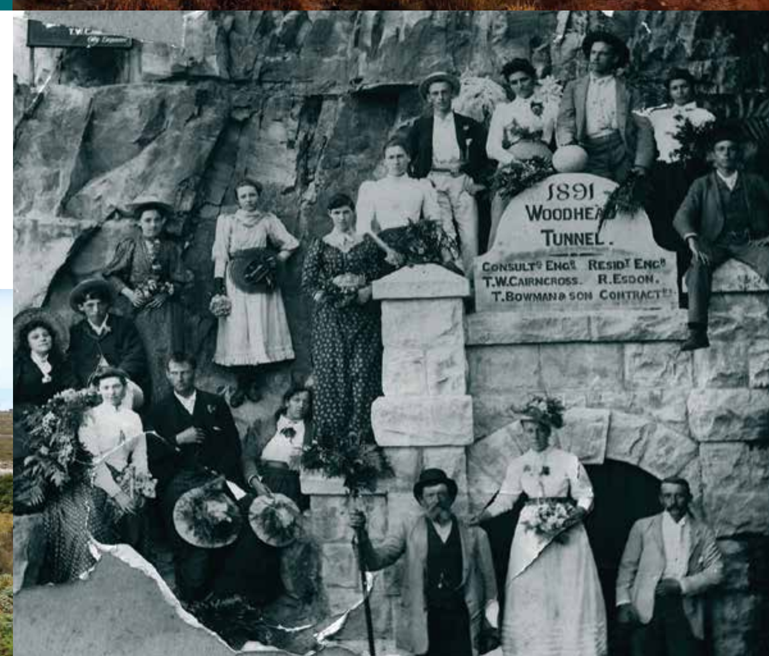
Hydrological Heritage Overview:

Cape Town

WHERE SWEET WATERS MEET THE SEA

WATER RESEARCH COMMISSION

HYDROLOGICAL Heritage Overview



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Hydrological Heritage Overview: Cape Town

Where sweet waters meet the sea

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(with photographic contribution by Gerrit Burger)

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WATER RESEARCH COMMISSION

HYDROLOGICAL Heritage Overview

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Preface

Our ancestors called it *Camissa* or The Place of Sweet Waters. For millennia the area we now know as Cape Town has attracted the weak and weary to its haven of springs and rivulets falling fresh from its greatest landmark, Table Mountain, one of the seven modern wonders of the world.

For European seafarers *Hoerikwaggo*, as the great mountain was first known, became a beacon of hope for recuperation amid their long voyages to and from the spicy riches of the East. It was Dutch sailor, Wouter Schouten who in 1655 declared the Cape's water "a heavenly liquid" tasting "better than ordinarily does the most exquisite drink in the world."

From this early settlement, between two of the Earth's great oceans, grew a cosmopolitan city enveloped in the cultures of Africa, Europe and the East. We still know it as the Mother City, one of the oldest continually inhabited places in South Africa.

Today, Cape Town is a first-class city surrounded by some of the most unique biodiversity found in the world. But like most of the Earth's urban spaces, Cape Town has had the challenge of sustainably marrying its concrete expansion with its natural environment.

Close to 4 million people now live within the municipal area known as the City of Cape Town, all requiring basic services such as water, sanitation and shelter. As the population has expanded, so has Cape Town's water needs, resulting in one of the most sophisticated water supply networks in Africa.

This book is the third in the Hydrological Heritage Overview series, the first two books featuring Pretoria and Johannesburg. This series aims to address the important power water has over Mankind and how we can harness that to our benefit without compromising the environment.

The selection of Cape Town supplies the opportunity to address the mechanical impacts of water: Table Mountain formed through the action of water, and was shaped into its characteristic landform due to subsequent erosion by water action. Additional emphasis on the power of water relates to aspects of hydropower, the impacts of floods and droughts, and additionally of the power of water as it is harnessed as a vital life supporting resource and as a means of recreation.

It is the hope of the Water Research Commission that the reader will come to realise the beauty and uniqueness of Cape Town's natural resources and the need to preserve it.

Dhesigen Naidoo

Acknowledgements

This product is the culmination of many people's inputs, opinions and insights. It is extremely hard to prioritise content, as including something implies that something else is to be omitted. Many people were involved in guiding these decisions to ensure a final book that addresses the relevant matters while keeping it concise and to the point. As every person has different interests, different people would prioritise different aspects: history, geology, sanitation, water treatment, water quality, etc. For the sake of this book, I hope it is a balanced overview of the most important matters related to Cape Town's water supply and that it will intrigue the reader to find out more.

Sincere gratitude is expressed to the South African Water Research Commission (WRC) for its commitment to the Hydrological Heritage Overview (H_2O) campaign. This endeavour was started with Pretoria (completed 2012) and followed by Johannesburg (completed 2015) and Cape Town. Thanks is particularly expressed to, Dr Shafick Adams (the Research Manager for this project) for his commitment to promoting water awareness.

Also from the WRC, thanks are expressed to Mrs Lani van Vuuren. Your ability to communicate science and your broad water knowledge are unequalled and it is a privilege to have your input in these projects.

The reference group of this project guided the research and contents throughout the project. What I envisaged initially differed from what is published here, and it is their guidance that redirected me to the critical aspects covered in this book. Thanks to Prof Johann Tempelhoff (North-West University), Mr Jude Cobbing (Independent Hydrogeologist), Mrs Lani van Vuuren (WRC), Mrs Elanda Schaeffer (SEFSA), Prof Kevin Wall (University of Pretoria), Mr James Boale (City of Tshwane), Mr Arne Singels (City of Cape Town) and Mrs Nomvula Mofokane (City of Johannesburg) for your input, comments, edits and peer review of this publication.

Matthys Dippenaar

Mr Arne Singels, in person, for all your contributions in the form of information and access, I want to express a special work of thanks. It is not always easy to be the mediator between the public and the municipality and

I believe you've done an exceptional job in supplying me with valuable information.

Mr Matt Weisse, thank you for the information and for accommodating our team on the tunnel tour. You opened my eyes to many interesting aspects of Cape Town's water story.

My colleague, Gerrit Burger, of Rockhouse Productions, took the bulk of the photographs for the book and made the documentary accompanying the publication. It is always easier and more interesting to tell a story accompanied by good graphics. Your photos give life to the story: thank you for this.

Lizelle Olivier from Clear-creative, thank you as well for the motion graphics used in the film and many of the still graphics used in the book. Your graphical timelines have become something of a trade mark and I thank you for your continued involvement and interest.

Ingrid Booysens and the GIS team at the University of Pretoria, who compiled the maps used: my sincere gratitude for the help with this. Maps give important context, and without context, text becomes redundant. Your willingness to help out, often at very short notice, is highly appreciated.

Elke Momberg, for designing the layout of the book: thank you very much for the beautiful designs and for the exceptional work. If people judge books by their covers, I am thankful to have you design it.

Finally, to the people who had to bear with me through this project – notably my colleagues Louis, Bredon and Luke, and my family Tharina and Femke – I cannot thank you enough. Your support and help in this regard are greatly appreciated!

Although this product supplies a glimpse into a much longer story, it is difficult to mention every aspect of Cape Town's water heritage. The purpose of this booklet is to become aware of water supply, and therefore a lot of content is omitted or toned down. It does not mean to be a book on history or a handbook on hydrology. The purpose is to acknowledge the role of water in our lives and to collectively become more involved in its protection.

Chapter 1: Introduction

South Africa is quite an exceptional country, being situated at the southernmost tip of the African continent where the warm Indian and cold Atlantic oceans meet. A coastline length of almost 2 800 kilometres ranks the country as number 44 internationally in terms of coastline length (www.world.bymap.org).

Cape Town is at this point where the two oceans meet. Cape Agulhas – just to the east of the city – represents the southernmost tip of continental Africa (with the exception of scattered islands further south) and Cape Town itself the southernmost city on the continent.

It is therefore no surprise that the area around Cape Town hosts tropical forests further to the east as well as near-desert conditions northwards along the West Coast. Highly variable climate and rainfall result in the breathtakingly beautiful landscape, the most conspicuous being the abundance of area-specific Fynbos which includes South Africa's national flower, the Protea.

Cape Town is truly the city shaped by water. The bulk of the rocks in the area was deposited by water. The landscape as we see it today has been incised by rivers and eroded by waves. In the past, springs supplied the city with water and canals drained the developed areas. The ocean was one of the first transport corridors between Europe and the East. Wetlands, in turn, depend on water to survive and support many types of flora limited to this part of the planet. Coupled with this, Cape Town is also the first city in South Africa to implement managed aquifer recharge to store treated water and to truly subject itself to water sensitive urban design.

For more than a millennium, water has played a pivotal role in Cape Town's history, and few places provide the opportunity to see the water cycle interacting as it does here.

Cape Town: South Africa's first Modern City

The establishment of Cape Town at the southern tip of the continent made sense with the prospects of international trade centuries ago when Earth was not yet fully mapped. Table Mountain with its abundance of springs supplied both freshwater and security, and since then the city has been continually expanding.

The city boasts world class arts and culture, and has a booming nightlife attracting international tourists and artists annually. Cape Town, South Africa's Mother City, is commonly considered to be one of the top tourism attractions in the world, and Table Mountain itself has since been named one of the seven new natural wonders of the World. The city is truly South

"This is a pretty and singular town; it lies at the foot of an enormous wall (the Table Mountain), which reaches into the clouds, and makes a most imposing barrier. Cape Town is a great inn, on the great highway to the east."

– Charles Darwin, in a letter to his sister, Catherine (1836).

Africa's cultural heartbeat where artists, film makers, designers and wine connoisseurs contribute to the tourism of the country. This exceptional city has grown from one of the oldest formal settlements in the country to a leading world city.

The City of Cape Town is a favourite tourist destination. With Table Mountain being one of the new seven natural wonders of the world, Cape Town is also uniquely positioned where the two ocean currents meet. Proximate environs play home to some of the most unique biodiversity found in the world with the fynbos biome protected in numerous reserves such as the Cape Peninsula, Table Mountain and Kogelberg Nature Reserves.

The natural environment has always attracted interest. South Africa is an exceptional destination for those with interests in geology and botany. The country hosts some of the oldest rocks and some of the most diverse vegetation biomes in the world. Even world-renowned naturalist, Charles Darwin, mentions Cape Town in his writings, describing his view from Sea Point.

Tales about Table Mountain, Devil's Peak, and Lion's Head are pondered by many, wondering how they came to be named. The mountain with its persistent cloud blanket has become a trademark of Cape Town. The region around the city is known internationally for its exceptional vineyards and wines.

Cape Town has established itself as one of the world's prime tourism destinations for those seeking adventure and culture. The city boasts world class entertainment; the vineyards and conservation areas in close proximity provide those quick breakaways from the city life. Even South Africans consider Cape Town to be a favourite holiday destination and numerous people from the inland – where the economical hub of the country is situated – visit the area annually.


© Elke Momberg

The Hydrological Heritage Overview Project

In addressing water beyond the scope of basic human needs, one has to understand water. We all know what water is – that molecule of dihydrogen oxide with its distinct high liquid density causing solid water to float on liquid water. But, in order to fully appreciate the importance of water, we have to understand the behaviour of water in the greater scheme of the environment.

The water cycle is a complicated process, which is often simplified to schematics about rivers, oceans and clouds. But water moves in many ways and influences everything around us. The complexity of the water cycle goes beyond the understanding of rain, evaporation and flow to also understanding how water moves through living organisms and how it is involved in geological processes. Living organisms such as plants and animals are made up essentially of water. Many rocks have water incorporated in their minerals or are formed by water-related processes.

This, therefore, highlights the importance of water in the lifecycle of any living species and in the geomorphological sciences, hydrology and sediment transfer. We need to consider rivers, for instance, not only as freshwater, but also as riparian wetlands, alluvial erosion agents, flood risks and transport corridors.

The Hydrological Heritage Overview aims to address the important power water has over Mankind and how we can harness that to our benefit without compromising the environment. The selection of Cape Town supplies the opportunity to address the mechanical impacts of water: Table Mountain formed through the action of water, and was shaped into its characteristic landform due to subsequent erosion by water action. Additional emphasis on the power of water relates to aspects of hydropower, the impacts of floods and droughts, and additionally of the power of water as it is harnessed as a vital life supporting resource and as a means of recreation.

HYDROLOGICAL Heritage Overview

The H_2O logo depicts a green urban setting encapsulated in water: urbanisation with a water-sensitive outlook, urban development and water supply, and sensitivity towards the environment (© Clearcreative).

Natural Landscape

Cape Town, best known for the remarkable Table Mountain, is also a paradise in terms of biodiversity. Fynbos occurs almost exclusively in the Western Cape Province of South Africa and is remarkably adapted to the highly variable climate of the region. The mountain itself, having formed during hundreds of millions of years, is now a renowned natural wonder of the world and also the only of these new natural wonders to be situated within a city. Two coastlines meet at Cape Point near the southernmost point on the African continent. Surrounded by oceans, vineyards, nature reserves and mountains, Cape Town is truly a natural splendour.

Urban Landscape

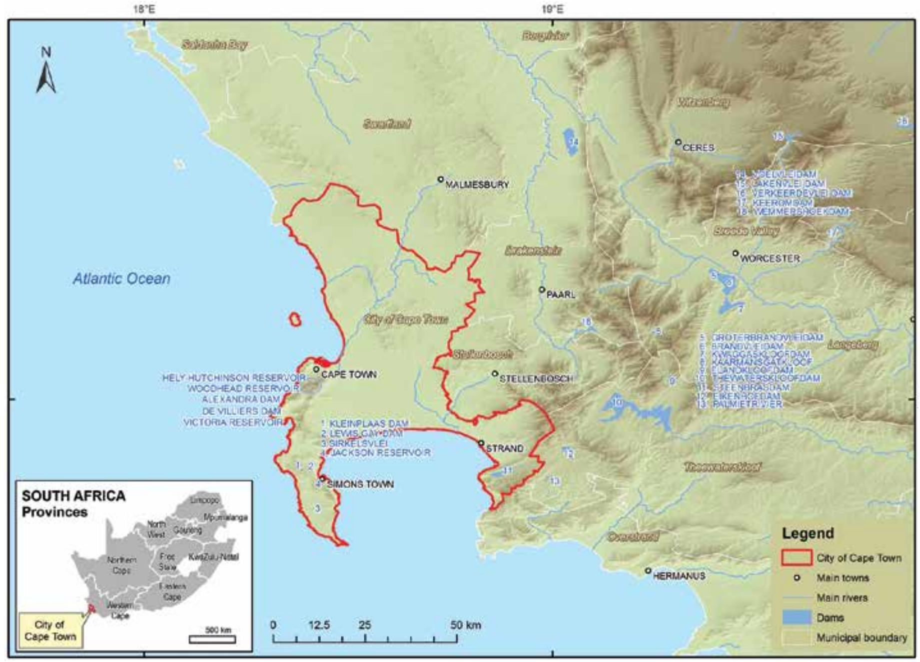
The City of Cape Town houses 3.75 million people (according to the 2011 census) in a municipality covering an area of almost 2 500 square kilometres. In just ten years, since the 2001 census, the population has increased by 29% from 2.8 million, clearly indicating the population growth in the area. The city remains a favourite tourism destination, both in terms of the natural environment and the lively city atmosphere. Seating the South African parliament, Cape Town is also renowned for its culture and arts, lately being a preferred locality for numerous international films and festivals. The night life entertains young and old alike, from all walks of life, and the city is often cited as one of the preferred tourism destinations worldwide. As one of the oldest developed areas in South Africa, the city has a long history of development, leading to the skyline and dense development of the inner city as it is known today.

Population Growth and Water Demands

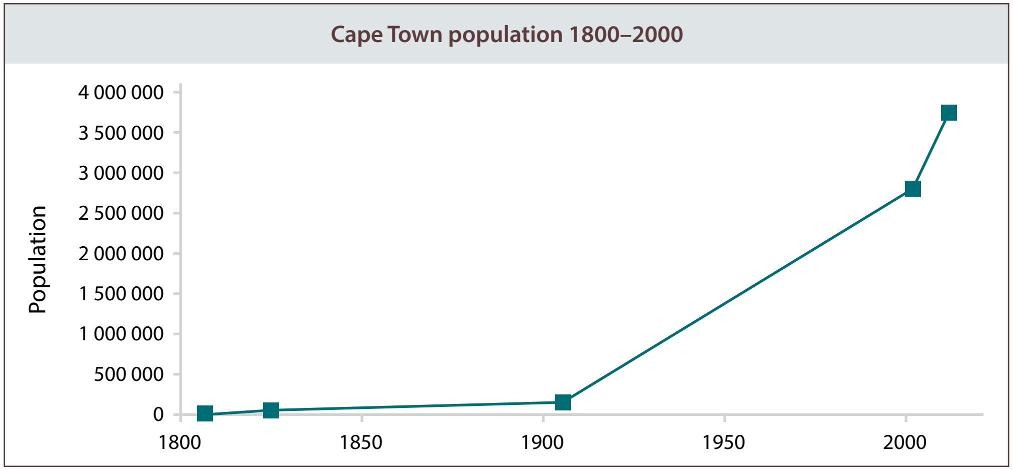
The City of Cape Town presently requires approximately 1 000 million litres of water per day to supply a population in the order of 3.75 million people in just over one million households. Within the large municipality of 2 500 square kilometres and incorporating just over 300 kilometres of coastline, water is mostly supplied for a variety of dams.

In achieving this, approximately 5 700 water samples are tested annually to ensure compliance with the Department of Water and Sanitation's specifications for drinking water quality. Drinking water standards are strict, and non-compliance can result in adverse health effects. Municipalities are therefore obliged to comply with the required minimum requirements. In achieving this, the Department of Water and Sanitation annually awards Blue Drop certification status to municipalities with exceptional performance in water supply. The City of Cape Town continues to be a recipient of this award.

The 2011 census indicates that 75% of the population has access to piped water inside a dwelling, 12.3% have access inside their yard, 9.3% within 200 m of their dwellings, 2.7% beyond 200 m, and 0.7% has no access to piped water. The matter of domestic water supply to all remains a goal all municipalities should strive towards, and the ultimate goal.



A number of dams, mostly situated outside the Cape Town and the Berg River Catchment the city is located in, supply the city with its water requirements. As the municipality has progressively increased both in size and in population, more water has been required to meet the ever-growing demand.



The Cape Town population has grown steadily since the early 1900s, after which significant growth followed. Substantial growth is evident in the early 2000s, making Cape Town the second biggest city in South Africa by population.

Cape Town's Water Supply at a Glance

Dam	Storage Capacity (million litres)
Table Mountain Group dams	2 376
Steenbras Lower	33 517
Steenbras Upper	31 767
Theewaterskloof	480 250
Wemmershoek	58 644
Voëlvlei	164 122
Total Dam Storage	**770 676**

Dam storage capacities supplying the City of Cape Town (in million litres) (taken from www.capetown.gov.za).

Reservoir	Storage Capacity (million litres)
Wynberg (Nos 1 and 2)	30.6
Newlands (Nos 1 and 2)	178.6
Molteno	188.1
Plattekloof	583.6
Tygerberg (Nos 1 and 2)	297.7
Blackheath Upper	48.2
Glen Garry	149.7
Blackheath jLower	537.6
Faure	640.0
Total Reservoir Storage	**2 654.1**

Storage capacities of reservoirs in the City of Cape Town (in million litres) (taken from www.capetown.gov.za

Dam	2012	2013	2014	2015	January 2016
Wemmershoek	76.1	87.8	90.6	76.3	58.0
Steenbras Lower	70.7	76.2	84.4	63.1	57.6
Steenbras Upper	93.2	92.1	98.8	99.3	76.9
Voëlvlei	76.0	82.4	88.7	81.9	29.3
Theewaterskloof	74.7	88.9	94.0	85.4	56.4
Berg River	89.2	91.1	98.6	88.1	60.1
Total Stored	697,390	786,958	837,774	756,556	475,080
% Storage	77.6	87.6	93.3	84.2	52.9

Dam storage is shown as percentage of total storage capacity for the period 2012 until January 2016. Note the very low levels of the dams following the 2015 droughts compared to the preceding four years (taken from www.capetown.gov.za).

The approximate areas of water distribution for the Blue Drop certified city are as follows (www.capetown.gov.za):

- Blackheath: Cape Flats, Mitchells Plain, Muizenberg, Fish Hoek, Southern Suburbs and Southern Suburbs (high lying areas on mountainside and Constantia valley), City Bowl, Bellville, Kuils River, Blue Downs, Eerste River, Khayelitsha, Durbanville, Elsies River, Somerset West, Strand, Nyanga/Gugulethu
- Brooklands: Simon's Town
- Constantia Nek: Hout Bay (water blended with supplies from Steenbras and/or Blackheath)
- Faure: Cape Flats, Mitchells Plain, Muizenberg, Fish Hoek, Southern Suburbs, Khayelitsha, Somerset West, Strand, Philippi
- Helderberg: Somerset West
- Kloof Nek: Camps Bay, Sea Point, Tamboers Kloof/Gardens (high lying areas)
- Steenbras: Southern Suburbs (high lying areas on mountainside and Constantia valley), Somerset West/Gordon's Bay (high lying areas), Fish Hoek and the Far South Peninsula
- Voëlvlei: Northern Suburbs (Atlantis to Milnerton), Epping, City Bowl, Green Point, Durbanville/Kraaifontein (upper areas)
- Wemmershoek: Paarl to Bellville, Northern Suburbs, City Bowl, Durbanville, Kraaifontein
- Witzands: Atlantis (water blended with supplies from Voëlvlei).

Wastewater and Sewage in the City of Cape Town

The 2011 census indicates that 88% of the population has access to flush toilets connected to the sewerage system. Alternative sanitation options are available for another 8% and almost 3% has no formal toilet facilities.

A total of 16 larger and six smaller wastewater treatment works service the city, ensuring compliance with requirements related to discharged water quality.

© Gerrit Burger

WWTW	Date commissioned	Capacity (Ml/d)	DWS licence (Ml/d)	Plant type
Cape Flats	1960	200.0	161.0	Activated sludge
Athlone	1923	105.0	110.0	Activated sludge
Zandvliet	1989	72.0	73.6	Activated sludge
Bellville	1950	54.6	56.0	Activated sludge
Potsdam	1957	47.0	43.9	Activated sludge
Mitchells Plain	1976	45.0	35.3	Activated sludge
Green Point	1993	40.0	27.3	Sea outfall
Macassar	1978	38.0	30.7	Activated sludge
Borcheds Quarry	1973	35.0	35.3	Activated sludge
Fisantekraal	2012	24.0	58.0	Activated sludge
Kraaifontein	1971	17.5	28.0	Activated sludge
Wildevoelvlei	1976	14.0	5.8	Activated sludge
Scottsdene	1976	12.5	10.0	Activated sludge
Hout Bay	1993	9.8	5.2	Sea outfall
Wesfleur Domestic	1978	8.0	6.9	Activated sludge
Wesfleur industrial	1978	6.0	3.2	Activated sludge
Camps Bay	1977	5.5	2.3	Sea outfall
Melkbosstrand	1977	5.4	3.6	Activated sludge
Gordon's Bay	1994	3.1	3.4	Activated sludge
Simon's Town	1970	2.5	1.8	Bio filters
Parow	1976	1.2	0.8	Activated sludge
Llandudno	1973	0.28	0.2	Rotating bio disc
Philadelphia	1996	0.086	0.08	Oxidation pond
Klipheuwel	2000	0.07	0.07	Rotating bio disc
Millers Point	1996	0.06	to be determined	Rotating bio disc
Oudekraal	1996	0.03	to be determined	Rotating bio disc
Groot Springfontein	1984	0.01	0.01	Oxidation pond

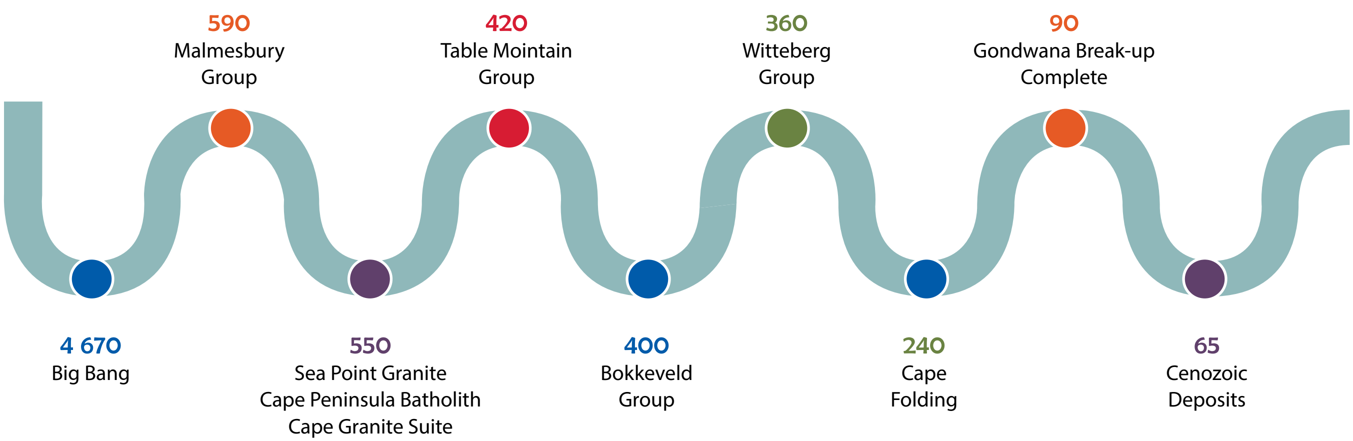
The City of Cape Town presently operates 22 wastewater treatment works (WWTWs). These ensure that all sewage is treated to acceptable limits for discharge (Source: www.capetown.gov.za).

Chapter 2: A Glimpse Through Time: Ancient History

"Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time. On some of the rocks are timeless raindrops. Under the rocks are the words, and some of the words are theirs. I am haunted by waters."

– Norman Maclean, A River Runs Through It and Other Stories.

CTN Ancient Timeline: Million years before present Geological Events



Timeline, shown in years before the present day, depicting ancient event shaping the planet in the vicinity of Cape Town, from the Big Bang to the present (© Clearcreative).

A Long and Intricate Geological History

History repeats itself continuously throughout geological time. Processes happening today have happened in the geological past and will continue to occur in the geological future. These processes weather rocks, erode sediment, and deposit sediment elsewhere where processes of lithification or cementation form new sedimentary rocks. The rock cycle is indeed a cycle, where the broken-down fragments of older rocks move through these processes of erosion to form completely new younger rocks.

Whereas weathering is the physical or chemical breakdown of rocks into finer (and often dissolved) constituents, erosion is the agent transporting the broken-down material to a different position. Transported soils – as opposed to residual soils that form in-situ through weathering but never get physically eroded – are named according to this erosion agent.

Probably one of the most common agents of erosion is also one that threatens habitation adjacent to drainage courses: rivers flood, and while they wash away vast amounts of soil on the banks and in the streams, they also serve to deposit these sediments elsewhere. This *fluvial* process forms the soil deposits termed *alluvium* and, depending on the flow rate and stream energy, sedimentary rocks represent the fine clayey materials from the flood plains, sandy deposits from the stream banks or pebbly conglomerates from the stream channel itself.

Water furthermore transports sediment through other parts of the water cycle. Coastal processes result in *marine* sediments, *lacustrine* sediments are associated with lakes and *deltaic* sediments are deposited in the deltas where rivers flow into the oceans. Depending on the mode of transport and energy associated with the transport mechanisms, different soil types and eventually different sedimentary rocks can form.

Ice transports sediment through *tillage* and *glacial* processes to eventually form rocks such as *tillite*. Wind-blown sands form *aeolian* deposits and gravity down hillslopes form *colluvial* deposits. Chemical weathering and dissolution result in the rock being dissolved in water that, when precipitating out, forms chemical sedimentary rocks such as limestone and dolomite. The erosion agent here is not only flowing water, but also chemical diffusion.

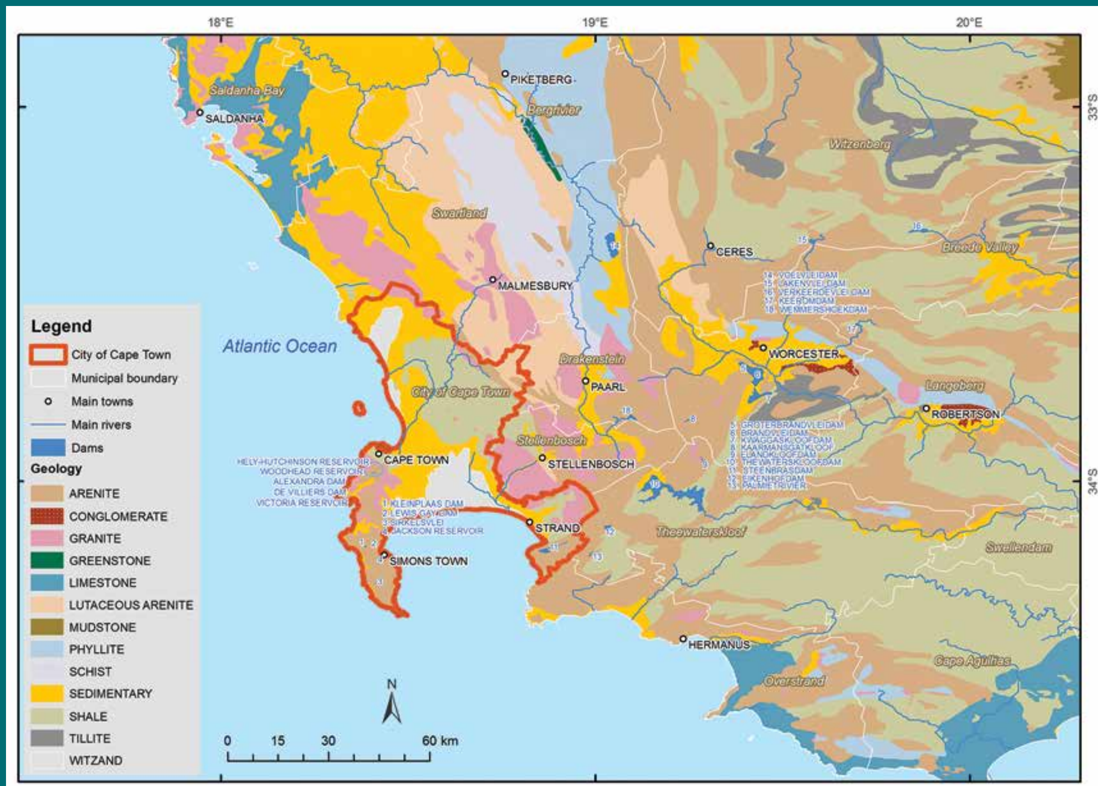
All of these different erosion agents occur daily and are eternalised in the geological record. We see, in Cape Town, the weathering process itself, the erosion agents, and the newly formed rock types and land forms.

The preserved rocks around Cape Town are associated with the Namibian Erathem and Cambrian Period, following the break-up of a supercontinent in the Mesoproterozoic. As this happened, the oceanic basins opened up and the Pan-African orogeny resulted in the formation of a number of Neoproterozoic mobile belts throughout the African continent.

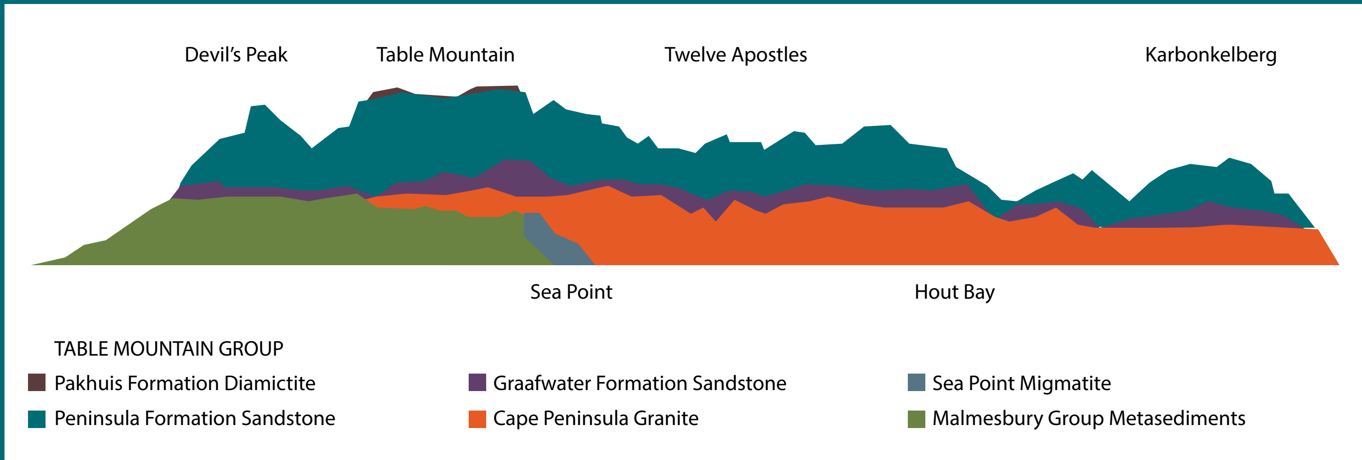
In the vicinity of Cape Town, remnants of these events are exposed in the so-called Saldania Belt. This low-grade orogenic belt along the southern and southwestern margins of the Kalahari Craton is exposed mainly through the Malmesbury Group which was later intruded by the Cape Granite Suite.

This was later followed by the deposition of the thick Cape Supergroup sedimentary rocks that have since been significantly deformed to form the Cape Fold Mountains.

Geology of Cape Town and Environs



The geology of the City of Cape Town comprises essentially metasediments of the Malmesburg Group, granites of the Cape Suite and sedimentary rocks of the Cape Supergroup.

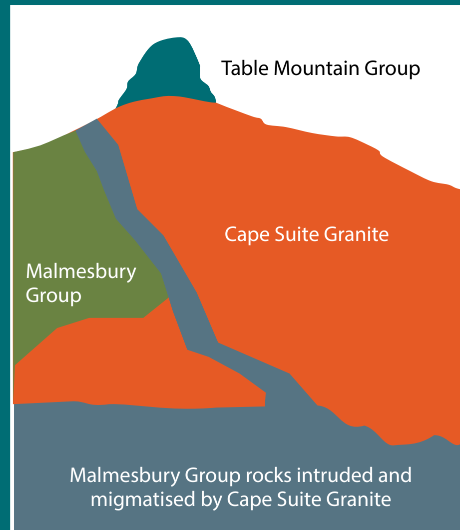


A cross-section from the northeast to the southwest depicts the major stratigraphic units of Table Mountain and Cape Town. The springs typical of Table Mountain tend to occur on the contact between the sandstones and underlying granite, the latter forming a low-permeability horizon. This causes water to flow out laterally rather than to percolate vertically downwards, causing springs to form. With this geological view of Table Mountain, one can appreciate the complex geological history having formed the landscape and this natural world wonder.

Age	Supergroup	Group	Subgroup	Formation	Lithology	Significant Intrusives and events
Cenozoic		Sand-veld		Elandsfontyn, Varswater, Velddrif, Langebaan, Springfontyn, Witzand	Various sands	
Cretaceous						Gondwana Breakup
Jurassic						
Triassic						Cape Orogeny
Permian						
Carboniferous	Cape	Witteberg	Lake Mentz	Waaipoort	Mudrock, sandstone	
				Floriskraal	Shale, sandstone	
				Kweekvlei	Shale	
Devonian				Witpoort	Sandstone	
			Weltevrede	Swartruggens	Shale, siltstone, sandstone	
				Blinkberg	Sandstone, siltstone	
				Wagen Drift	Shale, siltstone, sandstone	
		Bokkeveld	Bidouw	Karoopoort	Mudrock, siltstone, sandstone	
				Osberg	Sandstone	
				Klipbokkop	Mudrock, siltstone, sandstone	
				Wuppertal	Sandstone, siltstone	
				Waboomberg	Mudrock, siltstone, sandstone	
			Ceres	Boplaas	Sandstone	
				Tra-Tra	Mudrock, siltstone	
				Hex River	Sandstone	
				Voorstehoek	Mudrock, siltstone	
				Gamka	Sandstone	
				Gydo	Mudrock, siltstone	
Silurian		Table Mountain	Nardouw	Rietvlei	Sandstone	
				Skurweberg	Sandstone	
				Goudini	Sandstone	
				Cedarberg	Shale, siltstone	
				Pakhuis	Diamictite, sandstone	
				Peninsula	Sandstone	
				Graafwater	Sandstone, siltstone, shale	
				Piekenierskloof	Sandstone, conglomerate	
Ordovician						
Cambrian						Cape Granite
Namibian		Malmesbury		Tygerberg	Greywacke, phyllitic shale and siltstone, immature quartzite	
Mokolian						

The stratigraphic succession refers to the sequence of geological events and rock formation throughout history. The youngest rocks are shown at the top, and age increases towards the bottom of the column. The different geological times are indicated with the Mokolian and Namibian Epochs forming part of the Neoproterozoic Era of the Proterozoiz Eon. The Cambrian to the Permian Epochs all form part of the Palaeozoic Era, and the Triassic to the Cretaceous forms part of the Mesozoic Era, both eras part of the Phanerozoic Eon. The Cenozoic Era continues until this day. The Cambrian also marks the so-called Cambrian Explosion – a time in the geological history when life diversified and rapid evolution of new animal and plant species followed. Some of these fossils can be seen near Cape Town at Langebaanweg where excavations continue to this day.

Geology of Cape Town and Environs (continued)

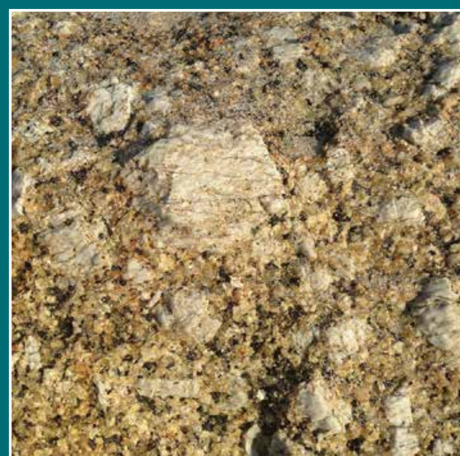


The view from Sea Point – the same as described by Charles Darwin in the 1800s – shows all major stratigraphical units commonly outcropping in Cape Town. The Malmesbury Group rocks were deposited first. Intrusion of the Cape Suite Granite immediately afterwards resulted in the formation of migmatite of which the exact extent is estimated here. The Table Mountain Group sediments were deposited later and are the youngest of these units. Unconsolidated Cenozoic deposits overlie all these rock types at different localities. (© Matthys Dippenaar).

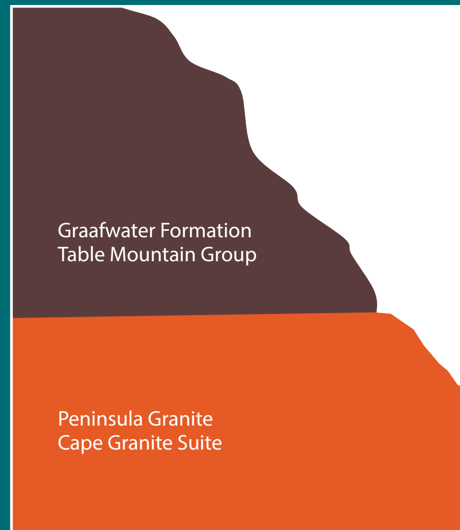
The metamorphosed sediments (metasediments) of the Malmersbury Group are highly variable as evident by the colours of the pebbles at Bloubergstrand. Rock types include greywacke sandstone and schist. Extensive metamorphism and folding ensued, exposing the now near-vertically bedded rocks. The rounded state of the pebbles implies high energy erosion over long distances. As rocks naturally fracture in angular shape, the movement of these rocks through river channels and wave action progressively round the corners and edges into rounded pebbles. (© Matthys Dippenaar).

Geology of Cape Town and Environs (continued)

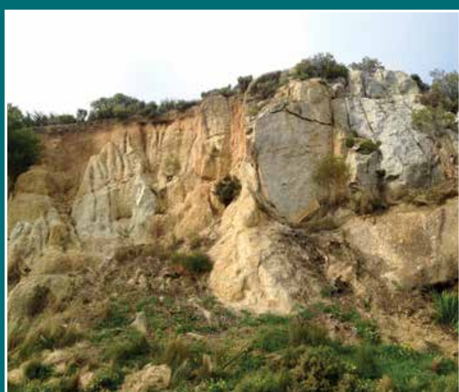
Migmatite form when magma intrudes into country rock, resulting in remelting and recrystallisation of the rock it is intruding into. Here, at Seapoint, one can clearly see the whitish Cape Granite and the recrystallized Malmesburg Group rocks, forming the coarse-grained light-coloured and fine-grained dark-coloured banding common in migmatites. Both rocks are used in the contruction of embankments and for erosion control. The wall at Sea Point and the boulders on the beach at Milnerton are good examples. (© Matthys Dippenaar).



The Peninsula Granite of the Cape Suite Granite – exposed here at Llandudno Beach – range from fine-grained to very coarse-grained and porphyritic. The latter is shown on the right where feldspar (a very common rock-forming mineral) forms very large crystals (called phenocrysts) in a matrix of quartz, feldspar and mica. Two different feldspars typically intergrow of which microcline dominates, resulting in it being called a microcline (potassic feldspar) perthite. (© Matthys Dippenaar).

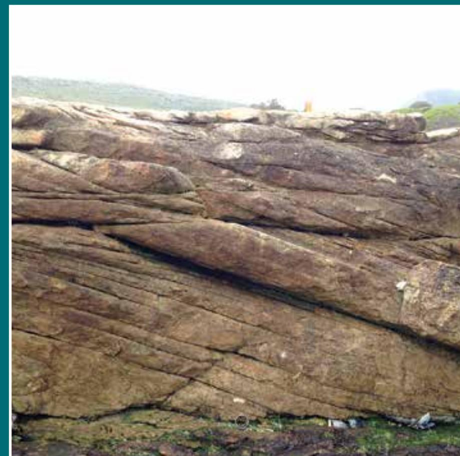


The contact between the Cape Granite Suite and the Graafwater Formation (which underlies the Peninsula Formation) is evident when driving along Chapman's Peak Drive. The road is constructed on the contact with the sedimentary rocks overlying the granite. This contact forms a prime locality for the formation of springs. (© Matthys Dippenaar).

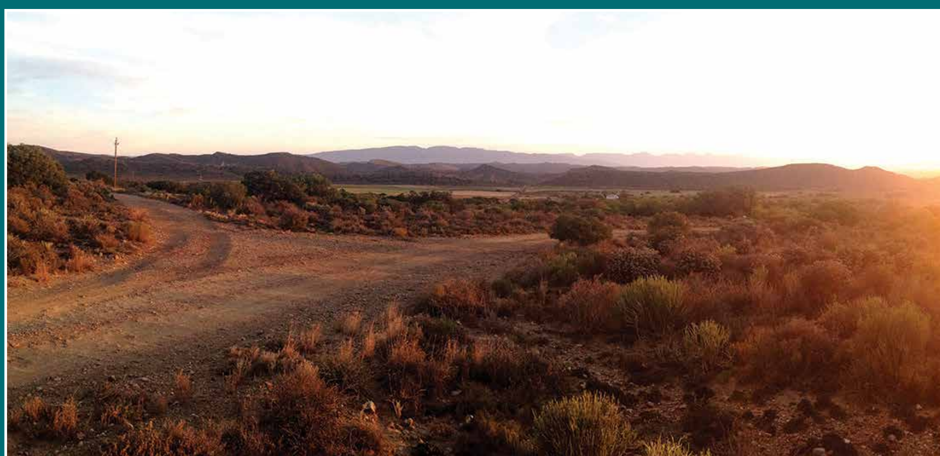


The Cape Granite has very variable weathering patterns. Bedrock topography (the interface between soil and the fresh rock) is highly irregular and distinctly different weathering products result. Completely decomposed granite on the left still shows the original rock colour and structures (such as joints), yet a few hundred meters away it forms deep pinkish red soils as shown in the centre. Probably the biggest construction issue, however, are large corestones which also form the large boulders on slopes and along the coast lines. (© Matthys Dippenaar).

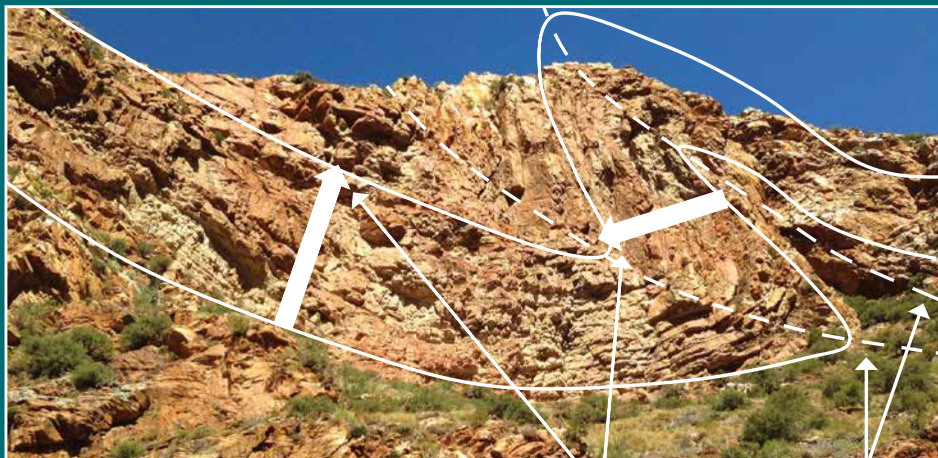
Geology of Cape Town and Environs (continued)



The Peninsula Formation form the bulk of Table Mountain, as seen here from the Hely-Hutchinson Dam. It comprises pebbly quartzite sand is overlain by the Pakhuis Formation comprising glacial tillite on the highest elevations of the mountain. The sandstones exhibit distinct cross-bedding, which is evident of a fluvial deposition environment. This is formed from the same process that form small ripples on tidal plains or rivers, with the direction of the cross-beds also indicating the historical direction of water movement when the rock was deposited. (© Matthys Dippenaar).



The landscape around the Warmwaterberg on Route 62 is characteristic of the Ceres Subgroup. (© Matthys Dippenaar).



The Nardouw Subgroup is well-folded in the vicinity of the Meiringspoort Waterfall in the Swartberg Mountains. The upward arches are termed antiforms (or sometimes anticlines, although this implies that it becomes younger upwards) and the U-shaped troughs synforms (or sometimes synclines if the youngest rocks are in the middle). These folds show some degree of overfolding, meaning that the strata are deformed upside-down in certain instances. This is indicated by the blue arrows in the schematic. (© Matthys Dippenaar).

The white sands of the Springfontyn Formation doubles as a temporary primary aquifer (called the Witzand Aquifer) in the region of Atlantis. These sands cover vast areas in the vicinity of Cape Town and were formed through aeolian (wind-driven) and coastal (wave action) processes. (© Matthys Dippenaar).

Malmesbury Group

The Malmesbury Group – the oldest major rock outcrop in the Cape Town area – is subdivided into three distinct terrains, likely separated by fault systems. The northeastern Boland Terrane is separated from the central Swartland Terrane by the Piketberg-Wellington fault zone, and the Swartland from the southwestern Tygerberg Terrane by the Colenso (Saldanha-Stellenbosch) Fault.

Cape Town itself falls within this southwestern Tygerberg Terrane with the Tygerberg Formation forming the only subdivision of the Malmesbury Group in this area. Rock types alternate between greywacke, phylittic shale, siltstone, immature quartzite and some sporadic and thin impure limestone and conglomerate beds. Most of these represent metamorphic rocks, implying that other rock types was changed due to immense changes in pressure and temperature during the geological past. Minerals change, recrystallize or change orientation due to these changes in conditions, resulting in the formation of a new suite of rock types.

A single volcanic event is present in the Blouberg Member of the Tygerberg Formation. Although active volcanoes no longer exist on the stable subcontinent, numerous other such lava deposits occur throughout the country.

Cape Granite

The Cape Granite Suite intruded into the somewhat younger metasedimentary and metavolcanic rocks of the Malmesbury Group during the same Pan African Saldania Belt event. Its composition is highly variable, ranging between olivine grabbro to leucogranite. Granites and granodiorites are, however, by far the most abundant throughout the Cape Granite Suite.

The granites are mostly undeformed and are subdivided into the eastern (around George), southwestern (around Cape Town) and northern (around Richtersveld) plutons. In the southwestern plutons, six typical rock types are encountered. Old, coarse porphyrytic granites are most common and show distinct phenocrysts of microcline perthite and accessory biotite and cordierite. A second phase of individual plutons or intrusions of medium-grained biotite granite followed, after which fine-grained leucocratic granites, often with tourmaline and muscovite, intruded into both the prior.

Latter bodies of amphibole-rich quartz syenites and alkali granites were followed by gabbro plutons intruded by diorite. Final stages involved rhyolite and rhyodacite volcanics, although these occur further north towards Saldanha Bay.

All rocks in Cape Town itself, however, fall within the Malmesbury Batholith and more specifically the Cape Peninsula Granite of the Cape Granite Suite.

Cape Supergroup

Following the Pan African Saldanian orogeny, a passive margin basin resulted in the present-day Western Cape of the supercontinent of Gondwanaland. Three main subdivisions are preserved in the geological record, namely the Table Mountain, Bokkeveld and Witteberg Groups. The Cape Orogeny later significantly deformed the rocks into the Cape Fold Mountains.

The oldest – the Table Mountain Group – is so named after Table Mountain itself. Ordovician to Early Devonian in age, shallow marine to fluvial conditions deposited mostly sandstones. Fossiliferous shale and sandstone of the Bokkeveld Group followed due to delta environments between the Early and Middle Devonian. The final stage – the Witteberg Group – followed during the Late Devonian to Early Carboniferous Age and comprises sandstone and mudrock in shallow-marine to deltaic environments.

The Table Mountain Group differs to the west and east of the 21 degree longitude. To the west, in the vicinity of Cape Town, it comprises eight formations mostly comprising sandstone.

Deformation

The Late Permian to Early Triassic epochs mark the events that resulted in the Cape Fold Mountains. Significant northwest- to north-trending folds are notable between Stellenbosch to Vanrynsdorp and the Great Fish River (near Port Alfred) and Swellendam. Although not as distinctly evident within the City of Cape Town itself, it provides the scenic route from the inland down the escarpment and exposes many of the old rocks to the surface.

It is estimated that the folding occurred between 278 and 230 million years ago through a series of four distinct events. This occurred mostly simultaneously with the deposition of the older Karoo Supergroup rocks, some of which was deformed during later stages. The Karoo Supergroup rocks occur in the Karoo area, after which is was also named, and covers approximately two thirds of South Africa's land surface.

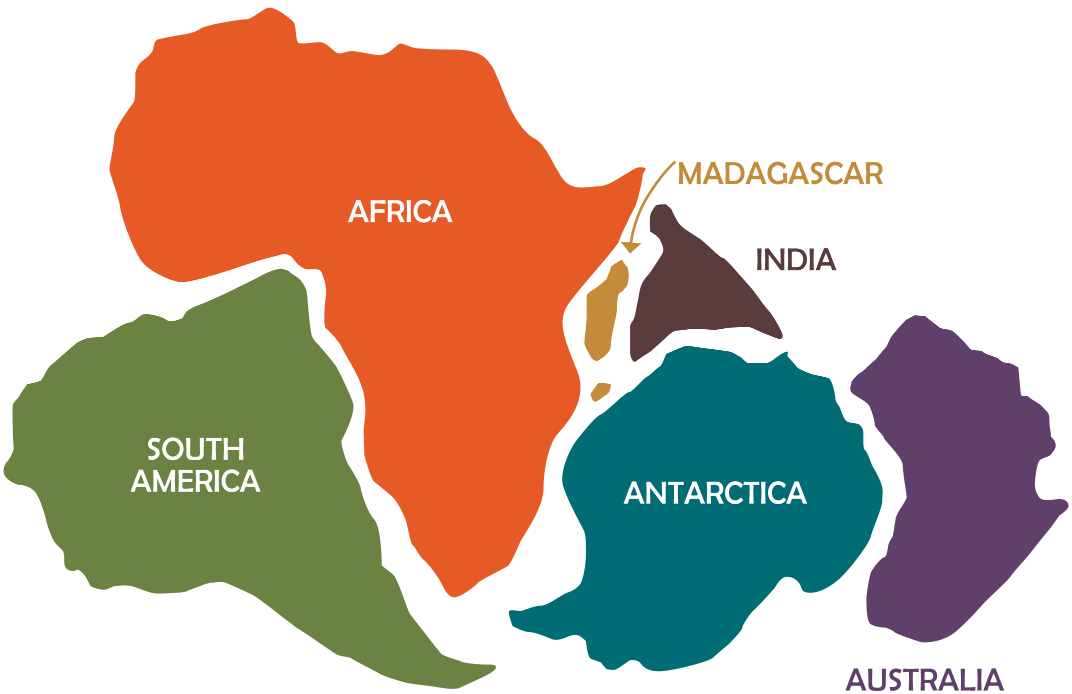
However, following the deformation of the Cape Fold Belt, the supercontinent Gondwana started breaking apart through five stages between 180 and 90 million years ago. Where initially Africa fitted in the centre of a jigsaw puzzle surrounded by South America, Antarctica, India and some smaller plates, the break-up resulted in the exposure of the present-day coastline, which was initially part of the inland.

Following all these tectonic events, the Southern African continental crust was elevated above ocean level and, due to buoyancy effects, rapid weathering and erosion resulted. This not only eventually carved the steep escarpment, but also generated sediment to be deposited along the coastline during the Cenozoic.

Cenozoic Deposits

The Sandveld Group include all Cenozoic deposits in the southwestern coast between Elands Bay and False Bay. The controls on these deposits include the Cape Orogeny and Gondwana breakup combined with historical climatic fluctuations. Six formations are distinguished, most described as sands, with variable archaeological and palaeontological significance. These formations, from oldest to youngest, include the Elandsfontyn, Varswater, Velddrift, Langebaan, Springfontyn and Witzand Formations.

These deposits are still classified as soils and has not undergone the processes required to be classified as rock. Nonetheless, each of these formations are distinct in its composition.



The breakup of Gondwanaland exposed South Africa to the ocean, eventually resulting in the formation of the great escarpment. Rocks and fossils correlating between South America and Africa are used to infer the original jigsaw puzzle that once formed Gondwanaland. It is clear that the southern portion of Africa was once in the central portions of Gondwanaland, situated a significant distance from the oceans. This played an important part in forming the extensive deposits of the Karoo Supergroup covering the vast majority of the inland. Eventual break-up of the continents (which happened over tens of millions of years) changed the system from one of deposition to one of weathering and erosion. The development of the landscape continues to this day.

Landscape Development and Surface Drainage

The water cycle

Water moves through the closed system that is Earth. The amount of water is fixed, but its disposition is continuously changing. Water occurs in the atmosphere as vapour until clouds form and precipitation results. This introduces water to the land or ocean surfaces. On land, water can either infiltrate into the subsurface, or it can continue on the land surface as runoff, eventually forming rivers. Some water also evaporates back to the atmosphere.

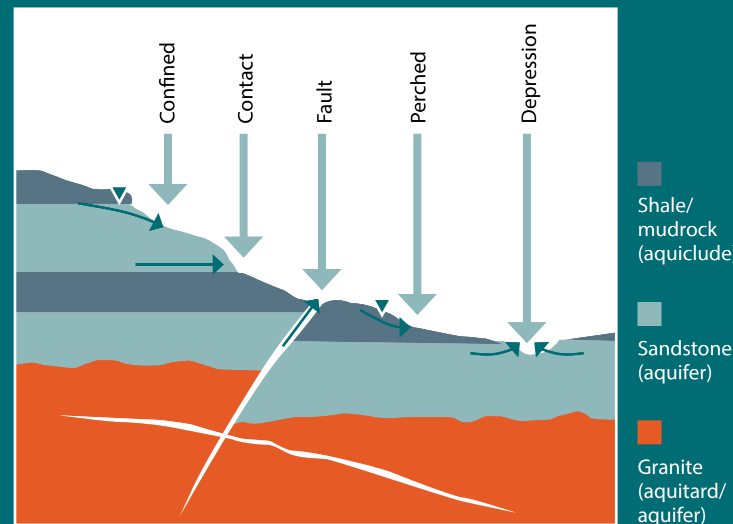
Plants use the infiltrated water and release the water back to the atmosphere through the process known as transpiration. The remainder of the infiltrated water moves as interflow to rivers, springs and wetlands, or it moves deeper into the ground to eventually recharge the groundwater. Groundwater also flows and can also discharge into rivers.

Rivers eventually move to the ocean, carrying erosion debris and dissolved salts with it. Upon reaching the ocean, evaporation is required to rid the water of the excessive salt content, resulting in freshwater rainfall.

This system is highly simplified. Little cognisance is given to changing water storage and movement underground, the incorporation of water in rocks, magmas and rock-forming minerals, or the movement of water between the physical environment and living organisms.

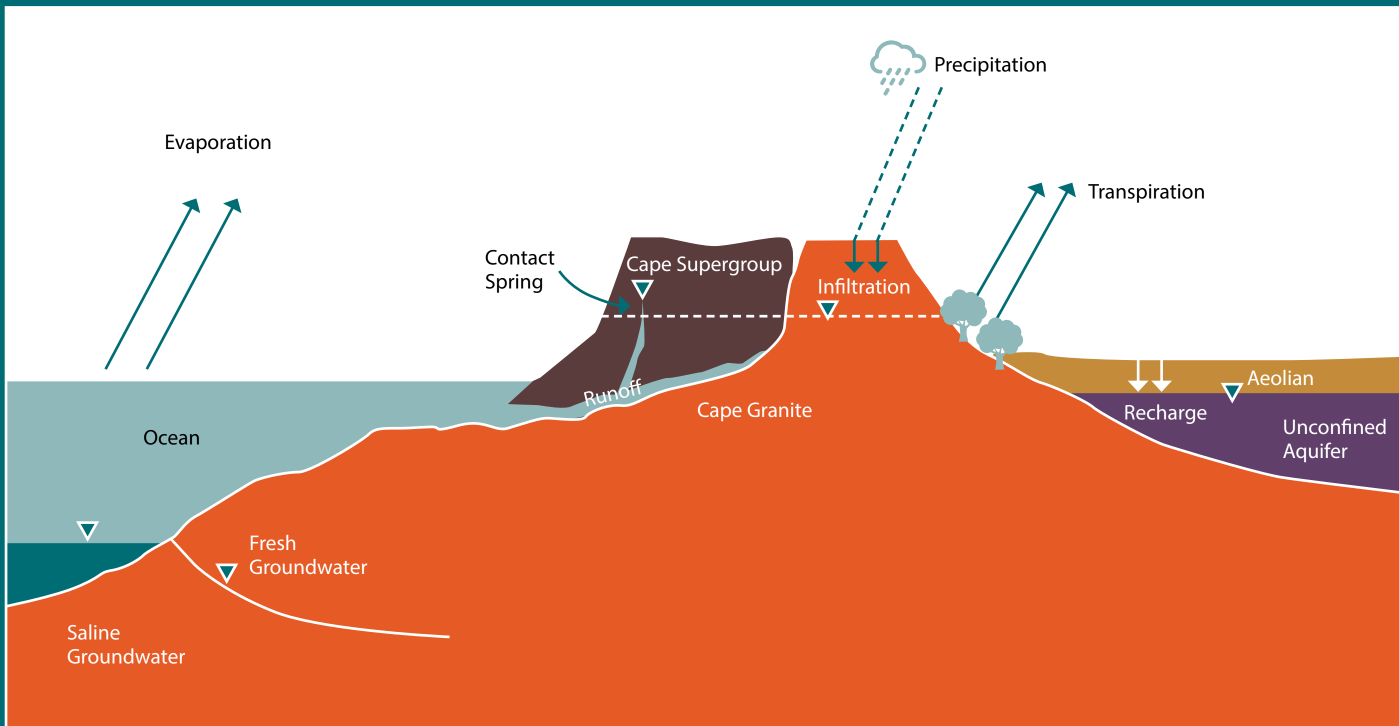
Yet, even in its simplified form, it is easy to see that the water cycle is sensitive to interference. Higher temperatures and warmer climates – as are ensuing due to climate change – affect the water balance and water distribution. Development interferes with drainage channels and water infiltration. Man has, in effect, become part of the water cycle.

Water Cycle



Springs, defined as those areas where the groundwater table intersects the land surface, occur due to a number of reasons. Aquifers confined above and/ or below by lower-permeability aquicludes can result in confined or contact springs. Depressions springs occur where weathering has exposed the aquifer to the land surface. Springs associated with faults often result in hot or warm springs as water is transferred from great depths along highly fractured zones. Finally, perched springs form through interflow water on hillslopes and are not associated with the regional groundwater table. All of these springs, together with river channels and other freshwater bodies, typically form conditions conducive to growth of wetland vegetation. As the areas are typically periodically to permanently waterlogged on surface, plants adapted to growth in wet conditions occur, often forming wetlands. These important doorways between groundwater and surface water are vital in promoting biodiversity and maintaining good surface water quality.

Water Cycle



The water cycle represents an intricate interaction between water in the atmosphere, on the land surface and underground. In coastal environments, saline seawater and saline groundwater form part of this cycle. The latter can also impacts negatively on fresh groundwater quality if overpumped, causing saltwater to intrude into the freshwater aquifers. In South Africa's climate, evaporation and transpiration can be excessively high, reducing the available water for infiltration and runoff significantly. However, plants are important in reducing the runoff flow rate of water, which can also promote infiltration, preventing all freshwater to discharge into the ocean.

Forming landforms

The land surface is not flat. Rather, the land mass of planet Earth is characteristically uneven, with gradual topographical changes as well as sudden deeply incised canyons and valleys. Mountain ranges and volcanism due to tectonic processes are some of the internal processes resulting in elevating portions of land, while isostatic readjustment – the same buoyancy effect noted in icebergs or ice in a glass – forces elevate land masses to sink deeper into the Earth's mantle.

With elevation comes higher potential for movement or erosion of weathered materials. Mass wasting is one such an example, where weathered rock and soil moves downslope under the influence of gravity. Rivers cut into rock to form channels, further washing away the finer soil and rock with the energy of flowing water. All of these processes aim to flatten all slopes to a neutral level, called a base level.

In steep slopes – such as those encountered in the Cape Fold Mountains or Table Mountain itself – fractures in rock and periods of water surplus can trigger slope failure and the process of mass wasting. Other than water, gravity forms the mechanism of erosion as sediment move downslope.

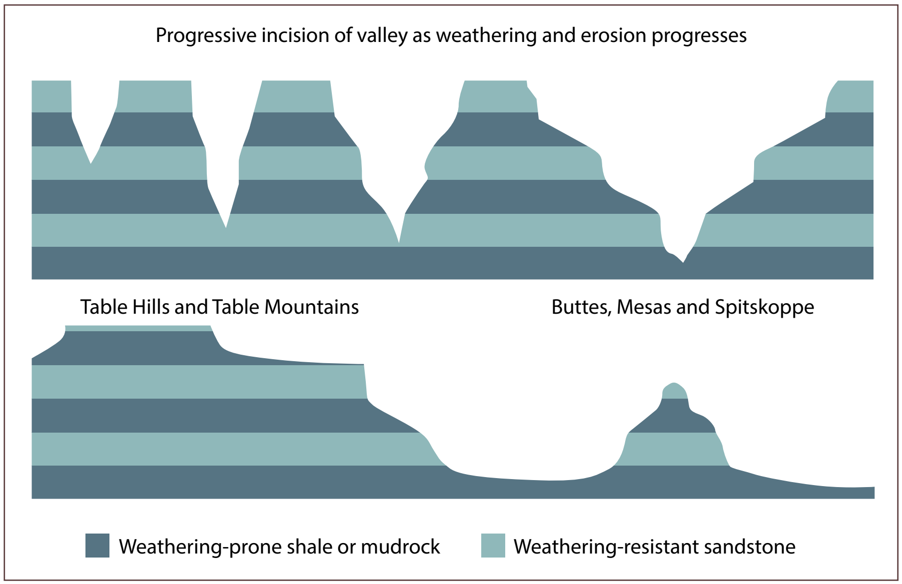
The steep escarpment associated with South Africa's coastline is subsequently progressively being cut back through weathering and erosion. From inland, rivers cut valleys and transport sediment to the ocean. From the coastline itself, ocean currents and waves weather and erode cliffs.

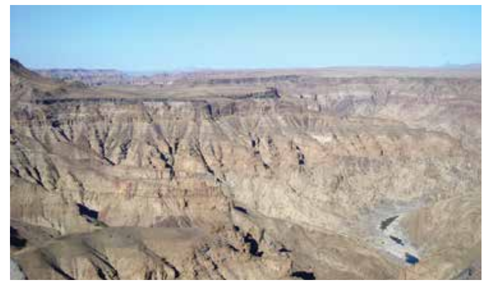
This escarpment remains as a remnant of the old supercontinent of Gondwanaland, where South Africa was in the inland between the southern tip of South America and Antarctica. Since, South Africa is situated in a fairly stable tectonic environment where internal tectonic processes are fairly stagnant. Weathering and erosion have subsequently taken over and the southern tip of Africa is slowly but surely being denuded to flatter topography.

As ice floats in water, so the liquid mantle underlies the solidified geological plates, essentially floating on magma due to buoyancy. Similar to ice in a glass, the continents are in a state of non-equilibrium, and are progressively weathered and eroded from the top and melted from the bottom. This process of isostacy aims to eventually reduce the complete landscape to a single elevation without topographical changes and with equal seawater depth. Luckily, ongoing plate tectonics processes ensure that the complete Earth has not been flooded yet.

A number of distinct erosion cycles shaped and continues to shape the land surface in South Africa. Six such cycles exist, each representing long periods of weathering and erosion to form a new set of base levels. These base levels represent levels to which the landscape is aiming to reach an equilibrium with very little distinct landforms.

The six erosion cycles are all associated with the break-up of Gondwanaland or the development of the geomorphology between then and the present. The first, the Gondwana planation, occurred around 190 million years ago, and was followed by the Post-Gondwana cycle (135 million years), African cycle (100 million years), Post-African I cycle (20 million years) and the Post-African II cycle (5 million years). The last, the Quaternary cycle, commenced around 2 million years ago.





Various landforms are common in near-horizontally bedded sedimentary rocks such as those of the Karoo and Cape Supergroups. The young landscape is typically characterised by the development of deep canyons with valleys becoming broader as weathering and erosion continues. Progressively weathering due to initial incisions by drainage channels develop over time onto the very characteristic landscape of, for instance, the Karoo. Over time, table mountains and spitskoppe result as bulk of the weathered materials are eroded to the oceans. Examples are shown of a deep incised valley at the Fish River Canyon (Namibia) and how table hills and spitskoppe form near Harrismith (South Africa).

Where two oceans meet

Cape Town is situated where different ocean currents meet, resulting in weathering of the landscape from different directions. The city itself is named after the geomorphological land form known as a *cape*, referring to a point of land that projects into any body of water. *Peninsula* is often used synonymously, although the name is derived from the Latin *paene* and *insula*, translating as "almost island". A peninsula is, therefore, a piece of land specifically bordered by water on three sides but remaining connected to the mainland.

A *bay* is associated to these, referring to a broad inlet of the sea where a body of water forms an indentation into the shoreline. *Coves* and *gulfs* refer respectively to smaller and larger bays. More formal definitions are freely available on the Internet (e.g. merriam-webster.com; thefreedictionary.com; wikipedia.org; dictionary.reference.com).

Cape Peninsula therefore specifically refers to the southernmost portions of Cape Town where the land mass south of Table Mountain extends into the ocean where the Indian and Atlantic Oceans meet.

Sandy beaches and salty seawater

The stability of common rock-forming minerals on Earth's surface and their resistance to weathering are often described according to Goldich's weathering sequence. According to this, the mineral quartz is the most resistant abundant mineral to chemical change due to weathering. The major rock-forming minerals fall within a group called silicates. As the silica composition increases, the mineral becomes more stable on land surface. Where darker coloured minerals containing a lot of other elements, such as iron, calcium, magnesium and so forth, weather to clay minerals with fair ease, those containing only silicon dioxide (such as quartz) are inert to chemical change in natural conditions.

These other minerals, such as silica-poor minerals, oxides, carbonates and clay minerals, progressively change mineral form first to more stable secondary minerals and eventually to complete dissolution as ions in moving water. Quartz remains the exception, as its composition of SiO_2 cannot readily be broken down into any other mineral. This is therefore one of the reasons, together with the abundance of silicon and oxygen that form the mineral quartz, why beaches are generally made up of quartz-sand. Most other minerals break down completely, eventually contributing to the salt content of the ocean.

The coastal landscape is therefore a function of long-term weathering and erosion of inland rocks. As minerals break down, weathered sediment and ions are eroded to the oceans by means of rivers and other agents. The eventual deposition of sand on beaches and precipitation of ions in the oceans form new rocks as part of the intricate rock cycle.

Chapter 3: A Glimpse Through Time: Recent History

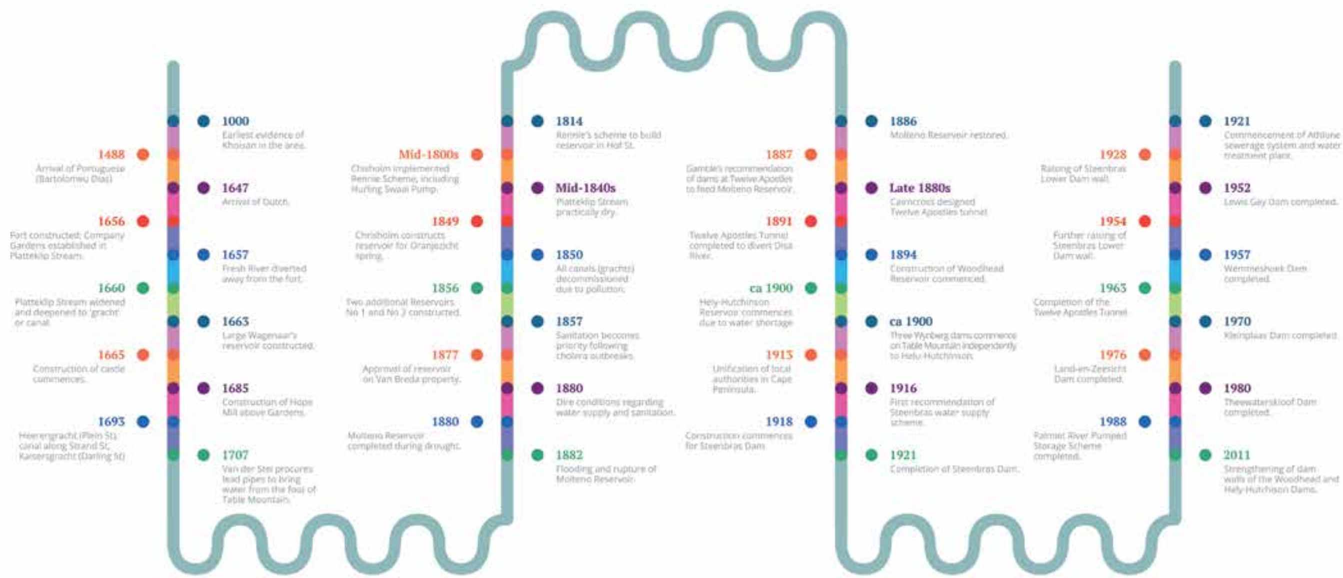
Cape Town is not the oldest city in South Africa, but it is one of the earliest inhabited places in South Africa. Its freshwater resources and position at the tip of the African continent quickly attracted nomadic Khoisan and early settlers with some of the earliest reference to the area made by Charles Darwin.

The city surrounding the mountain continued to grow – as did its intricate water supply incorporating springs, dams, canals, tunnels and more recently artificial recharge – into one of the best tourist locations in the world. Yet few people – including some local residents – are aware that Table Mountain is home to numerous groundwater springs and five of the oldest dams in South Africa, all with significant contributions to the water-supply history of this wonderful city.

"What are men to rocks and mountains?"

– Jane Austen, Pride and Prejudice.

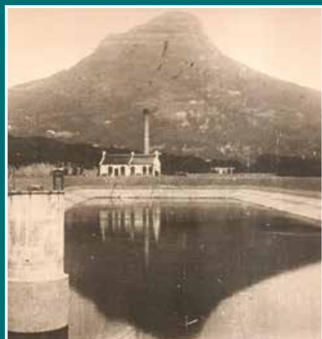
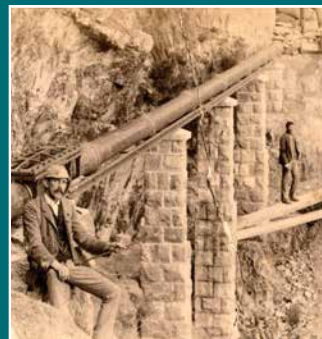
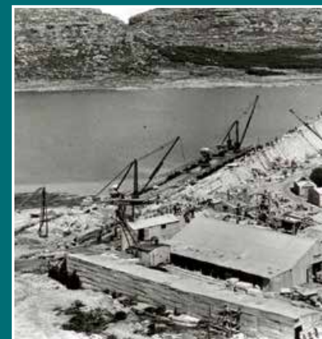
CTN Modern Timeline



Timeline, shown in years before the present day, depicting the development of Cape Town and the associated water infrastructure (© Clearcreative).

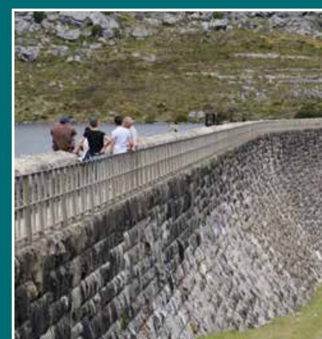
Cape Town Then and Now

THEN

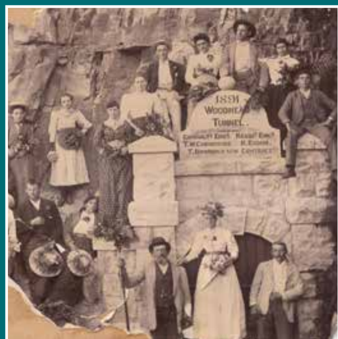




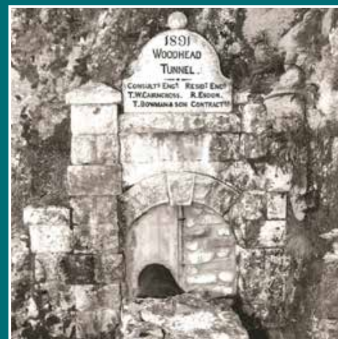

NOW

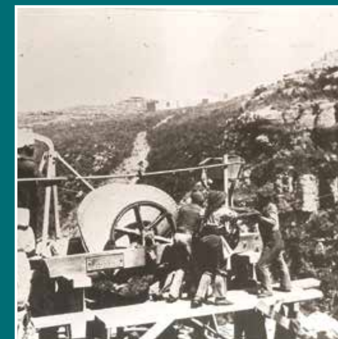


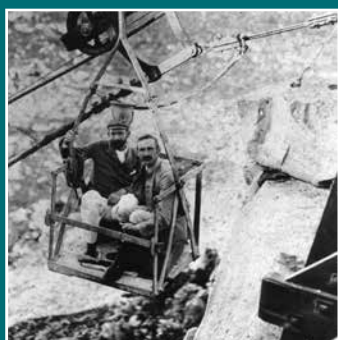


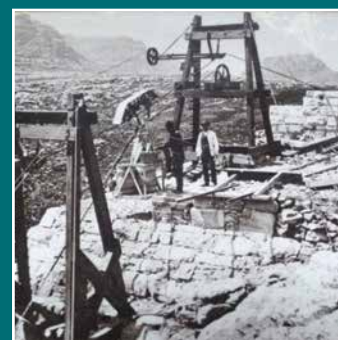

Old imagery © Cape Town down Memory Lane (Facebook) and individual authors; Arne Singels and Gerrit Burger.







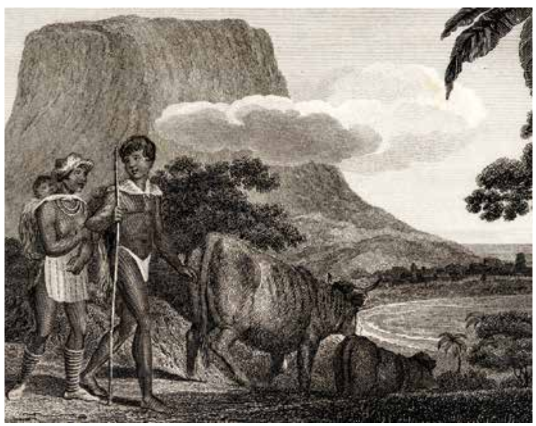




Pre-colonial Times

The first people to reside in the vicinity of Cape Town as early as the 1000s were the Khoisan, including the nomadic San hunters, the Khoi-Khoi and the Khoekhoen. The hunter-gatherer San people are believed to have inhabited the area for thousands of years until the settlement of the Khoi-Khoi along the western, southern and eastern Cape coastlines.

The Khoi-Koi lifestyle was more pastoral and these communities were more dependent on livestock. They named the area *Camissa*, which is the Khoi name for 'the place of sweet waters", and Table Mountain was named *Hoerikwaggo*, translating to "mountain in the sea". Both these names are still used in the area, with a recent organisation called *Reclaim Camissa* established with the aim of promoting awareness of Table Mountain's springs.



An early depiction of Khoi herders living in the area of Cape Town. © National Library of South Africa

Colonial Times

The Portuguese were the first Westerners to pass around Africa by means of ship as early as the fifteenth century, with explorer, Bartolomeu Dias, first making the journey in 1488 followed by Vasco da Gama in 1498. Two centuries later – on 25 March 1647 – the Dutch ship, Nieuwe Haerlem, stranded near present-day Blouberg. The stranded survivors decided to establish a post for the Verenigde Oos-Indiese Kompanjie (VOC, as established in 1602 under authority of the Here XVII) near Tafelbaai (Table Bay). Jan Anthoniszoon van Riebeeck arrived at Tafelbaai on 6 April 1652 with his ships – the Drommedaris, Goede Hoop and Reijger – and followed later by two further ships (the Walvis and Oliphant). Van Riebeeck's orders from the VOC were simple: to build a fort, lay out a vegetable garden, barter with the indigenous population for livestock, and build a flag pole to signal passing ships. The Cape was to become a halfway station for the VOC's ships travelling to and from the East.

Three waterways were believed to have existed in Cape Town around this time. The Capel Sluit was to the east of the saddle of Devil's Peak, another was more central from Platteklip, and a third was west of Kloof Nek.

Shortly after, in 1655, severe pollution issues were observed in the Cape. Placaat 12 of 1655 formed the first environmental legislation that forbade settlers to bathe or wash anywhere upstream from areas of water collection.

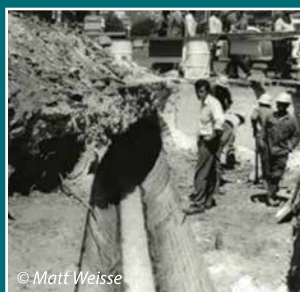
The first fort was constructed on the banks of the Fresh (Varsche from Dutch) River (a tributary of the Platteklip River) in 1656. The settlers, in the meanwhile,

The Castle, Canals and Tunnels

© Gerrit Burger

© Matthys Dippenaar

The Castle attracts numerous visitors annually and is one of the old remnants of Cape Town's rich history. The very popular Tunnel Tours also depart from the Castle and is definitely something anyone interested in history or water should consider.



© Matt Weisse

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Opening of the Adderley Street canal (left) and those in Strand Street (right) around 1973s.

© Gerrit Burger

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The tunnels are now decommissioned and are mostly used for tourism. The Tunnel Tours commence at the Castle and provides an interesting insight into the historical drainage of Cape Town.

grew in numbers from 14 to 1 368. The VOC gardens (or Company Gardens) was developed to supply Dutch ships with fruit, vegetables and herbs during this period, being in itself supplied with fresh water from the Oranjezicht springs at the top of Platteklip gorge. Water supply was by means of gravity with sluice gates along Orange Street. Canals were excavated on both sides of the garden for irrigation and to prevent animals entering in 1654. An old map (number CA M1/11) shows the Fort constructed parallel to the shore with the Platteklip and Kloof Nek stream. The garden was between Plein and Adderley Streets below Church Street to Ipit Street.

As the population grew, the garden expanded from 6 to 12 morgen and eventually to 20 morgen in 1656. A dam was constructed near the shoreline in 1663.

However, around 1657 to 1665, the new Company Gardens at Rondebosch gradually took over the function of these gardens. Further farms at Newlands, Liesbeeck and the upper Table Valley also contributed to the growing demands for water and fresh produce.

The lower course of the Fresh River was diverted to the sea away from the fort by means of a new, broader channel during October 1657. Water shortages ensued in 1661 and Van Riebeeck commenced the construction of the Wagenaer's Dam which was completed by his successor in 1663. This first modern reservoir is under the present Golden Acre building.

The remains of the Wagenaer's Dam was discovered in 1975 during excavations for the foundations of the Golden Acre shopping complex. The dam probably held about 3 million cubic metres of water. © National Library of South Africa

Construction of the Castle commenced in 1665 under Commander Zacharias Wagenaer (Van Riebeeck's successor) and was completed in 1679. In that year Simon van der Stel became the Cape authority. He established Stellenbosch as the first town in the inland in 1679. Drakenstein and Bergrivier followed around 1687. It was also during this time, in the late 1600s, that the French Huguenots arrived in the area and established some of the first wineries in South Africa.

The Hope Mill was constructed above the Gardens – 20 morgen in size at this stage – in 1685. The demolition of the remainder of the old forts and some houses were instructed by Commissioner van Reede during the same year.

The Dutch settlers established a series of water canals – much like existed in their home country. Heerengracht, one of the first canals, was supplied by a stream along Plein Street, and the slopes of Signal Hill were drained with a canal along Strand Street. Further canals flanking Strand Street, Whale Street, Queen Victoria Street (then Tuinstraat) and Lang Street were also constructed, with the last –

Oranjezicht Spring

© Gerrit Burger

© Gerrit Burger

The site at the Oranjezicht Spring was declared a National Monument in 1989. The 183 hectare farm Oranjezicht was established by Pieter van Breda in 1719. Historically the farm supplied fresh product to visiting ships such as those of the VOC. However, it was declared the suburb of Oranjezicht in 1901 when the springs became depleted due to municipal supply. Also referred to as the Stadsfontein ("City Fountain" from Afrikaans), it augmented Cape Town's water supply from 1886. Spring collection chambers are often constructed over the discharge areas to prevent contamination. However, these chambers also limit the influence of ultraviolet from sunlight, thereby reducing photosynthesis and algae growth.

© Matthys Dippenaar

The monument was erected at the old Oranjezicht homestead where a food market is now held over selected weekends.

© Matthys Dippenaar

Spring water is now pumped for irrigation of proximate sports fields given that the quality is no longer potable. The decline in water quality is mostly ascribed to the extensive development around the springs. As springs essentially flow out on surface, water becomes more vulnerable to pollution.

Kaisersgrachts along the present Darling Street – being completed in 1693. Darling Street itself was laid out in 1695, followed by the construction of the hospital on the corner of Wale and Adderley Streets in in the late 1600s and the establishment of the zoological gardens by Van der Stel above the Garden in 1700.

Willem Adriaan van der Stel succeeded his father as governor in 1699. His reputation for privatising many economical activities resulted in citizen unrest, causing Van der Stel and others to return to the Netherlands in April 1708. Water quality deteriorated during the early 1700s as waste polluted the canals. Van der Stel procured 200 lead pipes from the VOC in 1707 to bring water from the foot of Table Mountain to the jetty.

The new governor, Joachim Plettenberg, reached agreement with the Xhosa in 1778 to establish the Great Fish River as the eastern border of the new Cape Colony. However, shortly after in 1781, war broke out between the Dutch and the British. A French fleet arrived in the area of Tafelbaai around this time and Cape Town was shortly known as Petit Paris (little Paris).

Governor van de Graaf succeeded as authority of the Cape Colony in 1785. The majority of the streets were officially named in 1790, but, given financial troubles, the garden deteriorated rapidly during this time. Major James Craig and the British fleet arrived in Simon's Bay in 1795 and, as the Dutch gave over on 16 September 1795, British rule ensued for eight years. A Batavian management followed in 1802, until British general major David Baird besieged the area again in 1806 with a second British reign established on 18 January 1806.

General David Bairns was the acting governor following the British Occupation until he was succeeded by the count of Caledon in May 1807 and by Sir John Cradock in 1811. The population reached 15 600 by 1815 and increased to 26 000 by the mid-1820s as more British settlers arrived. Two new districts, Tulbach and Uitenhage, were proclaimed during this time. Until 1891, the whole of Cape Town was supplied with spring water.

As the VOC did not wish to overcommit to the halfway stop by investing too heavily in infrastructure, severe water shortages created constant problems for the Cape settlement. John Rennie, an engineer, proposed a 250 000 gallon reservoir in the present Hof Street to be filled with water from the Oranjezicht, Platteklip and Waterhof springs, which was eventually demolished in the 1900s.

Superintendent John Chrisholm oversaw the construction of a 12-inch diameter cast-iron pipeline in Long Street. Pumps lifted water for this scheme of which the Hurling Swaai Pump in Princess Street remains as a reminder and as a national monument.

Lord Charles Somerset acted as governor between 1814 and 1827 while residing at Tuynhuys or Government House using the gardens for his sole use. During this period, the population grew, with the garden very likely restored as a botanical garden to the public by 1826. 22 years later the botanical gardens were however only for subscribers with selected times available for the general public.

The canals became increasingly polluted and were decommissioned between 1827 and the late 1850s. The last portion of Heerengracht was covered and is under present-day Adderley Street. The last canals were closed in 1901 with the outbreak of bubonic plague.

A number of reservoirs were also constructed: No. 1 in 1849 between Orange and Hof Streets and supplied by the winter flow of the Oranjezicht spring, and No. 2 in 1856 supplied by the Main and Waterhof springs. The latter was used for irrigation of the Company Gardens and for fire-fighting.

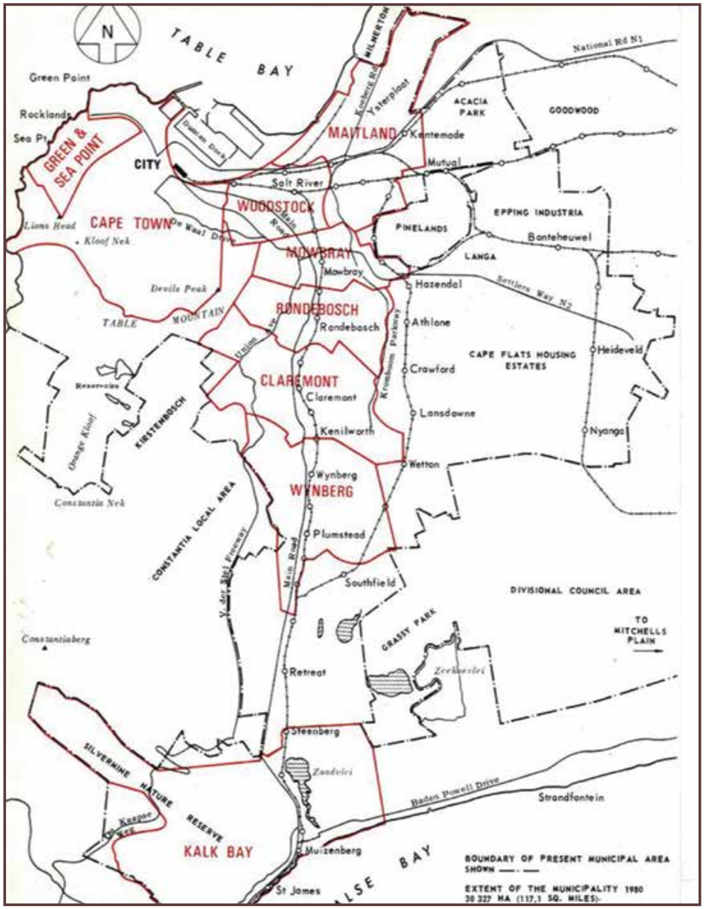
Around 1856 the municipality had acquired a portion of the Waterhof Estate, the Kotze spring on the Leeuwenhof Estate, and several mills along the Platteklip Stream. The Molteno Reservoir site at Kempement was also purchased by the Town Council in 1877. This reservoir was completed in 1880 and named after Sir John Molteno, the first Prime Minister of the Cape. With low winter rainfall, however, the 40 million gallon reservoir was empty until 1882, resulting in cracking during droughts and subsequent flooding of some streams. The resevoir was repaired by 1886 and still supplies water to the lower areas of Green Point and Sea Point.

The year 1880 was an exceptionally dry year, and the hydraulic engineer of the Colony of Good Hope, John Gamble, was instructed to consider additional water supply options. He supplied two tunnelling options: the first being through Constantia Nek and Kirstenbosch, and the other through the Twelve Apostles range. The plan was to construct the Woodhead Tunnel from the Disa River on Table Mountain through Slangolie Gorge. The town council sold the plans to the new Table Mountain Water Supply Co. in 1882, and in 1887 the city was forced to intervene and start on the scheme.

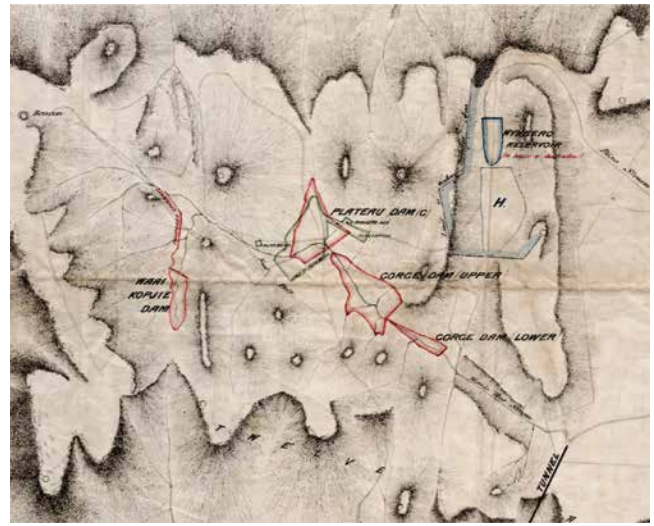
A pipeline was to transfer the water to Kloof Nek and then again to the Molteno Reservoir. The Woodhead Tunnel, 375-mm cast iron pipeline and pipeline to Molteno was completed in March 1881. Following repair of the Molteno Reservoir, the first dams were constructed on Table Mountain with Victoria Dam and Woodhead Dam being completed in 1896 and 1897 respectively. Woodhead Dam had an initial height of 21 m, which was increased to 37 m during the droughts of 1894. The other three dams – Alexandra, Victoria and De Villiers – were completed later in 1903, 1904 and 1910 respectively.

Tragedy struck on 4 June 1900 as aeronaut and balloonist Prof Isodore Michaels (travelling in a hot air balloon) drowned in the Molteno Reservoir. As the reservoir had to be drained, further water shortages ensued.

© Gerrit Burger



The nine old municipalities during British occupation were Cape Town, Green and Sea Pont, Maitland, Woodstock, Mowbray, Rondebosch. Claremont, Wynberg and Kalk Bay (and Muizenberg). All the smaller towns eventually merged to form Cape Town. (Courtesy of City of Cape Town; image © Arne Singels).



Map of the proposed dams by Thomas Stewart dated 30 July 1892. (Courtesy of City of Cape Town; image © Arne Singels).

Water from the Mountain: the Pipeline, the Tunnel and the Reservoir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The old pipeline along the renowned Pipeline Track moves the water from the five dams on Table Mountain to the Molteno Reservoir. This walk covers a few kilometres and should not be attempted unprepared. However, it is a beautiful track, well worth the effort, with some spectacular natural and historical scenes.


© Gerrit Burger


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The Molteno Reservoir, named after Sir John Molteno, the governor of Cape Town, is still in use today. The De Graaf Electrical Power Station, which has supplied Cape Town with its first hydroelectric power since 13 April 1895, is also situated here.

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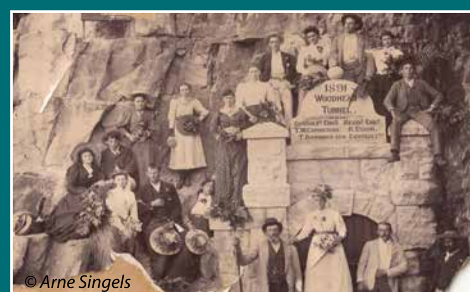
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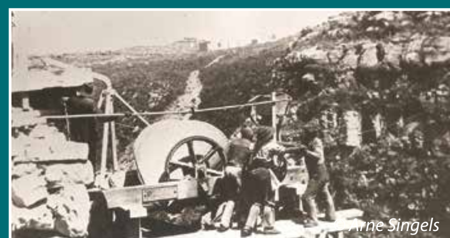
The Woodhead Tunnel was bored from both sides simultaneously. The tunnel is still in use today to transfer water from the dams on Table Mountain to the cast iron pipeline.

Water from the Mountain: the five Dams

The remnants of the upper gantry the old cableway through Kasteel's Poort used to move construction materials up the mountain for construction of the dams provides a spectacular view of Hout Bay. Archive imagery shows the resident engineer, Robert Esdon, and the engineer in charge, Thomas Stewart, aboard this 1 612 m-long cable way lifting a height of 664 m from the bottom station in Victoria Street, Camp's Bay.



Woodhead Dam with a present capacity of 955 million litres and a surface area of 8 hectares was named after the mayor of Cape Town, Sir John Woodhead. The wall's foundation is on bedrock using sandstone from a quarry on the mountain and concrete. Woodhead Dam was declared an international historical civil engineering landmark by the South African Institution of Civil Engineering and the American Society of Civil Engineers with the plague handed over on 1 August 2008.

© Arne Singels


© Arne Singels

A steam engine was imported from Scotland for the construction of the Hely-Hutchison Dam.


© Gerrit Burger

© Gerrit Burger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Hely-Hutchinson Dam, named after Sir Walter Hely-Hutchinson, has a present capacity of 925 million litres, surface area of 15.8 hectares and a dam wall 16m high. Archive imagery shows the final stages of construction of the rubble masonry type construction.


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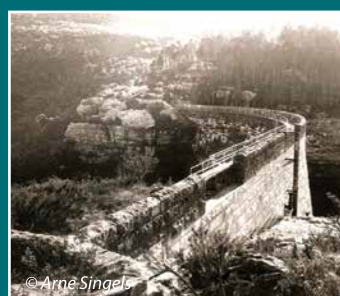
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The old Wynberg Municipality Dams are, from left to right, the Victoria Dam (128 million litres, 4.6 hectares, 6 m-high wall), Alexandra Dam (134 million litres, 2.7 hectares, 12.1 m-high wall) and De Villiers Dam (242 million litres, 2.6 hectares, 28.6 m-high wall). Insets show the Alexandra Dam (ca. 1903) and the De Villiers Dam (ca. 1910).

Modern Times

Following the founding of the City of Cape Town in 1913, a number of larger dams have been constructed to augment the water supply. The Steenbras Scheme was the first following the Table Mountain Schemes.

Construction of the Steenbras Dam was completed in 1921 and water from here is treated at the Steenbras Water Treatment Plant above Gordon's Bay. The Steenbras Lower Dam wall was raised twice – first in 1928 and again in 1954. As additional storage was required in 1977, the Steenbras Upper Dam was constructed. The Steenbras Lower and Upper Dams now also serve as a pumped storage scheme to supply additional hydroelectricity to the national grid.

The Southern Peninsula Schemes followed in the mid-1900s to supply additional water to the vicinity of Simon's Town. The Lewis Gay Dam was completed in the Woel River above Simon's Town in 1951 and the Kleinplaas Dam in the same river in 1970.

Lower Steenbras Dam.

The Voëlvlei Dam is supplied by smaller tributaries of the Klein Berg, Leeu and Vier-en-Twintig rivers to supply treated water to Cape Town, Swartland and Saldanha as part of the Voëlvlei Government Water Supply Scheme.

The Wemmers River was dammed by means of the Wemmershoek Dam in 1957 and the Land-en-Zeesicht Dam in 1976. The latter stores water from seepage wells and the Lourens River and supplies to the Somerset-West and Strand Water Treatment Works.

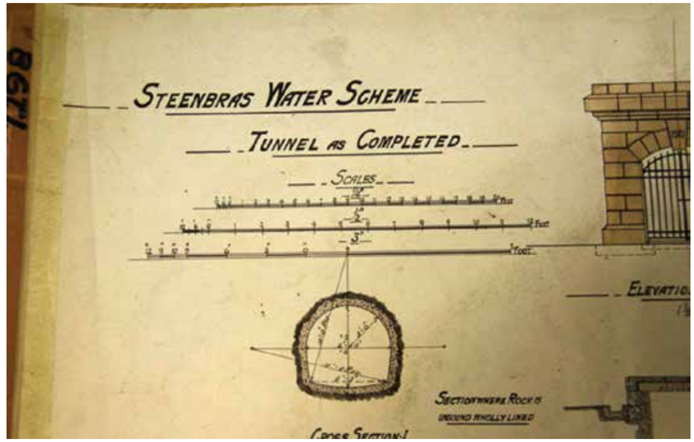
The largest dam in the Western Cape Water Supply Scheme is the Theewaterskloof Dam forming part of the Riviersonderend-Berg River Government Water Supply Scheme. This dam was completed in the Riviersonderend River in 1980 followed by the completion of the Palmiet River Pumped Storage Scheme between 1983 and 1988. The lower Kogelberg Dam on the Palmiet River and the upper Rockview Dam between the Palmiet and Steenbras Rivers also serve as a pumped storage scheme to generate additional electricity.

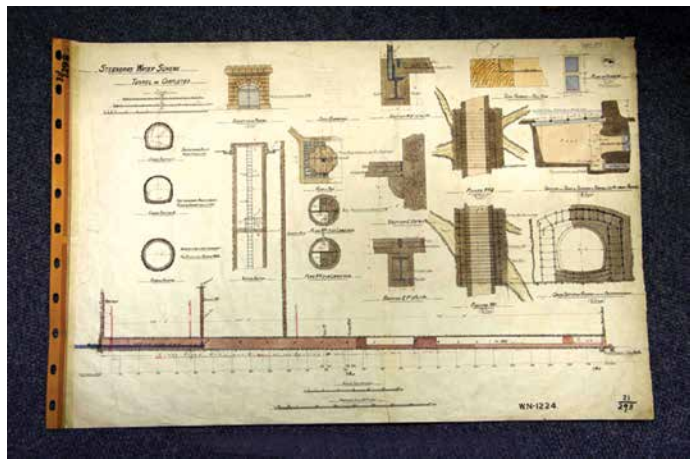
The Berg Water Management Area recently completed the latest dam and pumped storage scheme near Franschoek with water being impounded since 2008.

Further to this, the Twelve Apostles Tunnel followed in 1963, during which time 1.8 kilometre of the 5.3 kilometre cast iron pipeline was abandoned. The year 2001 saw the strengthening of the dam walls of both Woodhead and Hely-Hutchinson.

Apart from water for consumption, Cape Town is also South Africa's submarine communications hub. The ocean, for a variety of reasons, is used for communication purposes, with the first co-axial telephone cable laid between Portugal and Melkbosstrand in 1968. Subsequently, fibre-optic cables replaced this and the network was expanded to West Africa, Europe, Malaysia, Mauritius and India (Atlantic Cable 2007 from Fuggle and Rabie 2009).

At present, the City of Cape Town is actively pursuing alternatives to meet the ever-growing demand of the city of Cape Town. Novel ventures such as the Atlantis Artificial Recharge Scheme, possible inclusion of the Table Mountain springs and managing the demand are options, but the growing population and industry inevitably influences the supply.





Engineering drawings of the Steenbras Dam (property of City of Cape Town; image © Gerrit Burger).

Chapter 4: Cape Town's Water

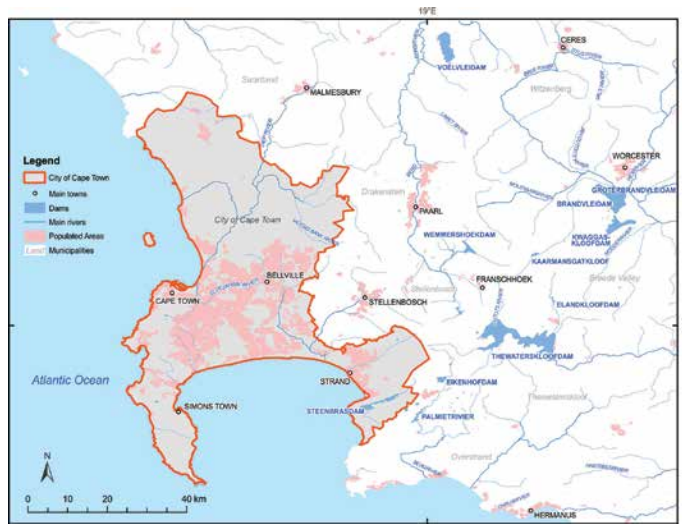
Water is not an apparent issue for Cape Town. With the vast oceans bounding the city to the south and west, it is almost unthinkable that this coastal city has problems with water supply. However, the water requirements for a city such as Cape Town are very easily misunderstood. Desalinisation of ocean water is a costly exercise that also requires vast amounts of energy, which in itself is a very scarce resource in South Africa. So, in order to sustain the growing demands for clean water, freshwater needs to be sourced.

Cape Town is situated within the Berg Water Management Area. It is estimated that roughly one-and-a-half times the irrigation demand is required for urban purposes. The actual figures for 2002 were 301 million cubic metres and 423 million cubic metres annually, which is still roughly 250 million cubic metres short of the current figures (DWAF from Fuggle and Rabie 2009).

Cape Town is supplied predominantly by dams catching surface water draining toward the ocean. Smaller contributions through localised springs, groundwater aquifers and treatment contribute for water in very specific regions or when potable quality is not required, but the bulk supply is still from surface water.

What is interesting is that almost all the larger dams are situated outside of the Cape Town municipal area and outside of the catchment. The bulk of the water is, therefore, imported and discharged (after use and treatment) to the ocean. Although the population and level of development in Cape Town require this amount of water, rendering imports a necessity, one has to be aware that this implies the removal of water from proximate towns.

"When you put your hand in a flowing stream, you touch the last that has gone before and the first of what is still to come." *– Leonardo da Vinci.*



Major rivers and streams of Cape Town shown in context of some of the major water schemes supplying water to the City of Cape Town to this day.

Groundwater and Springs

Groundwater has always played and continues to play a pivotal part in the water supply of the City of Cape Town. Too many to mention here, numerous springs occur in the city where water from the Table Mountain Group sandstones flow out on the land surface.

A spring is defined as the intersection of the groundwater table and surface topography. Wherever groundwater intersects a rock type of very low permeability and where this geological contact daylights on land surface, a spring will inevitably form. This is the case also for the springs around the mountain that have historically supplied the city with clean drinking water. Springs therefore form an interface between groundwater and surface water, making it a very important part of the water cycle.

The use of many of these springs has since ceased, mostly due to the significantly higher demands of present-day Cape Town and the vulnerability to pollution from urban sources. Nonetheless, those not in use by Man continue to play a pivotal role in biodiversity, supplying water for ecosystems.

The Table Mountain Group Aquifer (or TMG, as it is also known) is an excellent aquifer for the region, supplying water to smaller local municipalities, vineyards and the like within the Western Cape Province. The significant deformation – resulting in folding and faulting – caused extensive void space for the storage and transmission of underground water to be tapped for a variety of uses.

The TMG is not the only significant aquifer in the region. Young sand deposits of the Cenozoic form the Sandveld Group comprising the Cape Flats Aquifer and the Witzand Aquifer near Atlantis. Whereas the prior was very important during the initial years of Cape Town, also resulting in a significant groundwater flooding event, the latter is presently being used to store treated wastewater.

The Atlantis Artificial Recharge (AR) scheme stores vast volumes of water in the sands to prevent it flowing directly into the ocean. Further motivations for the system include that groundwater is somewhat more protected from surface-borne pollution and that it is not as likely to evaporate as water from dams. This is presently the only scheme of its kind in South Africa.

The possibility of using water from the vast Cape Flats aquifer has also been noted. However, given the dense development over large portions of this unconfined aquifer, water quality may be a concern.

Atlantis Artificial Recharge

© Matthys Dippenaar


© Rodney Bishop, CoCT

Recharge Pond 7 of the Atlantis Scheme serves to allow slow infiltration of treated domestic, industrial and residential sewage water and wastewater into the Witzand Aquifer. Water is then abstracted by means of boreholes for treatment at proximate water treatment plants prior to reticulation.

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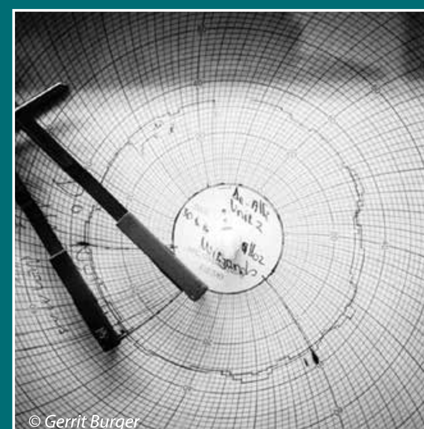
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Inside detail of the water works at Atlantis: treated water is allowed to recharge the porous Witzsand Aquifer for later abstraction.

Surface Water

Surface drainage in the Peninsula is broadly subdivided into four basins, namely the Peninsula, Cape Flats, Eastern Pluton and Diep (Milnerton) River Basins. Each of these drain a specific portion of the inland through a system of drainages towards the ocean.

The rivers in the region of the Peninsula itself are incised in the Table Mountain Group in the south and by Cape Granite and Malmesbury Group rocks to the north. Given the landscape and the strengths of these rocks, river valleys are steeply incised.

Towards the Cape Flats, drainage is over the flatter sand deposits but governed by the palaeo-channels of the Diep (or Constantia) and Kuils Rivers. Wetlands are formed due to sediment build-up, causing water flow to decrease.

The Eastern Pluton drains in a radial manner in for instance the Eerste River. Finally, the Diep River, drains southward towards Milterton lagoon.

A number of large dams have since been constructed in some of these rivers, supplying the city with drinking water to this day.

A number of wetlands also exist in the vicinity of Cape Town. Defined as a transitional zone between aquatic and terrestrial ecosystems, Cape Town plays home to marine wetlands (along the coastline), fluvial wetlands (within stream channels and their flood plains) and inland wetlands (associated with hillslope seeps and the like). Each of these has different frequencies of inundation or wetting, with the latter inland systems being seasonally, intermittently or periodically wet. The marine and other systems furthermore have distinct water quality differences with the prior being saline water and the latter freshwater.

A recent study found that 29% of the Cape's fynbos wetlands are in a better ecological health condition than 25 years ago, whereas 24% remained in the same condition. A total of 31% of wetlands deteriorated in health and for the remainder no scores were determined or the wetlands no longer exist. Improvement of wetlands is mostly ascribed to improved nature conservation efforts (WRC Report No. 2183/1/14).

Wetlands play a pivotal role in maintaining biodiversity and water quality. These systems naturally promote the migration of fauna and the establishment of special flora to generate very sensitive ecosystems. The plants further act as sediment traps and promote attenuation of many contaminants from the water.

Seawater

Similar to fresh groundwater occurring under the land surface, saline groundwater exists under the oceans. This poses some concern where groundwater is being pumped extensively in coastal towns and cities as saline groundwater can be mobilised and pumped into freshwater boreholes.

Given that saltwater contains up to 3% salts, it has a density marginally higher than freshwater. As there exists a freshwater aquifer containing fresh groundwater under the land mass, the ocean has its own saline (saltwater) groundwater. This, due to the density, occurs under the freshwater on the land mass near coastal areas. A mixing zone is present where the salt content gradually reduces from seawater to freshwater. Excessive abstraction of freshwater in coastal areas can thus move the saline groundwater upwards until saltwater is being pumped from terrestrial boreholes.

This is termed saltwater intrusion, and is a concern in many water-scarce coastal developments and, notably, islands such as Robben Island.

Once saline groundwater has been drawn into freshwater zones, its higher density makes it hard for freshwater to replace it again. Subsequently freshwater aquifers can be permanently damaged through this saltwater intrusion, having significant effects on freshwater supply to coastal areas.

Droughts and floods

Even though the amount of water within the Earth system remains fairly constant throughout time, climatic variation does result in significant localised changes in the water cycle. Without significant changes in the long-term average precipitation of rainfall for a given area, droughts and floods alternative throughout time as weather systems move moisture over the planet.

South Africa experienced one of its worst droughts on record during 2015 and 2016. Although this is also due to natural long-term climatic cycles and an El Niño event, the influence of Man on the Earth's climate can no longer be discounted. Such anthropogenic (or human-induced) impacts result in progressive heating of the atmosphere, deterioration of the ozone layer and more sporadic intense precipitation events.

Droughts and floods have always been around and have influenced Man's development for as long as history has been recorded. Nonetheless, the associated loss of life and livelihood make these natural disasters a risk for any development and economy.

Together with floods come erosion of fertile soil and failure of infrastructure, whereas droughts lead to crop failure and water scarcity. In densely developed areas such as Cape Town, the danger of severe flooding requires appropriate land use planning and development to minimise damage.

Urban Water Management

Urban areas pose very specific problems that are not common in less developed areas. Notably, water losses through leaking underground pipelines and complex water quality issues compromise our ability to protect this resource in densely developed areas.

However, recent developments, especially in the city of Cape Town, aim to ameliorate the stress on urban waters through artificially replenishing aquifers and to better manage urban stormwater. These are valuable lessons for all to learn as urban water management affects all downstream users and ecosystems.

Urban Water Management

Water losses in many municipalities presently contribute to water scarcity as vast amounts of reticulated water leaks in urban areas. The 2012 Non-Revenue Water assessment indicated that on average 37% of all reticulated water in South Africa is lost, resulting in an annual volume of 1.175 million cubic metres (billion litres). All municipalities are to reduce these water losses as it is not only a fiscal loss, but also a possible compromise to the integrity of structures in densely developed areas.

Urban contamination is also a concern in developed areas as the very versatile sources of contaminants and the vast number of sources of contamination make it harder to readily pinpoint the culprit. Sources include sewage, petroleum storage, industrial effluent, landfill leachates, roadside pollution and eutrophication of surface water, all contributing to the complex decay of water quality.

In terms of **sanitation**, the different options may mobilise different contaminants. The source of the contamination may also differ depending on whether sewage is moved off-site and on whether the system is dr or wet. Examples of dry on-site systems include pit latrines, whereas dry off-site systems remove the sludge by means of buckets or vacuum tankers. Wet on-site systems are most common in the form of septic tanks, while conventional sewerage comprising flush toilets is the most common means of wet off-site sanitation.

Managed Aquifer Recharge (MAR), such as the scheme developed at Atlantis, is becoming increasingly popular. In the vicinity of Cape Town, for instance, surface water and treated water discharged to streams flow into the ocean. As an alternative, storing this water in groundwater aquifers creates the opportunity to abstract the water during later periods of water shortage. Groundwater – as opposed to surface water – is also less influenced by evaporation, transpiration and is in generally better protected from surface pollution.

MAR essentially aims to increase yields for irrigation, reduce health risks, distribute water better and to reduce vulnerability to droughts and variations in rainfall. MAR is sometimes referred to as artificial recharge and can occur through a number of systems. In South Africa, it is done by means of infiltration ponds allowing water from surface to infiltrate to the groundwater table. Boreholes are then used to pump the water as needed.

MAR often forms part of **Water Sensitive Urban Design** (WSUD) practices, during which urban development occurs concurrently with a regard for environmental sustainability. Engineering and science combined result in improved planning of urban landscapes to synergise all components of the water cycle.

Interactions between WSUD systems and groundwater are common, and include leakages from cities (water losses, localised stormwater discharge, etc.), as well as infiltration devices (from treated wastewater, MAR or the interaction between urban rivers and wetlands with groundwater).

Sustainable Drainge Systems (SuDS) form another aspect of WSUD and refers to improved water drainage systems to accommodate drainage water in a more sustainable manner. These may include, for instance, allowing water to infiltrate in urban areas rather than being removed by means of sewerage systems to areas outside of the developed land, thereby promoting groundwater recharge and environmental sustainability.

Chapter 5: Harnessing Water: The Way Forward

"Water, thou hast no taste, no color, no odor; canst not be defined, art relished while ever mysterious. Not necessary to life, but rather life itself, thou fillest us with a gratification that exceeds the delight of the senses."

– Antoine de Saint-Exupéry.

Water supplies so much more than nutrition. Although we drink water daily and use it to irrigate crops, the natural environment also requires an ecological supply to ensure environmental health.

Mankind, however, harnesses the power of water in a variety of manners. We use water nowadays to generate electricity and for recreational purposes. We manipulate natural drainage channels to drain large areas without infringing on our development. We use water bodies such as rivers and the ocean as transport corridors for trade and travel.

Water has become so much more than a nutritional need. But, through our infringement on water's natural courses and our influence on the world climate, extreme climate events are progressively becoming more and more serious. Droughts and floods are realities resulting in loss of life and loss of livelihood. How we plan around these natural and induced disasters are becoming increasingly important.

Water makes up bulk of all living organisms and covers the majority of the Earth's surface. Yet, it is finding – within this apparent abundance of water – enough for the requirement and with quality that will not adversely affect human or environmental health.

As we continue to expand the domain in which we develop, construct and reside, we progressively interfere more on the natural water cycle. We inevitably compromise both the quantity and quality of water that will, in future, compromise the availability of our most important human need.

Water supply is not solely a matter of finding water. In addition to this, infrastructure to acquire, store and reticulate the water is very costly. Treatment is a requirement that adds additional costs to this important resource, and yet many people remain apathetic to the value of water.

Man and his manipulation of the water system now form part of the water cycle. We intercept water, remove it from one area and discharge it in another area through catchment transfer schemes. We affect groundwater recharge and surface runoff by affecting the natural equilibrium between these processes. And we compromise the water quality, eventually affecting human health or ecological resilience.

Our actions of the present influence our respective futures. With climate change, population growth, and increasing demands for natural resources, it is becoming imperative that we work together in the preservation of our limited natural resources. It is time that we do more to protect this resource, for our benefit and for that of our future generations.

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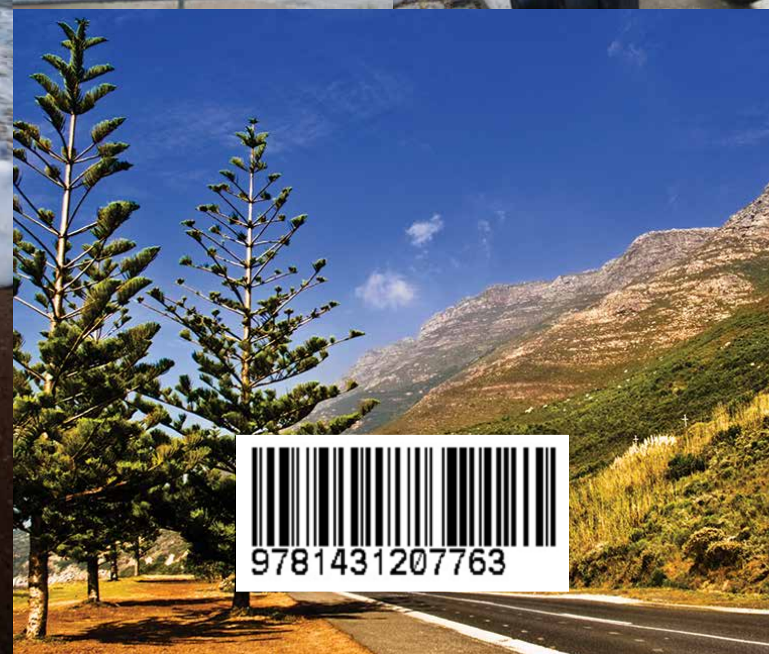

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