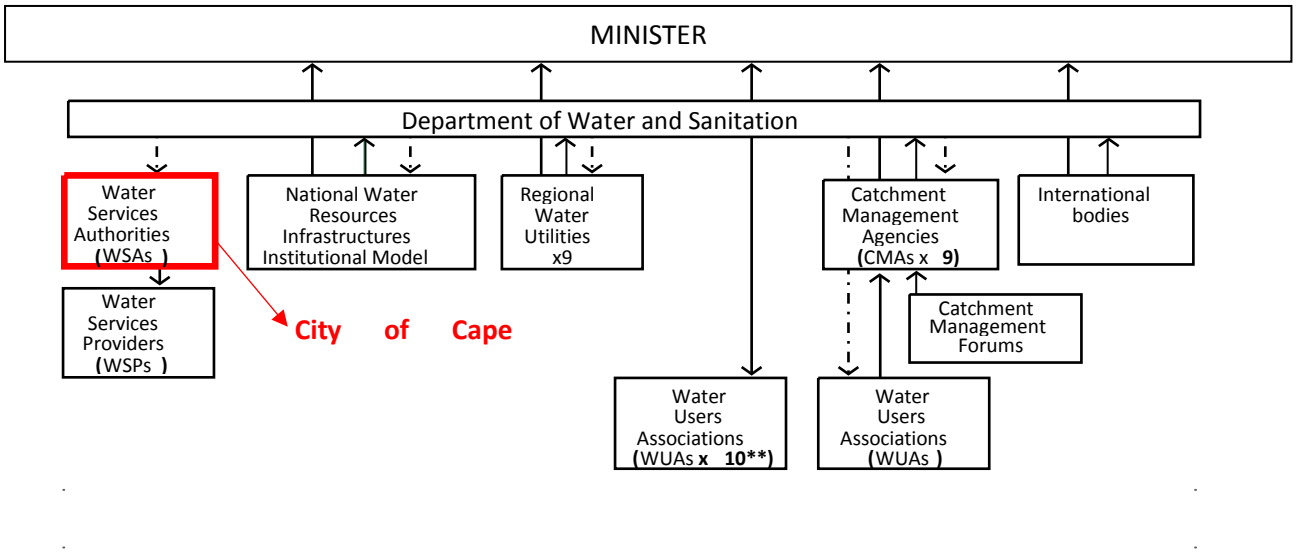

Figure 6: Water Governance Structure (GreenCape, 2015)

The Water Services Act (WSA) establishes the municipality's mandate and focuses on the practicalities around water service delivery including the quantity, quality and assurance of supply the institutional mechanisms and infrastructure (Water Affairs, 2013). Although the Constitution mandates municipalities to deliver water services as a Water Services Authority and/or institution, this role can be undertaken for example by a Water Board. The municipal responsibilities are however described in the Municipal Systems Act (2000) as ensuring universal access to essential services that are affordable to all.

Delivering water services is however subject to the availability of resources (DWAF; 1997) which is dependent upon the good management by national government of water resources. This makes it difficult for local government to ensure the provision of services to communities in a sustainable manner (South Africa, 1996), particularly as supply is dependent upon rainfall, over which no sphere of government has control.

The NWA provides for catchment management which experiences the following challenges:

Firstly, rain falls within catchments defined by mountains. These act as funnels directing surface water towards water bodies, such as rivers. Because these catchments are defined by topography, rivers may many non-physical boundaries. For example, the CoCT is dependent upon the Berg/Olifants River Catchment and dams located beyond the municipal boundary for water to meet its water service delivery mandate, but does not control the catchment management or the dams. This phenomenon results from cities' having ecological footprints that extend beyond political or management boundaries (Currie *et al*., 2017) (Figure 7). This is important because activity within a catchment, such as the proliferation of alien vegetation and poor land-use controls reduces the quantity and quality of water impacting on supply (WWF, 2016) and is a DWS mandate, which is poorly enforced.

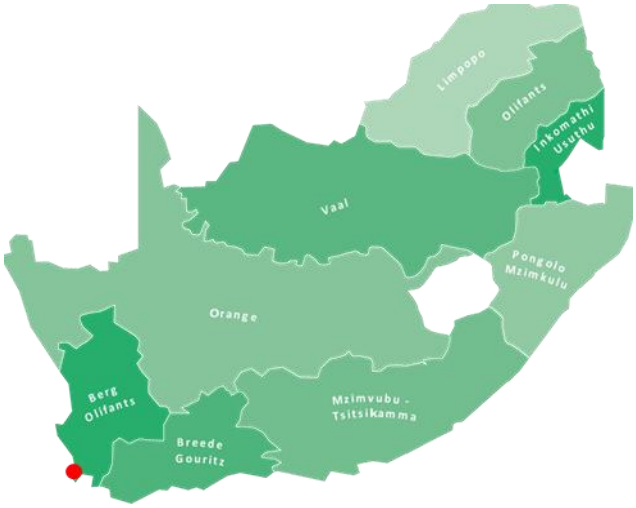

Figure 7: Water Management Areas across South Africa (Source: GreenCape, 2015)

Secondly, the types of land-uses and impacts on surface water resources create different challenges which are managed primarily through stormwater management. This management is referred to in a schedule of the Constitution where it is delegated to the municipality and comprises the management of the quantity and quality of stormwater. There is no further legal definition in the NWA or WSA relating to stormwater management and how it forms a part of an integrated water system. Technically, the moment rainwater enters the stormwater system, it is the CoCT's responsibility and yet, it is still part of a catchment which places its responsibility with the DWS this is an overlap that adds complexities to the legislation currently not adequately managed (Mosdell, 2011).

Thirdly, the NWA is a tool designed to manage catchments with a view to delivering water resources to municipalities. It further states that water must be managed in sympathy with the natural water cycle (NWA, 1998). This means that development should not impact on natural resources such as wetlands and rivers and that rainwater should be allowed to infiltrate groundwater reserves, rather than be disposed of as stormwater. The natural water system is comprised of aboveground and belowground water resources. The movement of surface water starts from when it falls to earth as rain and then moves in response to the topography into waterbodies/groundwater from where it evaporates into the atmosphere and forms precipitation. It is a simple system used by fauna, flora and agriculture, with limited wastewater generated. In comparison, the urban catchments are complex because they include urban settlements wherein a variety of activities occur. They also may well fall into larger natural catchments, or include smaller catchments within the urban boundary. The urban water cycle (discussed in the next section) is comprised of manufactured parts used to treat and transport water (and wastewater), including water resources which are fed into the system and transported via engineered solutions. This is a complex system with the water used within the system generating a variety of wastewater types that are disposed of back into the natural system.

The stormwater and wastewater generated in the urban water cycle impacts on the wider urban *and* natural catchments (Coulson, 2014), resulting in different issues to those experienced in natural catchments. The

natural water cycle is therefore different in an urban catchment where there is an urban water cycle and using the NWA to manage both, is consequently not advisable.

The legal, physical and functional disconnects and unmanaged overlaps frustrate the implementation of integrated water management and service delivery whilst adding layers of complexity and vulnerability. I consider the NWA to be ill-equipped to manage urban catchments which have greater levels of complexity.

The WSA limits an incremental, hybrid approach as follows;

Firstly, it favours a conventional system that assumes abundant water. The values that underpin it lack a sense and understanding of the limitations associated with water security that would be clearer if water were treated as a scarce resource using a fit-for-purpose approach. If there was this understanding, all water resources, including urban water resources such as stormwater, would be conserved and harvested for inclusion within the water mix.

Secondly, the infrastructure approach do not place water and nature at the centre of the system with a view to using the urban systems as a means towards enhancing the functioning of the natural systems (and water) because of their critical role in supporting life. I concur with Swilling (2011) that understanding urban infrastructure is necessary to grapple with the challenge of building more 'sustainable cities'. This understanding commences with reworking the material flows through the ecological and urban systems that are structured and directed by these infrastructures, referred to by Weisz and Steinberger (2010) as the 'urban metabolism' (Swilling, 2011).

Thirdly, the dislocation between national and municipal mandates creates resource inefficiencies, unsustainable water management and poor policy implementation. It enables rampant water use because by spatially dislocating users from the source, the connection to water is reduced which reduces the sense of responsibility because of a lack of awareness. Ultimately, despite adequate climate change warning, government has not implemented its plans and in isolating itself as the sole provider of water services dependent upon surface water, has limited the opportunities for wider participation and feed-in to the network. This simplistic system emanates from legislation and policy that is not designed for the complexities reflected in the status quo. It will be discussed in Section 2.6.

Lastly, the WSA stipulates that a person may not use water services from a source other than from a water services provider nominated by the water services authority (Water Affairs 1997). This stance is reinforced by the Municipal Water By-law that also prohibits connecting to a water source other than the City's, unless written approval from the Director has been obtained (Cape Town, 2010). Finding ways for an *uber*-esque participation in supplying and managing water resources is consequently not allowed in the law.

The Water System Structure and Institutions manifest in the water system and its infrastructure. As introduced in Section 2.2, the values and approach to a "system" have important implications and it follows that a centralised systems approach will result in a centralised infrastructural system. Proposing a different "system", such as a decentralised system will in turn manifest infrastructurally and institutionally, requiring organisational changes within catchments' water services management (Coulson, 2014) and (Fisher-Jeffes, 2015). Effecting a systems change must therefore commence with an understanding of the required institutional changes and a determination of available capacity within the institutions, and a detailed assessment of the legislation and policy where the system and mandates are defined.

2.5 URBAN WATER CYCLE

This section describes and analyses the urban water cycle which is the movement of water flows through urban areas via infrastructure (Figure 8). Whilst it does not strictly include the water resources upon which it depends, such as dams and reservoirs – the urban water cycle (the Cycle) does include the water distribution, wastewater treatment and stormwater collection networks within an urban area and in some cities, groundwater too.

How the Cycle is structured is in response to several influences, including the system identified in the water governance and the water governance itself. The system is derived from values, discussed in the preceding section and plans such as the CoCT's Water Service Development Plan, based on an Integrated Urban Water Resource Management (IWRM) approach (Department of Water and Sanitation, 2009).

Water governance creates the framework for the system including legislation, and institutional arrangements and the guidelines used by professionals in the built environment. These professionals (architects, engineers and landscape architects) participate at the granular scale by implementing design projects that rely and impact on the Cycle which makes them important roleplayers in the Cycle and the work that they do and the guidelines they respond to, of interest.

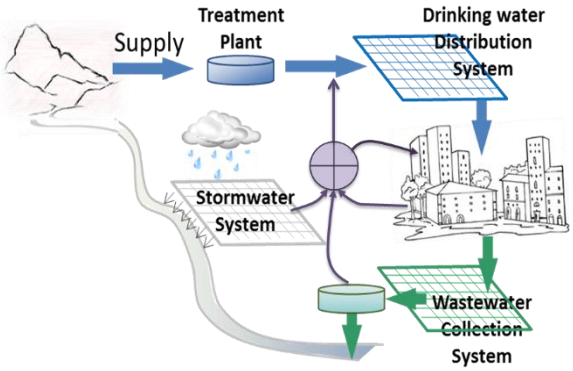

Figure 8: Urban Water Cycle (current) (Source: erams.com)

This section commences with an outline of water supply, before describing the CoCT's water infrastructure that is used to provide water services, including water, wastewater and stormwater.

2.5.1 WATER SUPPLY AND ALLOCATION

Until the recent drought in Cape Town, water supply was derived from surface water that emanates from the on average 490mm per annum rainfall. This rainfall is almost half the global average of 860mm (Figure 9) with Cape Town's most recent rainfall (490mm), falling well below historic levels (Figure 10).

An amount of 4% recharges aquifers with the remainder lost through runoff (WWF, 2017) (WWF, 2016).

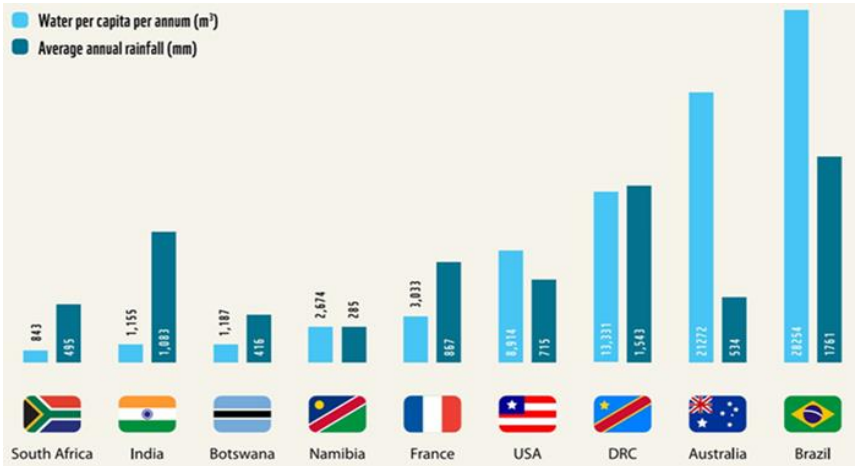

Figure 9: Water use per capita and Average Rainfall (Source: WWF, 2016)

The dams in the WCWSS are fed by and estimated 88% of surface runoff, with the remaining 12% recharging groundwater resources. Within South African catchments typically up to 9% of runoff is collected in rivers, with 4% recharging aquifers and up to 4% used by alien invasive plants that grow in waterways. Of this, only 9% is collected in rivers, with 4% recharging aquifers. Alien invasive plants that grow in waterways reduce up to 4% of surface water with the remainder lost through runoff (WWF, 2017) (WWF, 2016).

Staggeringly, only 8% of South Africa's land area contributes 50% to water in rivers. This 8% falls within catchments that include development and are therefore not designated exclusively for water supply purposes. In total, only 16% of South Africa's catchments are within natural protected areas. Cape Town's supplying catchments have varying degrees of protection with 71% of the Olifants/Berg protected and only 39% of the Table Mountain catchment (WWF, 2016).

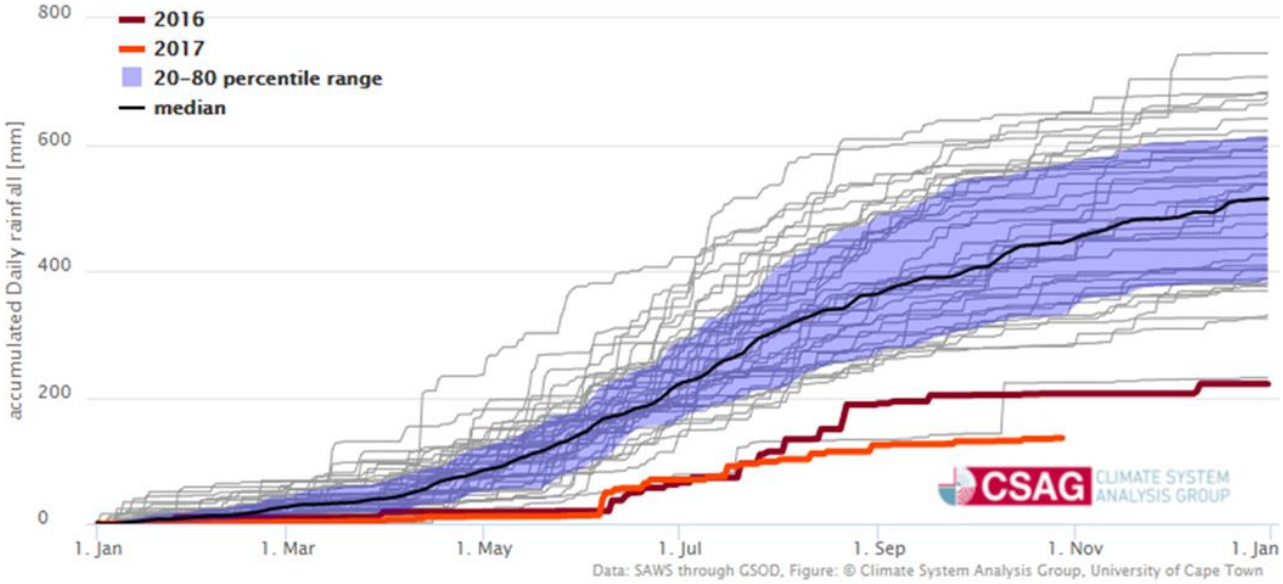

Figure 10: CoCT Historic Rainfall as measured at the Cape Town International Airport (Source: CoCT)

The DWS, as the water authority responsible for catchments and water resources, allocates water resources according to the Catchment Management Strategy and Water Allocation Plan. Of this national capacity, 98% has been allocated, raising questions around how the expected demand increase, anticipated to rise from 15 billion m³/annum to 17 billion m³/annum by 2030 will be met, a concern echoed by the Minister of Water and Environmental Affairs Edna Molewa in 2013 (Parker, 2013) and the National Development Plan (National Planning Commission, 2012).

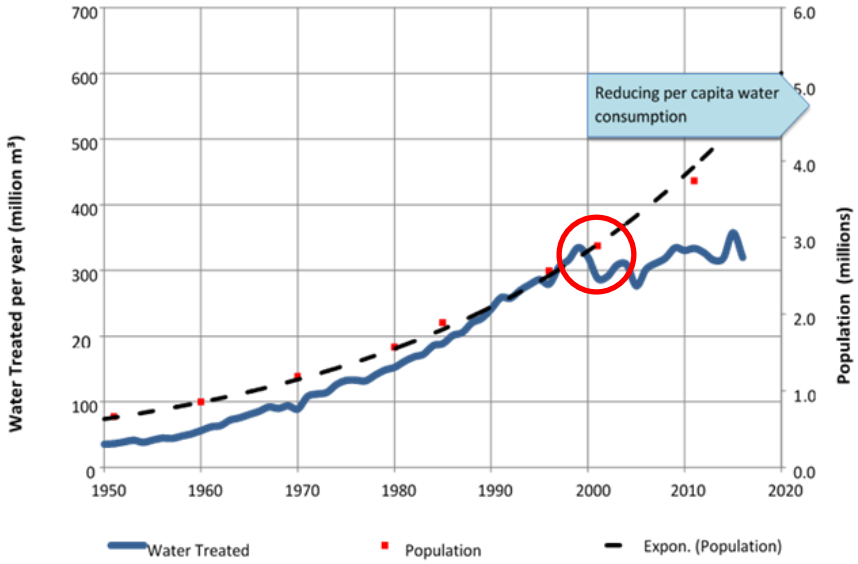

Figure 11: Graph illustrating impact of WCDM interventions (Source: CoCT)

The CoCT's Water Services Development Plan (2010) (WSDP) has three focus areas that include reducing demand, increasing supply and ensuring adequate quality. These three areas are elaborated in Water Conservation and Demand Management (WCDM) and Sustainable Urban Water Management. The WSDP's secondary aims include increasing effluent re-use by 15% in 2015/16 and improving security of supply for water systems to 120% of average demand by 2016/2017 in all areas, implemented via several interventions, including water efficient devices and alternative water sources (Roads and Stormwater Department, 2009).

It is noticeable that from 2000 the demand did not increase and remains relatively constant (Figure 11). There are a few possible explanations for this which range from reduced usage through WCDM that optimised the water network, to demand reductions through shifts to alternative water, to changes in economic activity, as discussed further.

An award-winning[7] WCDM plan was implemented at this time in response to drought. The interventions kept demand down and limited the water impact of population growth with a bulk infrastructure intervention anticipated for between 2011 and 2018 (Department of Water and Sanitation, 2009). However, at the time of writing this thesis in 2017, the drought interventions currently underway, despite being within the long term planning, had not been planned for implementation in the near future. This lack of urgency may be because of Cape Town's success in creating a more efficient system in 2000, supply was increased, negating the need for further interventions. These efficiencies to the functioning of the system have limited the scope for radical savings during the current meteorological drought, necessitating radically different measures.

[7] The CoCT received a C40 Cities Award for this programme (Source: CoCT)

Whilst the evaluation of the 2000 WCDM attributes successful reduction to leak fixing, the installation of water saving devices and some pressure management, the role that the shift of high demand households to borehole water use has not been fully calculated. Jacobs (2011) estimate that up to as many as 30% of low density homes registered drilled boreholes for garden irrigation between 2002 and 2003. The impact of borehole water use on households' average annual daily demand could be as much as 40% (Jacobs, 2011). So although there appeared to have been a reduction in demand, in practice, the demand had shifted in part to borehole water. This phenomenon artificially reduced the average annual daily demand, impacting on water planning guidelines (Jacobs, 2011).

Whilst the CoCT's *approach* to water resource management is consistent with international best practice, it continues to use an outdated "predict-and-provide" approach for forward planning that is based on historic use (CSIR, 2000) and upon an assumption of limitless abundance. It does not allow for incremental and organic growth and change (Campbell, 2011) and assumes that major problems can only be resolved with bulk infrastructure solutions, and not by smaller, incremental interventions.

This is evident in the infrastructure schemes, which combined with WCDM are planned to increase capacity such as river diversion, raising the height of dam walls. Alternative water sources comprised of groundwater (aquifer), seawater desalination, effluent re-cycling, wells, boreholes and rainwater (Roads and Stormwater Department, 2009) are also included, but until recently, had little momentum. These interventions will broaden the water supply options which are consistent with Minister of Water and Sanitation's Nomvula Mokonyane's 2015 budget speech (Department of Water and Sanitation, 2017).

They will also create greater resilience even if it is contradicted by the proposed large-scaled, conventional infrastructure which is not considered to be an appropriate climate change response (ICLEI, 2017). Smit (2017) in review of the CoCT's Medium Term Infrastructure Investment Framework concurs with this critique and recommends that the potential of an incremental approach and the role of environmental services be investigated. The wider adoption of alternative water (including recycling and re-use) at all scales is consistent with DWS's integrated water approach that entails a sustainable and holistic value chain of water supply from source to tap and from tap back to source (Department of Water and Sanitation, 2017).

Noticeably absent from the CoCT's water supply strategy at this time, is stormwater from their urban catchments. The surface water that discharges into the stormwater system along with contaminants from urban developments collected *en route*, combines with untreated sewage, greywater from informal settlements, pesticides and herbicides from agricultural lands, and poorly treated wastewater from wastewater treatment works (Coulson, 2014) before discharging into streams, rivers or the sea. Untreated, much of this water is not suitable for domestic, or non-domestic purposes (Nell, 2017).

The water supply also excludes the existing boreholes located on private property. Boreholes (or wells) abstract water from where it is stored in the spaces between soil particles and rock fractures underground. The NWA considers the use of this water as a resource on smallholdings and allows water to be abstracted for reasonable domestic use, such as gardening or watering livestock (NWA, 1998). This quantity is sufficient to supply most domestic needs on a medium-sized urban property. The large allocation suggests that an aggregated impact of multiple households using groundwater, as is now the case in Cape Town was not considered. Whilst ground and aquifer water is a critical part of the CoCT's water reserves, it is not part of their management mandate. As such, they are not responsible for the management or monitoring of this

resource and are completely reliant upon the DWS. At this time, it is unclear exactly how much water is available in this resource, how long it took to collect underground or how it will recharge. With the resource not receiving DWS attention and nobody delegated within the CoCT to undertake its management, the over-use of this resource is a very real possibility (Faragher, 2017).

The storage capacity from which the CoCT draws its allocated supply is 570 million m³ per annum. It is shared across 15 dams owned by the CoCT or the DWS. Divided between the two, DWS supplies 73% and the CoCT 27%. This capacity services a variety of consumers such as agriculture and the CoCT which receives 400 m³/million/annum, an amount that has been dropping and is anticipated to drop further from 345 million m³ in 2014/15 to 280 million m³ in 2016/2017 (Department of Water and Sanitation, 2009) (estimates prior to the drought).

Table 2: Water Supply and Allocation (Source: CoCT 2009/2015- various compiled by author)

	DAM	QUANTITY m³	ALLOCATION	% m³/annum	CITY SECTOR	%	USAGE	%
1	Voelvlei (DWS)	570 million	Other municipalities	7% 37 million				
2	Theewaterskloof (DWAS)		Agriculture	29% 158 million				
3	Palmiet (DWS)							
4	Berg River (DWS)		City of Cape Town	64% 400/345 million	Domestic	58,6	Recycle	7
					Domestic (cluster)	8,2		
5	Steenbras (CoCT)				Schools	2,0	Other	23
					Water contracts	1,6		
6	Wemmershoek (CoCT)				Other	0,5	Wastewater Discharge	70
					Commercial	12,3		
7	Smaller dams (CoCT)				Miscellaneous	4,5		
					Government	2,3		

The CoCT supplies the water it is allocated to various sectors (Figure 12: CoCT Water Budget (Source: CoCT). The largest allocation is given to formal housing with most of the water used by the owners of large, high value properties to irrigate their gardens (Heddon & Cilliers, 2014) and (Coulson, 2014). This data is surprising considering that the NWA was intended to redress previous inequality.

The water allocation is to supply the demand generated by the users of buildings, be it commercial, manufacturing or residential. These buildings are designed by architects and engineers who determine the demand based upon the Red Book. This guideline is enormously influential as it defines water use and demand. The South African National Standard is also commonly used and is part of the National Building Regulations promulgated under the Building Standards Act 103 of 1977 (NBR) with SANS 10252-1:2016 dealing with water supply and drainage for buildings (SABS, 2016).

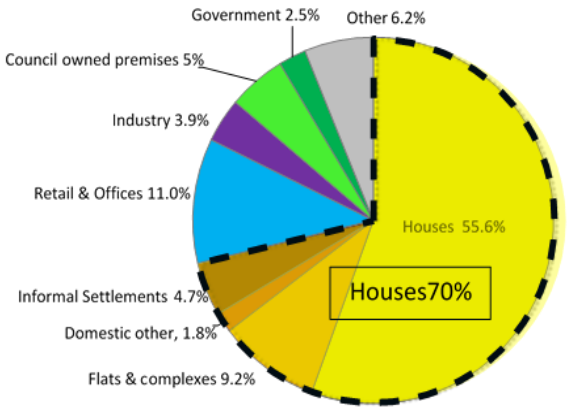

Figure 12: CoCT Water Budget (Source: CoCT)

None of these regulations integrate alternative water as a requirement, nor do they reflect its integration into water supply systems. Once the amount of water is determined, an application is made to the CoCT for draw-off from the water distribution network which connects consumers to storage and treatment facilities.

2.5.2 WATER INFRASTRUCTURE

Water infrastructure is comprised of water, wastewater and stormwater systems, assembled in a linear arrangement. Whereas water and wastewater are inextricably connected, stormwater is less so with contamination occurring due to the failure of the wastewater network.

The water distribution network is comprised of reservoirs, treatments works, pumpstations and distribution networks. The network structure is centralised, like a heart, and like a heart, it distributes water through varying sized pipes within a single, connected network which limits the potential for adaption.

As the water moves through the water distribution network and is used, so it becomes wastewater. Because of the inter-connectedness of the urban water cycle, reducing water demand and thereby use, has impacts for the wastewater system, which in the CoCT is largely waterborne. Reduced quantities of wastewater limits the amount of water in the system which impacts on its ability to flush sewage to wastewater treatment works. Reduced water usage and thereby generation of wastewater impacts on the efficacy of the wastewater system because with reduced input, it is unable to flush sewage through to wastewater treatment works causing blockages and infrastructure damage. Finding a balance is therefore important when seeking alternative water sources and wastewater treatment options.

Wastewater is transported via the wastewater reticulation network to a wastewater treatment works where it is treated. Of the available treatment capacity only 45% is currently utilised with the bulk of what is treated (70%) released into water bodies and the remaining 7% reused by industry and for irrigation (Department of Water and Sanitation, 2009). Encouragingly, recent indications are that uptake of treated effluent has increased to 10% (Official C. , 2017), which is still low by global standards.

Unlike Cape Town, Singapore uses 30% of its treated effluent for potable uses (Coulson, 2014). Considering the unused capacity, increasing the quality of wastewater to optimise the system's substantial spare recycling capacity, could greatly contribute towards meeting water demands, be it for potable or non-potable purposes. Unsurprisingly, emergency augmentation projects are actively looking at recycling more wastewater and in so doing, optimise existing infrastructure by limited technological upgrades. The distribution network necessary to deliver the enhanced service has however not been implemented and there are perception issues around the use of recycled water that have prevented greater uptake (Department of Water and Sanitation, 2009). Water scarce cities such as Cape Town do not have the extravagance of disposing of wastewater. Because treated effluent (basement and other treated effluent water) is considered to be wastewater it is less regulated and it is possible for smaller-scaled water treatment works to access and treat wastewater to a higher (even potable standard) without onerous red tape. At this scale, collaborations between water-intense manufacturers create the critical mass necessary to justify the capex for such a project. This approach to water supply is consistent with a multifunctional use of water resources approach as will be discussed in Part Two.

Stormwater is treated in a similar way to wastewater because it is highly polluted. It however differs in that it is collected from the surfaces around buildings, as opposed to from use within buildings. Stormwater is rainwater that has fallen to the ground and from where it lands, is manipulated by hardened horizontal surfaces towards stormwater collection networks to be disposed of downstream as efficiently as possible via waterways (Coulson, 2014). The CoCT's stormwater networks are not designed for infiltration and are therefore composed of impermeable materials. The momentum that runoff gains flowing off hardened surfaces increases as it moves through the network causing structural damage to river banks as it discharges, which reduces bio-filtration and bioremediation potential. Coulson (2014) notes that whilst this is the dominant system, it is not applicable to poor informal areas on the Cape Flats where water and wastewater infrastructure is not necessarily provided, or not provided in a formal way. The majority of Cape Town's stormwater network is designed and managed as described and is not best practice.

WSUD is achievable at all scales of design by ensuring that development in urban areas is holistically planned, designed, constructed and maintained so as to reduce the negative impacts of urban development on the natural water cycle and protect aquatic ecosystems (Roads and Stormwater Department, 2009). Practically, WSUD seeks to re-establish urban waters with the natural water cycle which includes enabling groundwater recharge via permeable surfaces; and limiting the concentration and acceleration of stormwater through pipe and canal networks (Roads and Stormwater Department, 2009).

Whilst WSUD includes the full water cycle, Sustainable Urban Drainage Systems (SUDS) applies specifically to stormwater management. SUDS is included in the CoCT's Management of Urban Stormwater Impacts Policy 1 (Roads and Stormwater Department, 2009). Its multi-disciplinary approach considers water management holistically throughout project phases from an environmental, social and economic perspective with a particular focus on including water cycle management into the built fabric. It includes for example the treatment train which is a combination of methods implemented in sequence or parallel. The purpose of the treatment train is to manage the quantity and quality of stormwater before it discharges into the environment. In comparison, the Red Book sees stormwater as a common enemy (CSIR, 2000) and insists that it must be removed from property, rather than stored and or used.

The National Public Works specification displays an equally poor attitude to stormwater and stipulates how rainwater must be discharged into rainwater downpipes and from there into channels, onto concrete slabs or into pipes (Public Works, 2000). It also stipulates that stormwater must be conveyed by means of shallow brick or concrete channels or flumes of concrete pipes (Public Works, 2000). If this specification is implemented, rainwater will not infiltrate groundwater or recharge aquifers in contradiction to the CoCT's Management of Urban Stormwater Impacts Policy.

Despite the adoption of best practice of for example WSUD within the policy, the implementation results in a conventional outcome with stormwater discharged from urban areas into the river systems that form part of the stormwater discharge network. It is estimated that stormwater represents two thirds of rainfall in Cape Town (Carden, 2017) which it water that could be harvested and used. One of the benefits of the drought is that it has (re)focussed minds and there is renewed interest in stormwater harvesting (Nell, 2017), which will open the way for its storage and use.

This section has focused on water supply and infrastructure. The analysis notes that the urban water system is based upon a conventional system that assumes abundant supply. This assumption is no longer

appropriate and as such, a new system and infrastructure approach is needed.

Important observations within the analysis include several augmentation opportunities within the status quo including stormwater and treated effluent. These opportunities must be exploited prior to the less affordable options, such as energy-intensive desalination. Whilst the desalination costs will already be higher than the current water tariff, these costs will not reflect the true costs, which should include the environmental costs associated with fossil-fuel generated energy and the resultant emissions (ICLEI, 2017). Water tariffs may not affect affluent citizens, but for poorer South Africans who comprise the great majority of the population, the impacts of a tariff increase may be devastating.

How government supplies equitable access, as per the legislation in the event of increased costs is unclear. Even greater questions pertain to the DWS, which is unofficially bankrupt and has been discredited and accused of disorganisation from within government (Parliamentary Communication Services, 2017). Allegations of this severity call into question the DWS's ability to deliver on its obligations to assist in managing the numerous water crises that have beset the country. I believe that there must be a call for a deep questioning of the current approach to water supply infrastructure and services because it is not optimal, sustainable or equitable. The assumptions that have enabled the efficient functioning of the urban water cycle up until the current drought, are no longer appropriate and are furthermore inconsistent with the legislation and policy as discussed in the next section. Because the infrastructure and institutional systems' structures reflect the legislation and policy, it follows that understanding this relationship is key to implementing an incremental approach towards a hybrid system.

2.6 LEGISLATION AND POLICY

The analysis and discussion in Section 2.5 concludes that the urban water cycle is a conventional system that does not include rain and stormwater storage and use. Because it is a manifestation of legislation and policy, I argue that the systemic cause must be embedded therein. This hypothesis will be tested by evaluating the legislation and policy against the following three questions:

a) Is alternative water mentioned in relation to water supply?
b) Is harvesting a specified requirement?
c) Are specific storage quantities required and uses stipulated?

A table that synthesises this analysis has been prepared to enable a comparison (Annexure B). It is noted that because this analysis is across all legislation and policy, there may be some repetition from previous sections.

My analysis of the legislation, policy, strategies and plans found firstly, that there is a lack of information around water types and water uses – including potable/non-potable and alternative; secondly that the terminology is ambiguous and inconsistent resulting in fragmentation and resource inefficiency. From the findings of this analysis I have concluded that the legislation, policy, strategies and plans limit the applicability of alternative water for on-site use (Jacobs, 2011., 2011). These observations are discussed in more detail as per the evaluation questions.

2.6.1 ALTERNATIVE WATER SUPPLY

Alternative ways of providing access to water services is mentioned in the NWA (DWA, 1997). The National Water Resource Strategy (NWRS)(2) builds on this and requires water authorities to seek new ways of reducing water demand and increasing availability that move beyond traditional infrastructure engineering solutions. These new ways include treated effluent re-use and rainwater harvesting (DWS, 2014). Reference to alternative water at the municipal level is made in the CoCT's WSDP that lists alternative water in its WCDM measures (Department of Water and Sanitation, 2009).

2.6.2 ALTERNATIVE WATER STORAGE

References to the storage of alternative water are largely disaggregated across water types and not collectively as 'alternative water'. This is illustrated in the NWA that allows for the storage and use of roof run-off (Water Affairs, 1998) and the treatment (but not storage) of stormwater (Water Affairs, 1998). In comparison, the CocT Stormwater Management By-Law, consistent with the Red Book (2003) does not enable stormwater harvesting or re-use, but does not specifically prohibit it. The CoCT's Management of Urban Stormwater Impacts Policy (1), in contrast, supports rainwater harvesting and temporary stormwater storage and re-use (Roads and Stormwater Department, 2009).

Similarly, the WSA includes storage within its definition of infrastructure under "water services work". It however does not clarify if the storage is for municipal water, rainwater, greywater or stormwater, or importantly, what the water can be used for. . The CoCT's Water Bylaw also refers to storage (tanks), and it is assumed that the intention is for back-up supply. This (assumedly municipal) water is typically required in the event of supply disruptions or other emergencies, but not as a part of a multi-sourced domestic supply system.

Of all the legislation and policy, the NWRS(2) offers the clearest direction. It is the only document that promotes rainwater harvesting in rural and urban areas and allows it to be used for domestic use, albeit in rural areas. Whilst the programme focus is on rural areas, the intention was to extend the programme to households and office buildings in affluent urban neighbourhoods thereafter (Water and Sanitation, 2013). At this time, it is not clear if this has been realised, or if the same uses would be permitted.

SANS10252-Drainage Installations for Buildings makes provision for the disposal of wastewater (SABS, 1993), but does not provide for the separate collection, storage or re-use of greywater. Greywater is not defined as something separate to wastewater/water source and is therefore considered to be part of the definition of sewage (Rodda, Carden, & Armitage, 2010). As such, the Building Regulations in terms of SANS10252 do not make provision for the storage and use of greywater on a property.

2.6.3 ALTERNATIVE WATER USE

Government's definition of permissible alternative water uses is critical to an incremental approach. The lack of this definition limits the implementation of a hybrid water supply system that includes alternative water. The disaggregation of water sources into types based upon quality is therefore important because it informs

how they can be used. This direction must be clear throughout the legislation and policy and must commence firstly with the requirement for alternative water, and secondly clear parameters for quality and use. The management of greywater is used to illustrate why the absence of definitions and recommended uses are an issue.

The lack of water source descriptions in the NWA and WSA impacts on the legality of, for example the CoCT Water By-law's (2010) which allows greywater to be used for toilet flushing and irrigation. The legislation does not differentiate greywater from sewage and combines them both as wastewater, which questions the legality of the CoCT's Water By-law (and others). Rodda, Carden, & Armitage (2010) recommend that this be clarified in terms of the NWA, particularly in light of the potential risks associated with greywater. Notwithstanding the former, whilst the use of greywater for small-scale irrigation is not specifically mentioned in the NWA, it is believed to be consistent with the intentions of the law (Rodda, Carden, & Armitage, 2010).

In comparison, the SANS 10252-1 Water Supply Installations for Buildings does make allowance for alternative water use, but does not define the uses, nor specify storage quantities or recommend uses (SABS, 2016). The system that it illustrates is a single system, unlike the CoCT's Alternative Water Installation Guideline (CoCT, 2017) that shows a variety of water supply options. However, because the guideline is not legally binding, it is not legally enforceable, unlike SANS 10252-1.

Table 3: The Compatibility of Various Water Sources with End Uses (Source: Couslon, 2014)

Source	Garden	Toilet	Kitchen		Laundry		Bathroom	
			Hot	Cold	Hot	Cold	Hot	Cold
Potable water	3	3	2	1	2	1	2	1
Treated blackwater	1	1	4	4	4	4	4	4
Greywater	2	2	4	4	4	4	4	4
Roof stormwater	2	2	1	2	1	1	1	2
Non-roof stormwater	2	2	4	4	4	4	4	4

1: Preferred use; 2: Compatible use; 3: Non-preferred use; 4: Not compatible.

Whilst the intentions of the Alternative Water Installation Guidelines and SANS 10252-1 are clear, there are other ambiguities. These emanate primarily from the WSA definition for water supply services which only refers to the abstraction and treatment of water to achieve potable water standards and does not discuss alternative sources or possible uses. This embeds the use of potable water and presents a challenge to the uptake of alternative water use. The lack of distinction between water quality and possible uses, referred to as fit-for-purpose (Table 3) (Coulson, 2014) results in a system that uses potable water for all uses.

Although the NWRS(2) and Water By-law refer to rainwater harvesting and storage tanks respectively, neither deal with WSA limitations as previously discussed. These state that "no person may use water services from a source other than a water services provider nominated by the water services authority having jurisdiction in the area in question, without approval of that water services authority" (Water Affairs, 1997). The vagaries in the water governance around the specification of alternative water source use and storage may be rooted in the water quality complexities, which are discussed in more detail in Section 3.5. Despite the NWRS(2) and the WSA - Cape Town continues to be reliant on potable water generated from surface water - for all uses.

It is unlikely that the legislation and policy had contemplated the crises that have swept across South Africa. As such, it is not surprising that alternative water and a decentralised system are not reflected. Consequently, it is also therefore not surprising that rainwater, stormwater and greywater harvesting are not consistently included and their quantities and permissible uses specified. This analysis has highlighted some of the issues that will need to change to enable integrated management and the potential implementation of an incremental approach.

2.7 PLANNING

National and local government are both responsible for water planning, but at different scales and at different parts of the value chain. The NWA governs water resources planning via the Water Reconciliation Strategy, the NWRS(2) and Catchment Management Strategy & Water Allocation Plan prepared by DWS. The WSA provides the same mandate for water services via the Water Services Development Plan prepared by the municipality. The municipality as per the Constitution is also responsible for stormwater planning which is currently undertaken separately from water service planning (RSA, 1996).

These plans and strategies form part of larger, municipality-wide initiatives that commence with the Integrated Development Plan (IDP) at the strategic level. The Metropolitan Spatial Development Framework (MSDF) forms part of the IDP at the spatial level. The financial planning is fleshed out in the Built Environment Performance Plan (BEPP) and the Medium Term Infrastructure Investment Framework (MTIFF) The Integrated Water Resource Management plan for the two catchments wherein the CoCT is located have not been reviewed in detail as they are not considered material to the proposal, beyond what has already been discussed. I have rather focussed on the municipal mandated planning tools for stormwater management, which is not included in Section 2.5 Urban Water Cycle.

The IDP is a planning tool required by the Municipal Systems Act (MSA) no 32 of 2000 and records the CoCT's five year agenda. The BEPP is an annual compliance tool that forms part of the suite of IDP documents that is also required by the National Treasury. It records projects and anticipated budget spending and to account for how expenditure has been made to and motivate for new budgets. This work is transversal within the CoCT and between other spheres of government and seeks to co-ordinate not only budgets, but also provides a level of spatial co-ordination.

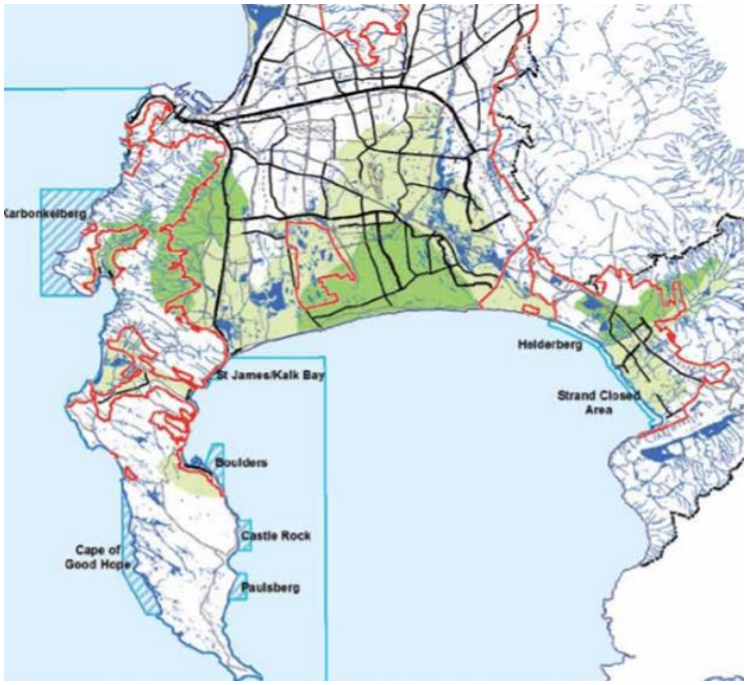

Figure 13: Extract from Aquatic Framework (Source: CoCT CTSDF, 2012)

The MSDF is important because it is the principal strategic planning tool that guides and informs long term planning and development in the municipality. It is an

example of the planning approach promoted in the Red Book whereby infrastructure planning follows spatial planning. I argue that it is problematic that infrastructure planning is viewed as subservient rather than as part of an iterative process between the various components. This argument is however moot, because the planning narrative has changed. The current driving narrative adopted in the recently re-drafted MSDF is transport-oriented development (TOD). This approach focuses on transport planning aimed at densification by capitalising on transport infrastructure and public transport that does not specifically include WSUD.

The MSDF includes development policies that support the spatial development plan (SDP). Policy 26 is pertinent to this discussion as it relates to stormwater management and seeks to mitigate the effect of urban development on all water systems (CoCT, 2012). It makes further reference to the sustainable use of water resources within the urban water cycle. This sustainable use is unpacked into water efficiency, recycling and re-use and the holistic and integrated planning of water (Department of Water and Sanitation, 2009). I have analysed the MSDF through these lenses and have concluded firstly that these policies are not spatialized across the metro; and secondly, that there is disconnect between policy and implementation. These conclusions were reached for the following reasons.

This has resulted because the water cycle has not been a foundational informant to the CoCT's MSDF. Areas for infiltration and recharge necessary for the functioning of the water cycle, are not spatially allocated, nor are areas for stormwater harvesting and treatment (Figure 13). These interventions are most effective at a catchment and district scale, but are difficult to retrofit because 80% of the city's footprint has been allocated (Official, 2017). I argue that the water cycle is a set of spatial relationships that should therefore be apparent within the MSDF. Spatializing these relationships (and policy intentions) within an urban context is therefore critical to support its functioning and this cannot be implemented in the absence of a spatial plan. Two successful examples of WSUD are Atlantis and Singapore.

Atlantis, an industrial area located 53km north of Cape Town, achieved integration and functionality through close collaboration between numerous departments, which is unfortunately not the CoCT's standard *modus operandii*. Spatial planning played a central role in the success of the project. Using design, it was possible to separate stormwater from the residential and industrial areas. This enabled the separate treatment of domestic and industrial wastewater allowing for the filtering and safe artificial recharge of the various water quality portions at different spatially defined points in the aquifer (Bugan, 2016). This aquifer water plays an important role in the CoCT's current augmentation plans.

In contrast, Singapore, a small, highly developed country with restricted potential for self-supply, is a world leader in integrated water management. It meets its water demand through a diverse mix that includes stormwater harvested from local catchments water, imported from Malaysia, desalination and wastewater recycled to a potable quality (Coulson, 2014). In 2061 the water agreement with Malaysia will end incentivising Singapore towards water independence. Key to achieving this objective is land use planning that allocates approximately half of the total land area for stormwater harvesting (Figure 14). Supporting infrastructure integrated into the urban fabric directs rainwater into the stormwater system via a network of drains, channels, rivers and stormwater collection ponds and from there into storage reservoirs. Through integrated spatial and infrastructure planning and by managing and planning landuse, Singapore has made substantial gains towards water security (Figure 14).

Atlantis is a district-scaled example contrasting with Singapore which is a city. The comparison of the two illustrates the applicability of WSUD at multiple scales. The Red Book and the Management of Urban Stormwater Impacts Policy (1) state that development of a certain size must manage stormwater on site. This requirement has spatial implications that are difficult to retrofit. I argue that stormwater design is a fundamental organising and structural principle that must be a leading structuring element rather than a subordinate one, if it is to be successful. The CoCT's development approvals process addresses specific issues such as flood control. It does not include an integration oversight to co-ordinate all the parts of the urban water cycle including stormwater harvesting, flood control, water supply and other issues.

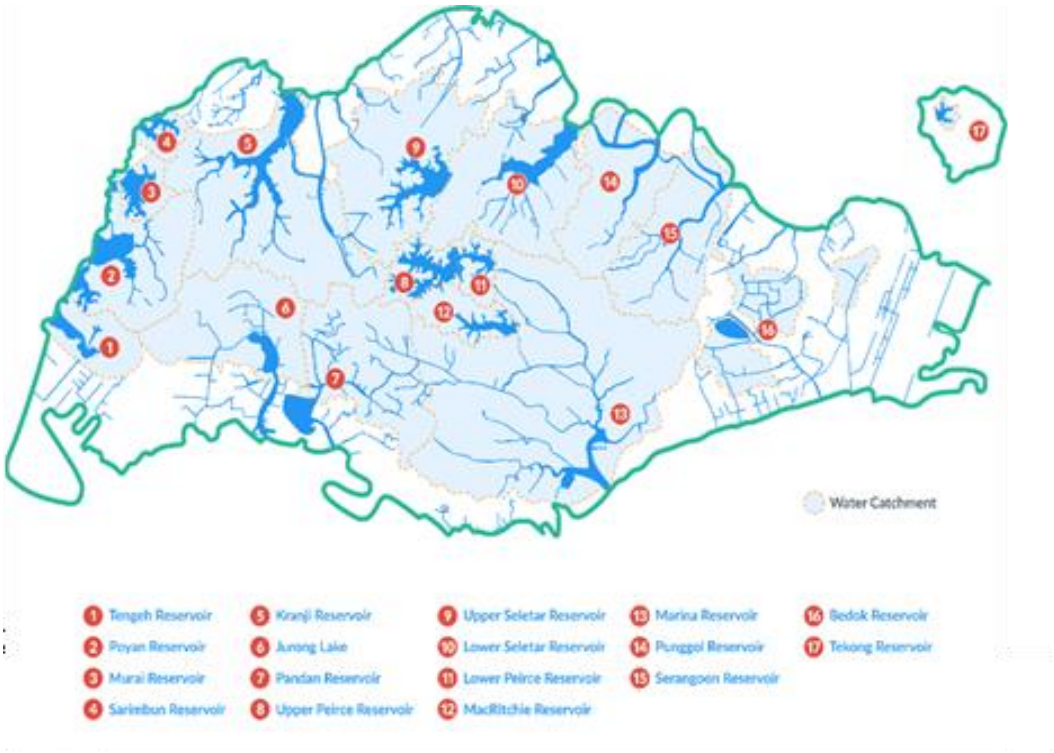

Figure 14: Catchment Plan, Singapore (Source PUB, Singapore's National Water Agency

Integrated planning must include the natural and urban water cycles and incorporate them with spatial informants into hard and soft open space because of the multiple functions and benefits they are able to deliver if planned in this way. Integrated planning has multiple functions and benefits. These include recreational space that improves social cohesion and health, provides eco-services such as improved air quality and reduced temperatures and offers cost efficiencies through onsite flood mitigation that also acts as stormwater harvesting and on-site irrigation (Figure 15).

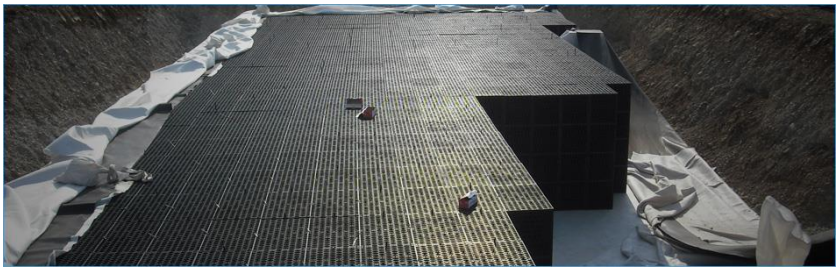

Figure 15: Subsurface stormwater harvesting cells (Source: Rainsmart solutions, Australia)

The Netherlands is a global leader in projects that achieve this, as illustrated in the Water Plaza (Rotterdam) (Figure 16).

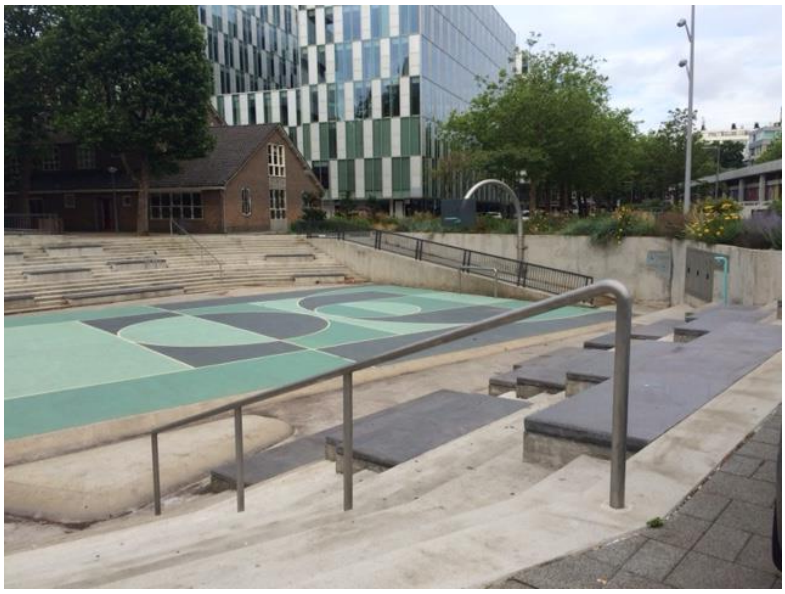

Figure 16: Water Plaza illustrating stormwater detention area, Rotterdam Netherlands (Source: author)

All spatial plans rely on funding for implementation. Understanding the financial planning processes is consequently part of understanding the full infrastructure context which commences with the Medium Term Infrastructure Financial Framework (MTIFF), followed by the BEPP and the IDP.

The MTIFF responds to anticipated growth across the CoCT and plans the future infrastructure demands and according to various TOD growth scenarios. Financial planning is inextricably linked to spatial planning because between the two, they set the spatial and budgeting agendas that inform implementation. Analysis of the financial planning indicates clearly what approach is favoured – conventional or alternative[8]. Whilst the MTIFF met its brief, it did acknowledge that the results are not consistent with planning for a resilient city (Smit, 2017). Whereas previous observations were that the hierarchical governance is problematic, in relation to infrastructure funding, it is less so. The IDP, BEPP and MTIFF are National Government competencies and Treasury budgeting and compliance requirements and budget applications are approved because they meet the necessary criteria, as outlined by the relevant national policy. Cities align their policy and budget priorities to these criteria to receive budgets. If the legislation and policy were truly integrated into all aspects of planning, it would be expected that it would reflect in the financial planning, but it is not. As such, if structured appropriately, these financial mechanisms would offer possible levers to change from the conventional to a decentralised, hybrid system that includes alternative water - using government budget processes.

Like the separation between water resources and water services legislation, planning and budgeting, there is a disconnection between water management's strategic[9] intentions and their spatial[10] application. This combined with the approach to water planning, has made Cape Town's water supply vulnerable. A Catchment Management Strategy (CMS) & Water Allocation Plan are mechanisms used by a Catchment Management Agency (CMA) responsible for the protection, conservation, development and management of water resources at the water management area level. They use Integrated Water Resource Management

[8] Alternative refers to decentralised, district/catchment-scaled infrastructure based upon an urban metabolism.
[9] A strategy is the mechanism for change and as such outlines the steps necessary to effect it.
[10] The spatial application would be the identification of strategic interventions within a spatial plan at a scale that puts definitive boundaries to the strategy and intervention.

(IWRM) discussed in Section 2.4 which promotes cost-effective and sustainable solutions to address water issues through the co-ordinated development and management of water, land and related resources without compromising ecosystem sustainability (Water Partnership, 2000).

WCDM, as per the Guidelines for Catchment Management Strategies (Department of Water Affairs and Forestry, 2006) and IUWM, is aimed at using scarce resources efficiently, maximising existing infrastructure and augmenting supply to meet the City's growing needs. It is implemented by interventions, including water efficient devices and alternative water sources.

The benefits of improving the water supply options is that it creates greater resilience. This resilience is however contradicted by the proposed large-scaled, conventional infrastructure which is not considered to be an appropriate climate change response (ICLEI, 2017) and is inconsistent with the MTIFF's recommendation that the potential of an incremental approach and the role of environmental services be investigated (Smit, 2017). As such, the definition of alternative water must be applicable at the bulk and household scale and include stormwater harvesting and greywater reuse. This is consistent with DWS's integrated water approach that entails a sustainable and holistic value chain of water supply from source to tap and from tap back to source (Department of Water and Sanitation, 2017).

2.8 GUIDELINES

The conclusions of the planning critique are not dissimilar to what has been found in the guidelines. This section discusses The Guidelines for Human Settlement Planning and Design – the Red Book (2000), The Green Star Communities Tool (the Tool) (2013), South African National Standards, National Norms and Standards for the Construction of Stand Alone Residential Dwellings (1999, revised in 2007) the (draft) National Norms and Standards for Domestic Water and Sanitation (2017) (the Norms), and the National Water Quality Guidelines (1996).

2.8.1 GUIDELINES OVERVIEW

The discussion commences with a general guidelines overview followed by detail around how they individually approach the incremental, decentralised alternative water sources and the contradictions and commonalities between them. In this section, alternative water is defined as rain- and stormwater harvesting, greywater reuse and groundwater (wells and boreholes).

The Red Book and the Tool similarly seek to present an integrated approach to development and as such, incorporate a wide range of professional inputs, whereas the other guidelines are specific to water. The Water Star Rating Tool is an example of this. It was recently developed by the CoCT and is aimed to encourage better on-site water management in industry. This is achieved by the voluntary monitoring of legal compliance, promoting water conservation and improving water usage and water discharge. It aims to reduce operating costs and the consumption of raw material, limit pollution and the impact to the environment whilst improving efficiency, compliance with legislation, by-laws and company image. The CoCT is using this tool to promote best practices in terms of water management, integrated water management

across a range of industries. It consolidates information into one document system, encourages companies to implement water related interventions and creates awareness.

The Red Book quantifies the demand by identifying land-use categories including, for example, government and municipal. The guideline uses historical consumption as a baseline that is measured using an annual average of water demand for a 100m² gross floor area. For this land-use 400 ℓ/day (CSIR, 2000) is recommended. The guideline assumes that the supplied water is potable and that it will meet all water needs, including irrigation, manufacturing and sanitation. Potable water storage is specified so to meet balancing requirements, for emergencies (e.g. firefighting) or planned shutdowns (CSIR, 2000) and roof tanks "should be" specified for water scarce areas (CSIR, 2000) as an important part of the infrastructure. Beyond these references, alternative water is not included as a fundamental part of water supply. Water supply can however be sourced from one or a combination of source (CSIR, 2000). The supplied list offers a range of sources that could be at a variety of scales, including springs; wells and boreholes; rainwater; surface water – rivers and dams and bulk-supply pipelines (CSIR, 2000). Research by Jacobs et al. (2011) observed that only 47% of suburbs' water demands fell inside the design envelope proposed by the South African design guidelines, the Red Book indicating a disconnection between the guideline and reality.

Whilst there are various Green Star Tools, I will discuss the Green Star Communities Tool because it deals with larger-scaled development issues. The Green Building Council of South Africa (GBCSA), an independent international organisation, promotes sustainability by using an evaluation system called the "Green Star". It has been widely adopted globally and is used by built environment professionals across South Africa. The tools establish sustainable buildings and communities' benchmarks and promote integrated design and lifecycle costing to raise awareness around building and community sustainability (Council Australia, 2012). The tools measure a project's sustainability by awarding points allocated per category and credit, which add up to stars and a rating.

The Red Book also aims to integrate the water cycle into design, but is less successful than the GBCSA Communities Tool. The Red Book's over-arching principles include the need to work harmoniously with the natural landscape and to recycle wastes such as using stormwater for irrigation purposes and treated sewage as fertilizer (CSIR, 2000). The Norms also indicate the need to conserve water and to re–use, where affordable and sustainable to reduce the overall demand for fresh water. The Tool speaks specifically to alternative water sources and leak detection in the potable water consumption credit criteria (Green Building Council Australia, 2012).

The Norms radically depart from the South African *status quo* by advocating that water service authorities, such as the CoCT, should augment water supply with alternative water sources and states that they must support self-supply.[11] Guidelines and advisory services for the treatment and purification of alternative water sources for domestic and personal use must be made available by the municipality to households

[11] Self-supply is defined as - people who meet their own need for potable water for domestic and productive use (drinking, cooking, hygiene) wholly or partly through own efforts and investment (The Norms).

intending to self-supply and municipal by-laws revised to allow for self-supply. For this to be implemented, the WSA and the Water Bylaw would need to change.

Whereas there is vagueness around the appropriate use of alternative water across the guidelines, the Tool does provide some specificity. For example, partial points are awarded according to the proportion of the general floor area (of the structure) that uses alternative water to meet all non-potable demand, including for the irrigation of all public open spaces (Green Building Council Australia, 2012) which unlike the other guidelines, does quantify amounts. Other recommended uses for alternative water vary across the guidelines, as discussed further.

The guidelines discussed above refer to some degree to each of the following alternative water sources, greywater, rainwater, groundwater and stormwater, as discussed in the next part of this section.

2.8.2 GREYWATER HARVESTING

Greywater typically refers to the reuse of water drained from baths, showers and washing machines. Some definitions, such as the Red Book's (2000) include water from kitchen sinks, but all exclude toilet wastes. In comparison, the use of kitchen greywater is cautioned against because it carries the highest loads of microorganisms, COD[12], oil and grease, and suspended solids (Rodda, Carden, & Armitage, 2010) which have higher health risks. There is consensus across the guidelines that greywater can be used for irrigation, with various limitations and directions for use.

The Norms include additional uses such as flushing toilets or washing yards, cars, pavements and driveways. Whereas toilet flushing is allowed in the CoCT Water Bylaw, the other listed uses should be reconsidered because best practice indicates that greywater reuse should be within a property eliminating other uses that may result in draining into the stormwater system beyond the property (Rodda, Carden, & Armitage, 2010). Unlike other guidelines, the Norms specifically refer to the inclusion of greywater when designing any new water installation and stipulate that water service authorities, such as the CoCT, must amend their laws and create awareness and demand for greywater re-use (Department of Water and Sanitation, 2017). This last point is controversial within the water sector where there are divergent views and is part of my proposal.

2.8.3 RAINWATER HARVESTING

Rainwater harvesting is like stormwater harvesting, except that it collects rain from roofs into storage tanks, whereas stormwater harvesting collects surface water from hardened surfaces such as roadways and paved areas. The Red Book, the Norms and the GBCSA all promote rainwater harvesting. The Red Book and the GBCSA make recommendations with the former only recommending irrigation and the latter suggesting not

[12] COD – chemical oxygen demand

only irrigation, but indoor use too. The Norms do specify the use of alternative water, but as previously discussed, it is assumed that self-supply would include using it for domestic uses.

2.8.4 GROUNDWATER

Groundwater is mentioned in the Norms as a possible alternative water source while the Red Book (2000) and the GBCSA only specifically refer to boreholes. The Tool however, sensibly, excludes fresh water[13] sources from their definition of alternative water, thereby eliminating groundwater. This distinction is important for Cape Town where groundwater plays such a critical role towards diversifying water sources and creating water security. Its use should be encouraged only after all other options such as rainwater harvesting and greywater reuse have been exhausted.

The Tool is also more progressive with regards stormwater harvesting and use than the Red Book (2000). The award of a point requires evidence demonstrating the percentage of stormwater runoff that is captured and state the water balance[14] of the site and total storage capacity of any systems that use stormwater. Reference to the water balance indicates an integrated, holistic approach, unlike the others. The Red Book guideline for stormwater offers inconsistent direction. For example, in some sections, it is recommended that stormwater be stored, but only temporarily before it is released in a river or the municipal stormwater system, whereas other sections suggest that it is stored and used for irrigation. If the user is not familiar with the document and uses it selectively, it may be assumed that stormwater must be stored only as a step towards discharge. In comparison, the Norms suggest that rainwater harvesting opportunities should be optimised through building and landscape design (Department of Water and Sanitation, 2017) indicating a very different attitude to stormwater management.

The contradictions within the guidelines analysed thus far are absent in the clearer National Water Quality Guidelines (1996).

2.8.5 NATIONAL WATER QUALITY GUIDELINES

The NWQG (DWAF, 1996) are the guidelines used to determine the appropriate quality for water uses. Water quality refers to the presence of living organisms or substances suspended or dissolved in water (CSIR,, 2000) which determines its appropriateness for particular uses. Whilst the NWQG provides the guideline for drinking or potable water, the SABS[15] has prepared SANS[16] 241. In terms of this standard, water

[13] Fresh water is naturally occurring water found on the Earth's surface and includes lakes, streams, aquifers, underground streams, springs, glaciers, wetlands and ponds.

[14] Water balance is a term used in hydrology and refer to the water resource availability in a particular area. Water is in constant motion in nature. The water balance is therefore a way to measure the inflows (and storage), and outflows to determine the balance so as to understand how best to manage the water resource.

[15] SABS – South African Bureau of Standards

used for domestic purposes[17] must be drinking quality, potable water that is treated and supplied by the municipality, which limits the applicability of alternative water to non-domestic[18] purposes such as toilet flushing and irrigation.

But what is domestic use? The WSA defines it as water that can support life and personal hygiene (DWAF, 1997). The NWQG defines domestic use as water suitable for drinking, cooking, bathing, washing of clothes and gardening. The CoCT Water Bylaw overlaps with this definition, but excludes washing of clothes and gardening whilst the Red Book refers to domestic use, but does not include a definition (CSIR, Vol. 2, 2000). The question therefore remains – what is domestic use?

At the outset of this research, because of my professional experiences, I had assumed that the legislation and the Red Book prevent the use of alternative water. However, it is now apparent that the issues are more complex and nuanced and include, amongst others water quality, inconsistencies between guidelines and the legislation and policy and within the guidelines themselves. Recent experience on the team preparing the CoCT's Alternative Water Installation Guidelines (CoCT, 2017) highlighted several issues with the NWQG. For example, all water, except for water intended for toilet flushing, regardless of its source requires testing and treatment according to the intended use (Annexure A). Swimming pool water, for example must be potable quality (SANS 241) which would require the testing and treatment of rainwater prior to use in a swimming pool (DOH, 2003). This prevents swimming pool top-up with untreated rainwater. The same testing and treatment requirements apply to the domestic use of rainwater. These requirements and the supporting governance limit the applicability of alternative water and contradict all others because notwithstanding the water source, the intended use would determine the water quality and trigger a particular guideline.

Research of urban rainwater tanks in Australia report interesting conclusions around the impacts of rainwater quality on health. It concluded that even though gastroenteritis is a significant cause of morbidity among young children, there was no reason to believe that those who drank tank rainwater regularly were at greater risk of contracting gastroenteritis than those who drank treated municipal water (Heyworth, Glonek, Maynard, Baghurst, & Finlay-Jones, 2006). Furthermore, there are only a small number of disease outbreaks and individual cases of illness attributable to rainwater (Sinclair, Leder, & Chapman, 2005).

Notwithstanding the above, the quality of water from rainwater tanks is more variable in both microbial and chemical quality than conventional tap water supplies. It would therefore be expected that higher risk situations would occur more frequently with rainwater supplies (Sinclair, Leder, & Chapman, 2005). These risks are related to the use of untreated rainwater for domestic purposes and would be greatly reduced for external, or low-exposure applications such as toilet flushing.

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[16] SANS – South African National Standard

[17] Domestic purposes includes drinking, body washing, cooking and cleaning indoor surfaces (DOH, 2017).

[18] Non-domestic purposes includes toilet flushing, outdoor uses including washing down paving, vehicle washing and irrigation.

One of the many advantages to an incremental approach, is that the risks are localised provided that the necessary safety valves are installed as per the CoCT (City of Cape Town, 2017)As such, because rainwater would not typically serve a large community, the outbreak would therefore affect a limited number of people, if the necessary precautions have been implemented. These precautions would include the installation of a reduced pressure zone (RPZ) backflow preventer to isolate the alternative water, such as rainwater supply, from the municipal supply and prevent possible contamination (City of Cape Town, 2017). This is important as water demand measures including pressure reduction is likely to be part of the CoCT's future water management.

The use of alternative water for domestic purposes would require regular testing and treatment to ensure that it is safe for use (DWA, 1996). The tests, which must be undertaken regularly to determine and maintain this standard, can cost anywhere between R500 and R6000 each, which for most South Africans is unaffordable. The range of water sources and possible qualities makes it impossible to implement a universal, simple and reliable water treatment process suitable for small community water supplies (Jacobs, 2011), highlighting the difficulties in implementing appropriate safety precautions to meet the NWQG and Scientific Services requirements. This means that the full implementation of an incremental approach that includes alternative water for domestic use, will have limited success, or – which is a more probable outcome, testing will not be undertaken increasing the potential risks. Neither outcome is satisfactory.

Collectively the Red Book (2000) and the Norms guidelines for water storage and use are vague and contradictory and do not specify the use of alternative water or the quantities required. An integrated and holistic approach would require this information as it would inform the water balance. Complementing this information would be the fit-for-purpose disaggregation of water types and uses that would identify either potable or non-potable water within the water balance, as per the Tool.

If the Norms draft is adopted, it will impact on all other guidelines that predate it, necessitating a complete overhaul, not only of the guidelines, but of the legislation and policy too. This will include impacts to the NBR and the NWQG.

2.9 FINANCIAL

The benefits of this are not limited to conserving water supply by reducing the consumption of municipal water, but in the likelihood of tariffs increasing, in making a smaller demand on municipal supply, it will potentially limit the financial impact of the tariff increases. The recently prepared *Urban Resilience – Cape Town (2017)* paper formed part of the CoCT's MTIFF work offers a different conclusion. It states that in the medium term the cost benefits of alternative technology do not substantiate the increased cost of capital investment but that longer term investment started to make more financial sense (Smit, 2017).

As the cost of water is likely to increase with the introduction of desalinated water and the like, the earlier assumptions around cost may well change as must the CoCT's regulations to enable a shift towards the greater use of rain and stormwater. This shift is accompanied by complexity within the tariff system which uses a percentage of water usage as the basis for the sewage tariff. Reduced water usage and or users electing to self-supply, will impact on both services. Usage reductions by large water users also impacts on CoCT revenue which is stepped upwards according to the quantity of water used. The reduction in water use

by large water users will shrink revenue and as a consequence limit the budget available to provide basic services to poor families.

The reductions in subsidies and increase in price that reduces the affordability of municipal water will impact on all Capetonians. Preventing the use of other water sources as per the WSA and the Water Bylaw, could result in death, which would be to deny the right to life.

The mandates are mutually exclusive in a situation where there are such incredible levels of uncertainty. However, if a municipality's water resources are compromised and it is aware that there is possible harm caused to human safety and it does not act, it may well be held accountable to the courts (Mosdell, 2011). T Consequently, if government elects knowingly to continue under the current water governance, it may well make the vulnerable even more so and be held accountable to the courts.

The current drought has at this time impacted on water revenue by an estimated R1.7 billion (Greyling, 2017). This loss is substantial and when combined with users becoming self-supplying, becomes more so. Coombes *et al*. (2002) assert that government limits users to water it supplies in order to generate an income to recoup infrastructure costs, a system established in the Industrial Revolution when water and sanitation infrastructure was first implemented. An incremental approach would compound the negative impacts on an already compromised fiscus. Or, it could be a means towards creating a sustainable and resilient water system, because water can no longer be the exclusive purview of government, who do not control rainfall.

An incremental approach will need to establish financial modelling that assumes a higher water tariff, worst case scenario, life-cycle costs; the resilience benefits of building redundancy into systems at all scales; and different funding models to make a sensible argument to the development sector.

This section summarises Part One and makes recommendations for the proposal.

1) Inconsistent terminology and allowable uses combined with onerous water quality requirements throughout water governance makes the implementation of a hybrid system difficult, as does the limitation with regards to self-supply. Alternative water is alluded to in the WSA, but there is not sufficient detail, nor definition to guide the implementation, other than in the NWRS(2), which has not been fully implemented at the CoCT;

2) All water uses are currently designed to be for potable water with alternative water such as greywater and rainwater suggested for irrigation or toilet flushing. The complete reliance on a single source results in wastage and inefficiencies;

3) Multiple water sources are not designed into development infrastructure;

4) Rainwater can be stored and used for all domestic uses in rural areas, but treatment is not contemplated. Its use is limited to irrigation and toilet flushing in urban areas. It is unlikely that rainwater would meet most irrigation demands, but it may well meet non-domestic uses including laundry;

5) Stormwater harvesting is not seen as a potential water source and its use is limited to irrigation. It is furthermore not planned spatially into the CoCT's layout;

6) There are no regulations regarding the need for rain- or stormwater harvesting nor regarding the quantity that should or could be stored. The imperative to harvest and store is lacking throughout;

7) There is no legislation for greywater which could create legal issues;

8) Groundwater legislation is inappropriate, use is accommodated but with limitations that are not appropriate to the scale. The mandate overlaps between spheres of government and impedes the implementation of integrated water management which is critical to sustainable and efficient water planning and management. Mapping and monitoring systems to be implemented;

9) Water quality issues are an important blockage to self-supply and the increase of water sources necessary for the implementation of an incremental approach and a hybrid system; and

10) Self-supply/off-grid is recommended in the Norms, but is otherwise unsupported by water governance.

This summary illustrates the inadequacies within the water governance as discussed in Part One and motivates for a change towards an incremental approach and hybrid system. This approach will be implemented by changing the water governance to require the storage and use of alternative water at a domestic scale and the greater re-cycling of wastewater and harvesting and treatment of stormwater at a larger scale district and precinct.These requirements must be embedded in water governance commencing with the NWA right down to the professionals' guidelines such as the Red Book (2000) and mainstreamed into the NBR as core parts of water supply.

Part 2 – Proposal takes these issues forward within a proposal aimed to address the water governance inadequacies via an incremental approach.

PART TWO – PROPOSAL

3 AN INCREMENTAL APPROACH

Part One – Status Quo described the water governance context and through critical analysis, identified issues that explain Cape Town's vulnerabilities to the unpredictability of climate change. It built on this explanation, and illustrated how the existing, conventional approach and water governance is not responsive to the challenges.

Caused by a variety of issues, Cape Town's vulnerability is most influenced by the conventional system that is linear and relies exclusively upon bulk-stored surface water and centralised water governance. This is combined with a bulk approach to water that treats all water types and sources in general terms and ignores the complexity. These globally experienced phenomena are stimulating wide debate (Segrave *et al*., 2006) (Pahl-Wostl *et al*., 2010) and includes possible alternative systems. My research has found several possibilities that I believe are appropriate responses to Cape Town's challenges of limited storage capacity and limited supply. When combined, these create an incremental, decentralised approach promotes multifunctional infrastructure that together construct an urban/circular metabolism, managed using Anticipatory Governance and the capability approach. My proposal draws on these alternative systems and composes an incremental approach that creates a resilient, hybrid system (the approach) able to respond to the vulnerability and unpredictability of climate change. It achieves this by limiting the demand on bulk supply and by augmenting the bulk storage capacity using incremental interventions and optimising the water within the water system using a fit-for-purpose, circular metabolism.

Whilst it is not proposed to eliminate the conventional system, changing the approach to water management is also not proposed. The shortcomings of IWRM, which according to the International Water Resource Association's President is incorrectly interpreted and implemented (Mosdell, 2011) are illustrated in Part One (refer Section 2.4). I argue that if IWRM were correctly implemented, a different system would result. This system would consider each drop carefully, not only with regards to its use, but also, with how it is replenished within the water cycle. The success of this system requires support for the functioning of the natural and urban water cycle.

Part Two discusses the proposal further and is structured into sections that connect the proposed incremental approach to previous sections in Part One to highlight issues and compare and contrast them to best practice whilst also identifying the points that will unlock implementation.

3.1 WATER SYSTEM STRUCTURE AND INSTITUTIONS

Part One identifies the system structure as a seminal cause of water insecurity and moving towards the proposed decentralised system, both infrastructurally and institutionally will therefore require adapting the system. This section discusses the structural and institutional changes in detail, before identifying those necessary in the water governance.

3.1.1 DECENTRALISED, HYBRID WATER SYSTEM STRUCTURE

The proposed system is structured using urban and circular metabolism thinking, combined with WSUD. It assumes that water is a scarce and valuable resource and that the infrastructural system must reduce water demand through WCDM whilst optimising all water (including water resources and wastewater).

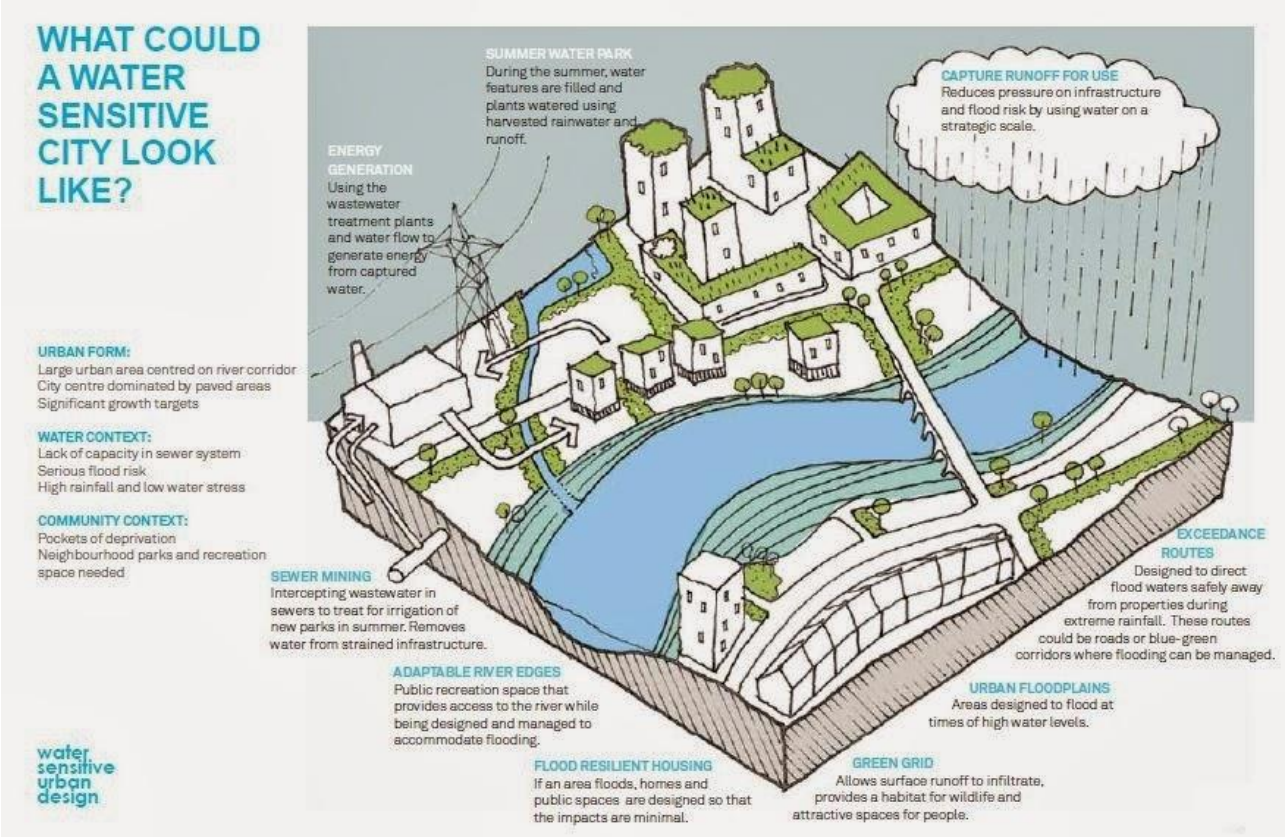

Figure 17: Urban Water System Structure (Source: http://cuspurbanict.blogspot.com)

It is a decentralised structure with a circular configuration rather than linear arrangement (Figure 17). Outputs are used as inputs for other uses to create a multi-source system that is not limited to potable water, but is rather fit-for-purpose to optimise use and reduce wastage. As such, assuming that all water types (including "wastewater") have value and can be used for particular purposes, results in the disaggregation of water types according to quality, whether it is greywater from homes, or stormwater in neighbourhoods which changes the infrastructural system.

However, the inconsistent terminology throughout the water governance documentation makes disaggregating water types and identifying uses difficult. Creating a clear lexicon is therefore a necessary first step to establish consensus and it starts with the definitions for water, domestic purposes, potable water, greywater, alternative water, self-supply, storage tanks and the like. Because water is the common thread throughout all aspects of life, the precepts for its use must be clear and consistent to ensure intra and inter-compatibility. Creating this clarity will establish the necessary framework to manage the complexity associated with multiple water sources.

Disaggregating and decentralising the water system makes the problem "smaller" and opens opportunities unavailable at the bulk scale. If conceptualised in this way, storage becomes smaller, more varied and compact. Like a sponge, the storage is composed of small cells that collectively store a large amount of water, but because the cells are small, they can be secreted within the urban environment in an incremental way. By distributing water storage throughout space, storage becomes less constrained by the need for a large footprint and land availability (Figure 18).

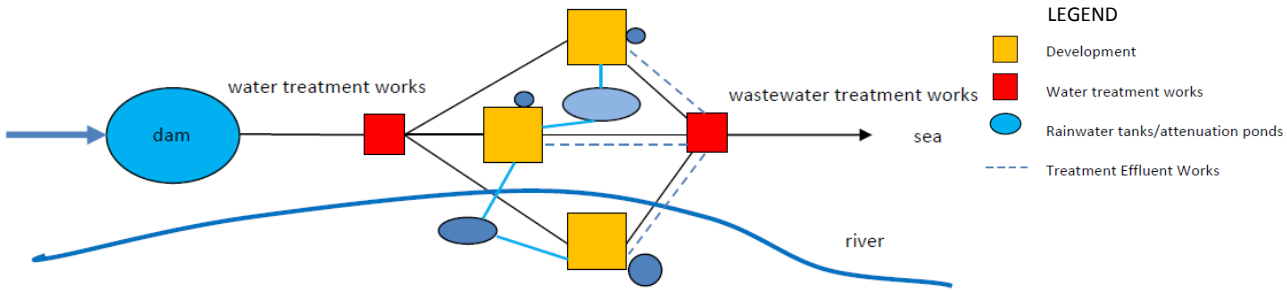

Figure 18: Incremental Approach towards a Hybrid System for Water

As per the concept of the "massive small", it applies the smallest intervention for the greatest impact and requires the existing network to supply hierarchy and order, wherein smaller interventions can occur (Campbell, 2011). Opportunities for multi-scaled interventions that could include, not only large-scaled desalination and aquifer abstraction are created in this way, as are smaller-scaled "cells" which could be the space between sand particles in an aquifer, a rainwater tank, a reservoir integrated into a roof garden or a detention pond. Optimising available space augments the bulk storage and creates options within multi-scaled, circular metabolisms, rather than a single, linear metabolism, as discussed in Section 3.2.

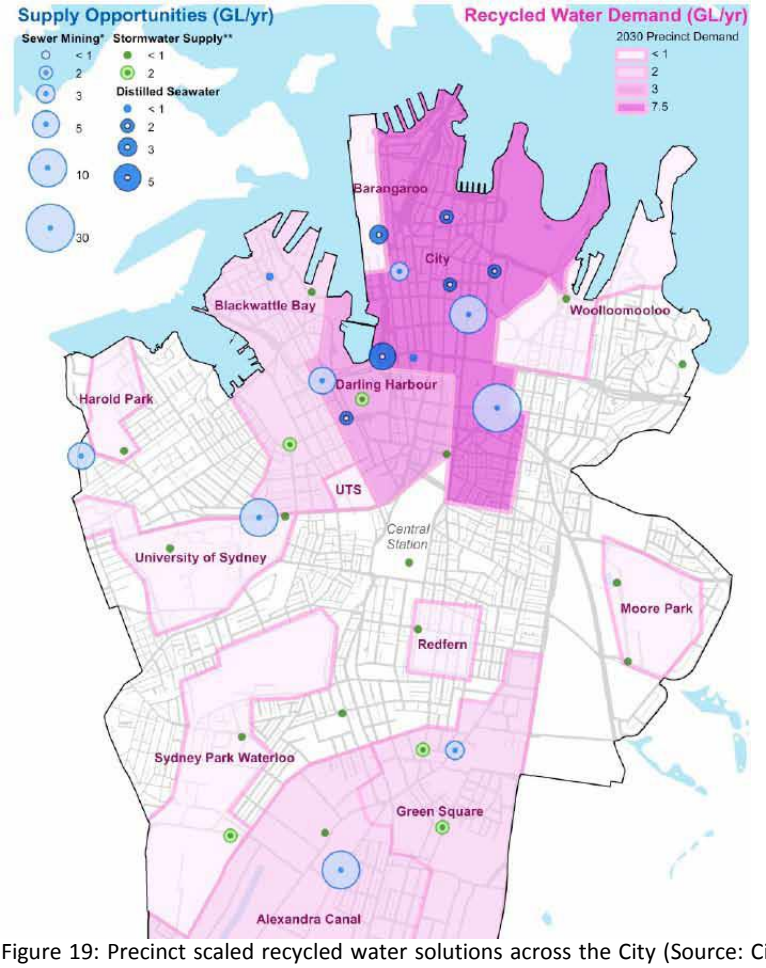

Figure 19: Precinct scaled recycled water solutions across the City (Source: City of Sydney, 2012)

To accommodate an incremental approach, infrastructure would need

firstly to become more varied and operate not only at the bulk, district, neighbourhood and household scale, and secondly, be articulated through separate systems. An example of this complex type of planning is in Sydney, Australia where sub-catchments and receiving water catchments are used as the basis to identify and map the opportunities for water efficiency, stormwater pollution reduction and water recycling (City of Sydney , 2012) (Figure 19).

3.1.2 INSTITUTIONAL STRUCTURE

Current water governance results in a conventional system therefore a change to an incremental approach will necessitate reforms to the legislation, policy and guidelines. The lack of institutional support for decentralised systems is identified by Coulson (2014) and Fisher-Jeffes (2014) as an impediment to implementation. The Norms specifically identify the need for municipalities to reform their regulatory framework to accommodate self-supply and provide training and support for those wishing to pursue this route, indicating an insight into the possible blockages to self-supply.

The nature and implications of these reforms must be understood in anticipation of their implementation because an incremental approach decentralises not only water infrastructure, but institutional arrangements too. Whereas the resultant incremental infrastructure is consistent with the WSA's requirement to provide alternative ways to access water services (DWAF, 1997), it also responds to the institutional challenges. Current mandates allow cities control of their water treatment and distribution infrastructure. Incremental interventions that optimise this infrastructure at the City scale, whilst consistent with the infrastructure system are also preferable because they are unhindered by inter-governmental management complexity. Intervention at this scale makes it easier for the CoCT, communities, households and individuals to augment their supply by making ecologically beneficial choices that multiply impact (ICLEI, 2015) and create the critical mass necessary for change.

These interventions are possible within the existing institutional arrangements. If the CoCT were to become a Water User Association (DWAF, 1998), IWRM across scales and between (all) water resources within its boundary, change would become possible. Becoming a Water User Association is consistent with the NWA's intentions regarding catchment management and the delegation of management functions significantly to enable *everyone* to participate (DWAF, 1998). I propose that the CoCT be thus mandated to enable optimal water resource use, improve management and limit mandate disjuncture.

As much as creating resilience within the CoCT's boundaries is important, the management of catchments by DWS is also critical. Alien invasive plant removal programmes would not only create much-needed employment, but increase the water resource supply. These programmes and land-use and agricultural consumption management, are an important part of the work that Catchment Management Agencies (CMA) must undertake. Even though I understand that CMA's will not be implemented as contemplated in the NWA, the intention that they include roleplayers, such as the related municipalities, must be integrated into whatever institution is implemented, not only to pool resources, but also to ensure co-ordination.

Integrating storage within the CoCT's built fabric will include everyone in water supply, which is consistent with the capability approach. This approach recognises human potential and acknowledges government's

limitations. It champions the capacitation of communities to self-organise as a means towards providing their own services (Sen, 2001).

Similarly, the multifunctional use of water resources approach uses the functioning of the system as the informant to the governance structure. It is achieved by disaggregating water uses as per a fit-for-purpose approach. In this way the recipients of different types of water become active stakeholders increasing and spreading the range of buy-in and responsibility. Wastage, over exploitation and pollution become unlikely when water is used multifunctionally since in these circumstances they threaten numerous interests, if not immediately then certainly in the long term (Deltares, 2013). A prerequisite for this approach is the inclusion of all stakeholders to influence water management policy to make the management more sustainable, which would decentralise management and shift away from South Africans' passive dependence on the State.

Whereas the capacity approach and multifunctionality refer to alternative institutional arrangements, Anticipatory Governance offers an alternative approach to operationalising water governance. Compatible with IWRM, Anticipatory Governance uses a model built on a knowledge-action system. It is a system of institutions, rules, and norms that reduce risk and increase capacity through foresight to enable early response (Segrave *et al*., 2006). This will be achieved by integrating fragmented parts via participatory processes in a way that is adaptive and anticipatory in response to reactive behaviour. It draws on a variety of types of knowledge in decision-making that seek to set organisational goals based on the lessons learnt from past interventions and the signals derived from exploring potential futures. External and internal input is combined to identify incremental changes to interventions.

This system allows for the inclusion of various knowledge types in decision-making processes. The design reflects methods of knowledge generation that use inputs from outside and inside the organisation, including from operational divisions (Segrave *et al*., 2006). The resultant processes are integrative with wide participation. It is sympathetic to an incremental approach because it integrates fragmented pieces, shifts from exclusivity to participatory, is adaptive rather than inflexible and is anticipatory rather than reactive. The created platform offers opportunities for co-ordination to manage mandate interfaces which will be more clearly articulated by the CoCT becoming a Water User Association.

The decentralised infrastructure required by an incremental approach requires appropriately decentralised institutional arrangements. Because of the scale and roles and responsibilities associated with the infrastructure system, citizens must be included. I argue that this infrastructure must be institutionalised using a capability approach, a multifunctional approach for stakeholder buy-in and Anticipatory Governance to facilitate institutional shifts and adaptive and anticipatory decision-making.

These ideas are not inconsistent with the current legislation, but are not necessarily practiced. As with the Integrated Water Resource Management approach, I do not propose to change the legislated framework completely, but to rather enact the core values and more appropriate institutional arrangements that are already provided. The following changes to the water system structures including institutions and infrastructure are recommended:

1. Install water scarcity as a central value and design and manage infrastructure to reflect this.

2. The CoCT become a Water User Association with mandates over all water resources including the urban catchments within its boundary.

3. First steps for the Water Association is to review all current policy, strategies, plans and budget processes. This review will inform the preparation of a new, integrated water policy designed to respond to the complexities of the natural and urban water cycles. It will firstly, manage and co-ordinate all water resources, including those currently considered wastewater, such as stormwater, treated effluent and basement water and secondly, incorporate multiple scaled interventions.

4. Establish CMA's for the catchments from which the CoCT draws its water, as per the NWA. CMA management structures must include the CoCT, other affected parties and specialists (professional and academic) for their input and co-ordination.

5. The CoCT delineate its stormwater management areas to reflect catchment areas, rather than by arbitrary boundaries and prepare decentralised water plans for each catchment.

6. The CoCT establish alternative water capability within its line departments to assist in regulating development to support the public.

7. The NWA and CoCT's Water By-laws change to allow citizens to connect to and use water supplied from sources other than the municipality and to utilise alternative water.

8. Water infrastructure planning includes catchment, district and precinct level infrastructure interventions to identify storage and treatment opportunities at all scales and possible synergies with the existing infrastructure.

These institutional and infrastructure changes will enable a radically different water system that empowers citizens and municipalities to grow and nurture a diverse water supply and service infrastructure system.

3.2 URBAN WATER CYCLE

Consolidating water supply and water service mandates, as proposed in sub-section 3.1.2, enables the integrated management of the treatment and distribution infrastructure necessary to create a circular metabolism based upon water balance or water carrying capacity[19] across sources within the Urban Water Cycle (UWC) (Figure 20). The UWC is a manifestation of the water system and institutional structure discussed in the preceding section. It follows that changes to the system and structure will affect the UWC.

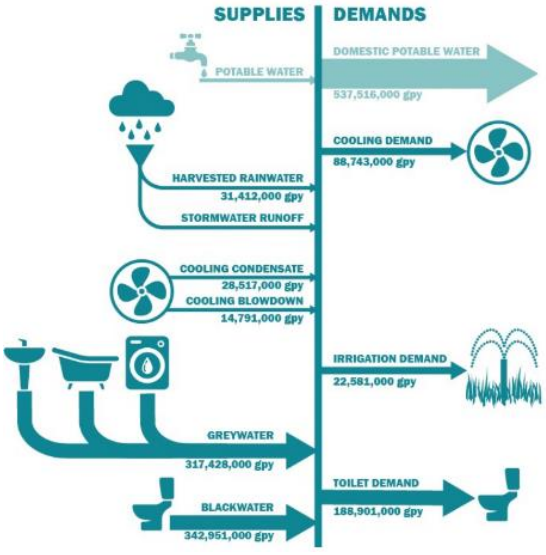

Figure 20: Water Balance (Source: Munoz, P; 2017)

[19] Water carrying capacity is the amount of water within the UWC available to service the population.

Two subsections follow including alternative water supply suggestions followed by a discussion on alternative infrastructure.

3.2.1 ALTERNATIVE WATER SUPPLY AND ALLOCATION

Water supply in South Africa is traditionally based upon potable water. Until the drought, supply has largely met demand. However, with the CoCT's drought, focus has shifted towards reducing demand and increasing the supply of non-surface water, whilst simultaneously reducing demand by implementing water demand management (WDM). WDM can reduce potable water demand by up to 30% (Coulson, 2014). When combined with behavioural changes, this can drop up to 40%, as shown in Cape Town where since the beginning of 2017, demand has fallen from a daily average of approximately 1000ℓ³/day to 600ℓ³/day. The current drought measures are allowing the CoCT to survive – for now, but is it sustainable in the long term?

As discussed in Part One, the outcome of the current water governance is a systemic dependence upon potable water derived from surface water that is used in a linear system (Figure 21). Shifting this system towards a circular metabolism by using alternative water for non-potable uses combined with WDM interventions, could reduce the total domestic water demand to 22.5% of what a business-as-usual scenario would demand (Figure 22) (DEADP, 2017).

Figure 21: Conventional Linear System (Munoz, 2017)

This argument is supported by research undertaken in the Liesbeek River Catchment (Coulson, 2014) to determine the possible potable water savings in response to rainwater harvesting and WDM. This catchment has a high rainfall, a large percentage of domestic landuse and represents 2% of the CoCT's water demand. A combination of interventions was modelled, including the use of rainwater.

The research reports that most toilet flushing, and laundry needs can be supplied throughout the year from rainwater. This would potentially reduce water demand in the highest domestic user category by 22% (Coulson, 2014). If applied across all land-uses, it could result in an up to 15% reduction. Whilst pool top-up was initially included in the modelling, it was removed due to the high demand needed to endure through the dry summer months. Domestic water consumption for the Australian cities of Brisbane and Melbourne (Sinclair *et al.*, 2005) though higher than the Coulson research (2014) assumptions, are not dissimilar and support the notion that substantial savings can be achieved even if alternative water, such as rainwater is only used for laundry and toilet flushing (Table 4).

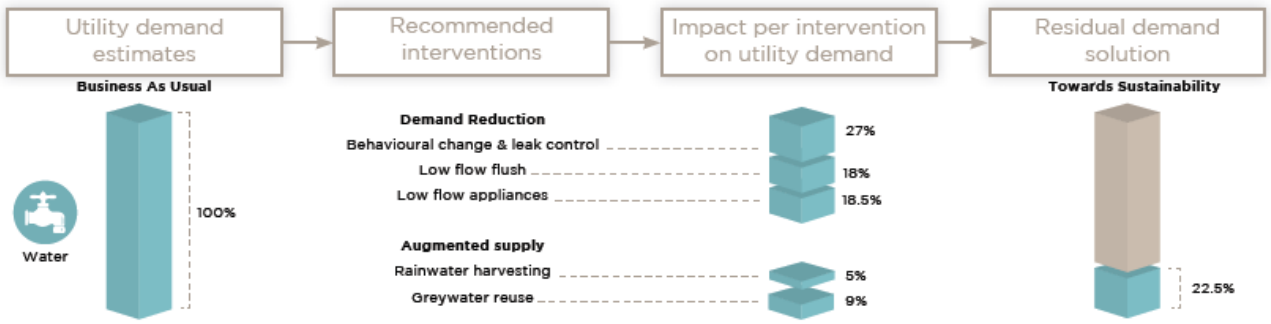

Figure 22: Sustainable Infrastructure Approach to Water (DEADP, 2017)

Table 4: Components of domestic water use (Sinclair, Leder, & Chapman, 2005, adapted and simplified)

Use	**Melbourne**	**Brisbane**	**Cape Town**
Outdoors (pool, garden etc)	35%	50%	30 %
Kitchen	65 %	50%	70 %
Laundry			
Bathroom			
Toilet			

Spread over a year, these demand reductions 'bank' bulk capacity for the summer months when alternative water may be less available. It furthermore creates a circular metabolism that uses outputs (which may include alternative water) for inputs to optimise resource efficiencies (Figure 23).

The benefits of rain and greywater are clearly motivated above. These two sources are appropriate to the household scale. However, due to the bulk, centralised, hierarchical system structure, decentralised opportunities at the granular scale such as stormwater are applicable at the domestic scale and are also currently not available to the larger system. A hybrid system that is designed to include bulk and smaller-scaled, incremental interventions will however expand the supply opportunities by connecting to these

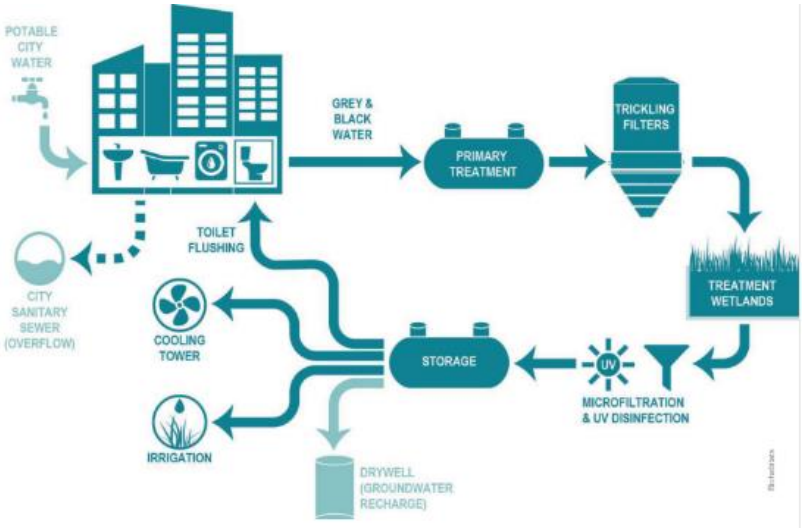

Figure 23: Circular Metabolism and Incremental Approach (Munoz, 2017)

other, more dispersed sources.

These sources include treated effluent (TE) that is already within the UWC. It is not dispersed or necessarily incremental, but optimising it does represent an opportunity to improve the UWC efficiency holistically. The CoCT currently re-uses 10% TE for non-potable purposes. This small percentage represents an enormous opportunity. Should all TE be treated to a potable standard, it could meet half of the CoCT's current daily demand of 600 million litres. Even if the CoCT were not to increase the quality of TE, it would still have enormous value to, for example large manufacturing companies who can treat to a potable quality if required, or to supply domestic and large-scale irrigation. Similarly, potable water savings can also be achieved by using xeriscapes[20] that can reduce irrigation demand up to 50% (Jacobs, 2011)

Detention ponds, rivers and streams form an integral part of the blue and green network within the urban fabric as part of the stormwater system, unlike desalination plants that have yet to be implemented. They are however not currently part of the CoCT's water supply network, but rather form the backbone for the stormwater discharge and flood management.

Whilst the impacts of urbanisation caused by hardened surfaces impacts negatively on the water cycle, the wasteful discharge of this efficiently collected water presents an opportunity. The issue will however be suitable locations for storage, which highlights the need for specific investigations to determine potential areas, apart from onsite storage at a property level. The stormwater impacts relate to increased quantities and the reduced quality of stormwater and limited groundwater infiltration. Studies in Wrocław (Poland) modelled SUDS across a variety of development typologies (including new and old developments) and concluded that new developments create greater volumes of stormwater runoff and that it is possible to retain up to 90% of stormwater runoff by providing permeable surfaces (Suma, 2015). These permeable areas (as per SUDS), such as permeable paving, green roofs or gardens reduce stormwater, runoff, improve water quality and allow for groundwater infiltration, whilst having the added value of providing storage and increasing the planted areas within urban areas. Promoting underground water storage reduces the exposure of water storage to heat and wind and therefore evaporation. Designing treatment trains throughout urban areas to aid infiltration will not only improve water quality by bioremediation before it is directed below ground, but also creates green infrastructure that provides a variety of eco-services (Andersson *et al.*, 2014) (Cameron & Blanusa, 2016) and is applicable at a variety of development scales.

Unlike the limitations of rain- and stormwater harvesting due to seasonality, those buildings with basements, may well have access to groundwater all year. Many buildings across the CoCT CBD and Atlantic Seaboard area however have basements that require dewatering throughout the year. This groundwater is usually pumped into the stormwater system, but can be stored for toilet flushing which represents 37% of their total water demand (Coulson, 2014), or if treated to the necessary quality, used for drinking water too. Anecdotally, it is known that there are a few buildings already using basement groundwater abstracted from dewatering for toilet flushing and irrigation. At this stage there are however few mechanisms available that can be used to make the surplus groundwater water available to others that do not involve red tape and

[20] Xeriscape landscaping is that reduces or removes the need for supplemental water from irrigation.

licencing. Notwithstanding the former, abstracted basement groundwater offers an alternative for non-potable uses such as toilet flushing, particularly for commercial buildings that do not generate large quantities of greywater.

As previously discussed large, high value domestic properties located in coastal areas are the highest water users in Cape Town (Heddon & Cilliers, 2014). Targeting this group for intervention will therefore have measurable benefits as these homes will presumably have sufficient roof size and space to store adequate quantities of water. Because of the enormous burden that could be removed from potable supply by increasing alternative water use and optimising water within the UWC, it makes good sense to roll out the infrastructure necessary to unlock these resources, before seeking other, more expensive sources such as desalination. By rolling infrastructure out and implementing the related institutional changes, it would appear feasible to limit the allocated water to what is necessary for drinking purposes and to transfer the responsibility for supplying the remainder to the individual.

Achieving a hybrid water supply system will require the following changes:

1. Implementation of catchment-scaled infrastructure planning within the IDP, MTIFF and BEPP processes;

2. Adopt a fit-for-purpose approach that identifies appropriate uses for the various water types so that potable water is not used for irrigation and or toilet flushing;

3. Supply limited municipal potable water possibly to ensure implementation of hybrid system;

4. Establish a common water language across all water governance to guide permissible uses and a fit-for-purpose approach;

5. Increase volume of available TE and improve quality to increase its applicability across water uses. Inputs required into water planning processes;

6. Institutionalise mandatory onsite alternative water storage, treatment and use within the NWA, CoCT Water Bylaw, Planning Bylaw and National Building Regulations;

7. Direct greywater to wastewater treatment works for recycling rather than onsite reuse, implement via water governance reform.

8. Stormwater, basement water and TE to be included in the NWA and WSA as water resources within the water balance, rather than treated as wastewater; and

9. Improved testing and support options to be investigated further to determine appropriate technologies.

The harvesting and use of rain- and stormwater, greywater re-use and groundwater as per a fit-for-purpose approach will increase the water supply mix. The paradigm shift is therefore not only away from bulk supply towards decentralised sources, but also towards multiple sources and alternative, decentralised supply and treatment.

3.2.2 ALTERNATIVE INFRASTRUCTURE

Changing the water system structure towards a hybrid system composed of conventional and alternative infrastructure such as incremental infrastructure, inverted infrastructure, and green infrastructure will, I argue in this subsection, result in a more resilient water system.

The proposed system structure is more resilient than conventional infrastructure because it operates at multiple scales and offers more services than conventional infrastructure, which has a very narrow focus. It redefines nature as infrastructure that supplies water and services such as flood mitigation and water quality improvement (ICLEI, 2015). Rivers and green spaces form the backbone of these systems and through their connectivity, support eco-systems and biodiversity (Andersson *et al*., 2014). When functioning optimally, they are able to supply eco-system services, such as recreation, improved air quality and reduced heat island effect (Figure 24).

Figure 24: Las Vegas Springs Preserve Desert Living Center Wastewater Treatment & Reuse – Las Vegas, Nevada (USA) (Munoz, 2017)

At a development scale, green infrastructure performs well if evaluated from a long-term, integrated planning perspective that is inclusive of life-cycle costing comprised of construction, management, maintenance, de-commissioning costs and impacts (ICLEI, 2015). From a system thinking perspective, green infrastructure could be an isolated detention pond it could also be a connected system of wetlands, detention ponds, swales, or permeable paving that operate symbiotically to collectively create a diverse system with a circular metabolism (Figure 25).

Domestic gardens or public open space, when viewed through this lens, are no longer a drain on water supplies, but are rather, a fundamental part of the CoCT's green infrastructure abundant in opportunities.

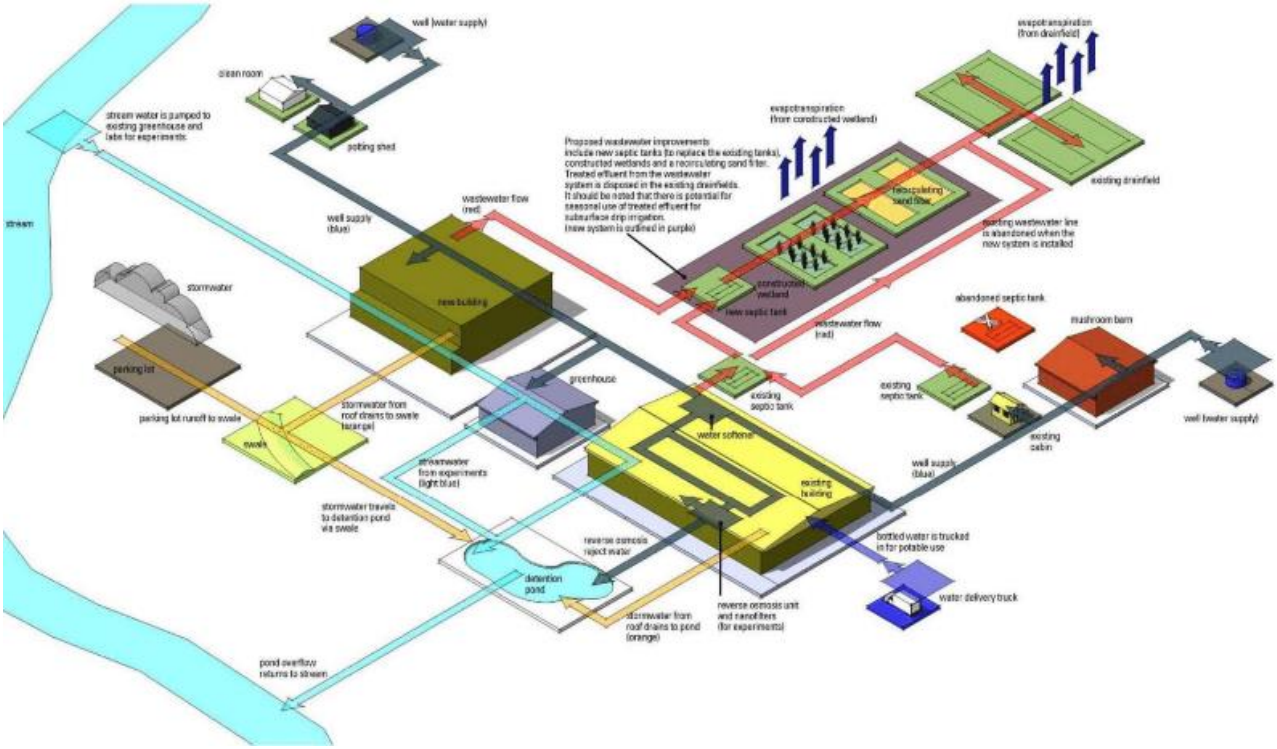

Figure 25: An integrated water system (Source: Munoz, 2017)

The role of smaller, alternative infrastructure within water service delivery has been limited in the past. If an "every drop counts" approach is adopted, the infrastructure that accesses alternative water resources that are unavailable at the larger scale become significant parts of a hybrid system. The most practical infrastructure to achieve this is incremental infrastructure (Zuckerman, 2007), as previously discussed. This type of infrastructure refers to the infrastructure and the funding which relies on independent, private investors who are unencumbered by central planning and high investment costs. These investors could be users who supply their own rainwater harvesting tanks or treat municipal-supplied treated effluent for their own use. By disaggregating water infrastructure into incremental interventions, it is possible to integrate the infrastructure into users' homes and businesses reducing the distant relationship between users and supply which foregrounds the infrastructure and thereby will presumably reduce the wasteful behaviour associated with hidden infrastructure (Coulson, 2014).

Treating water onsite as a WCDM and behavioural change measure at a site scale is beneficial as are those at a precinct and neighbourhood scale. By harvesting stormwater at this scale it is possible to channel and treat the typically polluted stormwater which improves the quality and opens more use possibilities. This approach is not currently accommodated within the stormwater modelling that assumes that the rivers are part of the stormwater discharge network and must accommodate the discharge of stormwater during a storm event. New thinking because of the drought now includes the identified need to model catchments with a view towards understanding the rainfall quantum throughout the year to determine storage opportunities across the CoCT's catchments (Nell, 2017). The storage interventions may include reservoirs and dams that have spatial implications. Locating these interventions requires transversal, collaborative planning between departments that will affect theory implementation through practice.

In spatializing stormwater harvesting, it will be possible to integrate WSUD and treatment trains (Armitage *et al*., 2017) as green infrastructure at a city-wide scale to create treatment trains that improve the water quality and to recharge groundwater and aquifer reserves. The spatial interventions must include, for example, more toilet facilities and drainage for greywater within informal settlements and solid waste removal in areas where there are large backyarder[21] communities.

By spatializing water, it will also be possible to create zoning tools to assist in protecting and enhancing the functioning of the green infrastructure and foreground water resources within public space to conscientise the public to water. The combination of spatial interventions, management and development tools will respond to the effects of climate change by increasing the water supply options and build resilience through Anticipatory Governance which is best suited to manage uncertain futures (Segrave *et al*., 2006).

Figure 26: Precinct Plan of Hasslo on 8th, Portland, Oregon (USA) (Source: Munoz, 2017)

Hasslo on 8th (Figure 26) illustrates the layers of value that can be extracted by applying an incremental approach. This example uses water infrastructure to inform the public space design. It exposes it to public view whilst also integrating it into the landscape in constructed wetlands that optimise the landscape in water treatment. The result is a fully functional space that provides infrastructure services and biodiversity whilst also creating an attractive landscape and iconic branding (Figure 27) (Munoz, 2017).

Figure 27: Photos of Hasslo on 8th, Portland, Oregon (USA) (Source: Munoz, 2017)

Effecting a hybrid system composed of conventional and alternative infrastructure such as incremental infrastructure, inverted infrastructure, and green infrastructure requires changes to the UWC. These include:

1. The adoption of infrastructure at different scales to allow for circular metabolisms.

[21] A backyarder is a person or family that has constructed an informal home adjacent to a formal home. These dwellings may be serviced with electricity, for example and have limited access to toilets. Issues have however arisen with the supply of waste bins resulting in the dumping of refuse (and sewage/greywater) into streets and river courses thereby polluting the water quality.

2. Review of implementation plans such as the IDP, MSDF, BEPP and MTIFF to understand how to better integrate existing policy into spatial and financial planning tools.
3. Promote partnerships at precinct scale between developers and the CoCT to optimise water resources optimally including their spatial, eco-service and biodiversity roles.
4. Establish new best professional practice that creates platforms for the type of multi-disciplinary work needed to effect green infrastructure.
5. CoCT to create capacity to manage private sector relationships.
6. Establish a mechanism such as a "water fund" to fund private sector infrastructure projects to augment CoCT infrastructure.

Adding variety to infrastructure, ownership and funding options will create a hybrid system. It will also add layers to water service delivery that will create complexity, but also resilience through alternative technology such as green infrastructure which is more sustainable and cost efficient.

3.3 PLANNING

Effecting the proposed changes will require their adoption at a policy level to establish them as implementable planning and budget priorities. The CoCT is mandated to establish its own policy, if it is consistent with legislation and national policy. The National Treasury however plays an important role in the implementation of policy and as such, must play a pivotal role in shaping infrastructure delivery through their BEPP processes. It follows that National Treasury can create policy to protect and rehabilitate green infrastructure networks to harvest stormwater and recharge groundwater. Close collaboration between the Water Department and CoCT planning department who engage with National Treasury regarding infrastructure planning would be a starting point towards systems change. This will be achieved through transversal planning and integration at a metropolitan and district scale, in combination with the water governance changes, particularly in relation to the guidelines.

Changes to effect planning reform:

1. Conduct an assessment of the metro using a WSUD lens;
2. Develop a plan for multi-scale water supply, treatment and storage within the IDP, MSDF and MTIFF (using the Sydney Decentralised Water Plan as precedent);
3. Consider water security against densification and transport imperatives;
4. Create zoning tools that protect the functioning and integrity of water resources, including aquifer and groundwater recharge areas;
5. BEPP requirements from National Treasury to be adjusted to stimulate implementation of resilient infrastructure;
6. Implementation of WSUD within the MSDF planning and design;
7. Enforcement of penalties for contraventions;
8. All new developments must use alternative water (excluding groundwater) for non-potable uses; and

9. Existing development must retro-fit alternative water for non-potable water use.

3.4 LEGISLATION AND POLICY

The importance of policy and budget processes in planning is discussed in the preceding section. Bazillian (2011) concludes that policy undermines adaptive responses to climate change, including those related to water services. The status quo analysis identified the non-implementation of policy as the central issue. The legislation and policy does not treat water as a scarce resource, nor does it locate water at the centre of economic and spatial development. The lack of clarity relating to the permissible uses and inconsistent referencing also detracts from the intentions of the NWA and the WSA.

If the CoCT were to change to a decentralised, incremental approach towards a hybrid system, it could catalyse social, economic and natural systems' change. This would shift its role from one of service provider, to one of community-builder whereby infrastructure is used, not only for social cohesion, recreation, health and urban liveability, but biodiversity and resilience too (ICLEI, 2015).

The status quo outlines the legislation and policy limitations and concludes that it is not designed for complexities within water cycles (natural and urban) or complexity in managing water resources within a time of great uncertainty (Pahl-Wostl *et al*., 2010). Anticipatory Governance addresses some of these issues and inverted infrastructure others. Inverted infrastructure developments emerge spontaneously and have more unpredictable outcomes than designed projects and the pivotal role of users makes it more adaptive to changing societal needs because it is less entrenched (Egyedi & Mehos, 2012). This flexibility allows for changes in water security scenarios with adaptations possible for greater or lesser water availability. It is like incremental infrastructure but differs in that it is typically user-driven and self-organised, rather than by government, which is currently the case in Cape Town. It is developed from the bottom up using individuals' investments as opposed to top-down government-funded projects, like the capability approach.

Broadening water supply to include the private sector and the public will increase water supply. Implementing this in conjunction with a fit-for-purpose approach will further broaden the water supply mix to include alternative water. Whereas harvesting and storing alternative water is broadly reflected in the legislation and policy, its permissible uses are not. Effecting wider permissible uses will require a revision of the NWQG, the establishment of new water testing requirements and the provision of support for non-municipal domestic water suppliers, as contemplated in the Norms (DWS, 2017) and the NWRS(2).

Fundamental to this shift are changes to both the WSA and the Water By-law. These changes must include:

1. Revise all legislation and policy with a view to separating urban and rural scenarios to create legislation that is more appropriate to the complex context;
2. Reconsider mandates (in relation to the above);
3. Revisions to the NWA and CoCT Water By-law (and any others) to permit the connection to and use of non-municipal water and the prescription of alternative water in all new developments;
4. The revision of the NWA to adapt a scale and location-appropriate approach to groundwater resources that considers urban water resources and the accumulated impact of demand.

5. It must, in conjunction with the WSA, include definitions for alternative water to allow for the broadening of the water mix across the water legislation to allow for integrated water management, which will include an Integrated Water Bylaw and supporting technical documentation.
6. Establish a common language and discourse to obviate confusion and create a universal understanding;
7. Provide wider options for service delivery and supply guidance and management of non-government water service providers; and
8. Define water types clearly with a view to including urban water types such as greywater and basement water.

3.5 GUIDELINES

The water governance guidelines require the same reforms as the legislation and policy regarding alternative water, definitions and quantity stipulations. The water quality issues, that impact on the former, are substantive and cannot be discounted. However, they can also not be knockouts in light of the variety of technology available on the market. Government has no choice but to endorse or develop technology to assist in water quality management as a means towards increasing the water mix and thereby, resilience. Government must also institutionalise these guideline reforms via its specifications and tenders to ensure its own best practice, also as means towards shifting the paradigm towards an incremental approach and hybrid system. Bedding down specifics around use and quantity in the guidelines, including professionals' guidelines such as the Red Book and mainstream within the National Building Regulations and by-laws as core parts of the water supply is a first step.

Effecting these changes will require a broad review of all the guidelines. Some changes are already underway with the CSIR[22] preparing a new water efficiency guideline and a "Green Book" to guide municipalities in their climate adaptation planning. The CoCT is also reviewing its policy and guidelines with a view to creating a technical manual that will establish the "new normal" within Cape Town. This document will establish a technical specification that includes WSUD city-scaled guidelines down to plumbing fixtures that build on the CoCT's Alternative Water Installation Guidelines (2017).

The guidelines must change in the following ways to enable the implementation of the proposal:

1. Common discourse established in the legislation and policy to be applied consistently throughout all levels of water governance and institutionalised in the National Building Regulations with specific reference to best practice and the practicalities around integrating the water cycle into urban environments, including alternative water use, particularly in the Red Book;

[22] CSIR – Council for Scientific and Industrial Research

2. Update of the NWQG to include greater support for the public around affordable alternative water testing, treating and use;
3. Consensus required across the professions with regards best practice and the associated re-training and overhaul of academic curriculum to embed in the professions;
4. National WSUD and SUDS design guidelines be prepared at a variety of scales that adapt principles into guidelines for implementation;
5. Implementation of stormwater guidelines and policy across all scales, so that it is not limited to the larger scales (≥4000m²);
6. Consistency across spheres of government with regards to what is permitted in urban and rural areas in relation to alternative water (all) harvesting, storage and use; and
7. Precinct guidelines designed to optimise water resources collectively with institutional directions to assist the private sector in establishing Water Service Providers.

The efficacy of these changes is however, connected to the eradication of misconceptions around the financial viability of alternative water, as discussed in the next section.

3.6 FINANCIAL

Various misconceptions abound relating to water and alternative infrastructure, primarily based upon incorrect assumptions around costs.

To date, South Africa has grossly undervalued and under-charged for its water resources. Alternative water sources have however typically been valued against municipal water supplied at tariffs within a water-secure scenario, not against the costs of imported water within a water-scarce scenario.

The results would understandably vary greatly. And even yet, comparative work undertaken by the Western Cape Government Department of Environment and Planning concluded that "business as usual" is not as cost efficient as sustainable infrastructure (including rainwater) and in fact reports that for every R1 spent, there is a return of R1.10 and substantial savings in the medium to long term through reduced operations and maintenance costs (Figure 28). It reaches these conclusions by taking a life-cycle approach that aggregates the impact, as opposed to the Fisher-Jeffes (2015) approach that only considers the cost to the individual based on the assumption of ongoing, artificially low water tariffs.

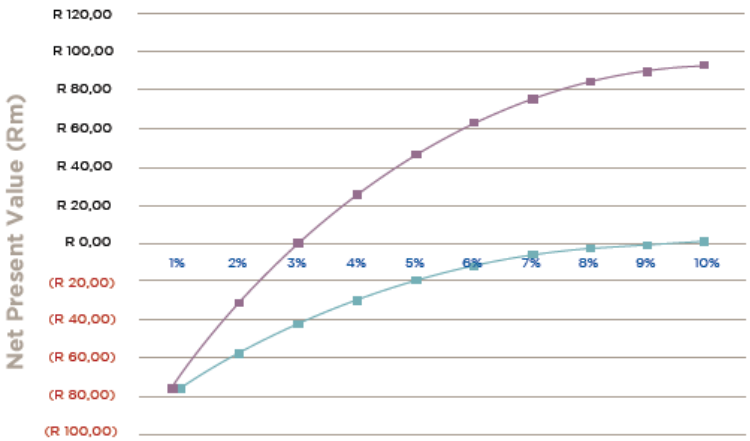

Figure 28: Comparative Graph Showing Cost-Benefit for Sustainable and "Business as Usual" (DEADP, 2017)

The Coombes & Kuczera (2002) assessment of the Figtree Place (Newcastle, Australia) also takes a life-cycle cost approach and reaches similar conclusions. The development was designed to achieve a 50% reduction in indoor water demand by using rainwater for hot water services and toilet flushing. The actual water reduction in the long term is closer to 45%. This project also uses stormwater harvesting to supply all outdoor irrigation needs and vehicle washing. A capital cost comparison for the construction of water sensitive design elements estimated them to be 1% lower than costs for a conventional stormwater system and the annual savings are estimated to total $3,422 (Sinclair *et al.,* 2005). These reductions also impact on larger infrastructure investment planning by delaying the need of large scale interventions, from anywhere between 27 and 35 years (Sinclair *et al*., 2005).

Perversely, these savings are part of the blockages to the implementation of water sensitive design. Whilst not the focus of this thesis, it is worth noting that the professional overlaps in work scope structure has material impacts. A water sensitive design approach forms part of the work around buildings and is therefore part of landscape architects work. Stormwater management is however normally part of the engineering scope and it typically ends up being an engineered solution that would generate higher fees. It is not often that the two professions collaborate, but where they do, the interventions have been found to have lower capital costs, notwithstanding the other added value through green infrastructure.

The cost of water will increase in July 2019 to reflect the increase in price linked to new water such as desalinated and borehole water. This increase and the earlier cost-benefit assumptions may well change as must the CoCT's regulations to enable a shift towards the greater use of rain and stormwater.

The impact of reduced water supplies during drought on municipal revenue is substantial (estimated at between R1.2 and R1.7 billion) and combined with users becoming self-sufficient, becomes more so. Coombes *et al*. (2002) assert that government limits users to water it supplies to generate an income to recoup infrastructure costs, a system established in the Industrial Revolution when water and sanitation infrastructure was first implemented. An incremental approach would compound the negative impacts on an already compromised fiscus. Or, it could be a means towards creating a sustainable and resilient water system, because water can no longer be the exclusive purview of government, who does not control rainfall.

The aggregation of these smaller interventions will undoubtedly impact on municipal revenue. But – they will also delay the need for water treatment plant, pumpstation upgrades and the construction of additional capacity (such as TE distribution) to reticulation networks whilst providing much-needed redundancy to contribute towards greater resilience. The current trend in the CoCT however indicates that it is the large water users who pay a premium for water who are becoming self-sufficient. The tariffs these water users pay, subsidises the basic allocation to poor families. The impact of this trend on the CoCT's revenue must be investigated further to prevent unintended consequences and to find mitigating measures.

Recommended changes to the financial part of water governance include:

1. The increase in water tariffs to reflect the true cost of water in a water scarce scenario;

2. Financial modelling to be undertaken to determine the impact of self-supply on municipal water revenue and remedial options investigated to prevent the financial burden on municipalities;

3. Financial modelling to consider life-cycle cost of water infrastructure and the associated risks inherent in systems failure and economic collapse;

4. Incentivise water savings and alternative water using a rebate system or the like;

5. Introduce the requirement for metering on sewage outflows for those who elect to self-supply water to allow for the measurement of sewage services;

6. Investigate the possibility of a water fund to assist the private sector in accessing funds for infrastructure projects; and

7. Consider the introduction of a stormwater charge to fund stormwater management, runoff quality improvement, harvesting infrastructure and treatment infrastructure.

The issues identified in Part One and the proposed interventions are listed in Annexure C which serves as a summary for Part Two.

PART THREE - CONCLUSION

The water governance complexity is a microcosm of the complexity and the associated wicked problems that plague all nations of the world, including South Africa. Providing sufficient food, water and energy within the context of global political uncertainty, and climate change is the boisterous challenge that governments wrestle daily. Akin to scenes from *Gremlins* where water spawns sinister, little furry creatures, so water seems rapidly to spawn many wicked problems, none of which can be resolved by "bright light".

The global complexities inherent within the context overwhelm the governance intended to enable and manage. I conclude from my research, that water security is not government's exclusive purview because of the inextricable linkages to behaviour. Whereas government is entirely responsible for the systems its water governance creates, the professional practise and users within the system are intricately connected to the way the system is used. The large scale of the system and single source reliance creates a 'monster' that lacks the nimbleness to respond to the rapid changes the CoCT has experienced. A three-year drought may not appear to be rapid, but in infrastructure timelines where large projects take a minimum of five years to deliver, it is.

I argue that establishing smaller, more nimble systems within the conventional system's framework will provide the resilience the current system lacks. Changing systems and approaches is however heavily reliant upon political leadership which was shown by the CoCT's Executive Mayor, Patricia de Lille who is responsible for setting the CoCT Water Services Development Plan (2015) aside and instructing the shift to the 'new normal'.

This thesis has taken six months to research and write. During this time, there have been several changes that support my initial questions around water governance. These include the CoCT's Alternative Water Installation Guidelines and draft amendment for the Water By-law (City of Cape Town, 2010). The former is a guideline and is therefore not legally enforceable and the latter excludes the highest water users, namely freestanding homes, which is bizarre and contradictory to the national DWS's Norm. The assumed reasons for this reluctance relate to the associated health and management issues which are seemingly greater than concerns for the potential health risks associated with complete system failure and a lack of water. It was not possible to obtain a legal opinion regarding the implications of the failure to supply water, as per the constitution and the subsequent potential threat to life itself, questions that should perhaps be considered, particularly if Cape Town's water supply is depleted before the 2018 winter rains.

Whilst it was not possible to obtain a copy of the revised Red Book, review of parts of the Green Book (draft) were encouraging. It is however hoped that the Green Book will provide more specific guidance as opposed to only high level principles. Some of the examples it promotes mirror those included in the alternative water infrastructure section such as WSUD and green infrastructure. I have concluded from my research that the Red Book and Water By-law are impediments to rain- and stormwater harvesting and the wider use of alternative water and incremental infrastructure. These findings echo and refine those made by Fisher-Jeffes' (2015) and Coulson's (2014) research to include the cheap price of water, regulations, practice and lack of policy implementation. As Cape Town has slid ever closer to "day zero", so the reality around water scarcity has crystalized for many. This awareness has come with a realisation that household water security versus dependence upon a common system over which there is little individual control beyond one's own

behaviour, is priceless. These practice and behaviour shifts suggest that the tide is turning away from conventional infrastructure and systems at a faster rate than those within water governance.

Whereas government does not control rainfall, it does control water governance and implementation. Extensive innovation is urgently needed to establish the 'new normal' to ensure that water is affordable and provided in a sustainable way that meets the requirements of the people, the economy and the environment (ICLEI, 2015). Shifting the paradigm towards the 'new normal' must therefore firstly start with further study into the municipal revenue model to ensure that there is equitable water access. Secondly, invigorating the legislation and policy reform will enable Capetonians to implement incremental interventions within a decentralised, hybrid system that enacts the CoCT's tagline which is to work together to make progress possible.

4 ANNEXURES

Annexure A- Matrix of Water Quality and Risk (Source: CoCT)

SOURCES OF WATER:	RAINWATER	GROUND WATER Boreholes, wellpoint	SURFACE WATER Springs and rivers	GREYWATER	TREATED EFFLUENT FROM THE CITY
	TEST FIRST, AND TREAT ACCORDING TO USE				
USES OF WATER:					
Plant bed irrigation (subsurface)	4	4		4	
Fire fighting	3 (Categories 3 & 4)	3 (Categories 3 & 4)		3 (Categories 3 & 4)	
Vehicle cleaning	3	3		3	
Food garden (subsurface) & lawn irrigation	4	4		4	
Outdoor hard surface cleaning	3 (Category 4)	3 (Category 4)		3 (Category 4)	
Swimming pools*	SANS 241*	SANS 241*		SANS 241*	
HVAC	3 (All 4 categories)	3		3	
Toilet flushing**	**	**		**	
Fish ponds	1	1		1	
Indoor surface and kitchen cleaning	1	1		1	
Laundry washing	1	1		1	
Cooking & food preparation	1	1		1	
Body washing (ablution)	1	1		1	
Drinking	SANS 241	SANS 241		SANS 241	
Water features (no contact)	1	1		1	
Water features (e.g. splash parks)**	SANS 241	SANS 214		SANS 241	

Annexure B - Legislation and Policy Analysis Summary Table

Item	Rainwater harvesting/ storage	Rainwater use	Potable water supply	Potable water storage	Stormwater Management	Stormwater harvesting/ storage	Stormwater re-use	Water Re-use	
The Constitution			X		X				
National Water Act	X	X			X				
Water Services Act			X	X					
National Water Resource Strategy	X								
Water By-Law			X	X					
Stormwater Management By-Law			X	X					
Water Services Development Plan	X		X	X				X	
Management of Urban Stormwater Impacts Policy	X					X	X		
Human Settlement Planning and Design – Guidelines	X	X	X	X	X	X	X	X	

Key		
		Prohibits storage and or use of rainwater or stormwater
		Enables “use” of rain or stormwater but does not specify use or specification is other uses other than domestic

Annexure C - Summary Table of Status Quo and Proposed Interventions

	STATUS QUO	INCREMENTAL APPROACH
1(a)	**WATER SYSTEM STRUCTURE (INFRASTRUCTURE)**	
1.1	Bulk, technical, centralised system assumes abundant water which creates a conventional, linear water system that is highly regulated and hierarchical and inefficient	Adopt fit-for-purpose approach within a closed, circular metabolism. An incremental approach to decentralise water governance and water supply. Install smaller, more affordable, low-tech, alternative water sources.
1.2	Hidden Infrastructure	District and household infrastructure places water firmly within the built environment where it is visible.
1.3	Infrastructure inflexible and material intensive - inefficient use of resources used to manufacture pipes etc.	Incremental interventions retrofitted over time into an existing urban environment, need for large infrastructure obviated.
1.4	Linear system limits supply to single water source and feed-in opportunities.	Multi-scaled interventions that could include not only large scaled desalination and aquifer abstraction, but also smaller scaled rainwater harvesting and grey water re-use as augmentation. Incremental approach is decentralised and less hierarchical with more opportunities to feed in and to create a circular metabolism that would potentially reduce water demand in the highest domestic user category up to 22%.
1.5	Not treated as a scarce resource (assumption of abundance)	Fit-for-purpose and circular metabolism treats water as a scarce resource.
1.6	Water (and natural resources/services) not seen needing support to enhance efficiency and respect dependencies.	Blue and green systems to be managed as critical infrastructure that supplies eco-services, achieved through spatial integration of WSUD.
1(b)	**WATER SYSTEM STRUCTURE (INSTITUTIONS)**	
1.7	Water authority must supply water services (or water board) not structured to allow for multiple partners within a single system.	Rain- and stormwater harvesting interventions for individual participation. Private sector able to engage as Water Service

	STATUS QUO	INCREMENTAL APPROACH
		Providers via a contract with the municipality. Multifunctional use of water resources approach
1.8	Dislocated mandates, centralised management (like infrastructure)	Anticipatory Water Governance and an incremental approach to integrate fragmented pieces.
1.9	Municipality dependent upon catchment and does not have control/mandate to manage water resources.	Establish CMA's for the catchments from which the CoCT draws its water. The CoCT become a Water User Association with mandates over all water resources including the urban catchments within its boundary. The CoCT delineate its stormwater management areas to reflect catchment areas and assume management of groundwater resources.
1.10	Legislation and policy not designed for complexities within water cycles or complexity to managing the resource.	Review and revise the NWA and WSA to include alternative water and fit-for-purpose approach. Integrated Water Bylaw designed to respond to urban water cycles including those currently considered wastewater, such as stormwater, treated effluent and basement water and secondly, incorporate multiple scaled interventions. Include multi-scaled interventions and differentiate urban and rural scenarios.
1.11	Water use limited to potable water (from municipality)	Establish alternative water capability within line departments to assist in regulating development to support the public. Change NWA and CoCT's Water Bylaw to allow citizens to connect to and use water supplied from sources other than the municipality and to utilise alternative water such as TE and basement water. Institutionalise guidelines such as the Norm and the Alternative Water Installation

	STATUS QUO	INCREMENTAL APPROACH
		guideline within an Integrated Technical Manual.
2(a)	**URBAN WATER CYCLE (INFRASTRUCTURE)**	
2.1	Urban water resources not included in supplying water, mostly from beyond the metro boundary.	Water infrastructure planning include catchment, district and precinct level infrastructure interventions to identify storage and treatment opportunities at all scales and possible synergies with the existing infrastructure. Rain- and stormwater harvesting interventions appropriate at an incremental scale because they are standardised, modular and interchangeable which allows for flexibility and greater options for individual participation. TE, groundwater and basement water must be included as part of the water supply mix.
2.2	Mandates gaps (national and metropolitan) result in unsustainable water management (boreholes not adequately monitored and inappropriate laws for abstraction)	Anticipatory Governance integrates fragmented pieces, shifts from exclusivity to participatory, adaptive and anticipatory. Establish Catchment Management Agency and (CoCT) Water User Association with mandates appropriately linked to catchments. Groundwater use in urban areas to be limited and controlled using water meters and tighter monitoring.
2.3	Resources not managed for use – stormwater disposed into the sea, not managed as a resource – polluted and therefore also needs to be removed	NWA and WSA to define and guide with regards to stormwater management mandates and use for adoption in municipal Integrated Water Bylaw.
2.4	Urbanisation impacts on water cycle, increases velocity and negatively impacts quality in rivers and not enough infiltration because of hardened surfaces.	Water cycle planning must be integrated into MSDF, BEPP and MTIFF with stormwater management applicable to all scales of development, rather than limited to larger developments.
2.5	Domestic gardens largest potable water users; use not fit-for-purpose and alternative water not included in the demand design or system.	Norms and standards to be revised to not only reflect current trends, but also reference against water carrying capacity.

	STATUS QUO	INCREMENTAL APPROACH
		Water demand assumptions to include the use of alternative water as opposed to dependence on potable water. Incremental interventions and landscape requirements (plants and irrigation) to be specified in the National Building Regulations and municipal bylaws. Limit the use of groundwater until sufficient mandates and management mechanisms are in place.
2.6	Distant relationship with source of water distances the relationship with water resulting in wasteful use.	Incremental infrastructure, such as rainwater tanks or greywater systems bring infrastructure closer to users at domestic, neighbourhood and district scales.
2.7	SUDS not adequately implemented and storage for harvesting or even recharge not designed and zoned into spatial plans.	Water planning must be integrated into spatial planning against clear guidelines and Integrated Water Bylaw requirements.
2.8	Practice and theory not aligned and not treated as a scarce resource.	Review legislation, policy, guidelines and practice to align with consistent application of the IWRM and the inclusion of alternative water, groundwater water, TE and basement water.
2.9	Government's sole responsibility for delivering water services limits scope of participation of private sector.	Reduce regulation and re-align mandates. The capability and multifunctional use of water resources approach include all stakeholders to influence water management policy to make the management more sustainable.
2(b)	**URBAN WATER CYCLE (PROFESSION)**	
2.10	Guidelines and professional practice do not respond to water as a scarce resource.	Restructuring work scopes around an agreed standard that establishes a water carrying capacity as the benchmark. Consensus required across the professions with regards best practice and the associated re-training and overhaul of academic curriculum to bed down within professions.

	STATUS QUO	INCREMENTAL APPROACH
2.11	Planning does not anticipate climate change effects and limitations of surface water.	Overhaul water governance to include anticipatory governance and greater resilience.
3	**LEGISLATION AND POLICY**	
3.1	Lack of clarity re. water sources and permissible uses.	Common language established in the legislation and policy to be applied consistently throughout all levels of water governance and institutionalised in the National Building Regulations with specific reference to best practice and the practicalities around integrating the water cycle into urban environments, including alternative water use, particularly in the Red Book.
3.2	Rain- and stormwater harvesting not contemplated in legislation nor is alternative water (although rainwater is referred to in the policy) not identified as integral parts of water supply mix.	Clarity required throughout water governance with reference to terminology, permissible uses, storage limitations and treatment regimes. Disaggregate water uses as per a fit-for-purpose approach to limit dependence on potable water.
3.3	Full water balance management not possible because all water sources, such as borehole water not included within a single mandate.	See Item 2.2
3.4	Because harvesting not contemplated, storage quantities are not recommended	See Item 3.2
4	**PLANNING**	
4.1	Water security, water cycle and resilience not spatialized and there are no planning mechanisms or incentives.	See Items 2.4 and 2.8
4.2	Departmental silos – not integrated	Anticipatory Governance draws on a variety of types of knowledge in decision-making that seeks to set organisational goals based on the lessons learnt from past interventions and the signals derived from exploring potential futures. External and internal input is combined to identify incremental changes to interventions.

	STATUS QUO	INCREMENTAL APPROACH
4.3	Water (and other eco-services/infrastructure) not seen as integral to City infrastructure systems	Develop a plan for multi-scale water supply, treatment and storage within the IDP, MSDF and MTIFF (using the Sydney Decentralised Water Plan as precedent) Consider water security against densification and transport imperatives. Create zoning tools that protect the functioning and integrity of water resources, including aquifer and groundwater recharge areas. Implementation of WSUD within the MSDF planning and design. National Treasury to stipulate WSUD as a development criteria for compliance within the BEPP and MTIFF.
4.4	BEPP considers bulk projects, not disaggregated in line with linear, potable water projects	BEPP requirements from National Treasury to be adjusted to stimulate implementation of resilient infrastructure.
5	**GUIDELINES**	
5.1	Contradictions between documents and within documents	Common language to be established in the legislation and policy to be applied consistently throughout all levels of water governance and institutionalised in the National Building Regulations with specific reference to best practice and the practicalities around integrating the water cycle into urban environments, including alternative water use, particularly in the Red Book. Consensus required across the professions with regards best practice and the associated re-training and overhaul of academic curriculum to bed down within professions. National WSUD and SUDS design guidelines be prepared at a variety of scales that adapt principles into guidelines for implementation. Consistency across spheres of government with regards to what is permitted in urban and rural areas in relation to alternative water (all) harvesting, storage and use. Precinct guidelines (similar to the Tool) designed to collectively optimise water resources with institutional directions to assist

	STATUS QUO	INCREMENTAL APPROACH
		the private sector in establishing Water Service Providers. Implementation of stormwater guidelines and policy across all scales, so that it is not limited to the larger scales (4000m²).
5.2	NWRS(2) and the Norms (self-supply) not supported by legislation	Consistency across spheres of government with regards to what is permitted in urban and rural areas in relation to alternative water (all) harvesting, storage and use. Precinct guidelines designed to collectively optimise water resources with institutional directions to assist the private sector in establishing Water Service Providers.
5.3	Limitations created by the NWQG	Update of the NWQG to include greater support for the public around affordable alternative water testing, treating and use; Use technology to assist in water quality management.
6	**FINANCIAL**	
6.1	Financial modelling assumes a low water tariff	Financial modelling to be undertaken to determine the impact of self-supply on municipal water revenue and remedial options investigated to prevent the financial burden on municipalities.
6.2	Water not adequately priced – too cheap	The increase in water tariffs to reflect the true cost of water in a water scarce scenario;
6.3	Life-cycle costs not included	Financial modelling to consider life-cycle cost of water infrastructure and the associated risks inherent in systems failure and economic collapse.
6.4	Limited funding options	Promote inverted infrastructure that it is typically user-driven and self-organised. Incentivise water savings and alternative water using a rebate system or the like. Introduce the requirement for metering on sewage outflows for those who elect to self-supply water to allow for the measurement of sewage services.

	STATUS QUO	INCREMENTAL APPROACH
		Investigate the possibility of a water fund to assist the private sector in accessing funds for infrastructure projects. Consider the introduction of a stormwater charge to fund stormwater management, harvesting infrastructure and treatment infrastructure.

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