informal NATURES

Landscape infrastructure design for resilient, equitable and adaptable socio-ecological systems in Cape Town

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abstract

Cape town stands at top of the most “water stressed cities” list in the world, like the other global south cities, it has disregarded its natural systems in its spatial planning and water management. This pushed the city to a Day Zero situation in 2018 implementing water restrictions on all residents of the city. But the scenario in the townships are different, these service and infrastructure deficit spaces are always and constantly in ‘drought’ like environment with limited water usage and informal areas within them with no access to water. In many ways, it can be defined as two parallel worlds. The spatial development of the city much dictated by its past apartheid mechanism has led to development of townships on the periphery and on vulnerable landscapes. These landscapes fall under the biodiversity hotspots of the city which are inaccessible, abused or undervalued.

The lack of addressing socio-ecological systems in the city’s water management has further increased the inequality in townships, therefore, requiring an integrated engagement of social, hydrological and landscape processes in disaster risk reduction and in building resilience for the city, townships and biota. The research question of the project investigates on how landscape-based strategies and design principles can be applied to mitigate the drought and social inequity in townships by reinforcing inter-scalar spatial planning toward water resilience & ecosystems restoration in Cape town. Three main lenses of landscape, water and townships are used in project elaboration with theoretical underpinnings that account for resilience, socio-ecological systems, operationalizing landscapes and considering townships as ethnic enclaves. Key conclusions to frame a vision for the city through in-depth spatial analysis of the natural & social systems of the city, followed by narrowing of micro scale locations – Kuils river and Khayelitsa township.

Systems interaction between the river and township are explored to design a landscape infrastructure to increase water resilience and local adaptation measures to capture, purify and reuse, to attain circularity by involving the community. The project further explains ways to spatialize and implement such ideas at neighbourhood level through two zones at Khayelitsa wetlands and Dunes at Enkanini informal settlement to create new socio-ecological possibilities and water security. Therefore, through multi-scalar and systems approach the landscape infrastructure design addresses the questions of social inequity, drought and environmental degradation to create an inclusive and resilient city.
This chapter includes the overall context and framework to the project. The global fascination allows the identification of common challenges in South Africa with specific enquiry on the recent extreme drought risk faced by the country. Taking Cape Town as the study area, questions are raised to explore opportunities through landscape based approaches.

Fig 4: Drying up Theewaterskloof dam
Source: Dora Hegyi
“By 2050, the world’s urban population is expected to nearly double, and over 90 per cent of this growth will take place in Africa, Asia, Latin America and the Caribbean.” UNFCCC, 2017

With rapidly growing cities in the developing countries, there is an increased encounter of climate change causing vulnerabilities of various dimensions. The unprecedented growth and the speed by which it does, largely influence the shaping of our settlements and built environment. As a result of global warming, the type, frequency and intensity of extreme events, such as tropical cyclones, floods, droughts and heavy precipitation events, are expected to rise even with relatively small average temperature increases. Changes in some types of extreme events have already been observed, for example, increases in the frequency and intensity of heat waves and heavy precipitation events (IPCC, 2017). Population expansion leading to large consumption takes heavy toll especially on the water sector in most countries. According to WRI, currently there are 37 countries that face “extremely high” levels of water stress, which includes South Africa, India, South America etc. In most cases, the disregard of natural systems in the spatial planning of the city causes irreparable damage leading to a complex problem. Losses faced due to disasters caused by climate change not only limits to our immediate lives but also hinders our support lifelines such as biodiversity, water, land etc that can only be experienced on a longer run.

UN-Habitat estimates that 881 million people or 30% of its working country urban populations live in slums (UN-Habitat, 2014). This could rise to 3 billion or 60% by 2050 (UN, 2014). The climate change discourse takes a rather different approach considering the urban poor. In the presence of inequity and inequality, the lack of basic services and infrastructure to sustain normal lives causes extreme vulnerabilities and exclusion from the existing urban fabric.

As a native of Chennai – one of the metropolitan cities of India, it has been subjected to disasters in the past such as tsunami, cyclones, droughts and flooding, which still goes through the challenge of reviving from damages that occurred while still running to be a “world-class city”. Lack of institutional capacity and haphazard development on environmentally sensitive locations challenged the city by 2015 El-Nino induced heavy rains leading to disastrous flooding. As a result, losses up to 200 billion and many lives were taken away. On the other hand, Bangalore is listed as one of the most water-stressed cities facing drought condition in the world, calling for immediate mitigation action. These two cities follow similar development trajectory as many Indian cities lacking resilience toward climate adaptation. One such phenomenon is the duality of water, co-existence of both droughts and floods. In the presence of inequity and inequality, the problem is further exacerbated in assessing the existing water infrastructure and access to resources in times of high risk. This ongoing phenomenon is scaled across several developing regions, therefore calls for an in-depth study of the water related issues in the Global South. Among all, the topic of droughts is chosen due to its recent events in many of these cities. By understanding the Indian context, exploring the neighbouring country of South Africa, since it tops the list of water-stressed cities as well as similar social situation to arrive at a broader yet in-depth solutions to respond to this problem.

The necessity to approach this complex issue by understanding the socio-ecological system and not as separate entities then become important. The post-apartheid city of Cape Town is the best example to explore on this topic, as it not only experienced “Day Zero” recently but is also highly fragmented spatially further increasing the complexity. Such questioning requires a multi-disciplinary approach of engineering, social science, psychology, water management, urbanism and landscape architecture that very well falls under the ideals of Delta urbanism, at the end aiming at Infrastructure and Environment Design annotation.

Fig 5: Flooding situation captured in Chennai city due to heavy rains caused by El-Nino. Unprecedented development on natural ecosystems and poor governance affected the city during floods.

Source: Modified by author
01.02 Climate change trends and risks in global south

According to the study done by World Resource Institute, 37 countries currently face "extremely high" levels of water stress, meaning that more than 80 percent of the water available to agricultural, domestic, and industrial users is withdrawn annually (WRI, 2013). Water scarcity caused by climate change is exacerbated by other factors such as poor governance, ineffective water management, ecological decline etc. Many cities are being added to the list day by day. The most astonishing finding from the study is that most cities are situated in the developing countries. With existing problems in place, water scarcity challenges these cities in normal functioning and to be able to grow in a sustainable manner. Drought is inevitable in many of these places, how can solutions be created to cater the on-going issue as well cater to the growing population in these cities. While the socio-economic dimension are often brought up in such crisis situation, most neglected is the environment which solely is the source of water. The most undeniable problem of today is the development that happens on sensitive ecosystems disrupting its natural functioning to reduce climate related impacts such as droughts, floods, heat etc.

Fig 6: (above) Water stress by country
Source: World Resources Institute

Fig 7: (right) Flooding in resettlement colony in Chennai, India
Source: Tamilnadu Slum Clearance Board; Modified by author

Top water stressed cities:

CAPE TOWN
SAO PAULO
CHENNAI
BEIJING
LONDON
TOKYO
CAIRO
BANGALORE
JAKARTA
MOSCOW

The picture that comes to one's mind hearing the words slum, poverty, disaster is usually a degrading settlement situated on or adjacent to a vulnerable natural environment. It is true not just in developing countries but in the developed ones too. In these spaces, water take up a dual role by being deficit through droughts or excess as floods. These are a result of neglecting the local natural systems and planning development accordingly. One such case to elucidate the problem is Semmenchery resettlement colony in Chennai, developed to meet low cost housing demands. Communities residing on or near vulnerable natural ecosystems were evicted from different parts of the city to avoid impending danger. The ironical part is that these communities were relocated to a more vulnerable location. Not only was it a low-lying area which will be subjected to periodical flooding but also took away the organizing means known to the community as they were housed in high rise buildings, previously lived in shacks. Many things can be learnt from this example, of which the key takeaways are,

1. Taking into account the local landscape to carefully develop and increase ecosystem services.
2. Involve the community in the development process
3. Design for the future of the community

To also account for is the very duality that can mitigate the effects of each other. Careful management of flood water can provide for the dry seasons to the local community and to the rest of the city.

01.03 Dual nature of water in the formal and informal

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It was predicted by many scientists and academics since 1970s that Cape town will be facing severe drought condition in the future. With no more sources to augment water supply, the city has moved to water demand management rather than supply management strategies (Visser, 2018). The City of Cape Town receives majority of its water from 6 major dams and three years of drought pushed it to a crisis point where the dams were filled only 1/5th their capacity. It was predicted to enter a day zero situation in May 2018 but due to effective management and public engagement, the condition is well under-control. It led the city government to restrict water usage to 200 litres/person/day. Mainly criticized to be governance failure, there are several reasons as to why the city stands in crisis today. The main causes of the day zero condition are a combination of both natural and urban phenomena.

Causes:
- **EL NINO** climate change
- HYPER-SEGREGATION apartheid
- **URBANIZATION**
- INFRASTRUCTURE DEFICIT
- GOVERNANCE FAILURE
- environmental degradation
- politics

Reservoir storage capacity during the water crisis

The impact of the water crisis hit several sectors ranging from residential to industries. The outcomes of it can be categorized into two, affecting the affected and the future. The restriction took a big blow on the tourism industry while it did not matter to the vulnerable communities as they were already living in the same conditions of day zero with minimal access to water.

Response:
- “South Africa’s drought-stricken Cape Town has pushed back its estimate for “Day Zero,” when taps in the city run dry and people start queuing for water, to 2019 from August of this year, and data show dam levels rising elsewhere in the country.” (Reuters, 2018)
- “Tough water restrictions, plus punitive tariffs, will drive down water demand, helping to postpone Day Zero.”
- “Due to the major impact of the drought, we need to invest in other water sources due to low and unreliable rainfall”
- “…new projects will also bring additional water from tapping into the aquifers and from desalination.”
Amidst the water crisis, parallel phenomena in the city that forms its overall fabric are:

1. Flooding in the townships and informal settlements. This goes back to the whole statement of the existence of excess and little water at the same time. These settlements are often found at the banks of river and wetlands posing a vulnerable threat to the environment and vice versa.

2. Equity problem. Its only in South Africa can one easily recognize the stark differences between neighbourhoods due to apartheid planning. Posh villas with large green lawn area vs tin shacks with no access to water nor sanitation. These informal settlements are often situated within townships and mostly identified as black communities.

3. Cape town is rich in biodiversity bringing tourists from across the world. The wide range of flora and fauna embedded in different landscapes create economic boost to the city and country through tourism.

The city sets a good ground to explore the dimensions of environment, equity and economy to engage further towards planning of drought mitigation strategies. The dearth of integrated design and planning is certainly the root cause of such extreme disasters. Therefore, studying the natural, urban and informal processes of the city can give great insights to replicate in other contexts across the world.

This worsens in the time of water related disasters, especially in service and infrastructure deficit spaces such as the townships, leading to further exclusion of these communities from the rest of the urban fabric. The failure to address informality in the formal spatial development and the location of townships in sensitive eco-systems add to the problem. In such complex situation, it requires an integrated engagement of social, hydrological and landscape processes through systemic landscape approach in disaster risk reduction and in building resilience for the city, townships and biota.
From the stated problems of the city pertaining drought, it is evident that it has other inseparable dimensions of social and ecological value. The goal of the project is to attain water security, ecological upgradation and social mobility in townships for a good integration with the rest of the urban and natural systems of the city. The presence of settlements on sensitive ecosystems further describes the complexity, thus requiring a landscape based approach to ideate new conditions to mitigate risks and increase capacity both in physical and social terms. “...urban landscape infrastructure offers a renewed understanding of the landscape as infrastructure, which needs to be explored on its opportunities and possibilities for strategic regional design and local interventions. It stimulates design disciplines like architecture, urban planning and landscape architecture to cooperate and review the agency of design giving shape to the built environment, and establishes relationships between ecology and socio-cultural aspects, between process and form, between the space of flows and the space of places.” (Nijhuis et al, 2015)

Consideration of landscape as infrastructure can help to respond to these problems in an integrated manner tying the three main E’s of equity, economy and environment, thereby, setting the scope to enquire other parameters. Theoretical underpinning on resilience, socio-ecological systems as well as identifying the essence of the ecological importance in this project. This approach will allow for the understanding of regional and local systems and unearth the potentials to operationalize the landscape. The over-arching and specific enquiry into these challenges can be explored with these research questions.

**Research Question:**
How can landscape based strategies and design principles mitigate droughts and address social inequity in townships by reinforcing inter-scalar spatial planning toward water resilience & ecosystems restoration in Cape town?

**Sub-research questions:**
1. How are the townships in Cape town linked to its natural environment and what are its ecological value. The goal of the project is to attain water security, ecological upgradation and social mobility in townships for a good integration with the rest of the urban and natural systems of the city. The presence of settlements on sensitive ecosystems further describes the complexity, thus requiring a landscape based approach to ideate new conditions to mitigate risks and increase capacity both in physical and social terms. “...urban landscape infrastructure offers a renewed understanding of the landscape as infrastructure, which needs to be explored on its opportunities and possibilities for strategic regional design and local interventions. It stimulates design disciplines like architecture, urban planning and landscape architecture to cooperate and review the agency of design giving shape to the built environment, and establishes relationships between ecology and socio-cultural aspects, between process and form, between the space of flows and the space of places.” (Nijhuis et al, 2015)

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1. How are the townships in Cape town linked to its natural environment and what are its ecological value.
2. What are the ways to create spatial conditions and improve eco-services to counteract social-inequity, drought and environmental degradation?
3. How to apply spatial strategies and principles to create flexible systems by activating and re-purposing green spaces in and around townships, as public good and conservation mechanisms of local ecosystems?
4. How to scale up local adaptation techniques to city and regional scale for integrated water & landscape planning and management?
5. What is the replicability of these landscape-based approaches for water resilience, social equity and cohesion in other neighbourhoods of Cape town, and their application in other global contexts?

The possible outcomes by responding to these questions will include strategic vision for Cape town with micro scale landscape-based approaches and micro scale landscape infrastructure design interventions in a township.
METHODOLOGY

In this chapter, the framework to carry forward the project is elaborated such as the theoretical underpinnings guiding the analysis and design approach. Theories like sustainable development, evolutionary resilience, socio-ecological, operative landscapes and ethnic enclaves drive the umbrella systems approach by enquiring three chosen lens in the elaboration of the challenges and creating framework for design exploration. It also contains the method by which the research was conducted with the framed research questions and how they inform each other.
There are five main theories guiding the whole process of research and design. Principles are derived from it and relevant projects are chosen that adhere to these theories. Further, there are sub-theories that looks at specific themes within each section of the theory column.

06 THEORETICAL FRAMEWORK

These further help in the design process to create dynamic and flexible spaces within the township that must also respond to the social needs of improved eco-services in relation to the local landscape. It is further elaborated within each section of the theory column.

The model is conceptually considered as the three-legged stool (Hasna 2006) of sustainability, where each leg is equally important in building a sustainability standard that is sound and balanced. It sets the overall scope of the project in bringing all three dimensions in research and design engagement. In the context of Cape town, its awe-striking urban fabric calls for new engagement in the case of water crisis. It requires an integrated spatial development accounting for water & biodiversity conservation, uplifting the quality of life for the discriminated population and creating economical sustenance conditions.

By giving equal weightage to the three E’s of environment, ecology and economy sets the overall scope for the project assignment by considering both the natural and urban systems in achieving a holistic design. Applying these principles through all scales makes sure to resolve the highly fragmented urban and natural landscapes. It also allows for the extraction of key principles that can be applicable in other global contexts especially in the post-colonial cities.

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The evolutionary perspective broads the engineering and ecological description of resilience to incorporate the dynamic interplay of persistence, adaptability and transformability across multiple scales and timeframes (Folke et al., 2010). To allow for such complex interaction, spaces should account for both social and ecological flows to provide enough openness for unprecedented future risks.

In this case it is important to imagine alternate resilience structures for the city and townships by turning crisis to opportunity (Davoudi et al, 2012). The overarching disastrous drought condition of the city and flooding in certain locations that are mostly in the informal settlements due of its lack of safe built structures and proximity to sensitive landscapes demands local resilient strategies. By addressing the problematic view of resilience as hierarchical which scopes down the dynamic nature of resilient building, the panarchy model of adaptive cycle suggests that resilience does not have to be in a sequential manner and occurs through nested adaptive cycles. The four main phases stated by the panarchy model in no specific order are reorganisation, growth, conservation and creative destruction. Adopting these in the conditioning of open spaces addresses different dimensions of landscape conservation, water production, provision of economical eco-services, communities gathering space etc. To make a successful planning strategy, it is important that it provides for self-organization by the local communities in such circumstances, demanding active participation in the process. Therefore, the spatial manifestation of such resilience creation asks for a multifunctional, shock absorbent patches through stakeholders’ interaction toward an all-inclusive and sustainable future.
Landscape as infrastructure

"Conceiving landscape as infrastructure can be characterised as a goal-oriented approach, where landscape is treated as an operative field that defines and sustains the urban development and ecological and economic processes are employed as formative design tools." (Nijhuis et al., 2015)

The main objective of the project to design resilient, equitable and adaptable socio-ecological systems by three chosen lens of landscape, water and townships have a definite need to take up landscape approach. It sets base to map the existing green-blue systems and urban systems attached to it. Its systemic view on urban development therein will take in to account the different scales – from regional to township level to identify the synergies and potential ways to mitigate risks by activating landscapes. Consideration of landscape to perform as infrastructure in mitigating the drought condition brings forth a multi-scalar and multi-disciplinary approach by bringing together the social and ecological aspects in designing space.

d. Operative Landscapes

"Ethnic enclave" can mean two things, one is an enclave economy while the other means a residential area concentrated by a particular ethnic group (Portes et al, 1992). Social capital plays a big role to establish migrant networks and reap its advantages in such enclaves (Massey, 1999).

The historical division of varied ethnic groups in Cape town has resulted in highly fragmented city. Therefore, it is key to take into account that each neighbourhood is unique and is defined by its people, their cultural and religious practices. Especially the townships serve as ‘arrival cities’, people throng these neighbourhoods in search of jobs and better life. The potential increase in crime and neglected by the rest of the society make these locations as separate pockets with its own characteristics and informal economy. Hence, the reasoning to understand enclaved areas also provides new insights in dealing with challenges different from the overall approach of the city and yet informing the larger urban development structures.

e. Ethnic Enclaves

Organizational chart

The overall method to address the questions and framing of framework to arrive at strategies can be understood through this scheme.
The research is based strongly on the principles of ‘operative landscape’ and ‘evolutionary resilience’ and thematic studies on climate change, apartheid, landscape urbanism, therefore involves extensive literature review of books and research papers on the above. Existing policy documents and spatial framework on water management, biodiversity and informal settlement upgradation are critically reviewed. Information on the local conditions are studied through online archives, books and interviews, mapping, photography, videography during the field visit.

**Thematic Studies**

Studies on climate change with specific focus on droughts globally and with location context on the vulnerabilities has been done. The development of the city based on its historical apartheid planning along with the landscape transformations of Cape town been done. Study on water circularity and local adaptation techniques have been given great focus in the research.

**Spatial Analysis**

Several thematic analysis across scales conducted in the study including vulnerability, landscape, urban development, density etc (refer organizational chart for others). The interactions of social and ecological dynamics sets foundations toward understanding the equity issue by bringing forth the settlement pattern based on the city’s landscape. The multi-scalar analysis enables the understanding of the watershed management systems and its relevance at local scale and vice versa.

**Systems Analysis**

Key systemic changes between micro and nano scale are explored in order to arrive at strategies to strike a balance to achieve the project goals. The systemic approach is further narrowed to local scales to map the inter-relationship between people and ecology and the overall eco-services provided by natural landscapes. This allows for designing specific to the landscape to support the existing and create new socio-ecological system possibilities.

The project works across multiples scales from basin water management level to neighbourhood scale in the townships. Interaction between scales is a key principle in the project therefore dictating the analysis phase to substantiate the design outcomes. This multi-scalar interrelationship is key in activating landscapes at micro and local scale.

**Identification of spatial strategies and design**

The key spatial strategies and design interventions are formed by taking the existing green and blue systems on the site. It is further developed by integrating transport infrastructures to create conditions for future development.

**Research by Design**

Reading of the local site through design explorations, bring-forth the practical and spatial implications of a certain design allowing further refinement to suit the local conditions. This exercise allows to reflect back to the initial research objectives for further iterations.

**RESEARCH METHOD**

**07.01 Thematic Studies**

**07.02 Spatial Analysis**

**07.03 Systems Analysis**

**07.04 Identification of spatial strategies and design**

**07.05 Research by Design**
The aim of the project Favela Bairro (from slum to neighbourhood) is to integrate the favela with the rest of the urban fabric, by providing basic urban and social services. It is still a forefront example in slum upgradation through landscape strategies through retroactive measures for overall well-being of the community rather than being traditional housing focussed (Costante, 2012). The actions taken adhered to create a neighbourhood by creating paved streets, plazas, urban furniture and public services. One of the main principles used in the project is penetrating the favela through a serviced street system which breaks the introverted orientation and create new connections for new spaces and social functions (The Shadow City, 2012). This principle will be apt for Khayelitsha in the integration of informal settlements with the rest of the community and natural environment. However, the project did face few failures, the most noticeable one is the unemployment rate which is still high provided its main goal to create social mobility and ill-maintainance of the interventions by residents (Getrevising, 2018). Therefore, these two parameters will be addressed in the local elaborations of the design project.

In 2015, the CoCT and WCG signed a memorandum to use the prime land between Black river and Leisbreek river to undo apartheid spatial planning in the area as well as to create opportunities for low income families. The main objectives of the project is to trigger social inclusion, restoring and preserving ecological integrity, sustainable mobility, medium density affordable housing, creating jobs, etc. (WCG, 2016). By acknowledging city’s past history and the current inequality, the project uses the landscape as a common ground to de-fragment the neighbourhoods. It sets a good example in the integration of green, blue and transport infrastructures in promoting new sustainable urban development.

Every year, Dunea produces 73 billion litres of drinking water for 1.2 million people through systematic purification process of river water in the natural dunes present at Hague. These areas are nature and recreation areas serving the local people and ecology, becoming more than an engineering project. The process involves sending water into infiltration ponds created on the top of the dunes which is absorbed and filtered by sand to reach the ground water table. The fresh water floats on top of the salt water, therefore excess extraction can lead to salt water intrusion. But the downside is that water is brought from River Maas, almost ninety kilometers away rather than finding closer alternatives and connection with local communities.

Whereas in Koksijde (Belgium), the drinking water company IWVA produces drinking water through two sources, natural groundwater (35%) and sewage water (38%). The reuse of sewage water is made possible due to “ultrapurification” and “reverse osmosis” in order to be used in the infiltration basins. By using black water, they are able to match the supply to the demand during peak summer times (The Bliedemaker, 2017). They also work closely with communities to educate and create awareness on the process to change their mindset on black water. Using sand dunes purification can be a huge asset in the context of Cape town.
This chapter covers the analysis of the different layers of the natural and social systems of Cape town and its interactions. The main takeaways is further analysed with the present water management of the city to arrive at planning and design strategies.

Fig 21: Confluence of Kuils-Eerste rivers into the Indian ocean
Source: Author
Cape town is unique in its landscape shaped by forces over a million years ago. Situated in the southern tip of African continent, the wind and tidal influence on the predominantly sandy area has produced varied landscapes within a small expanse of land. Around 500 million years ago, sandstone was formed under water creating the central plateau and cape fold mountains. At 300 million years, the sandstone ground solidifies in magma during the continental drift resulting in sandstone granite Table mountains that forms a scenic view along with the urban skyline in the city today. At 5 million years back, Cape Floral Kingdom containing the most unique plant species called Fynbos came into existence. This has located the city as one of the most biodiverse cities around the world. The city draws thousands of tourists and nature enthusiasts visiting many of the biodiversity hot spots. Each of these areas are unique in its ecosystems that form a larger ecological network having an important role in keeping the city healthy and diverse. Many of the indigenous and endemic species face threat as they are intertwined within the urban fabric falling prey to the human activity in and around the landscapes. There needs restoration in many of these ecosystems. In order to restore the existing biota and given the diversity in the landscape typologies require an integrated approach to enable the local communities to steward conservation. Especially the critically endangered species of Strandeveld in the Cape Flats Region(CFR), is further challenged by the growing informal settlements in the townships situated.
Sectional profile

The historical evolutionary processes has created distinctive landscapes from mountains to flat sandy area to smaller hills.

08.02
Landscape Typologies

The city has four types of unique landscape typologies:

1. Sandstone mountains in the south west land and east where the sandstone mountains of the Table mountain chain and the Hottentots Holland-Kogelberg ranges are situated.

2. In the centre lies the Cape flats, its sandy nature holds important aquifers namely Cape Flats aquifer and Atlantis aquifer.

3. Dunes and beaches in the western and southern coastal edges.

4. Low shale and granite hills which have historically been converted to farmland, located in the northern part of the city.
The resulting environment in the city due to its geomorphology are the locally restricted species or endemics that constitute the Cape Floral Kingdom. It is renowned for its high richness of plant species, thus is an important component of the Cape Floristic Region (CFR) which is one of the World’s Heritage Sites and plays an important role in the ecological structure. The CFR belongs to the Fynbos biome which is in high concentration within the urban matrix posing major challenges for conservation (Rebelo et al., 2011). These unique species make up to one-sixth of South Africa’s flora (Biodiversity report 2018, City of Cape Town).

The city supports a variety of wetlands and rivers where the lowlands contain many seasonal and perennial wetlands interconnected via the groundwater system (Day 1987). Marshlands and floodplain wetlands, locally called the ‘vleis’ are found mainly in the Cape Flats region. These vleis and marshlands have been modified due to urbanization leading to floods and ecological decline. Kuils river is a good example where it meandered across the Cape Flats in the past has been straightened to give way for development. Moreover, turning the seasonal river to perennial due to discharge of sewage water has resulted in loss of habitats for important birds and plant species (Biodiversity report 2018, City of Cape Town).

Shown below are some of the species located specifically in the freshwater ecosystems.
The settlement that would evolve to become the present-day City of Cape Town has been a gradual process driven by economic, political and environmental considerations, from a small refreshment station for passing ships into a busy city of over 3.7 million people (City of Cape Town 2012c). In order to get a clear understanding of its spatial formation, profiling its historical development across years through the lens of apartheid will give clues to planning strategies in de-fragmenting the urban fabric.

Irrespective of the efforts made by the city to reverse the apartheid effect, it still remains spatially fragmented and socially segregated. The apartheid mechanism of segregating through transport networks and open spaces has led to disintegrated neighbourhoods making interactions between different social groups difficult. Till date, the Cape Flats region remains deprived of services and vulnerable due to lack of capacity of many settlements. The location of townships on the sandy region and high ground water table make provisioning of basic services a huge challenge. Therefore, it is key to account for the high density, ethnicity, local culture and knowledge in addressing the drought problem. By doing so, renewed relationship of people and biota can be formed to create eco-services for the community and in making them inclusive with the rest of the city.
1300-1500s
Khoesan establish ties with the Portuguese

1652
Temporary refreshment for ships of Dutch East India Company

1658
Permanent settlement on eastern table mountains

1764
The city is strategically located for easy access to freshwater from the mountains and for protection.

British seized control; 17000 population

1800
Two railway lines connecting to Eerste river and Wellington laid, becoming main development lines.

The need to accommodate labourers who were predominantly black and coloured were pushed to the periphery of the city. Beginning from lodges to accommodate, it moved to the establishment of townships. The first one came up based on the Urban areas Act 1923, named Langa. On the other hand, the white suburbs adopted the Garden city model.

Eviction of coloured and black population from the city’s urban core to the periphery. Apartheid, a systematic categorisation and segregation of racial groups came into place. Due to increasing population, there were emerging squatter camps.

1960
More eviction of non-white population from city centre, eg: massive removal at District 6. As a result, new public housing development and townships were planned on Mitchell’s plain and Cape flats as land was cheaper due to sandy and infertile soil conditions. (Myers.L, 2013)

1970s
Re-emergence of slums in city’s periphery

Agglomeration of spaces along the transport networks

1980

1992

1983

Middle class row housing in Mitchell’s plain
Khayelitsha Township planned in Cape flats for legal African residents.

Apartheid was abolished and the racially based land acts were terminated.

HISTORICAL EVOLUTION of Cape town

Fig 39: Cover
Source: Dora Hegyi
Fig 40-46: (left to right)
Sourced from:

a. Author
b. https://tristannaarzuidafrika.reislogger.nl/berg.42666
c. https://adamson-eric.ekm.ee
d. http://www.capetown.at/heritage/history/apartheid.htm
Urban Development

The city’s growth began within the shelter of the Table mountains later growing along the transport networks. Its radial pattern results from the road and railway lines connecting to main ends of the city and with other cities. The historic centre is still the economic hub of the city where the citizens travel to, making it a highly centralized urban fabric.

Hyper Segregation

The resulting urban fabric after years of apartheid planning are socially segregated and highly fragmented spaces. The systematic division was created mainly through transportation networks and open spaces between the different neighbourhoods. These townships, in ways become ‘the arrival city’ where migrants from other parts of South Africa move for better life. Migrants of a particular ethnic group move to the township of the same ethnicity for easier social mobility and cultural habits.
Density

There is a large disparity between densities in formal and informal townships. The formal are usually low density with predominantly white neighbourhoods, they are well connected to the rest of the city due to private vehicle access. On the other hand, the informal townships have high density with black/coloured population located in the city’s periphery with limited access to public transportation system (Cape Town Metropolitan Spatial Development Framework 2018-25).
Cape Town gets over 95% of its water from a system of six rain-fed dams that also supply agriculture and other urban areas. The combined dam total storage volume is about 900 million cubic meters of water, which provides enough water for around a year and a half of normal usage by both agriculture and urban users, after taking into account evaporation. During periods of low rainfall, restrictions are implemented (Unpacking the Cape town drought: lessons learned, 2019).

The city has an estimated population of just over 4 million people, with 14% of households living in informal housing. The growing housing challenge has resulted in increasing numbers of people living in backyard shacks, with increasing demands on water and sanitation services. In terms of water use, residents in formal housing use 66% of the City’s water, while informal settlements account for only 4% of the consumption. About 1.5 million people, making up more than a third of the total population in the city, cannot afford to pay for water and therefore are eligible for a free allocation each month. There are several aquifers within the City of Cape Town municipal area, including Atlantis, Cape Flats, and Table Mountain Group. Access to the groundwater in these aquifers is via springs and boreholes (The watershed project, 2019). Large-scale groundwater abstraction of about 126 million m³/annum for both urban and agricultural use.

The 6 major reservoirs had only 26% of its total capacity in April 2018, pushing the city to impose restrictions on residents and find alternate solutions. It has been observed that such back-to-back years of weak rainfall happens only once in 1000 years, moreover the lack of infrastructure and population growth has exacerbated the problem.

The city’s high dependence on dams for its water and its ineffective management of water at micro-watershed level creates vulnerability to its residents and businesses. Provided its frequent exposure to droughts, it is important to manage water at local scale by harnessing its natural systems such as rivers and wetlands for holistic provisioning of water. Moreover, other types of water such as grey and black water should also be taken into account.

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Inter-relationship

11.01 Challenges

- Informal settlements
- Safeguard the city.
- Healthy functioning of natural systems
- Due to above mentioned points prohibiting risks, crime, unemployment, etc.
- Region highly vulnerable to climatic calamities.
- Packing all the poorer neighbourhoods to one region that is highly vulnerable to climatic calamities.

11.02 Vision

Cape Town’s Integrated Development Plan (IDP) 2017 – 2021
Cape Town Water strategy 2016

- Some of the most important principles from the visions and different projects led to forming of the city to be more inclusive, resilient and nature harmonizing.

Some of the most important principles from the visions and different projects led to forming of the city to be more inclusive, resilient and nature harmonizing.

Withholding the principles formed, certain main strategies were framed to respond to the existing challenges.

1. Water to be managed at micro-watershed level, in a way decentralizing water systems and governance structure.
2. Agriculture economy to become more sustainable and water efficient through reusing water and adopting new practices.
3. Restoration and conservation of biodiversity in townships to provide eco-services, especially in supplying clean water for all.
4. To promote and encouraging local cultivation and local governance structure.
5. Several economic nodes to be created across the city by considering local workforce provided to the townships.
7. Adopting circular systems in townships to make them self-sufficient and become water resilient.
8. Restoration and conservation of biodiversity regions across the city in establishing lost connections within and with larger ecological regions.
9. Micro-watersheds management through reusing water and adopting new practices.
10. Sustainable urban planning through reusing water and adopting new practices.

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These key strategies act as over-arching principles that assist in transforming the existing challenges.

Theoretical framework

Government policies

Visioning of the city to be more inclusive, resilient and nature harmonizing.

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These key strategies act as over-arching principles that assist in transforming the existing challenges.
This chapter explains the inter-relationship of the three chosen lenses of landscape, water and townships to arrive at focus areas. It also describes the overall strategies and principles formed for the city of Cape Town that guides the whole design project.
Three lenses

12

Townships vs the city

The sandy nature of the Cape Flats region, often seen as poor and difficult terrain to develop, was of least interest for the rich, making room for public housing and township developments. One of the main characteristics of sandy soil is withholding water both on surface and below ground level, in the form of wetlands and aquifers. The Cape Flats Aquifer produces a high amount of groundwater, grabbing enough attention of the city during the drought period to tap it. Full-fledged effort to use the aquifer for the city’s water supply is ongoing, but the pollution in the water caused by settlements make it unfit to use, at least for the moment. This is mainly due to a dearth of the local community’s interaction with their natural surroundings. While the city tries to find different means to grab water, in the same locality there are communities with no access to water or limited supply, raising the question of equity. These townships are either coloured or black, having different social and cultural identities. They often disassociate themselves from the city’s projects in their localities as they are not involved in the process. They disregard these projects being too “white”, therefore triggering local upheavals. It can be better understood through the case of Khayelitsha (fig5), one of the largest black townships in the city. Situated on the sand dunes and wetlands, the cultural connotation with open spaces developed within the township are much different than the spaces created by the city. The black community sees bird watching as a rather “white” sport which has no relation to them while their cultural connections to the river and wetlands are cattle grazing, religious proceedings, medicinal use of the vegetation, social gathering, etc. But the public projects in their locality as a measure to upgrade lack context. This often lead to protests by the communities categorizing it as vandalism by the city. Contestation to rightful space, land and basic services situate these communities and the local practices and relationships. These variations of development on landscapes show the need to have localized engagement in planning decisions.

Conclusion

Taking the lens of water, landscape and townships, the complexity playing out at all scales in Cape town can be understood. Reading the natural and human systems indicates how historical planning can lead to contested territories and landscapes thus becoming the underlying guide to dictate social segregation. Socio-ecological way of analyzing on a local scale becomes key to gain understanding to inform socially cohesive and environmentally just interventions. The existing lack of infrastructural capacity can be added to the ineffective functioning of the natural systems further exacerbates the climate risks.

Cape Flats, the “apartheid’s dumping ground”.

With close to 1 million black and coloured population living in Cape Flats and also given its rich biodiversity and location of one of the most yielding aquifers it becomes a good case to study. In order to explore local scales, the study is further narrowed down to Kuils river and Khayelitsha township which holds all the variables to explore the integrated approach towards drought mitigation.
13 MICRO SCALE & NANO SCALE

Area of exploration
By further exploring the Kuils river corridor, the combination of two main landscapes can be studied together to understand the systems interaction across scales to arrive at strategies and design principles.

1. River and wetlands
2. Sand dunes and beach

The social interactions are further elaborated at Khayelitsha township scale (nano).

13.01 Kuils River
**History of Kuils River**

Historically, the Kuils river was seasonal draining into a large area of sand dunes, and being a main source of recharging the Cape Flats aquifer. With catchment area of 240 sq.km, it never reached the sea but emptied into a series of pools or ‘kuils’. It begins from the affluent town called Durbanville and disappears in the dunes at Khayelitsha. Around 1980s, it gave way to low-cost development where several townships such as Delft, Mfuleni, Blue Downs, Khayelitsha were built on or near the original river bed. The Kuils river is closely associated with the townships, which largely sit on former wetlands which has considerably change the run-off pattern.

The Kuils river runs along various neighbourhoods, ranging from the rich Durbanville to poorer ones such as Khayelitsha township onwards connecting with Eerste river to finally discharge into the sea. Its course begins from Durbanville Golf club, into the industrial area running parallel to the N2 highway it reaches Driftsands Nature reserve and Khayelitsha wetlands where remnants of historical dune slacks are still visible (Rivers and Wetlands of Cape Town, n.d). Apart from wetlands giving way to development, the river has been modified through channelization and turned perennial due to discharge of effluents from waste water treatment plants. This also leads to high pollution of water, in turn pollution the cape flats aquifer.

**River profile & environs**

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**Historical development of Kuils River**

[Diagram showing the historical development of Kuils River with labeled areas and annotations.]

**River profile**

[Map showing the river profile with labeled areas and annotations.]

**Invasive species**

[Map showing invasive species along the river profile.]

**Sources**

Rivers and Wetlands of Cape Town, n.d.

Fig 60: ‘Kuils’ in the lower part of the river, 1987

Fig 61-63: Maps of the river profile with labeled areas and annotations.
1. 1970: Source canalized
2. 1988: Kuils river wetlands bulldozed to create Khayelitsha
3. 1990: Artificial canal built to drain Blue Downs development
4. 1991: Detention dam
5. 1991: Canalization at the industries
6. 1991: Kleinvlei canal draining into Kuils
7. 1992: Expansion of Macassar WWTP
8. 1995-97: Nooienfontein Vlei canalized
Feeding into Kuils vision

Khayelitsha is a formal township housing the ethnic group of Xhosa. It has and still faces the challenge of incoming migrants from Eastern Cape and the absence of enough housing has given rise to informal settlements. It is known to be the largest and fastest growing township in South Africa (wikipedia, 2019). Apartheid planning of township is seen as the neighbourhoods within it are divided by transport networks and open spaces, similar to the overall division of the city itself. Typical to any poor locality, the initial proposed infrastructure has lost its function or peaked its capacity due to rapidly growing population. The township situated on former wetlands has declined the health of river and aquifer quality. In turn, the settlement faces extreme climatic risks such as flooding, drought, fire etc., by also contributing in the deterioration of its landscapes. Spatially it divides many important green networks that are part of larger nature conservation region connecting the city with the coast. However, it still has indigenous practices of farming medicinal plants in wetlands and dunes, conducting religious and initiation ceremonies.

Overview understanding of Khayelitsha, indicates the need to design of infrastructure specific to the location as well as find means to correlate with Kuils river. In a way operationalizing landscapes in different manner which will be further explored in the upcoming sections.
The township has unique presence of varied landscapes in short span of area, which can help in establishing circular water systems – one of the ways to look at it, is to see how water can be captured, purified, recharged and reused. In this case, water can be captured in the lowest points, purified through plants and further purified by higher dunes which then can recharge the ground water table. Rain water harvesting should also be installed within the houses. This improvised way of dune filtration process can provide and secure water for the township.
EXPANDING INFORMAL SETTLEMENTS UNDERUSED AND UNSAFE GREEN SPACE DIVIDED NEIGHBOURHOODS ROAD INFRASTRUCTURES AS BARRIERS AQUIFER POLLUTION UNDERUSED AND UNSAFE GREEN SPACE SAND MINING

The river goes through ‘NIMBY’ (Not In My BackYard) situation right from the north till the south, where the buildings face against it with almost no access nor public parks.

Canalization increases the water runoff thereby causing floods and holds limited capacity during heavy rainfall.

Pollution caused at the industrial area and by water effluents from WWTPs.

The other challenges that the township faces are unemployment, limited housing, safety and lack of basic services.

Apart from the water pollution caused by the township, such as the aquifer, wetlands, dunes and the river, these neighbourhoods are segregated by transport networks from its neighbouring communities.

The townships act as arrival cities where slums are built over night, most often on sensitive ecosystems facing vulnerability of floods, fire etc. They also become a polluting source at the wetlands due to discharge of sewage and disposal of garbage. As a result, the aquifer water gets polluted.

Sand mining near Macassar poses as a potential threat to sea level rise upon extensive excavation. It also threatens the indigenous vegetation growth.

Most green spaces are inaccessible due to fencing, function and safety.

The challenges included in the township are employment, limited housing, safety and lack of basic services.

Canalization increases water runoff by causing floods and holds limited capacity during heavy rainfall.

Pollution caused at the industrial area and by water effluents from WWTPs.

The townships act as arrival cities where slums are built overnight, mostly on sensitive ecosystems facing vulnerability of floods, fire etc.

Apart from the water pollution caused by the township, such as the aquifer, wetlands, dunes and the river, these neighbourhoods are segregated by transport networks from its neighbouring communities.

The other challenges that the township faces are unemployment, limited housing, safety and lack of basic services.
Kuils river: Vision

Since the challenges in the locality are beyond ecological, the vision incorporates a comprehensive and integrated strategies addressing blue, green and road infrastructure that can enable a water resilient area and promote social inclusiveness. This vision will be a guiding force in developing strategies and landscape infrastructure design strategies at Kuils river and integrated water resilience plan at the township scale.

**RIVER AS DEVELOPMENT SPINE**

It looks at the river as a development space connecting all neighbourhoods.

**DEVELOPMENT NODES**

The green spaces along the river act as multi-functional spaces for water absorption and for community engagement.

**MULTI-FUNCTIONAL GREEN-BLUE SPACES**

Each neighbourhood will be anchored at the development node having a seamless connection between them through integrated infrastructure.

**BIODIVERSITY GREEN NETWORK**

Connecting disjoint green spaces along the Kuils river Corridor such as the Driftsands Nature reserve and also connect it with larger city green networks such as False Bay nature reserve and coastal network.

**HYBRID ROAD AND LANDSCAPE INFRASTRUCTURE**

Development of road networks to promote pedestrian and bicycle usage and allow for key ecological functioning.

**IN-SITU UPGRADATION+DENSIFICATION**

The slum situation is to be minimized with in-situ upgradation and densification in the townships.

**INCLUSIVE NEIGHBOURHOODS**

Each neighbourhood will be anchored at the development node having a seamless connection between them through integrated infrastructure.

**FALSE BAY**

Khayelitsha

DURBANVILLE

MACASSAR

At the end, water circularity is to be achieved in the neighbourhoods which can be understood through the case of Khayelitsha. The local adaptation technique will then inform and contribute to the other larger scales toward a holistic water management and spatial development plan. The plan will also address other ecological and social problems within the township.
Having formed an overall vision and strategies for the townships along Kuils river, specific layers can be extracted to identify and explore key systemic changes between the river and township to design a circular water system in Khayelitsha.

14.01 Exploring with water cycles

The design objective to make the township autonomous in producing its own water for drinking, farming and for other domestic use. It aims to make use of the wetlands and dunes in the process of capturing, storing and reusing of water. Therefore, water cycles from the river and township are explored. By doing so, it is also seen if and how far can other objectives such as ecological upgradation and social upliftment be achieved in adopting a particular condition. A schematic expression of the involvement of actors, biota for the same can be found.

14.01.01 Current cycle

The river is perennial with water fed by storm water, recycled sewage from WWTP and pollutants from various sources, whereas the SWDs at the township are disconnected and some functioning lines drains back into the polluted wetlands and to the sea. The lack of green buffer along the river leads to excessive evaporation. Due to its perennial nature it supports less biodiversity as compared to its original potential. The involvement of community in the overall river is fragmented with few parks, however when it comes to water, it is bureaucratic with no participation of people.

14.01.02 Condition I

In this condition, the immediate problems of the river are mitigated by introducing constructed wetlands for further purification of the recycled sewage water before letting it into the river and by increasing the buffer zone. Capturing of water in the wetlands will still pose threats of pollution, thereby excluding its use in the production of clean drinking water from dune filtration process. The township will also have to depend on the river for proper functioning of the river, therefore will lead to longer period for implementation and the perennial nature will still make the river be monotonous in its biota.

14.01.03 Condition II

In this condition, the river is made seasonal by disconnecting the WWTPs the water from which will be recycled at high levels to directly introduce to the water grid of townships. Tapping water from the river will still make the water production highly dependent on the river, facing risks of pollution. Since Kuils river is relatively small and one of the main sources of CFA recharge, it could potentially reduce its function of recharging and as ecological support.

Therefore, by trying to create best and suitable condition for producing water at the township, the river is proposed to be restored to its seasonal nature and be of ecological support to the varied unique landscapes in the area and in recharging the aquifer. This way effective functioning of dunes for water purification and wetlands to recharge aquifer can be achieved.

14 SYSTEMS INTERACTION

Having formed an overall vision and strategies for the townships along Kuils river, specific layers can be extracted to identify and explore key systemic changes between the river and township to design a circular water system in Khayelitsha.
Kuils river corridor vision and strategies

Strategies for Kuils are based on Condition III, harnessing its seasonal character and to increase its ecological functions and create public spaces.

1. Restoration of river source which is a golf course now, should be made more inclusive for all walks of life and to increase green cover and its sponge capacity to retain water.

2. Decanalizing and reclaiming open spaces along the river for more space for flooding.

3. Afforestation along the banks of the river to increase sponge capacity.

4. Constructed wetlands are created for further purification of sewage water from WWTPs and from industries to be able to reuse it in the same area.

5. Seasonal wetlands are formed in this process boosting ecology and new social interactions with nature.

6. Restoration of remnant dunes in the wetlands from getting eroded from vegetation removal, pollution and over-grazing. These dune-slash wetlands will become part of larger eco-tourism and landscape conservation.

7. Restoration of river source which is a golf course now, should be made more inclusive for all walks of life and to increase green cover and its sponge capacity to retain water.

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12. Restoration of remnant dunes in the wetlands from getting eroded from vegetation removal, pollution and over-grazing. These dune-slash wetlands will become part of larger eco-tourism and landscape conservation.
15 Township scale: Khayelitsha

15.01 Systems level problem identification

While water systems at regional scale has been analysed and proposed for, further understanding the layers from three lenses of landscape, water and township will help in identifying specific problems within the township. It will provide for precedents in designing an integrated landscape infrastructure, where the existing challenges can be turned to potentials.

15.02 Vulnerability

The biggest socio-ecological challenges in the township that should be accounted for the design are:

1. Informal settlements are situated on wetlands, low-lying areas and dunes preventing natural mitigation of floods and droughts. It also leads to the destruction of vegetation that are endemic to the area.
2. Invisible and disconnected storm water drains lack social interaction.
3. Large institutions established in the wetlands, Swartklip and on sand dunes causing ecological degradation.
4. Lack of basic services in many of the informal settlements, putting a large amount of people at risk due to lack of capacity. While some of the informal settlements have access to public toilets and yard taps, few others don’t.
5. Road infrastructure lacks pedestrian paths and faces risk to flooding.
6. Large open spaces along major road networks and schools that have no functions.
7. Heat island effect due to lack of green space within, leading to fire of shack in summer.

These are the main inferences made at the systems study at township scale that informs few key design strategies feeding into local scale design.

15.02 Vulnerability

Fig 80: (left) Systems interaction at township scale
Fig 81: (below) Section along Khayelitsha indicating the problems

Water service delivery

There are three types of water connections in Khayelitsha- in-house, yard taps and stand pipes. The standard of stand pipe proximity is 200 metres, however it is still deficit due to high density. The average amount of water consumed by a person from middle income group is 148 litres/day, whereas from informal settlements is about 17 litres/day well below South African standard of 25 litres/day (Smith, L. and Hanson, S., 2003). Therefore one of the main goals is to fill this gap to enable the community to access water from their surroundings and in sensitizing the issue.
There are existing processes in the township that make way for new possibilities for developing the design. Beginning from the community, who have an extensive and unique relationship with the wetlands and sand dunes, which can allow for new plans to engage people in landscape development and water production. They’re also involved in sustenance farming initiated by NGOs that involves women in the economic sector. The other important aspect is the availability of open spaces along the road networks and schools which are already accessible by people and also give room for new landscape development.
15.04 Envisioning Khayelitsha: Landscape Infrastructure design

The design visions Khayelitsha as a dynamic system with landscapes performing different operations, mainly for the production of water that acts as conditions for new economic activities and landscape restoration. The landscape infrastructure design, therefore propose to be:

1. **Restorative**
   Enabling the recharge of aquifer and biodiversity conservation leading to eco-tourism. This is an extension of the Kuils river vision. Therefore the manifestation are in the form of wetlands development and dune management.

2. **Capture**
   Capturing and storing of rainwater along the SWDs, enabling the regulation of water and the slow movement of water across constructed wetlands and bioswales till the reservoir enables purifying before the ultimate purification step.

3. **Purify**
   Captured water is purified through sand dunes by creating infiltration ponds on the sand dunes that will be extracted for use. This is piloted in combination with an in-situ development scheme.

4. **Engineered**
   Sewage water purification through ponds purification system as part of the waste water treatment plant. The water can be used by the community for economic purposes and for gradual acceptance of black water which can be of potential source for drinking water production in the future.

5. **Productive**
   Community-based economies such as farming, weaving by setting key socio-ecological processes in place. These activities are spread across the township, thereby ensuring stewardship of landscapes by the community. In a way allowing the community to reap different eco-services of monetary benefit.

It is approached by considering three main spatial elements to act as activators of aforementioned functions:

- a. Open lands along the existing storm water drain lines
- b. Roads and informal pathways
- c. Open space in schools

These three infrastructures are used as the base to deliver the function but also in addressing other key parallels that come across in order to realise the design. Mainly:

- a. Redesign of road infrastructures
- b. New housing development scheme

They are further elaborated in the upcoming section.
Landscape infrastructure layer:
Natural Landscapes

The main functions of drinking water infrastructure is to capture, store and filter. It follows the traces of old remnant wetlands and existing storm water drainage line for these actions. These spaces are already accessed by the community as short routes between neighbourhoods, therefore traces of informal pathways are taken to shape the newly created wetlands in these spaces. By creating the wetlands, it allows for percolation and also slow purification. They also become interesting public spaces and reduce heat island effect by growing indigenous vegetation. It also supports new programs and facilitates tourism in the area which is key in Khayelitsha for community involvement with the rest of the city.
View A

- Trees planted along pedestrian pathway in settlements
- Market area activating the fringe of the open area
- Indigenous tree planted for congregation
- Growth of dune strandveld
- Constructed wetlands

Market area activating the fringe of the open area
These landscapes are socially connected with existing public facilities to engage the community in initiatives such as urban farming, vegetation management of wetlands and in construction of new development houses. These spaces become densification points and ensuring equity through introducing new economies. It also makes sure of the first phase usage of black water from the Zandvliet WWTP.

The process of deploying water to create new landscapes in these spaces begins from collecting water through water collection points along the main rail network and services through water trucks to conduct farming using Jojo tanks (local term for plastic drum used to store water).

Landscape infrastructure layer: Productive Landscapes

These landscapes are socially connected with existing public facilities to engage the community in initiatives such as urban farming, vegetation management of wetlands and in construction of new development houses. These spaces become densification points and ensuring equity through introducing new economies. It also makes sure of the first phase usage of black water from the Zandvliet WWTP.

The process of deploying water to create new landscapes in these spaces begins from collecting water through water collection points along the main rail network and services through water trucks to conduct farming using Jojo tanks (local term for plastic drum used to store water).
Informal market

New housing development

Sustenance farming

Safe play area for children
The main goal to incorporate existing mobility networks are to act as lines for new storm water drains to connect different constructed wetlands, in introducing pedestrian and bicycle pathway, make newly created spaces accessible and act as guide in creating water storage. These involve the main roads and the informal pathways.

The existing main roads that connect most neighbourhoods are taken as line for the SWDs with integrated pedestrian pathway. The bicycle route runs all along the Kuils river connecting Durbanville till the coast. It has intermediary routes into the township to increase the social activity and inclusiveness and facilitating as new eco-route. The informal routes on the other hand are for the community as its most used by them to create different spatial experience for them but also taken as guiding line in the wetlands and dune area to create watch towers or to access baptism points or to reach the highway. Some of these lines are temporal in nature, however not submerged in water it experiences different water levels during different seasons.

Landscape infrastructure layer: Adaptive mobility networks

- Integrating green medians and bicycle pathway along N2 highway
- Bioswales integrated in the main roads of township
- Informal pathway patterns guiding the new constructed wetlands
- Integrating pedestrian pathway in N2 highway
- Integrated storm water drain lines in main roads
- Existing informal pathways as framework to create spaces for constructed wetlands
- Kuils river corridor bicycle pathway
- Adaptive pathway connecting township to N2 highway in the wetlands
- Adaptive pathway acting as protective barrier from fluvial flooding and protection from informal settlements growing into the wetlands
- Existing bridge
- Proposed new bridge
To facilitate the creation of landscape infrastructures, it requires some of the existing settlements that are situated on sensitive ecosystems or on the proposed infrastructure to be relocated elsewhere. The main goal is to resettle the evicted families in the same township. In this manner it also enables new sustainable development that can promote alternate imagination for the community to live in coexistence with natural processes. It is done through two main strategies:

1. Relocation to the ‘productive’ landscapes for new community living in school plots and along the transport networks promoting transit oriented development.

2. In-situ development that is adaptable to the landscapes.

Landscape infrastructure layer: Housing development scheme

- In-situ ugradation
- Main street networks for initial provisioning of services
- Service triggering in-situ upgrading of houses
- Creation of rain gardens or community spaces at the junction of main streets

New housing in school plots
16

FOCUS AREAS

To elaborate further on the integrated spatial manifestation of the proposed landscape infrastructure design and to synthesize with the vision of Kuils river and city of Cape Town, two areas within the township are chosen for detail design. The locations are chosen in a manner to capture different landscapes and socio-ecological systems that comes with it. These two locations will be able to showcase the overall design principles and framework created.
This chosen site is situated along the wetlands, which at present are used by the community for various cultural, religious, recreational and economic purposes. It is also home to the most endangered endemic vegetation, dune strandveld which over years has been destroyed due to development of the township. Many informal settlers live these wetlands therefore facing risk of flooding but also becoming source of pollution to the wetlands. Therefore the design incorporates the challenges and potentials of this particular area with regards to socio-ecological systems but also adhering to the regional plan to conserve the seasonal characteristics of the wetlands. The design measures taken are also to increase the sponge capacity of the wetlands and new conditions created to mitigate risks and provide water to the local settlers.

**Decomposing layers: ZONE A**

**Adaptable pathway**

Existing informal pathway running along the fringe of the wetlands is redesigned to act as flood protection and retaining the existing community route. Built with the dredged soil and its profile allows the growth of fruit and medicinal trees that the community can use. The soft intervention will seamlessly connect the community with the wetlands and benefit from the different conditions created by the same.

**New canals and retention pools**

The water-flow connectors in the wetlands branching from the Kuils river are dredged to increase capacity and facilitate longer route for canoeing. It is coupled with retention pools within the wetlands to allow for water percolation into the aquifer and ensuring purification. Further more, water is withdrawn through new ditches which creates new conditions for species like arum lilies, cape reed that the community can use that connects the wetlands to the community creating different spatial characteristics and relationships. It gives water to livestock and also for small scale farming.

**Social hub**

Social hubs are created along the pathway which consists of rain garden pit connected to a water storage tank. The pit consists of reeds and gravel that purifies the water before reaching the tank and can be tapped by the community for their use. This space also gives room to shed their livestock or for the community to gather for work especially women. It is flexible enough to house any function that the community requires.

**Vegetation**

Invasive species such as acacia or reeds are systematically over a period of time removed by the community to source of materials in building cow sheds and for weaving. Wet conditions are created to further growth of arum lilies for material source. The higher grounds are to plant fruit trees that are drought resistant.

**Connection to landscape infrastruc- ture design**

While the water is predominantly tapped from the wetlands for minimal use, during high water or extreme raining conditions, the water is re-directed to the storm water drain line which will get stored in the pool created in the Khayelitsha wetlands park ensuring future availability of water.

**ZONe A Khayelitsha Wetlands Development**

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**16.01 ZONE A**

**Khayelitsha Wetlands Development**

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**Proposed Plan**

- **Kuils River**
- **Silvertown**
- **N2 Highway**
- **KWP: Khayelitsha Wetlands Park**

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**Diagram Notes:**

- **Dunes**
- **Low wetlands**
- **Reservoirs**
- **Existing green (parks)**
- **Large water infrastructure**
- **Farming**
- **In-situ slum upgradation**
- **Existing public infrastructure**
- **Roads**
- **Invasive pathways**
- **Water channels**
- **Kuils River**

---

**Informal Pathways:**

- **Existing informal pathway running along the fringe of the wetlands is redesigned to act as flood protection and retaining the existing community route.**
- **Built with the dredged soil and its profile allows the growth of fruit and medicinal trees that the community can use.**
- **The soft intervention will seamlessly connect the community with the wetlands and benefit from the different conditions created by the same.**

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Adaptive Pathway

- Raised pathway on an informal route connecting neighbourhoods to the main roads and to the highway. Serves as protection from fluvial flooding, laid by city officials.
- Pathways of different heights across different landscapes.
- Main street networks for initial provisioning of storm water drains and public squares.

Water system

- Dredged and widened primary river channel in the wetlands supporting recreational activities and to supply to the secondary and tertiary channels proposed.
- Secondary channels filling the reservoirs.
- Tertiary productive ditches to provide conditions for farming.
- Water reservoirs to purify polluted waters and recharge of Cape flats aquifer.
In-situ up-gradation of Silvertown informal settlements. Service provisioning through integrated SWDs in streets.

Farming and species such as arum lilies, cape reed as materials.

Community space to shelter livestock and rain garden pockets along the proposed streets.

Wetlands to street

Ditches are created at the wetlands following the axis of the new streets laid following the axis of the formal housing adjoining the settlement. This orientation will allow for easy movement of people across neighbourhood and visual connectivity to the wetlands. Social hubs at the fringe of the pathway acts as check points to reduce the growth of squatters into the wetlands. SWDs are created in the streets. Water from the storm water lines drain into rain gardens that go through considerable amount of purification for water storage to supply basic local needs.

New ditch to create wet conditions to allow growth of arum lilies, cape reed as new economy for the community. Its close proximity to the settlement makes it easily accessible by the community members.

Landuse layer

Dry season

Wet season

Water pool to store water fro dry periods for community. Pollutants removed through phytoremediation.

Sandy soil to support growth of potatoes, turnips, spinach, eggplants, beans etc rotated over dry and wet periods.

Water collected in the rain garden to be stored in the community water tanks.
View C

- New housing development (e.g., Empower shack project)
- Mixed use land use (shops, market, community centre, etc)
- Rain Garden
- Water storage tank

Flexibility in use of space

Water storage tank
Section A-A

Creation of different habitats within the wetlands area, ranging from functional to ecological and the social connections to maintaining the wetlands brings out the dynamic nature of it. These habitats support different plant and bird species, especially wet conditions are created at certain parts to let the endemic species of strandeveld to develop.

Adaptive pathway

Canoeing in the channel

Protected sand dunes

‘Kulls’ created in the wetlands

Clearing of invasive acacia species as wood material for the community and to increase indigenous tree growth

Protection of sand dunes from over-grazing by creating ha-ha and fencing

Silvertown with new streets and community squares
The proposed pathway not only serves different functions but also is adaptable to the unforeseen climatic conditions of sudden heavy rainfall to the usual weather.

**Sectional view B-B**

- Water hand pump
- Rainwater collecting pit and storage tank
- Multi-functional pathway
- Drought resistant trees
- Wet farming

- Year 2050+

**Wet farming**

**Drought resistant trees**
During drought periods, the rain water collected in storage tanks will allow for activities such as farming to continue.
Enkanini informal settlement
Enkanini is a high density informal settlement spread across the undulating sand dunes developed in the last few years. The haphazard construction makes the settlement extremely vulnerable to climate risks. Like the design strategy for Zone A, this zone incorporates larger principles by creating conditions for future development and resilient towards any impending danger.

**Design conditions**

The design objective is to condition for future development provisioning of water which can be collected from water collection points that adjoin main street networks. These identified main streets are taken as development lines connecting the dune extraction point to delivering it to people. In this case the open spaces are used for farming and recreational activities for the people.
Section C-C
Cutting across the water purification and extraction system on the dune hill present within the settlement.
Pilot project

Creation of dune filtration system in Enkanini is to demonstrate the workability of the system, where community involvement becomes key in managing and producing water. Initially the water is provided only to this neighbourhood. Upon success, it can be expanded in adjoining dunes for further extraction for the whole township and other localities nearby.

Resilient hubs

Typical overview of school plot development and natural landscapes creating a renewed space for socio-ecological relationships.
Sectional view D-D
Cutting across the proposed new streets at the flatter region of Enkanini which will be serviced with SWDs and line to cater drinking water at the pavilion.

Bioswale

Drought resistant trees

Water collection point

Wild food farming

Self-constructed houses

Water collection point

Drought resistant trees

Wild food farming
Landscape infrastructure design creates water resilience, social equity and ecological upgradation in an integrated manner in Khayelitsha.
The nature of the project having a strong area-based development with community becoming stewards of change in both social and ecological development, the intervention requires a robust interaction between different stakeholders in order to implement and for successful management of the project.

Kuils river corridor development and Khayelitsha township development are two projects which has both executive and non-executive actors ranging across administrative boundaries. The project demands initial action of the executive actors such as the water and sanitation department of Western Cape Government (provincial), Transport and urban development authority from City of Cape Town (municipality) to other local players such as the Zandvleit waste water treatment plant. Even though the initial ideas/intervention are to be done by the aforementioned players, it needs the involvement of the local community therefore the community leaders, NGOs that already have built a relationship with them over time must be brought into the loop.

These interactions will also equip the community with necessary knowledge and training to deploy the interventions in a phase-wise manner, in a way that promotes behaviour change within the community.

The following scheme represents the key players and their importance in a particular project. It is also important to notice that there are few actors that are common in both projects and some unique to each.

**Stakeholders**

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The governance model envisioned for Kuils river and Khayelitsha seeks a middle ground in setting equal power of implementation to the municipality and local residents in order to reach the design goals in a timely manner. Even though, the initial framework is laid by the City, the construction, management of the landscape afterwards will be done by the community but with constant training and mobilization by non-governmental players. While this is true at the township scale, at Kuils river scale the players are rather at city and provincial level but with the involvement of representatives from private establishments and residential areas. However, there are other non-executive players who are responsible in steering other developments or in mobilizing the community in achieving a certain goal such as that of environmental awareness for community or training to farm in wetlands.

The scheme describes the intensity of influence of actors in implementation a certain intervention. It displays an ideal model where all stakeholders work in a holistic manner.
18.02 Flexibility in implementation

There are always probabilities of governance failure when it comes to large scale projects such as this, reasons being lack of funding or simply the multi-stakeholders platform does not function as effectively, thereby creating a domino effect where certain implementation becomes impossible due to failure of another. Therefore, new alternatives can be found with the proposed design where the community takes the lead in organizing water through downscaled interventions. In addition, as support for knowledge and training the private institutions and NGOs will be working closely with the community.

This option will shed light both on the strengths as well the weaknesses it may hold. Some of the key socio-ecological processes needed in order to retrieve water or other ecosystem services that the community can obtain on its own are shown on the right. The design intervention has the flexibility to function based on different players and for different climatic pressures.

The natural landscapes infrastructure can still be implemented through community’s efforts of creating smaller clay pits, in turn water can be tapped by the community. While this can be assisted by NGOs as well as some funding from private universities in setting up a pilot project. However, since this is a common land there might be a huge objection from the City, in that case roping them in for coordinated and guided implementation of “constructed wetlands” becomes important.

Ditches can be created by the community to allow the growth of species but with the guidance from specialised groups such as environmental NGOs or extension of KRCF (Kuils River Catchment Forum) who can steer the local community in taking these measures.

Water collection at the sand dunes if it were to be organized by the community, it should follow a certain amount of steps. Beginning with restoration of the dune itself, the Enkanini community can work with CTEET, SANBI or Cape Nature in relocating to new housing development in the school plot within the same neighbourhood. Some of the community members will be Eland monitors in guiding the ecological development of the dunes. In 5 to 10 years time, small water pits can be developed and tapped by the community. Collected water can be further cleaned by downscaled water purification system to attain potable nature.

The water storage tanks proposed in the original design evolving from pits to cisterns either underground or overhead can be replaced with JoJo tanks at several of these water collection points.

Construction of the multi-functional pathway can be built as clay dike with the material retrieved from dredging of canals or digging of retention pools in the wetlands.
19 Systems Performance

The landscape infrastructure is designed with a certain capacity, however the size can be varied based on more scientific calculations and that’s the advantage of the proposal because its flexible to changes. There are few conditions to the explained capacity calculation and fig 95-103 should be referred for further calculations made to arrive at the number mentioned here.

1. Calculations are based on basic thumb-rule derived from reference projects and rational method calculation for run-off for three landscapes such as built, open and roads.

2. The amount calculated for the different landscapes capacity are for a particular time, meaning the water level could be half the amount at different seasons and times as the water is always in movement to be purified and to reach the dunes.

3. There will be huge loss of water due to evaporation and the amount is not calculated, but is mitigated by planting vegetation and trees.

4. The storage capacity value excludes the tanks which can be installed by a household, it could give more clarity on the storage amount by calculating it.

5. Grey water cycle has not be included, however it is important to consider in the calculations.

Total required water for township = 78MLD
(approximately 28 billion litres annually)
Formal = 58MLD
Informal = 21MLD
Deficit = 15 MLD

---

<table>
<thead>
<tr>
<th>Natural Landscapes (10MLD)</th>
<th>Reservoir (10MLD)</th>
<th>Waste water treatment plant (10MLD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>540mm annual rainfall (10MLD)</td>
<td>1000mm annual rainfall (38MLD)</td>
<td>We will be able to produce approximately 1300 million litres of drinking water</td>
</tr>
<tr>
<td>(approximately 3600 million litres/year)</td>
<td>(approximately 14000 million litres/year)</td>
<td>500 million litres/annually</td>
</tr>
<tr>
<td>501 million litres</td>
<td>926 million litres</td>
<td>72 million litres</td>
</tr>
<tr>
<td>601 million litres</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Maximum Capacity (at a particular time)
- Storage
- Purification
- Other activities
- Grey water

- NL (Natural Landscapes)
- D (Dune filtration ponds)
- R (Reservoir)
- H (Household)
- W (Waste water treatment plant)
This chapter covers the conclusions of the inter-relationship of scales and reflection of the whole project.

Fig 92: Temporary toilets for informal settlements
Source: Dori Hegyi
CONCLUSIONS

The landscape infrastructure design intervention at Khayelitsha township demonstrate ways of approaching integrated spatial and water management at local scale through systemic balance at Kuils river allowing landscape to perform in a certain way locally, which is further demonstrated through the two focus areas of Khayelitsha wetlands and Enkanini dune area. It shows the strong interconnectedness between the scales to form strategies for different landscape typologies. By considering different water cycles and designing to use it, activates other key social, economic and ecological mechanisms. Taking into account both the present and future it creates synergies between scales and responds to the over-all city issues. Therefore, by adopting landscape based design solutions and by setting these local adaptation techniques, Cape town will become a water resilient, equitable and adaptable in times of disasters or otherwise.
The thesis is a culmination of strong research and landscape-based design ideas addressing the socio-ecological challenges that exist in the towns of Cape Town. Therefore, by answering the research questions coined in the previous sections, the overall landscape and its adjoining environments such as Khayelitsha wetlands and Macassar sand dunes, which not only supports unique biodiversity but also provides services such as flood mitigation and food production, conservation of local ecosystem. Furthermore, such landscape-based approaches require a river basin level governance structure to a micro-watershed management system. This way it allows for healthy ecosystems and supporting green and blue infrastructure such as Khayelitsha wetlands for flood protection, dunes including its vegetation and water quality. However, such circular systems across the city, will reduce the risk of failing if the local community does not accept the new sustenance or economic development in the Khayelitsha wetlands for flood protection, and localized problems in the overall drought situation. The landscape sets its adjoining environments such as Khayelitsha wetlands to provide framework for design. Apart from the city having its own unique practices and knowledge, each area has its own characteristics and phenomenon borrowed out from the ethnic groups especially in a post- apartheid city. Therefore, it was key in this project to consider each township/neighborhood as ethnic enclaves. By doing so, it was important for the team to understand these values, characteristics and behaviours by not just visiting the focused neighborhood but also to interact with the whole city too. Especially with the city having several biosomes spread across, localized analysis of Biwa which involved the town planner to understand the whole city’s natural and urban system in order to design a system to connect this with the local socio-ecological relationships. Interviews were conducted to target the local practitioners from the field. The system was a vector for analyzing and addressing the existing Berg river basin water management infrastructures and present local conditions among the neighborhoods at the river basin level. Creating such circular systems across the city, will reduce the risk of failing if the local community does not accept the new sustenance or economic development in case of extreme droughts. This line of thinking was adopted as scientific study but are important line of thinking for future research. Informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as flexible to withhold informality in the whole process where it is as
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>WWTP</td>
<td>Waste Water Treatment Plant</td>
</tr>
<tr>
<td>CFA</td>
<td>Cape Flats Aquifer</td>
</tr>
<tr>
<td>CFR</td>
<td>Cape Flouristic Region</td>
</tr>
<tr>
<td>SWDs</td>
<td>Storm Water Drains</td>
</tr>
<tr>
<td>City/CoCT</td>
<td>City of Cape town municipality</td>
</tr>
<tr>
<td>WCG</td>
<td>Western Cape Government (Provincial)</td>
</tr>
<tr>
<td>Jojo Tanks</td>
<td>Local term for water storage tanks/drums</td>
</tr>
</tbody>
</table>
APPENDIX

Fig 94: Macassar sand dunes
Calculations

Kuils river

Upper stream

WWTPs

Belleville

Zandvlei

Macassar

(Windows calculated for Kuils-Eerste Catchment area, the actual amount for Kuils river will be lesser)

Lower stream

 believers

12m

240km

Total capacity = 115.2 billion litres

Water from Kuils is for ecological restoration and for the purpose of aquifer recharge only.

Khayelitsha Water consumption

<table>
<thead>
<tr>
<th>Category</th>
<th>Existing water consumption (population x current consumption/day)</th>
<th>Water requirement (litres/day)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal settlements</td>
<td>391749 x 57978852</td>
<td>57978852</td>
<td>X=148 litres/day considered (existing)</td>
</tr>
<tr>
<td>Low Income</td>
<td>308251 x 5240267</td>
<td>20961068</td>
<td>X=68 litres/day considered (derived from average low income category usage)</td>
</tr>
<tr>
<td>Middle/High Income</td>
<td>63219119 x 78939920</td>
<td>1570801 litres/day water deficit</td>
<td></td>
</tr>
</tbody>
</table>

Gap

15720801

Calculation of water production capacity through proposed design

Dunea

1.2 million population

73 billion litres of drinking water

Space required for infiltration ponds is approximately 2.7 million sq.m

Proposed design

0.9 million (after accounting for the incoming population)

1.35 billion litres of drinking water

Therefore, space required is approximately 49,931 sq.m

Average water consumption per household

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount (Litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal</td>
<td>41.366</td>
</tr>
<tr>
<td>Low Income</td>
<td>496</td>
</tr>
<tr>
<td>Middle/High Income</td>
<td>900</td>
</tr>
</tbody>
</table>
The Rational equation is the simplest method to determine peak discharge from drainage basin runoff.

By approximately taking the annual rainfall to calculate the storm water volume in Khayelitsha township to decide on the size of the interventions and if it will be able to serve its purpose at different rain conditions.

Annual rainfall = 540mm (drought times)

Annual rainfall = 1000mm (peak times)

### Rational Method Equation

**Run-off Volume:**

\[ Q = (K \times I \times A) \]

- **K**: run-off coefficient
- **I**: intensity of rainfall
- **A**: drainage area

### Run-off Coefficients:

- **Buildings**: 0.5
- **Asphalt/concrete**: 0.85
- **Forest/vegetation**: 0.10-0.2
- **Open/Bare land**: 0.05-0.3

### Run-off (Q) = KxIxA

- **Built-up**: 0.5, 540, 18267412
- **Open**: 0.05, 540, 6,089,137
- **Roads**: 0.8, 540, 0.8
- **Total**: 10025

**Total area (sq.m)**: 10025000

**Total**: 38879000

### Water Capacity

- **Natural landscapes**: 3506944, 350694, 752
- **Dune infiltration ponds**: 50000, 50000
- **Reservoir**: 128810, 128810
- **Storage tanks**: 40% of 540mm rainfall
- **WWTP**: 72

**Data Source**: https://www.lmnoeng.com/Hydrology/rational.php

**Different land uses** and for two different rainfall intensities.

**Figure 98**: Average water consumption by the households in Khayelitsha

**Figure 99&100**: Calculation of storm water run-off and coefficient values for different land uses

**Figure 101&102**: Equation to calculate storm water run-off and coefficient values for different land uses.

**Figure 103**: Calculation of capacity to function by the different landscapes and interventions.
**Drought resistant Tree species list for Cape Flats**

Indigenous trees well suited to the Cape Flats, west coast and coastal sites in the Western Cape - i.e. very windy conditions, sandy soils, flat - possibly alkaline soils, winter-rainfall, summer drought (coastal sites on mountain slopes could also use water-wise trees on fynbos list)

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Common Name</th>
<th>Height</th>
<th>Water-wise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachylaena discolor (Coast Silver Oak)</td>
<td>(4-10m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Elaeodendron croceum (=Cassine crocea) (Red Saffronwood)</td>
<td>(8-13 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dodonaea viscosa var. angustifolia (Sand Olive)</td>
<td>(2-5m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Dodonaea viscosa var. viscosa (Sand Olive)</td>
<td>(3-5m to 10m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Euclea racemosa (Sea Guarri)</td>
<td>(1-6m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Harpephyllum caffrum (Wild Plum)</td>
<td>(6-10 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kiggelaria africana (Wild Peach)</td>
<td>(4-13m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Maytenus procmbers (Dune Koko Tree)</td>
<td>(3-6m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Olea europaea ssp africana (Wild Olive)</td>
<td>(3-14m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Olea exasperata (Coast Olive)</td>
<td>(1-8m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Phylaca buxifolia (Box-leaf Phylica)</td>
<td>(3-6m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Salix hirsuta (Silver Willow)</td>
<td>(2-4m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Searsia crenata (= Rhus crenata) (Dune crowberry)</td>
<td>(1-5m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Searsia lancea (= Rhus lancea) (Karree )</td>
<td>(5-8m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Searsia pendulina (= Rhus pendulina, R.viminalis) (White Karee)</td>
<td>(to 10m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Sideroxylon inerme (White Milkwood)</td>
<td>(to 10m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Syzygium cordatum (Water Berry)</td>
<td>(8-15m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syzygium guineense (Water Pear)</td>
<td>(5-10 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarchonanthus camphoratus (Camphor Bush)</td>
<td>(4-9m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Tarchonanthus littoralis (Coastal Camphor Bush)</td>
<td>(3-5m)</td>
<td>(Water-wise)</td>
<td></td>
</tr>
<tr>
<td>Virgilia divaricata &amp; V. oroboides (Keurboom)</td>
<td>(5-10m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**Existing Khayelitsha wetlands species**

Spatial strategies incorporates the existing vegetation found in the wetlands. Note that the dune strandveld is almost non-existent due to the informal settlements.

---

**Data Source:** Map developed based on the data from referring thesis work “Exploring the ecological and social benefits of the Khayelitsha Wetlands Park” by Fezile Mathenjwa from University of Cape Town.

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**Bare patch**

**Cape flats dune strandveld**

**Emergent aquatic macrophytes**

**Acacia species**

**Marginal grasses**