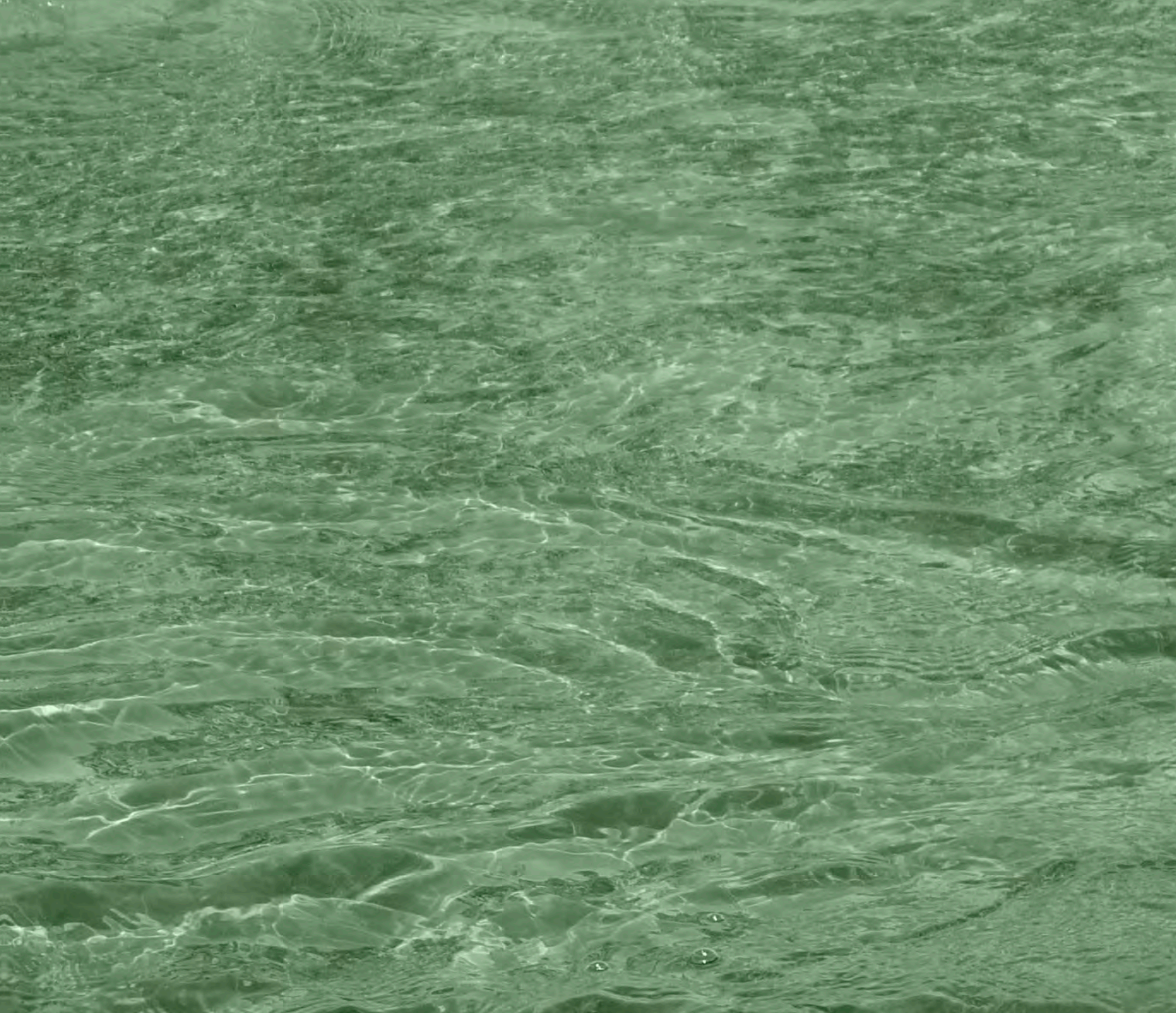
In the Footsteps of Giants

– Exploring the history of South Africa's large dams

Lani van Vuuren



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Shongweni Dam on the Umkomaas River was officially opened in 1927.

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Author's note

A country's history is inextricably linked with that of its water resources. Love them or loathe them, without its many dams and water transfer schemes South Africa could not have become the powerhouse that it is today.

This publication started as a few pages on water infrastructure history in the Water Research Commission's (WRC's) public water science magazine, *the Water Wheel*. Launched in 2008, this regular feature has generated remarkable interest in a time when our past is so easily forgotten.

Dams may have recently fallen out of favour, but there is no denying the role that these impressive structures have played in the history and development of South Africa. The country's estimated 500 large dams hold back millions upon millions of litres of water, allowing us to pursue activities that would otherwise have been near impossible in a semi-arid climate. Dams bring us water for consumption in our large cities, irrigation to grow our crops, water to drive our main economic ventures and to generate power, all while holding back huge volumes of floodwaters that might have otherwise engulfed our settlements.

Far from being mere earth and concrete structures, our dams serve as monuments of our past and beacons on our path to socio-economic prosperity. Behind each dam lies a tale of imaginative thinking, daring spirit, and resolve to make South Africa a better place to live in. South Africa's history of dams goes back at least four centuries. Many of our most important dams were built with nothing more than bare hands and sheer determination. This book is not only dedicated to the pioneering engineers who dared to dream big, but also to the thousands of labourers who toiled in sun and dust to turn dreams into reality as well as the families who supported them.

"Water is not for fighting over. Water is for conserving. Water is for bathing. Water is for drinking. Water is for sharing. Water can be our catalyst for peace."
Kader Asmal

In the Footsteps of Giants takes the reader on a journey through the history of South Africa's large dams, starting with the traditional attitudes towards water resources prior to European settlement and ending with a glimpse into the future of dam building in the country. It explores the reasoning behind the construction of these massive structures, the laws that guided their development, and the people and institutions that made them possible. Woven in between are the tales behind some of the country's most iconic dams and dam engineers.

South Africa is home to some of the leading dam builders in the world, and many engineering innovations were developed here. While some engineering aspects are included in the book, this has been kept to a minimum so as to keep the publication relevant for a wider audience. Other remarkable publications have been published on the engineering aspects of South African dams, most notably the South African National Committee on Large Dams' (SANCOLD's) *Large Dams and Water Systems in South Africa*, published in 1994, which does much more justice to this aspect of dam history. Including every single dam in South Africa proved to be an impossible task for this lone author, and it will probably take a lifetime to record the tale behind each of these structures. However, it is hoped that the reader will find interest in the dams' stories which are included in this publication.

While appreciating the role that dams play, we are not denying the mistakes of the past. Most of South Africa's dams were built in a different milieu, at a time when human rights were often ignored and the importance of a sound aquatic environment was neither comprehended nor appreciated. There are many arguments for and against the construction of dams, and it is not the aim of this publication to either condone or condemn the actions of the past. Rather, the book aims to salute achievements and record mistakes so that we can avoid them in the future.

There are a whole host of people without which this book would not have been possible. Firstly, thank you to the WRC, and specifically Director: Water-centred Knowledge, Dr Heidi Snyman, for supporting this publication. Thank you also to staff at the National Library (Pretoria branch), the National Library visual section (Cape branch), the Cement and Concrete Institute Library and the South African Institution of Civil Engineering (SAICE) for patiently providing reference material and always being courteous and friendly. Acknowledgement must also go to everyone who graciously contributed photographs, especially eWISA and the Department of Water Affairs. To my colleague, Drinie van Rensburg, thank you for an inspirational design and layout. Last, but not least, thank you to my husband, Michael, and my son, Jadon, to whom my heart belongs, for allowing me to pursue my dreams.

The construction of large dams might have slowed drastically in South Africa, but the country has not yet reached the end of this era of dam-building. It is the hope of the author that as we move forward any decision to build new dams will be inclusive, transparent and negotiated, with full recognition of the alternatives that exist.

In the words of former Water Affairs Minister Kader Asmal: "Water is not for fighting over. Water is for conserving. Water is for bathing. Water is for drinking. Water is for sharing. Water can be our catalyst for peace."

South Africa's five largest dams

Dam	Height (m)	Volume (million m³)	Storage capacity (million m³)	Water surface area (km²)
Vanderkloof	108	1,3	3 187	133
Sterkfontein	93	19,8	2 617	67
Pongolapoort	89	0,6	2 267	132
Gariep	88	1,4	5 343	352
Vaal	63	1,4	2 610	323

SANCOLD

2

Dams and development in South Africa

Mankind has been damming rivers for millennia for his own purposes. In South Africa, modern artificial structures have been thrown across rivers since the seventeenth century, and for a long time the country was one of the leading dam-builders in the world. This chapter explores the factors behind the history of South Africa's large dams and looks at the role that these structures have played in the country's socio-economic development.

Building dams is one of the oldest tools known to mankind in ensuring a steady water supply. Evidence of these structures are found among the remnants of ancient civilisations around the world, although most of the world's dams have been built in the last four decades. Since the advent of environmental consciousness in the twenty-first century, great dam structures have largely lost their appeal, and in many developed countries, such as the USA, more dams are being decommissioned each year then are being constructed. Today, at least two-thirds of the Earth's rivers have been altered by dams and their associated infrastructure. Some of the world's mightiest rivers, the Nile (Africa), Yellow (Asia), Colorado (USA) and Murray (Australia) no longer

Camdeboo Municipality

Nqweba Dam outside Graaff-Reinet was one of the first large dams to be constructed in South Africa. A dam is typically defined as 'large' when it has a wall height of over 15 m and a capacity of greater than a million cubic metres.

reach the sea because of them. The latest figure places the world's dams at the 45 000 mark, half of them in China.

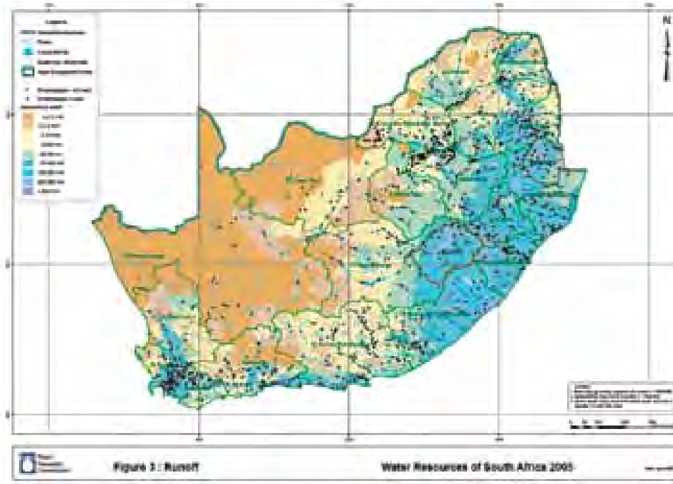
South Africa has over 500 large dams scattered across its landscape, more than any other country in Africa. The need for these bulk water storage structures has mainly been dictated by the country's semi-arid climate – South Africa is one of the 30 driest countries in the world. The country has a rainfall that fluctuates widely (both in space and time), comprising only 55% of the global average. Added to this is the abundance of sunshine – South Africa's evaporation rates are far higher than the average annual volume of rainfall. Every year, less than 9% of precipitation eventually reaches river systems.

At last count the country had a total mean annual runoff of only 49 210 million m^3/year – about the equivalent of the annual runoff of the Zambezi River in the north of the region. Added to this is the fact that South Africa is characterised by hydrological extremes. The country is periodically afflicted by severe and prolonged droughts, and it is not unusual for these droughts to be immediately followed by floods. These extreme climatic conditions may occur simultaneously in different regions of the country, even in adjoining watersheds.

Since rivers provide South Africa's only large-scale resources of freshwater the country had no choice but to construct storage dams to provide reliable supply of water for its various purposes. South African dam builders have mastered the art and science of manipulating water flows to allow the country to unlock its economic potential. Our bulk water supply infrastructure is integrated and sophisticated, often involving numerous large dams, pipelines, pumps and water transfer schemes. Had it not been for these large dams, major cities such as Durban, Gauteng and Cape Town would not have been able to exist and grow. The country's major dams have a combined capacity of around 50% of the total mean annual runoff, enabling assurance of supply of 98% to be maintained throughout the year, no mean feat for a country as dry as ours.

Dam construction in South Africa has never been a cheap

The mean annual runoff of South Africa.



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Morguefile

A dry riverbed. Only one quarter of South Africa's rivers are perennial, meaning they flow throughout the year. These rivers are mainly situated in the southern and south-western Cape and on the eastern marginal slopes of the country.

affair. In fact, our dam building costs are generally much higher than in other countries because of the high storage capacities required on South African rivers to achieve equivalent yields. For example, the Vaal River, which supplies water to the economic heartland of South Africa, requires a storage capacity of 200% of the mean annual runoff to ensure a dependable gross yield of 75% of the mean annual runoff during a 1:50-year drought. During the era of large State-aided irrigation works in the 1930s, water storage infrastructure in South Africa cost £20/acre compared to £2/acre in India, where a similar programme was being rolled out at the time (and where most hydrological engineers working in South Africa were receiving their practical training). As the more suitable engineering and hydrological sites have all been used, dam construction is set to become incrementally more expensive in the near future. For this reason, the spotlight is increasing falling on alternative measures to augment water supply, such as desalination, the re-use of wastewater and water demand management, with dam construction being considered a last resort.


DWA/eWISA

The Marico-Bosveld irrigation scheme construction site in 1932. The bulk of South Africa's large dams were constructed in a 50-year span between 1920 and 1980.

SOCIAL AND ENVIRONMENTAL IMPACT

Today, it is recognised that dams are not only major water management projects, but that they seriously affect socio-economic development and the environment. Most of South Africa's rivers have had their natural systems disrupted due to barriers thrown across their banks. Dams impact the seasonality, size, duration and frequency of river flows. In many cases these modifications have adversely affected the ecological goods and services provided by rivers. By reducing floods, dams diminish biodiversity, change natural resource systems and opportunities for flood-based livelihoods downstream, such as fishing, recession agriculture and livestock rearing, which in turn increases the vulnerability of the poor who depend on such services. In the past, the dislocation of people to make way for dams was often seen as a mere side-effect of development. Thankfully, these communities are now fighting to be heard.

Historically, the needs of rivers downstream of dam sites were hardly ever considered in the design of dams and their operating rules, not only in South Africa, but around the world. Most dams were constructed with the emphasis on maximising the abstraction of water at the most economical rate. Up until the 1980s, environmental and social impact studies were not even legally required for dams (or for any other water infrastructure) in South Africa. In many cases, the site of a new dam would be dictated by a politician's wishes rather than an in-depth technical investigation.

There are several examples across the country where the construction of large dams has had unintended adverse environmental consequences. For example, when the Gariep and Vanderkloof dams were built in the Orange River during the 1970s, it modified the original flow peaks and troughs in the river. Higher winter flows as a result of the release of water from the dams to generate hydropower created a suitable habitat for overwintering blackfly larvae, an agricultural pest. Adult female blackflies usually need a blood meal to complete the development of eggs, and their large numbers and tendency to crawl into ears, eyes and noses creates

Eskom/eWISA

problems for livestock and people. Following the construction of the Orange River dams more regular outbreaks of blackflies have seriously affected agriculture and tourism along the middle and lower reaches of the river. Millions of Rand have been spent on curbing the problem, including the spraying of insecticide.

Most existing dams have not been physically designed to make environmental releases that are able to mimic natural river flows. Environmental flood releases, for example, require large capacity outlet structures. In some instances, it is not possible to retrofit appropriate release mechanisms to existing dams. Depending from which dam reservoir level water is discharged the water can either be warmer or colder than the downstream riverine temperatures. These temperature fluctuations can suppress the growth, spawning and breeding levels of indigenous fish. Drastic temperature fluctuations can also affect river health by reducing or altering food sources available for animals within the aquatic food chain, including microorganisms, insects, aquatic birds and frogs. Unseasonal releases of cold water into the Orange River below the Gariep Dam, for example, has caused poor reproductive success of the smallmouth yellowfish and subsequent poor recruitment to commercial fish stocks.

Left: Higher winter flows due to the generation of hydropower have resulted in blackfly outbreaks along the middle and lower reaches of the Orange River.

It does not take a large dam to affect the aquatic environment.

In the early years after the completion of the Kleinplaas Dam on the Eerste River, in the Western Cape, extra water was released from the dam for an annual canoe race. The water was released mid-spring at a time of naturally decreasing flow for the impending dry season. Water was released in a 'tidal wave' down the river at a time when overwintering aquatic insects were preparing to emerge by moving into quiet edge areas of the stream. This yearly wave of water gave the animals little time for evasive action and proved detrimental to some components of the biota.

It does not take a large dam to affect the aquatic environment. In the Outeniqua-Langeberg mountain areas, which fall in the rain shadow of the little Karoo, several of the normally perennial streams have had almost all of their water removed for human uses. The Red Data species, the slender redfin minnow, now only occurs upstream of the weirs in these streams because water abstraction results in the total absence of flow at certain times of the year. These fish populations are now isolated from each other, placing a shadow of doubt over their long-term survival and genetic variability.

A NEW ERA BEGINS

It is only from the 1970s onwards that the attitude of the public towards dams changed as a result of greater social and environmental awareness. This increasing appreciation of the ecological value of aquatic ecosystems and their role in maintaining supplies of useable water has generated a growing body of expertise in river ecology and highlighted the need to conserve rivers as valuable ecosystems. It is increasingly recognised that modifications to river flows need to be balanced with maintenance of essential water-dependent ecological services. The flows needed to maintain these services are termed 'environmental flows'. Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and human livelihoods and well-being that depend on these ecosystems.

In 1998, South Africa became one of few countries in the world to entrench the environment's right to water in its water laws. Known as the 'Ecological Reserve' each water resource (river, wetland, estuary, and groundwater source) is entitled to the quantity and quality of water needed to protect its aquatic ecosystems in order to secure its ecologically sustainable development and use. Following the release of the final report of the World Commission on Dams, which reviewed the effectiveness and impact of large dams, in 2000, its findings were evaluated and amended by a local forum for the South African policy, institutional, environmental and social context.

South Africa's new water and environmental legislation places significant additional constraints on dam development

Lani van Vuuren

Above: *South African soils are highly susceptible to erosion causing high sedimentation levels in dams.*

Below: *The Berg River Dam outside Franschhoek, in the Western Cape, is the first dam in South Africa that has been designed in such a way that it makes provision for flood releases specifically intended for the downstream aquatic ecosystem.*

TCTA

as compared to the past. Among others, these measures require environmental and social studies to be undertaken during the planning stages of the project, public participation, application for environmental approval to implement, preparation of an environmental and social management plan and the creation of a monitoring mechanism during and after construction. These requirements, although onerous, are not considered impossible to achieve and must now be factored into the project plan and cost.

South Africa has again led the way for a new generation of dam builders with the construction of the Berg River Dam outside Franschhoek in the Western Cape. This dam has received international recognition for its integrated planning, design and implementation. The dam caters for environmental flows in the Berg River all the way to the estuary and its outlet works have been designed to release both low flows and high flows with provision of a peak release of up to 200 m^3/s. It is the first dam in the country in which provision has been made for flood releases that are specifically intended for environmental purposes.

WATER MANAGEMENT CHALLENGES

South Africa's dams are not only expensive to construct, they are also generally expensive to manage. South Africa suffers from serious erosion of its soil and the consequent sedimentation of its dams. In many areas, natural geological erosion has been accelerated by inappropriate land use, for example, slash-and-burn agriculture and overgrazing. According to SANCOLD, the average loss in the capacity of large reservoirs is around 10% per decade in high erosion hazard regions such as the southern and eastern Cape. The worst affected reservoir has been the Welbedacht Dam near Bloemfontein. This dam lost 82% of its capacity within 19 years after its construction.

Another challenge is that of eutrophication of water resources. Eutrophication, or the enrichment of water with nutrients, is a natural process that is intensified by urbanisation, agriculture and industry. Soluble nutrients such as phosphates and nitrates in effluent promote excessive increases in algae and other aquatic plants in water resources, reducing the degree of fitness of the water for many uses.

In South Africa, eutrophication has been recognised as a priority water quality problem for over 30 years. The country has some of the most nutrient enriched water bodies in the world, highly problematic considering that, as a water scarce country, South Africa is hugely dependent on the water stored in its dams. At present, around 35% of the total storage available in our dams is either eutrophic (very nutrient enriched) or hypertrophic (extremely nutrient enriched). If we add to this percentage the number of dams in which the conditions are approaching eutrophic, then a total of 60% of the country's stored water is impaired (Van Vuuren, 2008). Most eutrophied dams are located close to large urban centres where the human population is concentrated and large volumes of wastewater are generated. Hartbeespoort Dam, for example, receives effluent from at least a dozen wastewater treatment plants in the catchment. South Africa's abundant sunshine and warm temperatures also create ideal conditions for algae to flourish.

Water bodies that are eutrophic experience an increase in algae (especially cyanobacteria or blue-green algae which can be toxic) and weedy aquatic plants, such as water hyacinth, which choke waterways. Extreme and prolonged eutrophication leads to the deterioration of water quality, taste and odour problems, oxygen depletion and a decline of more desirable fish species. The resultant prolific growth of algae also disrupts water treatment, which means the water is more expensive and difficult to treat for drinking water purposes. Nutrient enrichment, therefore, remains one of the leading causes of water quality impairment in the world.

Another persistent water quality problem in South Africa is that of salinisation. As AH Conley explains, evaporation can increase the salt concentrations in reservoirs considerably, particularly under long retention periods (SANCOLD, 1994). The raising of dams to meet growing demand and to compensate for sedimentation compounds the problem by enlarging the evaporative surface area and diminishing the flushing effect of floods. Thus, the mean salinity level of the water in reservoirs rises gradually. The higher salinity restricts the number of cycles of industrial reuse which are practicable, requiring a greater content of water to compensate for its poorer quality. When the water is used for irrigation, the dissolved salts are concentrated in the soil by evaporation and evapotranspiration.

Like many other African countries, South Africa shares its major

Heidi Snyman

Eutrophication problems have persisted at Hartbeespoort Dam since the 1960s.

Lani van Vuuren

Rowers navigate through stretches of water hyacinth at Roodeplaat Dam, outside Pretoria.

Chapter 2

river systems with its neighbours. This means that whatever alteration of the river system takes place in one country will affect the downstream country. While some rivers cross boundaries (e.g. Orange River) others serve as the international boundary (e.g. Limpopo River). The management of these rivers is led by the Revised Protocol on Shared Watercourses in the Southern African Development Community to which South Africa is a signatory, while the National Water Act gives international requirements a priority that is second only to basic human needs and the Ecological Reserve. This means that no infrastructure may be developed in any transboundary waters without considering the needs (or without the involvement) of the other countries concerned. South Africa has also signed and ratified the United Nations Convention on the Law on the Non-Navigable Uses of International Watercourses, which promotes the principle of equitable and reasonable utilisation and the obligation not to cause significant harm (to downstream users).

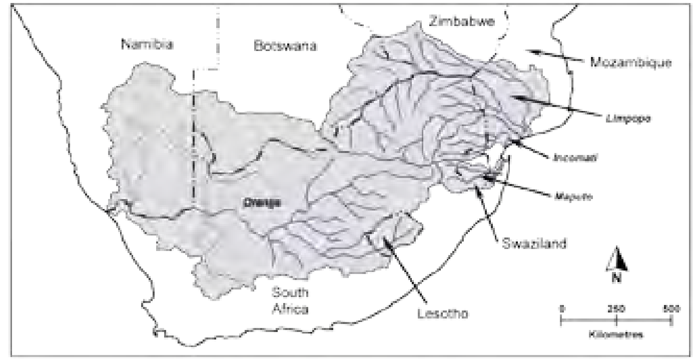
Not only can South African dams potentially adversely affect the water resources of neighbouring countries, the reverse is also true. When the Massingir Dam wall was raised in Mozambique during 2005/6, it caused the flooding of the Olifants River gorge in the Kruger National Park, a renowned crocodile breeding site. The action has been cited as one of the triggers of mass crocodile deaths experienced in 2009/10 in the Olifants River due to pansteatitis.

THE FUTURE OF DAM BUILDING IN SOUTH AFRICA

Almost all of South Africa's available water resources are currently being tapped, with overallocation of resources occurring in many of the country's catchments. Population growth is placing further strain on limited resources, with the poor quality of wastewater discharges driving our water sector into a critical state.

As far as the development of bulk water infrastructure is concerned, dam construction has slowed dramatically in recent years, although it has not ceased completely, and there remains a strong political demand for these impressive structures. The Department of Water Affairs is investigating the possibility of constructing at least 12 more dams in the near future. Apart from the current two schemes being constructed in Limpopo and KwaZulu-Natal, the South African government is also negotiating with Lesotho to start construction of Phase 2 of the Lesotho Highlands Water Project in an effort to enhance supply of water to the economic heart of the country.

The positions of the four river basins that South Africa shares with its six neighbours.



In its water resources planning, the department is also facing many uncertainties, which is being exacerbated by the potential impacts of global climate change. While climate change is an accepted global reality the impact is not yet obvious in South Africa. The long-term predictions are for a drier western half of the country and for far more variability, with more extreme events, to the east. These long-term predictions will have to be considered in planning scenarios.

Despite the significant environmental and social impacts associated with water storage and diversion, the development of large infrastructure remains essential for human survival and economic development, especially in South Africa with its limited water resources and erratic climate. Dams allow us to develop our economy, grow our food, generate electricity and power our industries. Until we can find a reliable alternative to dams as a way to store water in South Africa it is up to the new generation of dam builders to devise and implement schemes to sustainably manage our water resources, which must be matched by a commitment to retain or conserve as far as possible the fragile ecosystems on which they are constructed.

Water storage prior to European settlement

In the quest to capture the history of the development of South Africa's dams the tendency is to ignore water resource management methods prior to the permanent settlement of Europeans in 1652. While no evidence has been found of the construction of pre-colonial dams per se, it is nevertheless important to consider the relationship of early southern African cultures with their water resources.

This rock art situated at the foot of Domboshawa rock in Zimbabwe is said to be 15 000 years old.

Andy Worner

Historically, communities lived very close to Mother Nature and their understanding of her whims, coupled with a low population density, negated the need for large-scale storage of water. In pre-colonial times, water from rivers, springs and fountains were generally free for anyone to use. In times of drought rather than store water or seek ways to increase water supply, communities used to drastically reduce their water consumption. Colonial records remark on how little the Tswana-speaking tribes of the dry northern areas of South Africa would drink in times of need, for example.

This extra special bond between the ancient peoples of southern Africa and water has long been realised. The high variability of the region's climate, both in space and time, would have made historical communities extremely reliant on their deep-seated knowledge of the water resource landscape for their survival. This knowledge would have been passed on from generation to generation.

Unfortunately, little is known about the use of water, especially for irrigation purposes, prior to the arrival of European settlers in the fifteenth century. As Johan Tempelhoff aptly puts it: "There seems to be a historical blind spot regarding the acknowledgement of the heritage of indigenous irrigation technology." (Tempelhoff, 2008).

THE SAN AND THE KHOI

South Africa is one of the few regions in the world where humans have lived continuously for nearly two million years. Modern humans gradually began to emerge during the Middle Stone Age between 200 000 and 100 000 years ago. In South Africa, the oldest anatomically modern humans have been discovered at Klasies River mouth west of Port Elizabeth – dating from around 100 000 years ago. These forefathers of the Khoisan had to gather food where they could, and South Africa's 3 000 km of coastline proved a rich source of nutrition as the work of archaeologists has shown us. According to Francis Wilson, the coastal areas of the country are increasingly being

Gareth Weeks

Southern Africa's coastal areas proved a rich food source for ancient communities; in fact these areas are seen as the place where humans are likely to have first evolved.

Historical groups are said to have frequented the banks of South Africa's largest river, the Orange.

Drinie van Rensburg

seen as the region where humans are likely to have first evolved – with the Cape being the forerunner (Wilson, 2009).

Humans of the Later Stone Age came to settle mainly in the Orange River basin. Their last representatives were the San people. The San were hunters, gatherers and fishers. They lived in small groups and their population density remained low so that they were able to live a comfortable life off the natural resources in their immediate surroundings. It is believed that the San historically inhabited the areas where agriculture and pastoralism (the mainstay of later indigenous cultures) could not be practised, especially in the mountains of the Drakensberg, the Western Cape and the semi-arid Karoo and Kalahari.

Right: *San and Khoi communities supplemented their diets with meat from unfortunate hippopotami who fell down the Augrabies waterfalls on the Orange River.*

If water could not be found, historical communities depended on desert fruit, such as the wild melon or tsamma (Citrullus lanatus) (middle right) or the gemsbok cucumber (Acanthosicyos naudinianus) (bottom right).

Marle van der Walt

Drinie van Rensburg

Drinie van Rensburg

The Stone Ages

The **Earlier Stone Age** in southern Africa dates from about 1,8 million years ago to about 250 000 years ago.
The **Middle Stone Age** dates from about 250 000 to about 25 000 years ago.
The **Later Stone Age** dates from about 25 000 years ago to within the last few hundred years.

In these mostly rainless areas every drop of moisture was savoured, and over hundreds of years the San developed an intimate knowledge of the weather, the climate and the natural world they depended on. Life centred on the limited water points, and rain was revered, playing an important role in San folklore. Depending on its intensity, rain was regarded as male (hard rain) or female (soft rain), with the latter being most favoured, and numerous rock art still in existence today tell the tale of San shaman who were said to possess special rain-making abilities. As far as water storage was concerned, however, this was limited to what one person could carry, for the San were a nomadic people. Water was carried in gourds and animal bladders, as well as that prized possession, the ostrich egg. Ostrich eggs were filled with water and stored in strategic places for when the need arose.

About 2 000 years ago, some San groups started acquiring stock (sheep and horned cattle) in present-day Botswana and began spreading over the western half of South Africa. It is believed that the livestock was probably acquired through contact with early Iron Age peoples moving south. They called themselves *Khoikhoi* (meaning ‘men of men’). At the time of the Dutch settlers’ arrival in Table Bay in 1652, the Khoi were organised in a number of clans and tribal entities which fanned out from the Cape Peninsula to deep into the western and eastern interiors of the south-western Cape through to the Eastern Cape.

Hunters and pastoralists, the Khoi’s existence was centred on the ownership of livestock, which was viewed as commodities rather than food. They practised a semi-nomadic lifestyle, dictated by seasonal variations. During dry times they would rely on their cattle and sheep for their livelihoods.

Extract of San poem about rain

The rain that is male is an angry rain.
It brings with it lightning loud like our fear.
It brings water storming, making smoke out of dust
And we, we beat our navels with our rigid fists.

For we want the other, the rain that is female,
The one that falls softly, soaking into the ground,
The one we can welcome, feeding the plains
So bushes sprout green, springbok come galloping.

(Wilson, 2009)

NLSA

NLSA

Above: *This 1804 engraving by T Wallis from an original illustration done by WM Craig depicts a Khoi man and woman with the Cape of Good Hope in the background.*

Right: *A Khoi man, as depicted by SC Cook in 1790.*

THE FIRST FARMERS

At around the same time as the Khoi the first iron-using farmers arrived in southern Africa from the north. These Bantu-speaking people not only brought with them new knowledge about making pottery and smelting metal, but also about agriculture. They reached the south of the Limpopo River around 350 and 450 AD. Unlike the Khoisan, the Bantu-speaking people preferred a more established lifestyle. They tended to settle in a certain geographical area (usually where the annual rainfall exceeded 200 mm), thus they dominated the wetter, eastern parts of southern Africa. Communities first settled in what is now KwaZulu-Natal by 400 AD and in the Eastern Cape by 600 AD. These early settlements sometimes extended for kilometres and housed as many as 10 000 inhabitants. Since rain was considered more important that rivers, the locations of settlements were dictated mainly by the availability of other resources, such as thorn trees to construct fences. Water sources were historically used for different purposes, for example, fountains and springs were solely used for drinking and cooking, while rivers were used as sources of washing and bathing water. These communities understood the importance of protecting their water resources and so settlements were usually located a short distance away from rivers and springs from where water would be fetched by women and children.

The Bantu-speaking people practiced agro-pastoralism, and agricultural produce included the growing of grains such as sorghum, babala, manna and rapoko, pulses such as black beans and peanuts, as well as members of the pumpkin family, such as calabash and sweet melon. Wild plants were also exploited for food while cattle were a source of meat and milk, with their hides used for clothing and battle-shields. Information regarding the irrigation practices of these early cultures is still largely lacking. At first it was thought that these early farmers only practiced dry land farming, but we now know that they applied rainwater harvesting and other traditional irrigation and water storage techniques. Traces of pre-colonial irrigation works have been reported at various sites. For example at Nyanga in eastern Zimbabwe, a veritable archaeological treasure trove was discovered in the late nineteenth century. Archaeologists found a vast number of old aqueducts on the site, some 3,2 km or more in length, running from artificial dams on the mountains streams, and crossing form hill to hill. "Indeed the humble irrigation furrow of the subsistence farmer was just as important to an insular community of Bantu-speaking people in pre-colonial times, as is the sophisticated irrigation technology in present-day South Africa" (Tempelhoff, 2008). Further examples of traditional irrigation have been found at other sites around southern Africa from the Limpopo River catchment to the Drakensberg escarpment.

Carrying and storing water

A recent study by the University of KwaZulu-Natal into Zulu indigenous practices in water and sanitation (Mbatha, 2008) shows that in traditional southern African cultures water was fetched using gourds and sometimes ostrich eggs. Women had mastered the skill of carrying large quantities of water using these instruments. Traditional clay pots were historically used to store water. While the clay kept the water cool, the oval shape of the pot prevented the contamination of the water by crawling insects.

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TRADITIONAL IRRIGATION STILL PRACTICED TODAY

As Tempelhoff (2008) explains, notable at the Nyanga site are the stone terraces covering an area of about 22 000 ha. It is believed that these terraces, which vary between 1,5 m and 3 m in width, were built mainly (although not exclusively) for agricultural purposes. They tended to be slanted downwards which ensured a natural form of irrigation and drainage that reached different levels along the hillsides.

Investigations into indigenous water harvesting and conservation practices by Jonathan Denison and Luvuyo Wotshela found that this practice of stone terracing is still being practised in some rural communities in South Africa (Denison & Wotshela, 2009). For example, at Gogela Village, in the Kokstad district in KwaZulu-Natal, terraces, which could be as high as a metre, are still used to arrest and divert surface runoff. According to the researchers this practice is largely geared for water-flow management as well as soil preservation. These stone walls are usually stacked at the base of slopes or downhill areas. By creating a barrier runoff is prevented from cascading further down the fields. The debris and top soil that goes with the runoff gets deposited at the lower portions of most arable fields.

In 1956, anthropologist AC Myburgh discovered a pre-colonial irrigation site on a farm near Carolina, in Mpumalanga (Tempelhoff, 2008). There were a number of canals on a fairly level tract of land and a dam of sorts had been built to take from water from the Gemsbokspruit. Consequently,

Mapungubwe

One of the most important examples of pre-colonial farming settlements in southern Africa is Mapungubwe (meaning 'place of the stone of wisdom'), in the Limpopo River basin. The site, located close to the South African border with Botswana and Zimbabwe at the confluence of the Shashe and Limpopo rivers, was once an important centre of civilisation. The settlement was supported by an economy based on livestock and trade and we know that the residents of Mapungubwe traded gold and ivory with China, India and Egypt.

At its peak the Mapungube settlement was home to around 10 000 people.

Mapungubwe Museum/UP

Mapungubwe was established around the 13th century. The site provides the first evidence of class structure in southern Africa, with rulers living on top of the hill – where rain-making took place – and the commoners in the valley below. All of the soil atop the hill, as well as water had to be carried up. Water was probably collected from the Limpopo River about 3 km away, and stored in two large 'reservoirs' carved into the rock.

Mapungubwe Museum/UP

The iconic golden rhino of Mapungubwe.

At its peak it housed an estimated 10 000 people. The city was abandoned shortly after Great Zimbabwe's rise to prominence in the thirteenth century, although drought is suspected to be a possible reason.

Reading the stars

Star constellations were not only used by ancient mariners to set their course across the seas. Historically, southern African cultures also used the appearance of the 'digging star' *Isimelela* (the Orion constellation) in late autumn to signal the start of *gelesha umhlaba* (meaning 'hoeing or the tilling of soil after a crop harvest'). The intention of the practice was to ensure that any precipitation, be it rain, dew or frost, would penetrate the soil and so provide valuable moisture for the next planted crop.

Jonathan Denison

a floodplain was formed and water could siphon through the lands. Myburgh noted that the canals were obviously made for the purposes of irrigation because there were no direct indications of a settlement in the vicinity of what must have been a patch of agricultural land. Another canal on the same farm was presumably used to provide water to the local community resident on the land. Elements of terracing have also been studied in the southern Highveld region of Mpumalanga and the Free State.

Right*: The villagers of Gogela Village, in KwaZulu-Natal, still use stone terracing to harvest rainwater.*

Bottom right: *A young woman carries water in a calabash, circa 1900.*

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Another well-known pre-colonial agricultural system was wetland farming, also known as dambos, mapani, matoro, amaxhapozi or vleis. They are primarily situated in wetland environments that retain water close to the surface for the greater part of the year. Sorghum, pumpkins and later maize were planted in this way.

So, while these methods were not the damming of water per se it stored water and channelled it in different ways. There is no doubt that water played a crucial role in the lives of southern Africa's oldest communities. Water was not only a necessity for economic prosperity of the San, Khoi and Bantu-speaking peoples, but was also important for their spiritual and political well-being. The arrival of European settlers in the 1600s would have an underlying impact on the social structure of the indigenous population of South Africa and, in many ways, change their relationship with the water sphere. ◈

4

Canals, dams and the Dutch occupation (1652-1806)

When Dutch sailing ships offloaded their cargo of settlers and seeds at Table Bay on 6 April, 1652 it formalised the Cape's unofficial status as a refreshment station for passing western ships on their way to the Orient. This seemingly insignificant act of settling Europeans at the tip of the African continent would change the landscape forever.

Not only did it shape the socio-political milieu of the country for centuries to come, it also heralded a new era of organised agriculture and closer, westernised settlement that would lead to the construction of the dams in the country.

By the sixteenth century, the European spice trade with East Asia was in full swing. Spices such as pepper and cloves were highly coveted items, especially for their ability to preserve and flavour food. These spices were literally worth their weight in gold, and it was a highly lucrative trade. The Portuguese were the first to stake their claim in this extremely profitable business, later to be ousted by the Dutch. Countries started establishing trade companies to maximise on profits gained from their operations in Eastern countries. The biggest trade company of them all was the *Vereenigde Landsche Ge-Oktroyeerde Oost-Indische Compagnie*, better known as the Dutch East India Company, or simply the VOC.

Formed in 1602 through an amalgamation of six companies, the VOC had extensive powers and privileges. In its first 21 years it had a tax-free monopoly over the eastern trade. With its headquarters in Batavia, the Company virtually operated as a state within a state. The executive directorate, known as the *Heren Sewentien*, reigned with an iron fist. The Company was authorised to build forts, establish colonies, mint coins and maintain a navy and army as required. Nothing stood in the Company's way to power and profits. By 1670, the VOC was the richest corporation in the world, paying its shareholders an annual dividend of 40% on their investment despite financing 50 000 employees, 30 000 soldiers and 200 ships, many of them armed.

Amsterdam Municipal Department for the Preservation and Restoration of Historic Buildings and Sites

The VOC shipping yard in Amsterdam, the Netherlands, circa 1750.

REFRESHMENT STATION

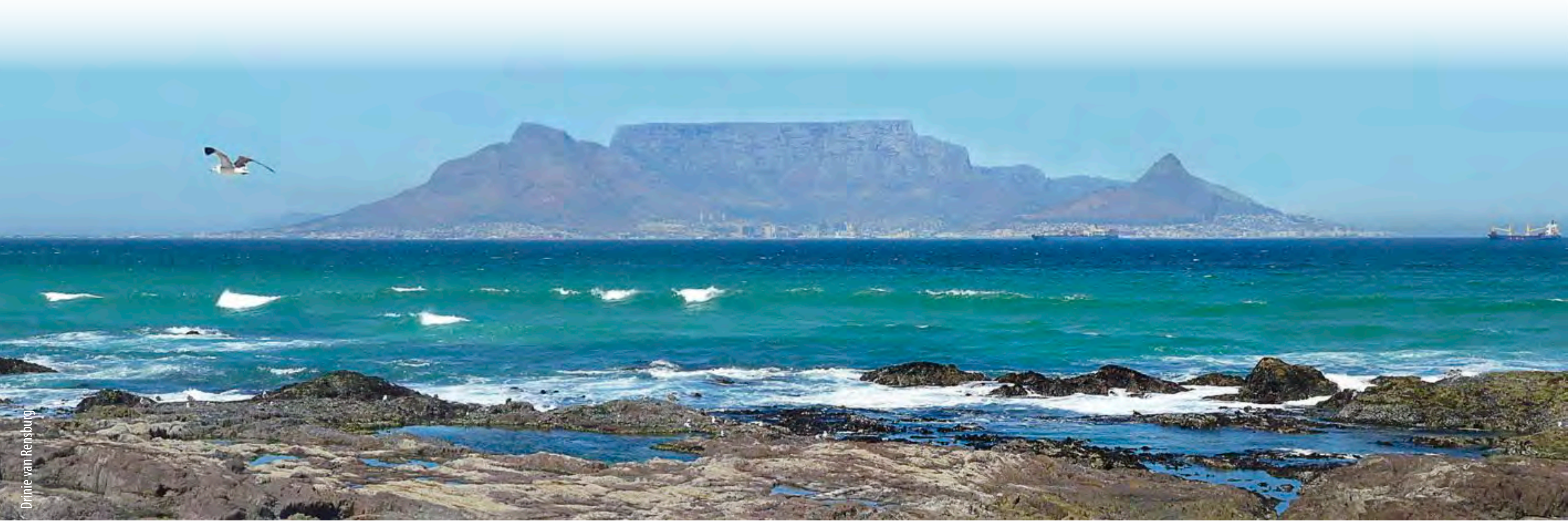
The voyage from Europe to the East Indies was a long and arduous one with many a sailor succumbing to scurvy and dysentery. Sometimes the situation was so serious that it would lead to the loss of entire vessels along with their precious cargos. European sea captains had discovered that it was feasible to sail directly north-east across the Indian Ocean from the southern tip of Africa. This had momentous results and made the Cape an important port of call for taking on water and fresh supplies. Ships sailing to and from the East started to call in regularly at the bay below Table Mountain to take on fresh water, and barter with the indigenous Khoisan.

To the Khoi, the land around Cape Town was known as Hoerikwaggo ('mountain in the sea').

In fact, it was Spanish grandee Antonio de Saldanha who first 'exported' water from the Varsche River as it was later dubbed by the Dutch. He sailed into the then unknown bay in 1503. He climbed up the flat-topped mountain which guarded the bay (De Saldanha was believed to be the first white man to do so) and discovered there a strong stream of fresh water to replenish supplies on his ship. "This water was far more important to the survival of the sailors than the cow and ten sheep they bartered from the Khoi – a ship's crew could sail longer without meat than they could without water," notes Kevin Wall (Wall, 1983). De Saldanha reported favourably on the bay as a refreshment post and it consequently became known as *Aguada de Saldanha* (water place of De Saldanha).

In 1619, two English captains, Shillinge and Fitzherberg, took possession of the Cape in the name of King James I. However, this endeavour was not recognised by the English government and nothing came of it. Then, on 25 March, 1647, while a homeward bound fleet of the VOC was at anchor in Table Bay, one of the ships, the *Haarlem*, was wrecked in a storm. Her cargo was salvaged, however, it could not be carried home by the remaining vessels, and 60 of her crew were left behind to guard it.

The sailors made a camp, and hunted and fished to while away the time. They even laid out a little vegetable garden "finding that the soil was fertile and that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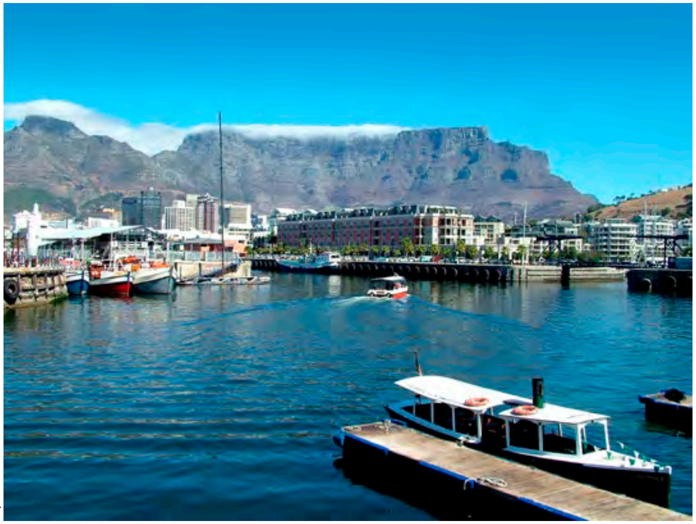


Wynand van Niekerk

Left: *Cape Town harbour has its origin in the Dutch settlement at the Cape in 1652, however, long before Jan van Riebeeck arrived did European ships call on the South African coast to replenish water and food supplies.*

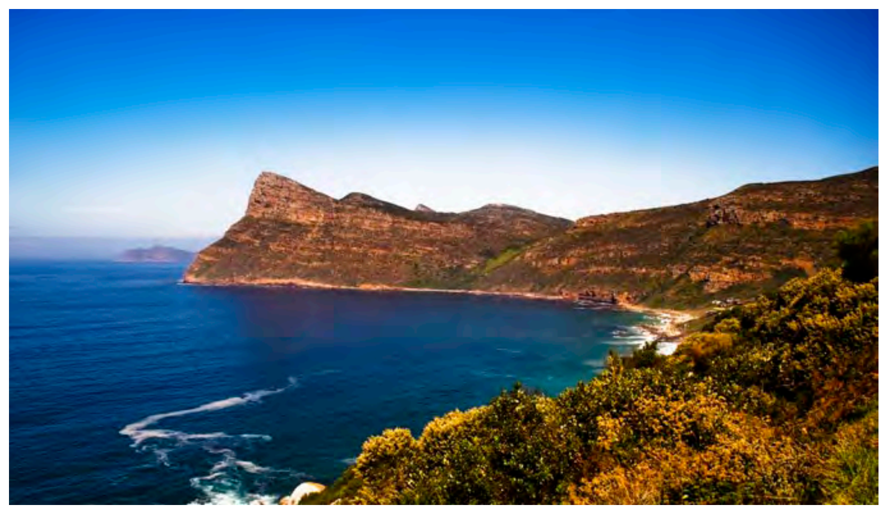
everything grew well." (Walker, 1929). *The Haarlem*'s cargo and guardians were picked up a year later. Once they arrived in the Netherlands, two of the officers, Leendert Janszoon and Nicolaas Proot, were asked to present a report to the *Heren Sewentien* on the suitability of the Cape as a refreshment station.

In their report, dated 26 July 1649, the two officers warmly recommended such an undertaking, describing the southern tip of Africa as a kind of paradise where vegetables and fruit could be produced 'in abundance' and the sick restored to health quickly. This report did much to persuade the heads of the VOC, and so on 6 April 1652, three ships laden with seeds and tools under the command of Jan van Riebeeck landed at the Cape.

Van Riebeeck's orders 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 first fort, known as Fort Good Hope, was not the impressive Castle that we know today. It was a mere mud and timber structure, threatening collapse after every severe rain storm. The settlers mainly relied on the five streams flowing off Table Mountain for their water needs, namely the Varsche River to the north, the Liesbeek River to the east, the Diep and Spaanschemat rivers to the south-east, and the Disa River to the south-west. Wouter Schouten, who tested the water on the mountain in 1655 declared: "We found it quite sweet and exceptionally pleasant in taste. Our heavenly liquid now tasted better than ordinarily does the most exquisite drink in the world" (Burman, 1991).

The Company gardens were situated outside the Fort. They were tended by Company employees under the direction of Dutch gardener Hendrik Boom. Within a year, passing ships were supplied reasonably well with cabbage, carrots and other greens. Ten years later the garden had grown to more than 18 ha. In addition to a fruit and vegetable garden, Boom also laid out a herb and medicinal garden. Producing enough produce for passing ships turned out to be much more difficult than initially thought, however. The African land would not let her be tamed so easily.

The Company gardens were watered from the Oranjezicht springs through a series of canals. In 1654, a canal was dug on each side of the garden and water from the Varsche River led into it. Boom also had a series of minor irrigation furrows built – the country's first modern irrigation system.



Vivek Chugh

Bottom: *Cape Point.*

www.sxc.hu

Above: *A figure sits atop the Castle completed in 1686.*

Top right: *An illustration depicting the VOC's grain stores at the Cape in 1657.*

Right: *View of the parade and heerengracht (now Adderley Street), in 1763.*

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The garden was a constant headache for Van Riebeeck, however, and he requested seeds from Amsterdam and Batavia constantly. It was frequently devastated by winds and rain and regularly raided by wild animals. The Company's own farm and orchard was situated at Rondebosch. With the Khoi unwilling to barter large numbers of animals, the Cape settlers remained dependent on their homeland for meat along with other foodstuffs such as bread, salt, meat, rice, and beans. Sometimes these passing ships had to come to the rescue of the European settlers.

Wherever Dutch colonists settled, they were inclined to build canals in the manner of their homeland. The Varsche River ran straight through to the Bay, fed by rivulets running down the mountain, namely Platteklip Gorge and Silverstream. The Company's gardens were fed by this river through a series of furrows. One of these furrows continued to run straight down to the sea, where it served the needs of passing ships. These furrows were soon widened and deepened to form canals with names such as Heerengracht, Keisersgracht, and Buitengracht, which would remind the settlers of Amsterdam. The canals were crossed by little bridges and fed with water from the river. Simon van der Stel, who was responsible for some of this work, writes in 1687: "The work of leading the water in wooden pipes was this day completed...upwards of 1 000 bored trees, fastened together with iron rings, were thus used."

The canals later became polluted with dust blown in by the southeaster and by the runoff from the rudimentary streets, while slaves (first imported in 1657) found it a convenient place to dump household waste. These canals also formed a traffic hazard, and it was not uncommon for people to fall in, especially at night. Within a short while the canal water was undrinkable and the settlers started relying on water from springs on the mountainside.

We do not know much about the Dutch officers' dam-building activities, but it is thought that they did not extend much beyond the district borders of what was then known as the Cape of Good Hope. In 1660, the Varsche River furrow leading down to the sea was widened, and a small dam

Early days of wine-making at the Cape

The first vineyard at the Cape was planted under the watchful eye of Governor Jan van Riebeeck in 1655, who had brought some vine cuttings with him from the Netherlands. The first wine was made from Cape grapes on 2 February, 1659. This led to the planting of vines on a larger scale at Roschheuvel, known today as Bishopscourt, Wynberg. The first cultivars originated from France, Italy, Spain and Persia.

When the first vryburgers were allowed to leave the services of the VOC they were strongly encouraged to plant vineyards, however, initially most of them were reluctant. Most of these farmers knew practically nothing about producing wine and, in fact, the early wine produced at the Cape is said to have been of poor quality, only good enough to be consumed by labouring classes in canteens or by slaves and free labourers on farms as part of the dop system, where farm workers received a percentage of their payment in the form of alcohol. The quality of the wine was also compromised by the acute shortage of oak vats, and it is reported that farmers were obliged even to use vats in which salt had been brined. Thus the volumes of wine exported remained extremely low. This only really improved with the arrival of Governor Simon van der Stel, who had great knowledge of wine-making and produced exceptional wines at his Constantia estate – still known today the world over for the quality wines it produces.

Historically, the wine farms at the Cape were extremely dependent on slave labour. A prosperous wine farmer could own as many as 50 slaves, who were actively involved in all the viticulture and wine-making processes, from preparing the soil and planting of the vine stocks, to gathering the harvest, pressing the grapes by foot and controlling fermentation by sulphuring barrels and continuously pouring over the wine into other vessels. When the wine was ready for sale, the slaves were also responsible for transporting the wine by ox wagon to be sold in Cape Town. When British authorities abolished slavery at the Cape in 1834 many slaves remained on farms as free labourers. They formed the bulk of the ancestors of the present day labourers on farms in the Western Cape, and part of the so-called 'coloured' community.

During the early years of Britain's occupation of the Cape, during which it was also at war with France, exports of Cape wine soared. However, in 1861 Britain resolved her differences with France and South Africa's wine exports collapsed. In 1886, the disease phylloxera was discovered at the Cape resulting in the decimation of many vineyards. Further hardship was experienced by the wine industry during the South African War, and it was only decades later that a viable sector was established.


Dominic Morel

constructed near the jetty for filling water casks for passing ships. It is thought that the previous collection point may have been a back lagoon of the Platteklip Estuary.

WAEGENAERS DAM

During the first decade of the Cape station (1652-1662), 205 ships with 40 200 people on board sailed to the East, while 103 ships with some 13 000 people returned to the Netherlands. The Cape is a winter rainfall area, and the normal flow of its rivers in summer is light. When droughts hit there was no water for passing


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The Waegenaers Dam was a masonry structure built near the Fort. It probably conserved around 3 million m³ of water.

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Archaeologists working at the Waegenaers Dam site in 1975. The site was discovered when foundations were being excavated for the Golden Acre complex.

ships. In 1661, Van Riebeeck started construction of a dam to ease shortages (plans for the dam go as far back as 1655). The task was eventually completed in 1663 by Van Riebeeck's successor, Zacharias Wagenaer.

Fed by the Varsche River, this masonry weir was constructed near the Fort with a sluice at its seaward end where water was drawn off. The dam measured 'sixteen roods by four and a half rood deep' (about 55 m by 15 m and 1,5 m deep) and probably conserved about 3 million m^3 of water. The inside of the reservoir featured stone masonry work, while a wall of about one metre in height was constructed around the structure to keep out livestock. Steps ran down the one side from which sailors could fill their water barrels. Construction was done fairly hastily as a drought was raging at the time. All able-bodied men were required to work on building the dam, including gardeners, servants, soldiers, sailor, slaves, and even clerks. This motley gang of labourers was later joined by 15 young Khoi who were persuaded to help (at a price no doubt).

Once the dam was built it solved the problem of water shortage, however, there was still the challenge of transporting the filled water barrels to the ships. Rolling them over rocky soil damaged the barrels. The problem was solved through the construction of a stone watercourse from the reservoir to the jetty. Interestingly, this work was thrown open to public tender. Wouter Mostaert, the local brickmaker and miller, was the successful tenderer. Completed in 1671, this is thought to be the first water scheme constructed under contract for a public body in South Africa.

It is uncertain when exactly Waegenaer's Dam fell into disuse. A sketch plan of Cape Town city dated 1725 does not feature the dam. The stone and brick remains of this pioneer water engineering work were dug up when foundations were excavated for Cape Town's Golden Acre building in 1975. Part of the dam wall is preserved in the lower concourse of the shopping centre and is now a national heritage site.

After the building of the Castle and a new jetty in 1686 water was led off from the Platteklip Stream to service reservoirs lower down from which it was distributed to the town, the Castle and the jetty. From this time onwards there would be continuous competition between the growing town and the gardens for the available water.

Following Waegenaer a succession of commanders governed the settlement at the Cape, but none stayed very long. It was only with the arrival of Simon van der Stel, the founder of Stellenbosch, and later his son Willem Adriaan that any substantial infrastructure development took place.

Irrigation water was not only required for vegetables, but also to grow vines. The first wine was produced at Wynberg as early as 1659 (hence the name). With the influx of the French Huguenots the industry progressed rapidly, and the early history of irrigation development is said to follow closely on the growth and fluctuations of the wine export trade.

Irrigation was practiced for the first time on a considerable scale in 1699. Willem Adriaan had obtained a 30 000 ha farm on the slopes of the Hottentots Holland mountains which he named *Vergelegen*. Here he planted 400 000 grapevines and a quantity of wheat. Six years after he started planting vines, Willem Adriaan had half a million vine stocks. He laid out fruit orchards and orange groves, planted camphor and oak trees, and established 18 cattle stations with 1 000 and 1 800 sheep. Reservoirs and irrigation canals were constructed to water his lands. (Unfortunately, the young Van der Stel was found guilty of corrupt practices and after only six years in office was called back to the Netherlands in disgrace)


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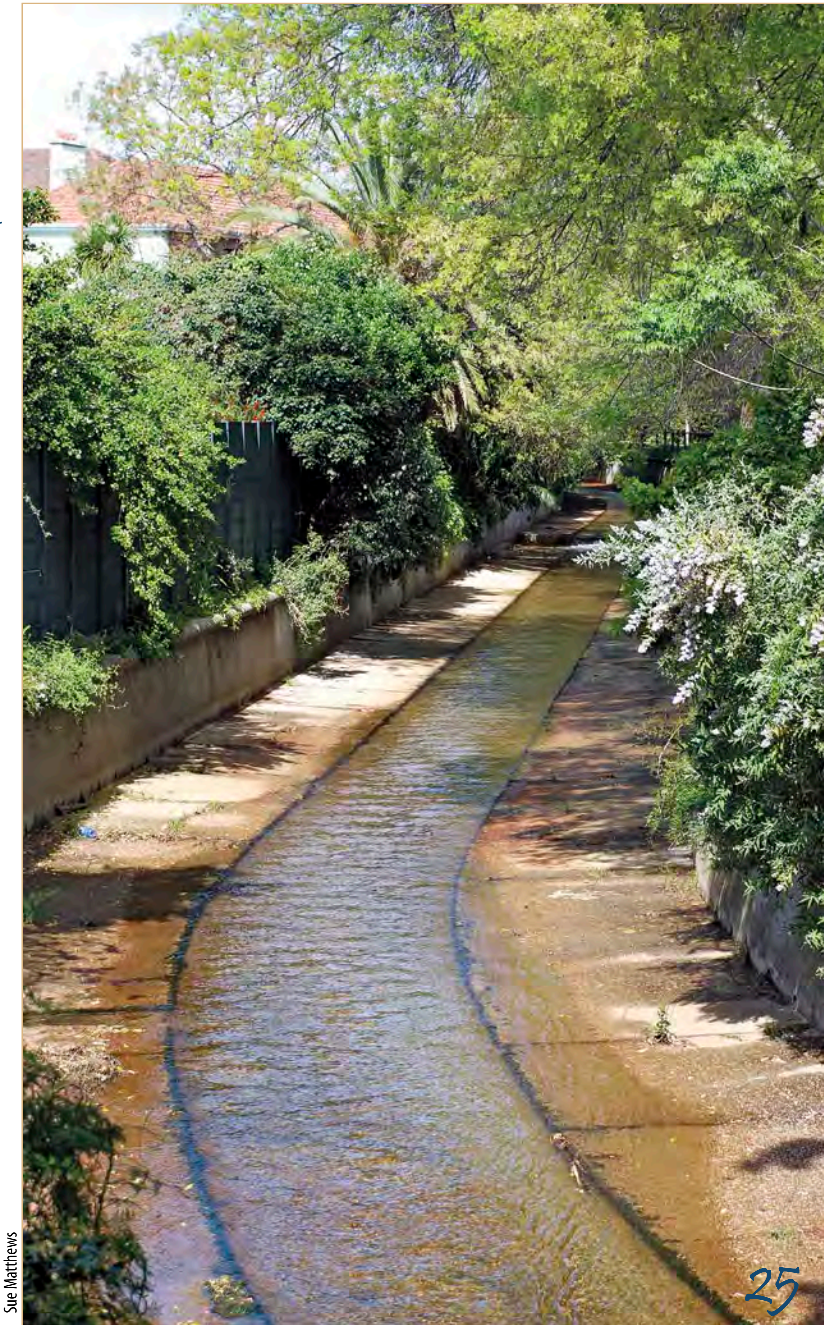
Left: An illustration of Willem Adriaan van der Stel's farm, Vergelegen.

Right: Jan van Riebeeck called the Liesbeek River 'the loveliest of fresh rivers' on discovering it in 1652, and later allocated farmland along its banks to the first free citizens of the Cape settlement. Today, some 40% of the river is canalised.


Sue Matthews

FREE CITIZENS

The VOC never intended to colonise the Cape. In fact, the Company's only intent was for a 'neat, compact settlement that would not extend much further beyond the shadow of the coastal fort' (Gilliomee, 2003).

Van Riebeeck, however, despairing at the disappointing results emanating from the Company garden, already in 1655 pleaded with the *Heren Sewentien* to allow some of the employees of the Company to be freed to work their own plots of land. Van Riebeeck hoped that these men would be attracted by the prospects of grain and be attached to soil in such a way that they would 'in time be weaned from Holland and make [the] place entirely their fatherland' (Walker, 1929).

While these men would be known as *vryburgers* (literally meaning 'free citizens') they would be by no means free from Company control. The right to possess land would be granted under very specific conditions. Farmers would still be subjected to VOC rules – they would have to plant what and when the Company wanted (mainly wheat for food and vines to beat off scurvy on the ships), with the VOC being the sole purchaser – at a price it would set itself for the produce. As in the Netherlands the farmers would be expected to grow crops in rotation (including clover to allow the soil to recover) and provide fodder for a limited number of cattle, with manure collected for fertiliser. The conditions on which they held their farms could be changed at the whim of the VOC. The Company would remain master of everything at the Cape.

The VOC directorate begrudgingly granted Van Riebeeck his request, and in 1657 nine volunteers were given pockets of land (about 11,3 ha in size) along the banks of the Liesbeek River (one of these first vryburgers was former Company gardener, Hendrik Boom). Areas subsequently established include Koornhoop, Groote Schuur, Krommeboom and Bosheuwel (Wynberg Hill). Each farmer signed an agreement whereby they were bound to cultivate the land diligently for 12 years and grow wheat and other grains (including rye and barley). During that period the land would not be taxed.

The Company would supply the farmers with trek-oxen and with cows and sheep for breeding at fixed prices, and with farming implements and rations at cost price. Rations would be supplied on credit, the Company taking the wheat crop in payment of the debts so incurred. Only garden produce could be sold freely to passing ships, but the farmers were not allowed to go on board until three days after the arrival of the ship. At first, bartering with the Khoi was only allowed with special permission from the Commander, and later completely outlawed.

However, conditions were unlike those in the Netherlands and the land turned out to be much less suitable for crop growing than expected. Crop failures and inadequate cultivation techniques – along with the poor prices paid by the VOC – gave the vryburgers little profit, and most of them remained heavily indebted to the Company. If they refused to do the Company's bidding they were threatened with a cut off from supplies. In 1662, when Van Riebeeck relinquished his command on promotion to a post in the East, there were only 36 vryburgers. More than a decade later, in 1679, this number had only increased slightly, while the number of European settlers had nearly doubled.

In the early 1700s another problem reared its ugly head – that of chronic over-production. The Cape market remained

This illustration by JC Philips illustrates agricultural practices at the Cape in 1727.

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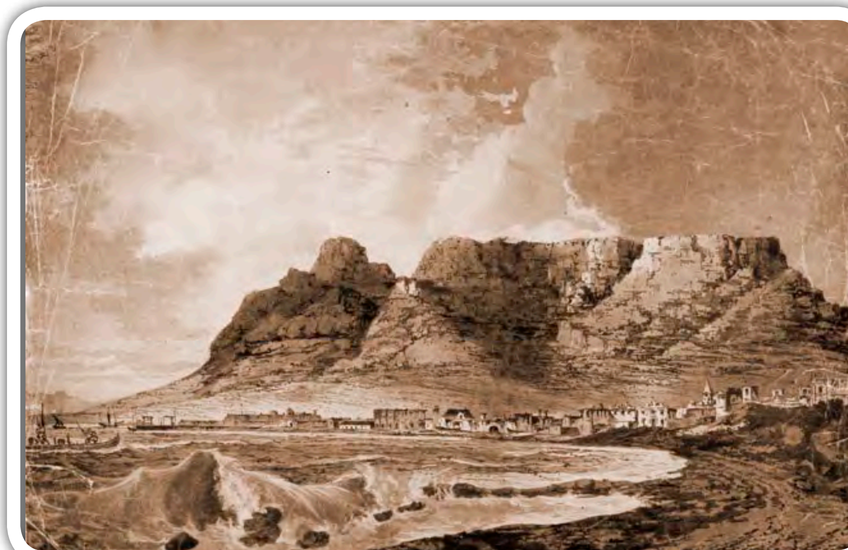
small, and those ships returning from the East usually had bellies already bloated with produce, leaving them unable to take on any extra stock for export purposes. The situation was not made easier by the fact that the Commanders and senior officers of the Company had started themselves to produce wheat and other products for the market. With their insider knowledge they could work out the best deals for themselves, leaving little room for manoeuvre for the vryburgers in the market. So it is reported that by 1705, the Commander himself owned 20 000 sheep, produced 1 000 bags of wheat and produced 600 leaguers of wine, enough to practically meet the entire demand of the settlement all on his own. In this environment, the farmers found it impossible to prosper. By 1707, some 40% of the 570 farmers whose fate is known had either returned to Company service, been given permission to leave the colony or stowed away on departing ships.

Strict control was maintained over water in the Cape Colony. Water resources were managed based on Roman Dutch law, whereby water belonged to the State and the government had the right to control its use. The needs of the VOC were regarded above that of any individual. So, for example, in 1661, an increasing demand for water for irrigation was countered with the establishment of limited hours for irrigation in favour of the continued operation of the VOC's maize mill.

ADVANCE OF THE TREKBOERE

Cattle farming turned out to be much easier than wheat growing. Farmers grazed their cattle on open land adjoining their fields. Many sent their cattle deeper and deeper into the interior to find good pasture. Farmers could get much higher prices for their livestock from passing ships and from bartering with the Khoisan communities than from the Company. When further trade with the ships and indigenous people were outlawed, they continued to do business in secret, despite the threat of severe penalties.

The size of the farm would be determined by walking for half an hour in every direction from a centre beacon. This beacon was usually a fountain or other such landmark.



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A view of the Cape of Good Hope in 1787.

The VOC's Directors were perturbed by this gradual expansion of European settlement. Being severely profit driven, they wanted to keep their complement at the Cape as small as possible, spending as little as possible on infrastructure and administration. In 1661 the *Heren Sewentien* wrote to Van Riebeeck: "We have remarked that you are gradually tending towards the building of a town there, and the enlarging of the colony; but as we look upon it, this idea should be abandoned, and you should get along with the men and the free men whom you have with you at present, without extending any further' (Walker, 1929).

At first, the VOC sought to control this movement by licensing grazing activities. This was later expanded to exclusive grazing rights to a limited area. Grazing licenses cost six rix-dollars in 1703. The farmers did not own the land and no title deeds were given, nor were any official measurements made. In 1732, the


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system was changed so that the farmer would own his homestead (*opstal*) but not the land surrounding it. Rather this would be given to him on long lease (quitrent tenure) of 15 years. The size of the farm would be determined by walking for half an hour in every direction from a centre beacon. This beacon was usually a fountain or other such landmark. Thus the early farms were circular rather than square.

Judging by the way they acted in drought situations, the early trekboere did not construct much in the form of water storage infrastructure.

The half-nomadic pioneers, dubbed *trekboere* ('roaming farmers') were not the least perturbed by the Company's efforts to reign them in and they easily swapped one farm for the next once the best grazing had gone, thus trekking further and further away from the original European settlement. As soon as a new border was established to the north and the east, they would simply cross it, egged on by the promise of sweeter water, greener pastures, and the scent of the hunt. By the late eighteenth century, the trekking farmers reached what would become the district of Graaff-Reinet. In the 1770s, they were at the Fish River. By this time, stock farmers formed two thirds of all farmers in the colony.

By the late eighteenth century, the VOC had become an obese monster, pockmarked by greed and corruption. The company was declared bankrupt in 1798 and its assets, including the Cape of Good Hope, taken over by the Dutch government.

The frontier farmers did cultivate small tracts of land for their own use, however, we do not know whether they actually stored water for irrigation purposes. Since under the Dutch system their farms could be taken away from them at any time for government use it is thought that they were rather discouraged from spending too much on developing the land. Rather they mainly developed existing springs, cutting away the soil and rock around the water source and leading the water away through canals. At most, the farmers constructed earthen dams to store runoff during rains.

Fixity of tenure and survey were only introduced and made compulsory for all holdings in 1813 by Cape Governor Sir John Cradock. On 6 August of that year he issued a proclamation which permitted occupants of loan farms to have their tenure converted to that of perpetual quitrent. Each farm was properly surveyed at the expense of the occupant and a diagram was to be registered in the deeds office.

Judging by the way they acted in drought situations, the early trekboere did not construct much in the form of water storage infrastructure. We read of farmers that only managed to graze their cattle on some farms for two months of the year as a result of the acute lack of water (Van der Merwe, 1988). Rather than constructing infrastructure and storing resources for times of need, these farmers would simply move on to the next piece of land. In areas where perennial rivers were scarce or non-existent, farmers would settle for tracts of land containing springs and fountains (the names of many areas today still allude to the importance of these water sources to the farmers of old).

The European population grew quickly, and families were large. Younger sons were forced to set up for themselves further in the interior rather than stay on family farms. In this way each succeeding generation moved further from civilisation and became of necessity less dependent on its amenities. Owing to the vast distance to Cape Town and the complete absence of roads and bridges, the frontier farmers were forced to concentrate more and more on cattle farming.

At the start of the eighteenth century conflict with the Xhosa peoples on the eastern frontier and the harsh, dry climate of the northwest, prevented any further expansion. Soon, the best areas had been taken, leaving only lands of lesser quality. In the upcoming decades, the British would bring new legislation, professional hydrological engineers and a desire to advance the storage of water in large dams in the country. ◈

A 1794 depiction of the Cape of Good Hope.

5

The Cape pins its hope on irrigation (1806-1912)

Only once the Cape became a British colony were the first steps taken towards establishing large dams in South Africa. As cities and irrigation farming grew, so did the need for adequate water storage. Along with British administration came the first Royal engineers, some of whose foresight led to the establishment of the most significant dams in the country.

Political turmoil in Europe first led the British to take control of the settlement at the Cape in 1789. This occupation lasted for eight years, until they relinquished control to the Batavian Republic in 1803. In 1806, Britain occupied the Cape again, this time permanently. For the next century the Cape would be part of the Royal Empire and administered as a British colony.

By the time the British became the new custodians of the settlement at the southern tip of the African continent, the capital city alone was home to 17 000 people. But the water infrastructure had not kept pace with population growth. Cape Town residents were still dependent on a handful of springs and reeking canals, with water being conveyed through a series of wooden pipes to only a few selected buildings. There was no sanitation system to speak of. Still, they were better off than the people living on farms and in small towns, who had virtually no services to speak of apart from those they constructed themselves.

At first the British were as reluctant to invest in water infrastructure as the Dutch had been. The Cape of Good Hope's economy was small and it had achieved little by way of export. And so in the first few decades of the nineteenth century most of the development in the water infrastructure realm had come either from private individuals on farms or from newly-established municipalities.

The source of the saaidams remain a mystery, however, it is thought that the method was adapted from similar structures used by other southern African cultures.

SAAIDAMS

As time went on, well watered lands became scarcer and farms got smaller as fathers divided up their properties equally among their sons (as stipulated by the Roman Dutch law of inheritance). It started becoming imperative for stock farmers and produce farmers alike to increase their water supply and make it more permanent. Dams were expensive to finance out of one's own pocket (not to mention the lack of engineering skills persisting in the country) and so those with riparian properties started constructing less expensive weirs in order to divert floodwater onto their lands. From the 1830s, the increased commercialisation of stock farming, prompted by the British settlers, also promoted the development of water infrastructure.

In the arid North Western districts of the Cape, particularly the areas of Calvinia, Frasenburg and Carnarvon, farmers began making use of a rainwater harvesting

Merino sheep farming in South Africa

South Africa was the first country outside Europe to farm with merino sheep, which originate from Spain. The first merinos were donated to Colonel Jacob Gordon, the military commander at the Cape, in 1789. They were actually a gift from King Charles IV of Spain to King William V of Holland, but did not do well in the moist climate and so were sent on to the Cape as an experiment. Interestingly, not long after the sheep were received instructions came from Holland to return them as they had been sent 'in error' (the Spanish were very protective over the merino bloodline). Cleverly, Gordon sent back the original number of sheep, but kept their offspring.

Early trekboere were mostly reluctant to give up their hardy local fat-tailed sheep, on which they depended on for fat, skins and meat in exchange for this commercial breed. However, the British settlers who arrived in 1820 to take up land in the Albany district had no such reservations. Merino flocks were first established there on settler farms in the 1820s and 1830s and from there spread over to other districts. In 1834, the Great Trek started and soon the Voortrekkers took their sheep flocks northwards with them.

Within a few years the merino had spread to all parts of the country. Wool exports increased from £500 000 in 1838 to £12-million in 1855 and £20-million by 1919. Merino wool became the Cape's number one export product and remained so until the discovery of diamonds and gold in the late nineteenth century.

When serious drought threatened the country's water supplies in 1865/66 it was suggested that a levy on wool should be introduced in the Eastern Cape and that each town would get its proportion of the money raised for its individual water scheme. (The wool farmers, brought practically to ruin by the intense drought, entirely dismissed the idea)

Today, there are about 15 million merino sheep in South Africa.


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technique known as *saaidams* (literally meaning 'sowing dam'). By constructing low (1 m to 2 m) earthen embankments, farmers diverted floodwater into a series of large, flat basins for planting purposes. These basins could extend as far as 100 ha. Effectively the saaidams were none other than flat, shallow dams. The water would be left to soak into the fertile alluvial soil. Once the water receded, the land which had been submerged would be ploughed, most often with grains, and later with lucerne.

The system (which is still in use today) is particularly suited to areas where the soil is very fertile, the rainfall low and the valleys particularly flat. The source of these saaidams remain a mystery, however, it is thought that the method was adapted from similar structures used by other southern African cultures, such as the Tswana, who used low earth dams to contain water in vleis and to trap fish after rivers flooded their banks.

Construction of the saaidams (as with every other dam or weir constructed at that time) was quite a laborious affair. The farmers did not have access to machinery and fancy tools; however, they did have oxen and labour. Measurement was done using *oogmaat* (measurement by eye). Earth was dug up and loaded onto dried cattle hides, with trampling done by teams of oxen. In some cases sheep or even donkeys were used where no oxen were available. The cattle hides were later replaced by wooden scraping boxes and then wheeled scrapers, although these still had to be pulled by oxen.

In the beginning the slopes of the earthen banks were constructed quite steeply and pitched with bushes, mostly kareedoring (*Lycium cinereum*) taken from the surrounding veldt. This practise was later abandoned for flatter slopes with no pitching, as the bushes tended to harbour rodents which liked to burrow into the banks, jeopardising the safety of the dams.

The saaidam system proved extremely successful. In 1922, Irrigation Department engineer Tom Hopwood writes: "During a trip through the zaaidam (sic) districts one cannot help being struck by the enormous tracks of land covered with glorious grains and one realises what an asset to the country the farmers are who have developed this principle of irrigation, the only one possible under the circumstances, and who


Lani van Vuuren


Lani van Vuuren

***Above**: A close-up of a water wheel or bakkiespomp of which a few still remain at Kakamas.*

***Left**: The Kakamas area is renowned for its export table grapes, raisins and wine.*

***Right:** Today, all the irrigation canals at Kakamas are lined with concrete.*


Lani van Vuuren

Church irrigation scheme at Kakamas

Christiaan Hendrick Wilhelm Schröder was of German parentage and trained as a carpenter before becoming a Reverend in the Dutch Reformed Church. He devoted himself to missionary work, and in 1871 established a missionary station at Olyvenhoutsdrift (Upington). He recognised the potential of irrigation from the adjacent Orange River early on and, despite the lack of engineering training, successfully started work on an irrigation furrow with assistance from young trader Japie Lutz. This scheme (known as the south furrow) was successfully completed in 1885, allowing the people at the missionary station to irrigate their gardens with water from the Orange River.

In 1897, the Cape Parliament granted two farms on the left bank of the Orange River, about 100 km west of Upington, to the Dutch Reformed Church for the establishment of an irrigation settlement for poor whites. Lutz (who was also not a professional engineer) again came to assist. The site for the intake was chosen at Neus, just upstream of the Neus Falls, where the river drops some 9 m. Work started on 4 July, 1898 with about 23 white labourers, paid three shillings a day. Most of these labourers were former farmers who had lost their lands, and means of making a living, as a result of drought, Rinderpest and other causes. They came with the promise that, if they proved 'suitable' they would be allotted pieces of irrigation land for their efforts. Food and clothing was supplied to them at cost price.

Most of these workers were inexperienced and ill equipped for this type of work, and it must have been tough going. Merely getting materials and equipment to site proved quite a challenge. The nearest railway ended at De Aar some 418 km away, and all tools, dynamite, and other materials had to be transported from there by wagon. Rifles, to which spirit levels were attached, were used as instruments to determine the levels of the canals.

By April 1899, the left bank furrow was completed to about the eleventh kilometre where the first erven were cut up for the 60 men who had worked longest. Lots were drawn for choice of plot, each being 5 ha in extent. No work was undertaken during the South African War, but construction resumed after the peace accord was signed, and in 1908, the left bank furrow, with extension to Marchand, was finally completed. This was followed by the completion of the right bank furrow in 1912.

A significant feature of these irrigation furrows was the extensive use of drystone walling to save on blasting of deviations. Despite criticism from the Cape government engineers, this method of construction proved highly economical and efficient.

Each settler was allowed a leading sluice consisting of a short pipe 150 mm in diameter with stopper, and they were allowed to open it for eight to ten hours a week (in periods of low rainfall allowance was reduced accordingly). The farmers themselves were responsible for cleaning the furrows. Each man was responsible for the length running along his plot, the common portions being maintained by a system of calling up labour. The farmers did not obtain title to the ground they occupied, rather it remained the property of the church, and they paid an annual rent of £10. Schools were also established for the children which they had to attend.

One of the most endearing characters of the Kakamas colony was Ouma Chrissie Viviers, who with her husband joined the labour settlement in 1904. In the absence of a hospital or clinic she served the community as a nurse for many decades. She had no formal training, but mixed her own remedies based on traditional Boer medicine and was a competent midwife. It is said that no distance was too far for her to travel, and not even the Orange River in flood could stop her from getting to her patients. During the outbreak of Spanish Influenza in 1918 the Kakamas community was found to be far less affected, thanks to Ouma Chrissie's traditional medicines. Not even the arrival of Dr Van Niekerk in 1927 stemmed the flow of patients to this traditional healer. She still had many patients up to her death in 1940.

Kakamas was one of many settlements established by the Dutch Reformed Church in the 1900s. In exchange for plots of irrigated farm land the settlers had to abide by strict church rules, including communal upkeep of the water distribution system, compulsory education for settler children and a high standard of conduct for the adults. Most of these schemes were later taken over by the government.

www.wikipedia.org

Japie Lutz

by their efforts produce thousands of tons of wheat annually" (Hopwood, 1922).

One of the largest saaidams we read of was the one known as the 'Seven Foot' owned by Zak River Estates. In the early 1900s this consortium bought the farm *Twee Riviere* along the Sak River from Donald Bain, descendant of famed road-builder Andrew Geddes Bain. By 1911, the consortium had established more than 257 km of low earth walls, trapping enough water to irrigate 546 ha of land. (Unfortunately, the company later faced problems with rust in their wheat and salinisation of the irrigated soil and it was closed in the 1930s). The Cape government also had several saaidams at Nelskop (near Brandvlei), irrigating 200 ha of land.

THE HANKEY TUNNEL

European missionsaries started to arrive in South Africa in the nineteenth century. By 1884, 15 missions ran at least 380 mission stations. They played an important role in establishing irrigation in the country. Many of these mission stations were located on land granted by a traditional ruler who sought missionaries' technical expertise and advice. In fact, it is said that the missionaries' acceptance by local communities was more often than not based on their technological ability to introduce agricultural techniques such as furrow irrigation and ploughing than on their religious teachings. For example, the Moravian missionary at *Hemel-en-Aarde* at the Onrus River started an irrigation scheme in 1823. A furrow of 546 m was constructed to irrigate the mission's vegetable gardens. The water was also used to drive a mill.

***Right**: Vuyani Dlomo of the Gamtoos Irrigation Board at the outlet of the Philip Tunnel. The entrance is completely caved in.*

***Bottom right**: The foundations are all that still stand of the Hankey Mill, which once took its water from the Philip Tunnel.*

Gamtoos Irrigation Board

Gamtoos Irrigation Board

Another early example of the influence of missionaries on the agricultural landscape is that of the Hankey Tunnel, constructed by William Philip of the London Missionary Society (LMS). This was the first irrigation tunnel to be constructed in South Africa.

Three years after his arrival at the Cape, Superintendent of the LMS, Dr John Philip (William's father), paid a visit to the Eastern Cape. His aim was to purchase land to grow maize for the society's main station at Bethelsdorp and to spread the gospel. For this purpose he purchased 1 619 ha of the farm *Wagendrift* in 1822. Two years later he founded the Hankey Mission Station. Situated at the foot of a ridge along the Klein River, a tributary of the Gamtoos, the mission was named after William Alers Hankey, Secretary of the LMS. It initially housed 25 families with surnames as diverse as Windvogel, Stuurman, Dragoonder, Matroos, Konstable and Kettledas.

Despite the apparent abundance of water and fertile soil the mission did not turn out to be the oasis that Philip had intended. Hankey's inhabitants were often plagued by droughts. In 1829, James Wait started digging the first irrigation canal from the Klein River with the assistance of 50 workers and 50 head of cattle. A year later the canal was finished and 1,6 km^2 of land could be irrigated.

William Enowy Philip was John Philip's eldest son. He was sent to London for his schooling but ran away from College to join the Royal Navy and later the merchant navy to become a navigator. In 1833, after an adventurous cruise on the Indian Ocean, he came back to South Africa to study surveying in Cape Town. Following his training, William accompanied his father to England where he studied for the missionary. He returned to Hankey in 1841 with his Scottish wife, Alison, on his arm.

Upon his return, William was put in charge of the Hankey mission station. At the time, Hankey was experiencing a serious water shortage with the meagre crops there being devastated by locusts. With little food to eat people started leaving the mission station. Young William was desperate to find a way of feeding the people of Hankey. It is said that he found inspiration from the natural window known as the Bergvenster, in the hill between Backhousehoek and Vensterhoek from which the valley can be seen.

After a careful survey of the valley William found that the land on the southeast side of the Vensterhoek Mountain was more than 3,65 m lower than the bed of the Gamtoos River on the northwest side of the Mountain. He could therefore irrigate the fertile soil by digging a tunnel through the mountain.

William had no practical engineering experience before tackling construction of the 228 m-long tunnel through the mountain. Descendant of John Philip, Ron Philip, later wrote of William's undertaking: "Although William Philip was a qualified surveyor and had some knowledge of engineering, it was all theoretical. He must have had a clear vision of what would be achieved and had tremendous courage and enthusiasm to undertake this project. His enthusiasm was not shared by everyone and he had to contend with doubt and disbelief as well as the physical aspect of penetrating the mountain. His only instrument was a sextant with which he must have been an expert after his navigational experiences on the oceans" (Malan, 1970).

William's boldness and confidence in the accuracy of his surveying is shown by the fact that he started work in April 1843 with two work parties, one on each side of the mountain. The labourers were all members of his congregation set to work day and night. The primitive methods used caused progress to be painfully slow (about 0,3 m a day). The hole in the mountain had to be dug out with picks, shovels, hammers and chisels, with all the excavated rock being carried out in baskets. Light inside the tunnel was provided by candles and lanterns. There was no ventilation and the threat of rock falls and collapse was constant. One can only imagine what it must have been like to work under these conditions. It is remarkable that even though no protective measures were taken not one injury or death is recorded on this project.

Fortunately, the conglomerate encountered consisted of hard pebbles in soft matrix which made excavation with such primitive tools possible. During the project William wrote to a friend: "We work day and night on both sides to meet in the middle. The workmen for some time have heard the blows of each other, which are every day becoming distincter."

Just over a year after the start of the project, at 02:00 in the morning of 13 August, 1844, the tunnel was holed through and the work parties met each other with jubilation. William described the breakthrough in a letter to his mother: "At about 2 am a shot was fired off at my bedroom window. I knew the signal – the tunnel is through. I looked out of my window and saw the messenger still running with a flaming brand towards the village, screaming as he ran. The measurements have all proved more accurate than I had reason to suspect so that my first lesson in practical engineering has been successful."

The original cross-section of the tunnel measured a little more than an average person's height, and just under a metre wide. By how much were the parties off line when they met? It is estimated that the error in alignment was in the order of 0,8 m. It is thought that as the parties came within hearing distance of one another, the advance was by sound rather than survey.

Hankey was experiencing a serious water shortage with the meagre crops there were being devastated by locusts. With little food to eat people started leaving the mission station.

A typical farm dam ca 1900.

For the next 123 years, Hankey's water supply flowed through this tunnel. The tunnel was twice extensively damaged by floods – once in 1847 and again in 1867. Both times it was repaired. On each occasion it took many months before the rock falls had been cleared. Sadly, William did not live long to enjoy his engineering achievements. On 1 July, 1845, on a calm, sunny day, William and his nephew, 11-year-old Johnny Fairbarn, crossed the Gamtoos River using a flat-bottomed boat to inspect the diggings for the water channels. They returned around 13:00 but never reached the other side of the river. Their drowned bodies were later recovered. William was only 31 years old.

On 9 July, 1845, William's death notice appeared in the *Eastern Province Herald*. The journalist wrote: "The writer of this notice examined the works in question only a few weeks before the fatal catastrophe and both himself and his fellow travellers were astonished at the magnitude of the enterprise, and the perseverance of its author, especially considering the nature of his material and resource. It is a labour totally unprecedented and equal, if not superior, to any of the public works in the Colony" (Anon, 1845).

From mid-century fill dams started to appear, and there were increased calls for large-scale State-funded irrigation projects. According to William Beinart, one of the most powerful advocates for State intervention in irrigation was FW Reitz, farmer and politician in Swellendam. "Reitz saw large-scale irrigation as opening the tap to a flow of wealth and increased revenue" (Beinart, 2003). Among others, he advocated that Cape students be sent for education in hydraulic engineering.

In 1858, one of the first surveys was undertaken by Patrick Fletcher. Under instruction from the Colonial Secretary, he studied a 36 km stretch of the Olifants River (in the Cape), starting at the mouth and travelling as far as Ebenezer. In 1860, he submitted plans for two dams on the Olifants River, one at 'Blaauwkrantz' to irrigate 971 ha, and one at 'Huilkrantz' to irrigate 1 821 ha. A few years later, in 1842, the Colonial Secretary issued a circular to several Civil Commissioners throughout the colony to determine, among others, what irrigation works existed or were planned in their divisions. With but few exceptions, the replies all tell of irrigation being practiced in some way or the other, mainly by diversion. The Select Committee on Irrigation was established that same year, chaired by JC Molteno, who later became Prime Minister of the Cape. The Committee considered the construction of large dams, their economic impact, the settlement that might result and financing through government loans and foreign capital.

DIAMONDS AND GOLD

Up to the 1860s, South Africa's economy was mainly based on pastoralism, hunting and subsistence agriculture. This all changed in 1867, when two children picked up a 'brilliant pebble' at Hopetown on the Orange River. The pebble turned out to be a diamond of 21 carats,

Left: The diamond fields of Kimberley in 1870.

Below: An 1873 illustration of diamond diggings on the Vaal River.

worth £500. Not long after that another gem was picked up on the banks of the Vaal River, followed by several more in 1868 and 1869. Large numbers of prospectors rushed to the river diggings at Pniel and Klipdrift (later Barkley-West) and later to dry diggings at Dutoitspan and Bultfontein. In 1870, a large find of diamonds was made about 30 km south of the Vaal. The diamond diggings later became Kimberley. Virtually overnight, a vibrant modern city sprang up where before had only been a dry, sparsely populated landscape. The 'Big Hole' promised unimaginable riches – in its first ten years it yielded an income of £60-million. And so South Africa welcomed its mineral revolution.

As the diamond mines were dug deeper, industrial machinery was required for haulage and for pumping of floodwater, and the individual claim holdings gave way to capitalised companies. The mines were thirsty and the miners hungry. Farmers (black and white) now found themselves with a huge potential market where before they scarcely grew enough crops for own consumption. Many moved into diversified

farming practices, which eventually increased the need for water storage. Transport of produce to market also became easier with the laying of railways and better roads (financed by the revenue from diamonds). The railways did not just take out produce, they also brought with them technically skilled people, which would later bode well for the development of irrigated agriculture.

JOHN GAMBLE

The mineral revolution and consequent increased demand for water set the stage for the country's first hydraulic engineer, John Gamble. Born in 1842, 'Honest John' as he later became known, was the son of a naval surgeon and a mathematical genius. He attended the Royal Naval School, graduating at the age of 17, and then went on to study mathematics at Oxford with a bursary. After graduating top of his class he remained at Oxford, among others, teaching mathematics at Lincoln College. During this period he was awarded the Gold Medal for the Johnson Memorial Prize Essay, his subject being 'The Laws of the Wind'.

With his rare combination of excellence, great mental gifts and a 'sweetness and modesty of character', he secured the esteem of those with whom he worked at every stage of his career. In 1866, the young Gamble left academic life and started practical training under engineer JC Hawkshaw. Soon he was appointed Resident Engineer to construct a series of engineering projects, including sewage outfalls. His designs were astoundingly accurate and precise, especially when one considers the instrumentation available to him at the time. A few years later, in 1874, Gamble, along with three colleagues, was sent to Brazil to collect information in order to advise the government on several of the important harbours in the country. Two of Gamble's associates fell ill and died (presumably of yellow fever) while a third could not handle the heat and humidity and had to return home, leaving Gamble to complete the job alone.

In 1875, the 33-year-old engineer arrived at the Cape to take up the most important position of his career, that of Hydraulic Engineer to the Government of the Cape Colony. So important did he consider this post that he studied Dutch while en route to the Cape, thus enabling him to gather information better during his tours of the land. His situation reports proved extremely useful in later years. He made recommendations to several towns regarding

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***Above**: The Robinson gold mine at Johannesburg in 1898.*

***Right:** John Gamble.*

***Far right:** Workers at the Molteno reservoir to supply water to Cape Town ca 1890.*

their water supply, including Port Elizabeth, Queenstown, Riversdale, King Williamstown and Graaff-Reinet. Gamble also located the position for the first reservoir on Table Mountain and the Woodhead supply tunnel. When this reservoir collapsed in 1882, Gamble was appointed to find the cause and remedy.

In 1877, the Cape government passed new legislation aimed at encouraging, by means of financial assistance, settlement on farms and the development of private irrigation schemes. Any group of farmers owning a certain amount of land, who were willing to cooperate to form irrigation districts, qualified for these favourable loans from the State. While the Irrigation Act of 1877 stimulated some works, most farmers were uneasy about taking major loans, especially as the legislation stipulated that irrigation repayments would take precedence over other debts. Many feared that the dams would silt up before the 24-year span for interest payments was complete. In addition, some farmers linked this legislation with other forms of State intervention and increased taxation. Despite this resistance, by the end of 1886, £54 000 had been advanced in irrigation loans.

Robertson Irrigation Scheme

One of the oldest State-supported irrigation schemes in the country is situated at Robertson, in the Western Cape. From about 1860, the possibility of irrigating the rich soils along the north bank of the Breede River, reaching form the Vink River to the Kogmanskloof River, was discussed among farmers and in Parliament. As far back as 1862, Civil Commissioner of the Robertson District, Mr Le Brun, requested State assistance to establish an irrigation scheme in this area.

Between 1865 and 1875 some minor attempts to use the river for irrigation were made with a certain degree of success. But it was not until 1896, backed by the Irrigation Act, that concrete moves were made to establish irrigation in the area on a large scale. Between 1896 and 1897, at the request of the landowners, surveys were made by the Cape Public Irrigation Board to undertake the scheme on their behalf. Parliament approved a loan of £23 500 (later increased to £33 000). The period for repayment was fixed at 40 years at an interest rate of three-and-a-half percent. Tenders were called for the work, but the Irrigation Department disapproved of all the submissions received and decided to construct the work itself on behalf of the Irrigation Board.

Construction of the scheme started in February 1900. Work comprised a diversion weir across the Breede River, about 8 km outside the town of Robertson. Government engineer TE Scaife was appointed Resident Engineer and work was carried out through small contracts and by day labour. The weir was described as being of 'singularly bold design', consisting as it did of a thin concrete wall some 2 m high and up to 0,9 m thick, flanked on both sides by steep slopes of loose rubble without mortar of any kind or other means of securing cohesion. In addition, the base of the wall was not founded on rock, but on gravel about 2,4 m below the riverbed. It was 366 m long.

Construction was interrupted by the South African War and further delayed by the river being in flood. The scheme was not completed until 1904. In 1902, considerable damage was caused to the unfinished weir by high floods in tributaries of the main river where they cross the line of the canal. Surprisingly, this unusual structure withstood the test of time and floods. In 1923, Cape Town Circle Engineer W Farrant notes: "A very small amount of maintenance has been necessary during the last 20 years. It is only recently that some of the loose stone on the downstream slope has been washed out. Floods have rise over 9 feet [2,7 m] in depth on the crest of the weir" (Farrant, 1923).

At the time the main crops produced through irrigation from the scheme were grain, lucerne, wine and fruit.

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Chris Marais/Karoospace

Above: Vanwyksvlei Dam, in the Northern Cape, was one of the first large State dams to be constructed in South Africa.

Right: The cracked earth of a dry Vanwyksvlei Dam. Constructed in 1883, it is still in use.

Chris Marais/Karoospace

In 1893, an Act was passed enabling private individuals to borrow money for irrigation works on the same terms as those which applied to an Irrigation Board.

One of the first large State fill dams to be constructed under Gamble's advice was Vanwyksvlei Dam in the Carnarvon district (Northern Cape). The dam was completed in 1883 with a height of 15 m and a crest length of 311 m. Designed and built by young engineer Cawood Alston for the Vanwyksvlei Irrigation Board, the reservoir had an original capacity of 75 million m^3. Unfortunately, the dam, which was fixed to suite the level of a natural landscape used as a spillway, was hardly ever more than half full, and was later described as a 'white elephant'. The water in the dam also became saline, and during the end of 1912, on orders of the Director of the Irrigation Department, Vanwyksvlei was drained completely to rid it of its salinised water. A total of 1 078 bags of salt were obtained from below the dam during December and January. When drought hit the area in 1923 the dam was completely empty and many of the farmers had to resort to eating donkey meat to stay alive. Government drillers were consequently sent to drill emergency boreholes to try and relieve the situation.

Another early dam was the one established at Rooiberg on the Hartebeest River in 1898-99. The 7 m high earthfill dam caused a lot of heartache as the wife of the Resident Engineer died of typhoid fever during construction. On 26 March 1900 a devastating flood caused the dam to breach.

In 1890-91 the State, through the Department of Agriculture, constructed a weir across the Vaal River at Douglas. Barely a year later the first structure was destroyed by floods, and had to be rebuilt. It was then constructed as a masonry wall 610 m long and about 1 m thick. This structure was completed in 1896.

Gamble induced the government to establish rain-gauges at every magistery, thus raising the number of trustworthy recording stations to 250. This enabled him to produce the first rainfall maps and publish the first daily weather bulletins. He compiled a catalogue of all publications (in all languages) about southern African climate and collated a list of all reliable altitude records of the land form.

In 1878, Gamble married Constance Brounger, daughter of WG Brounger, Engineer-in-Chief of the Cape Government Railways. They went on to have three daughters. Unfortunately, when the Cape economy entered a depression in 1886, Gamble's position was abolished. He had to return to England and did not see the outcome of most of his plans and suggestions. Gamble furthered his career in the public service by taking up a post as Chief Hydraulic Engineer in Ireland in 1887. Here he planned several early water supply schemes. In 1889, his life was cut short when he contracted typhoid fever. Gamble, considered the father of hydraulic engineering in South Africa, died on 7 November, 1889. He was 49 years old.

After Gamble left the Cape there was a gap of two years when Thomas Charles John Bain, seventh son of Andrew Geddes Bain, was appointed to the post of Geological and Irrigation Surveyor. In 1893, Bain's work was transferred to the Chief Inspector of Public Works where it remained until the establishment of the Cape Irrigation Department in 1904. During this time there was so little interest shown in the Irrigation Act that it was said to be 'almost inoperative', and so it was only in 1898 that the first Irrigation District was proclaimed.

OSTRICH – WORTH ITS WEIGHT IN GOLD

While cooperation irrigation settlement failed to take off in the nineteenth century something else did which forever changed the face of South African

Frances Magee

agriculture and lead directly to the construction of the first large dams in the country – the ostrich feather industry. Ostriches had long been revered in South African cultures such as the Zulu (for its feathers) and the San (for meat and eggs), but it was not until the arrival of European settlers that the trade in ostrich feathers became a commercial industry in South Africa.

It is thought that as early as the eighteenth century farmers caught ostrich chicks in the wild and reared them as pets. Swedish traveller Dr Anders Sparrman notes in 1775 that many of these flightless birds were moving around freely on Cape farms. However, before the domestication of ostriches between 1857 and 1864 the only way

Drinie van Rensburg

__Left:__ At one time ostrich feathers were South Africa's fourth-biggest export product.

__Right:__ Ostriches in the Prince Alfred district in 1911/12.

__Bottom right:__ Queen Marie Antionette of France's wardrobe is said to have sparked the fashion for ostrich feathers.

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to the birds' plumes was to kill them and pluck the carcasses, and thousands of ostriches were hunted down at the start of the ostrich feather boom. In fact, in many areas the species was almost totally eradicated prior to its eventual domestication. In South Africa, the destruction was checked to some extent by the passing of a special law for the preservation of wild ostriches in the Cape Colony in 1870.

Several farmers in the Karoo and Eastern Cape succeeded more or less simultaneously in breeding and rearing ostriches from the 1860s. The development of the incubator allowed the sector to grow in leaps and bounds, and soon everyone was keeping at least one ostrich in their back yard. This can clearly be seen in the increase in numbers of tamed birds and sale of ostrich feathers. The total weight of feathers exported from the Cape in 1865 was 17 522 pounds, which came mainly from wild birds, the 80 tame birds supplying only 120 pounds. Ten years later there were more than 32 000 tame ostriches in the colony. By 1895, this figure had grown to 253 000. This increase took place in spite of the severe drought in the country and a consequent unknown epidemic during 1889/1890 which killed thousands of birds. Even Natal with its altogether different climate produced ostrich feathers for export.

Effective selection and clever cross-breeding improved the


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Workers stacking lucerne in 1920. The introduction of this crop to South Africa was as a direct result of the growth of the ostrich feather industry.

quality of South African ostrich feathers until plumes from the tip of Africa became the most sought after in the world. By 1880, Cape feathers were sold at an average price of £5,8 per pound, chicks at £10 to £16, breeding pairs at £200 and exceptional birds at £1 000 each. More than 3 600 pounds of feathers were exported from the Cape in that year. Next to gold, diamonds and wool, ostrich feathers became the colony's largest export product. By 1920, there were 800 000 tame ostriches in South Africa.

In markets such as England and France ostrich feathers were considered especially exotic because of their African origin and size. One of the most expensive hat decorations, it also becme a status symbol.

Farming with ostriches became extremely popular not only because it was so profitable but because it was so much easier than other agricultural pursuits. It required comparatively little capital and less work and stock increased fast with the aid of artificial incubation. An average ostrich farm could also be managed well with few labourers. Ostrich feathers were also much easier to transport to market over bad roads. In his 1907 report, the Cape Director of Irrigation writes: "In a country where the cost of transport is often prohibitive, ostrich feathers form almost an ideal form of produce. Then again the prices realised are so remunerable that farmers are encouraged to develop their farms in a manner which, with any other kind of produce or stock raising would be impossible." Ostriches were difficult to herd and it became more efficient to enclose flocks in a paddock and provide them with fodder.

And so ostrich farming introduced a new crop to the country – lucerne. Introduced to the Cape in the 1870s by Oudtshoorn magistrate Mr Scholtz to feed his ostriches, it is this crop that greatly boosted irrigation and the development of dams in the country. By 1907, a lucerne farmer earned £9 to £20 per acre a year (based on sales of baled lucerne hay). If he did not bale it, but used it on his farm for feeding stock (not only ostriches), his profits were even greater. With such returns, farmers, especially in the Karoo and Eastern Cape, were encouraged to lay out capital on irrigation works and lay their hands on lucerne. Once established, it was a perennial crop, so that annual sowings were unnecessary. In fact, in regions such as Oudtshoorn, one planting could last for more than seven years. No wonder then that early farmers dubbed lucerne 'a miracle crop'. By 1920, South Africa produced more than 83 000 tons of lucerne a year.

The ostrich feather sector peaked in 1913, resulting in the export of a million pounds of plumes at £3-million. Then the First World War broke out and ships exchanged their loads of feathers for guns and soldiers. The market slumped then crashed completely. Farmers chased their flocks into the veld and turned back to conventional crops, now boosted by the development of irrigation infrastructure.

WATER SUPPLY TO CITIES AND TOWNS

Meanwhile, towns hitherto dependent on rivers and springs found themselves running out of water to support growing populations. The situation was exacerbated by the serious drought conditions of 1865/66, reportedly the worst in recorded history. While the State started assisting irrigation farmers (albeit at a slow pace), municipalities were pretty much left to their own devices, and had either to appoint a town engineer or pay for assistance from a consulting engineer to assist them with their water storage and supply infrastructure. Those who could afford neither, simply relied on their own innovations.

Low dams and weirs were constructed in rivers and around fountains and springs to augment town water supply, often consisting of nothing more than 'sods and stone'. These dams would


Lani van Vuuren

***Left**: Traditional leivore still provide water to many town gardens in the Western Cape.*

***Right**: The Fish River in flood outside Cradock in 1903. Large dams would later regulate many of these floods.*


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often prove so unsteady that they would wash away with every large flood, leaving the town without water for days or weeks at a time when repairs were made. Upon visiting many of these early structures, Gamble described them as 'resembling the construction of beavers'.

Originally, many of the towns were laid out with quite sizeable plots, and the main use of public waters was not drinking but rather irrigating produce, both for own use and for market. One might say these town erven were, in fact, mini farms, and it was not uncommon to find one's neighbour keeping cows and sheep (and later ostriches) on their parcel of town land. Many towns made use of a system of canals or *leivore* to distribute water to erven (some are still in use today to a limited extent). Water would be made available at certain times of the day or week and every plot owner would get their share. Metering took the form of a water bailiff, permanently employed by the municipality.

The old folks took their water supply very seriously, as perhaps we should today. Conflict over water was quite a regular affair, and cunning rather than fairness was often used to increase one's share of this scarce natural resource. Such a situation was uncovered by Gamble when he visited Oudtshoorn in 1877. At that time the town was dependent on water supply taken directly from the Grobbelaar's River, led in furrows and shared by about 300 erfholders. Each erfholder was entitled to 12 hours of water a week. "There is a great deal of fighting, those who have not time to look after the water-leading frequently give up what is an unequal contest with others who have time to watch the sluits, and see that they get their due share of water," Gamble wrote in a report to government.

The situation was made worse by the fact that the division was not done with sluice gates. Instead an opening was made in the furrow bank with a spade. Of course, the bigger the opening, the more water one would receive. If one wanted to prevent one's neighbour from receiving his share, one could simply drop a piece of sod in this opening.

In Beaufort West the terrified water bailiff, S Davids, requested a gun following an incident where he was stoned by six angry men after an argument about water allocation (this request was not granted by the town council). One also reads about how he was hauled out of church during the service one evening by an angry resident to inspect a garden that was allegedly receiving water 'when it was not supposed to' (Vivier & Vivier, 1969).

With advice and assistance from Gamble and other early engineers, towns increasingly started constructing larger, more stable dams from the 1880s. As the few examples below illustrate these early water infrastructure schemes were rarely properly planned, but rather constructed on a piecemeal basis, and always only when crisis proportions had already been reached.

CAPE TOWN

When the British took permanent control of the Cape in 1806, Cape Town was still dependent on the springs on the western slopes of Table Mountain as well as various wells scattered throughout the town. Getting water to one's house was a laborious affair and it was not uncommon for richer households to employ slaves whose sole task was fetching and carrying water. Despite the growing population, there were no water storage facilities in town. The public wells were later equipped with hurling swaai pumps. These pumps were operated by swaying the handle back and forth. One of these old pumps is still to be seen in Prince Street.

When the Cape Town Municipality was established in 1840 water supply became the town council's first priority. It started by buying up a number of private springs and water rights. However, this did little to alleviate water scarcity. By 1849, the municipality had to enforce severe water restrictions to reserve resources for fire-fighting, and public wells were closed at night.

An early depiction of the hurling swaai pump in Prince Street, which still exists to this day.

Iziko Museum/Africa Media Online

This affected especially the city's poor working class, who worked during the day, and could not afford to pay others to fetch water for them (collecting water paid up to 3 pence for two buckets). As a result, there was a rush to the pumps following office hours, with long rows of 20 to 30 buckets often leading to quarrels.

Only then did the municipality decide to construct water storage facilities. A storage reservoir (known as 'Number 1') with a storage capacity of 11 000 m³ was completed in 1852, followed shortly


Issy Simon

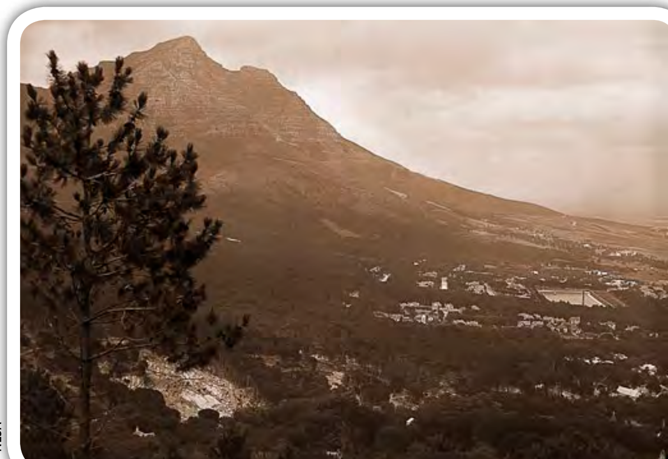
thereafter by the construction of a second reservoir (Number 2) with a capacity of 12 000 m^3 in 1856. In 1869, the town council constructed a filterbed in the gorge of Platteklip Stream. To save water, the town started watering the streets with sea water (an activity that was later discontinued).

Water scarcity persisted and by 1873 the average daily consumption was only about 6 ℓ per person a day for a population of around 30 000. The effect of the severe lack of water was described by *the Cape Times* in 1881: "The suffering from want of water is intense among the poorer class of people... when the pump handles are free so fierce is the competition for the use of them that weak folks have no chance in the struggle, and so are compelled to go away empty."

When Gamble arrived in 1875, he was tasked to seek solutions to Cape Town's water supply challenge. He set about placing rain gauges on Table Mountain. His subsequent report pressed for the construction of a tunnel through the Twelve Apostles Range in order to tap the large catchment area of the Backwater Stream, running into the sea at Hout Bay. The scheme also included the construction of a pipeline and a reservoir. The municipality rejected this proposal for being too expensive and instead opted for the construction of a reservoir to augment the springs on the property of a Mr Van Breda in the area now known as Oranjesig. Construction of Molteno Reservoir started in 1877. It was named after Sir John Molteno, the first Prime Minister of the Cape. This earth dam, with a capacity of 182 000 m^3 was completed in 1880. The reservoir was over 12 m deep and lined with stone pitching and concrete. The following year the reservoir ran dry and in 1882 when the drought was broken the reservoir wall gave way sending a torrent of water down the street. Luckily no lives were lost, although considerable damage was done to housing. The reservoir was not restored until four years later.

Above: *A view from the top of Table Mountain, where Cape Town's first dams were constructed.*

Below: *A panoramic view from the slopes of Lion's Head looking down on Molteno Reservoir & Oranjesig, 1910.*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Death at Molteno

Disaster struck the ill-fated Molteno Reservoir on 4 June, 1900, when celebrated aeronaut and hot-air balloonist, Prof Isodore Michaels, ascended from Good Hope Gardens in his hot air balloon.

The wind drove him towards the mountain. Michaels escaped via parachute and landed in the middle of Molteno Reservoir. Entangled in his parachute ropes, he consequently drowned. The reservoir had to be drained and cleaned, leading to another water shortage for the city.

Chapter 5

Thomas Stewart


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Hydraulic engineer Thomas Stewart is widely believed to have been the first consulting engineer in South Africa. Many of the dams and water supply schemes he designed all those decades ago are still in use today.

Stewart was born in Craigend, Pertshire, in Scotland, on 30 March 1857. When he was a mere 16 years old he became a pupil of DH Halkett. Three years later he was appointed as assistant engineer in the Glasgow Corporation Waterworks. It was only then that he thought to turn his practical experience into an engineering degree and he went on to study at the University of Glasgow, Anderson's College and the College of Science and Arts.

In 1881 he became an assistant in the office of Sir John Wolfe Barry. Barely a year later, 25-year-old Stewart decided to seek his fortune in the settlement at the Cape. He arrived on 28 December with fellow young Scottish engineer, James Rawbone. It is said that the two young immigrants were less than impressed by their first impression of Cape Town, which was windy, dusty and badly drained. They wanted nothing more than to climb on the first ship home. However, duty called as both of them had contracts to fulfil. Stewart took the post of assistant to Hydraulic Engineer to the Cape Colony, John G Gamble.

He reported for duty on 1 January, 1883, only to find that the programme of the day involved an official picnic on Table Mountain, attended by such well-known politicians as John X Merriman. It was here that he was first introduced to the potential sites for the water storage dams that he would later help design and build for the growing City of Cape Town.

He travelled with Gamble across the country to advise on water supply and irrigation works, among others assessing the potential of the Olifants River at Clanwilliam and the Vaal River at the Harts River Valley for irrigation (both of these schemes were implemented decades later). When the Cape Town municipality asked Gamble to investigate why its Molteno Reservoir had burst, Stewart was the one crawling through dark pipes searching for solutions. He also worked out water supply schemes for Barkly West, Cradock, Burgersdorp and Aliwal North.

In 1886 he resigned his government post, and after a brief spell in Scotland, returned to South Africa to set up his own practice in Cape Town. His office was situated at No 16 St George Chambers, Cape Town. Stewart was responsible for the design and construction of the five reservoirs on Table Mountain for Cape Town and Wynberg (still used by the City today) as well as for the Steenbras waterworks for Cape Town (as joint engineer), the Zuurbekom waterworks for Johannesburg and for water supply and sewage disposal works for many cities and towns in the Cape and Rhodesia (Zimbabwe), while in 1914 he prepared a scheme for the water supply of Beira (Mozambique).

The Cape government appointed Stewart as the engineering member of a commission for the Steynsburg irrigation scheme in 1896. The State later condemned the scheme, however, it is interesting to note that the tunnel of the Orange-Fish scheme constructed 70 years later emerges near Steynsberg. Other municipalities, including Rondebosch and Woodstock, contracted Stewart to find potential water sources for them, and after much surveying he identified the sites on the Wemmershoek and Steenbras rivers where dams were constructed years later.

He also served on the Geological Commission of the Cape of Good Hope, on which he served until its work was taken over by the government of the Union of South Africa after 1912. During the South African War (1899-1902) Stewart was attached to the Royal Engineers as a Major (without pay), and he was mainly engaged in the construction of defence works in Cape Town.

In 1932, on the fiftieth anniversary of his arrival in South Africa, leading local engineers (including FE Kanthack, George Stewart, Alfred Snape and Ninham Shand) presented him with an illuminated address to mark the occasion and to express their admiration for the achievements of the 'doyen of the profession in South Africa'.

Stewart married Scottish bride Mary Mackintosh Young in 1902. She bore him three sons, but sadly passed away on 3 October, 1921. A few years later, in 1928, Stewart married the widow of FR (Matabele) Thompson, the Rhodesian pioneer. He passed away at his home in Cape Town on 23 October, 1942 at the age of 85.


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Woodhead Dam on Table Mountain.

More than a decade later Gamble's idea finally came to fruition when City Engineer Thomas Cairncross designed the Woodhead Tunnel through the Twelve Apostles range. This was completed in 1891. The delay was largely due to the municipality selling the plans and the developments rights of the scheme to a private company, the Table Mountain Water Supply Company. Hindered by financial constraints, the company did not manage to construct the scheme themselves, and in the end sold the plans back to the municipality.

The 700 m-long tunnel takes the shortest route through the mountain, emerging in Slangolie Ravine. Part of the tunnel was arched in stonework, but most of it is raw rock. Initially, water from the Disa River was simply diverted into the tunnel and then piped to the Molteno Reservoir, but after a year or two it was plain that a dam would be necessary.

Still, it took many years to convince the town council that the expenditure was justified and it was only after many heated debates that the municipality gave the go ahead for a dam to be constructed atop Table Mountain. Young Scottish consulting engineer Thomas Stewart was appointed to design the structure and arrange for its construction.

Construction of Woodhead Reservoir on the Disa River started in 1893. The dam was named after Sir Thomas Woodhead, the Mayor of Cape Town (who received his knighthood in appreciation of his efforts to establish the dam). Initially, the short-sighted town council capped expenditure on the project at £50 000 – only enough for a 21 m high dam. A drought experienced at the start of 1894, however, seems to have changed their minds, because it was then decided to build a dam of 43 m high and 248 m long, affording storage for 0,9 million m^3. Thankfully Stewart designed the dam in such a way that it could be constructed higher than the original plans without too much extra effort.

Transporting men and materials to a building site on top of the mountain is no mean feat even with today's modern technology and equipment at hand. The site could only be accessed via a newly-constructed pipe track to Kasteelpoort gorge. While this route sufficed for personnel, small equipment and provisions, another solution had to be found for the transport of casks of cement (imported from England) and heavy equipment. The innovative Stewart responded by constructing an aerial cableway from Camps Bay to the summit of Kasteelpoort and laying tracks

__Top right__: Most of the work on the Woodhead Dam was done by stonemasons and quarrymen from Scotland.

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__Bottom right__: Workers transporting pipes to the site of the Woodhead Dam.

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Left: Labourers working on the Woodhead Dam wall. Note the primitive wooden scaffolding.

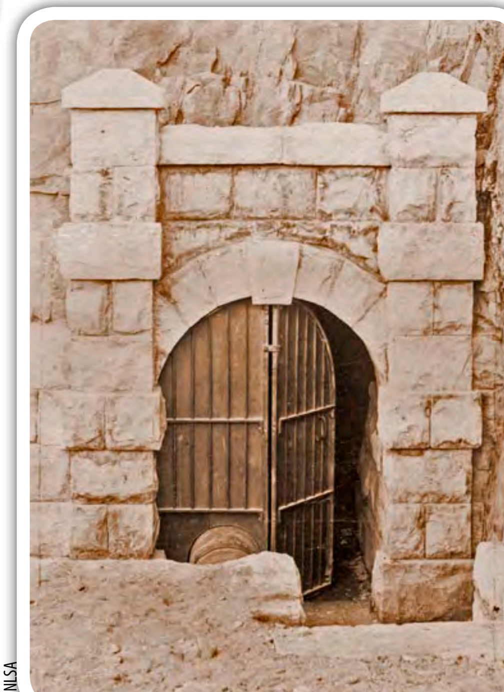
Below: The entrance to the Woodhead tunnel.

across the plateau to the construction site. The tiny wooden car, an open skip, could seat two people (or three barrels of cement) and took 20 minutes to reach the summit, climbing a vertical height of 700 m.

All machinery and fittings were imported from Scotland, dismantled at the base station, hauled up the mountain by the cableway and re-assembled on the summit. Mules were used to transport everything to site. The dam wall was to be of masonry-faced, concrete gravity design and skilled stonemasons and quarrymen were recruited from Scotland and housed in a small town built at the work site, which included a post office and a bank. At the height of construction more than 500 men worked on the dam wall. Sandstone for the dam was quarried from the buttress of the mountain above Camps Bay and a railway ran for about 2,6 km serving stone dumps and a block-making depot.

While construction on Woodhead Dam progressed, Cape Town also initiated a sewerage scheme which greatly pushed up the demand for water. And so no sooner had construction ended on the first dam on Table Mountain than construction had to start on the second, namely Hely-Hutchinson Dam. Named after Cape Governor Sir Walter Hely-Hutchinson, this dam acts as an extension to Woodhead Dam. This dam has a capacity of 0,927 million m^3. The dam also has a masonry wall, 528 m long, with a maximum depth of 16 m.

When the Hely-Hutchinson Dam was built, a small steam locomotive was procured to replace the mules. Constructed by Andrew Barclay, Sons and Co Ltd in Scotland 'Mountain Meg,' as the locomotive was dubbed, was dismantled when it reached Cape Town harbour. While lighter pieces of the locomotive were taken up via the cable system the remaining, heavier, pieces had to be hauled up the Kasteelpoort ravine using wooden sleds. Coal to drive the engine was imported from Wales. Progress of the dam was hampered by the outbreak of the South African War (the resultant influx of British troops seriously added to the water shortage) and it was only completed in 1904.



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Stewart also designed and oversaw construction of three other dams on Table Mountain. The Victoria Dam (completed in 1895) and the Alexandria Dam (1903) were built to supply water to the small independent Wynberg municipality. In 1903, the Mayor of Wynberg reported: "Consequent upon the works in connection with the strengthening and heightening of the lower dam on the mountain, only one storage reservoir was available during the past summer, and a certain amount of inconvenience was caused thereby; but happily this only extended to the water supply for gardening purposes. With the completion of the work on Table Mountain there need be no anxiety for a shortfall next season."

Left: *Sir Walter Hely-Hutchinson, after whom the Hely-Hutchinson Dam on Table Mountain was named.*

His words were scarcely cold when the municipality was faced with a situation where demand had outstripped supply. Construction of De Villiers Dam, below the other two reservoirs, started in 1907. To bring equipment to site, Stewart, who also designed this dam, first constructed an aerial cableway similar to the one used at the Woodhead and Hely-Hutchinson dam sites, but this proved unsatisfactory due to the nature of the ground. Instead he made use of a trolley track with a set of lines laid on sleepers. There were two trolleys, one going down with ballast as the other ascended. Originally, the power for the track was supplied by two horses walking round a drum at the top station. This was later replaced by machinery. De Villiers Dam was completed in 1910. The water from the Victoria, Alexandra and De Villiers dams ran down to Orange Kloof from where it was piped across Constantia Nek and so to Wynberg.

All of the new water supply infrastructure did not end Cape Town's water woes. The city would now look to other catchments to quench its insatiable thirst. Even before the completion of Hely-Hutchinson Dam, in 1902, the municipality requested of its specially elected Water Committee to investigate other possibilities of water supply. Among the schemes investigated were Franschhoek, Wemmershoek, Twenty-Four Rivers, the Steenbras and the Palmiet rivers (at all of these sites dams have since been constructed).

In 1904, John Parker, Chair of the Joint Water Committee, in his final report writes: "The rapid development and expansion not only of the city, but the neighbouring suburbs in the last decade has placed the need for an increased supply of water in the position of first importance, demanding immediate and serious consideration. An adequate water supply is the most important municipal question at present before the people of the Cape Peninsula; without exaggeration it is a matter of life or death to many of its inhabitants." (Parker, 1904).

Right: *Children with an ox-drawn water cart outside Port Elizabeth circa 1897.*

PORT ELIZABETH

The municipality of Port Elizabeth was promulgated in 1861. The town's origins lie in the arrival of 4 000 British settlers in 1820. At that time, the town basically comprised Fort Frederick (a stone fortress constructed by British forces in 1799), a mission station situated at Bethelsdorp and some small groups of Gonaqua people. Many of the British settlers had little to no farming experience and found they could not cope with the harsh conditions on the farms. As a result, many of them moved to towns to apply their skill as tradesmen and so the town of Port Elizabeth grew around them. The town was named in memory of the wife of Sir Rufane Donkin, who was acting Governor of the Cape Colony in the 1820s.

In the early years the townsfolk depended on water from rainwater tanks and from the many creeks and streams in the town area. In 1829, enterprising businessman, Fortuin Weys, built a pump to pipe water for sale to passing ships from a well on the western edge of Market Square. This well later also supplied the town and was supplemented by a stone tank constructed over the Baakens River as well as additional public wells. Most of these wells were lined with masonry and covered with strong oak, teak or yellowwood frames with trapdoors to avoid contamination. But spurred on by the upcoming wool, mohair and ostrich feather industries, Port Elizabeth continued to grow as an important commercial port, and by 1860 the town had to shut its public wells from 9 am to 4 pm owing to the scarcity of water.

The new town council decided to hold a competition, with a 100 guinneas prize, for the best proposal to augment Port Elizabeth's water supply. The competition was won by Clement Frames, and the Frames Dam was consequently constructed in the Shark's River. Completed in 1863 this was a masonry gravity dam, which supplied water to the town via a pipeline. The dam had a capacity of about 2 273 m^3. The Frames Dam did not serve all the residents of Port Elizabeth. Those living on the Hill still depended on well water from horsedrawn carts as well as residual water from rainwater tanks. In 1894, the dam wall was heightened to serve the growing needs of the town. However, water from the dam was condemned as unhealthy because it contained high concentrations of magnesium salts, which caused diarrhoea. Even ships refused to take on water from this dam.

Meanwhile, the town council made plans to implement an additional water scheme. Gamble

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***Above:** A view along Port Elizabeth's main street showing the obelisk in front of the town hall. On each corner is a water trough for horses and cattle.*

***Left:** An illustration showing a panoramic view of Port Elizabeth from the sea in 1873.*

South Africa's narrowest dam

South Africa's narrowest dam is known as Hell's Gate, situated near Uitenhage. It was constructed in a narrow gorge of the Klip River by farm owner Robert D Hough, in 1910.

Designed by hydraulic engineer William Ingham, the dam is 26 m high, and only 4 m wide. It has a capacity of 26 Mℓ. It is essentially described as a 'concrete plug' with packed stone upstream and downstream faces. The stone was dragged up the riverbed to the constructed site by oxen. The crest length is 4,9 m and it is 3 m thick on average, with a base thickness of 5,5 m.

In the 1920s plans were under consideration to raise the dam wall by 10 m, but these were never realised.

visited Port Elizabeth to advise the municipality on their water supply matters. He studied the proposal which came second in the municipality's competition all those years ago. Titled 'Oude van Staaden' the scheme was originally submitted by engineer and surveyor Robert Pinchin and comprised a weir in the Van Staden's River linked to town via a pipeline. Gamble found this to be economically viable. The town council subsequently made submissions to Parliament and, in 1877, the Port Elizabeth Water Act was passed allowing the town to proceed with the scheme.

Technical expertise was required to carry out the scheme, and Gamble sent to England for a suitable candidate. Twenty-six-year-old engineer John Hamilton Wicksteed arrived on the *Edinburgh Castle* which lay anchor at Algoa Bay on 29 December, 1877. Young Wicksteed was born in Leeds in 1851, the fifth son of Rev Charles Wicksteed. His uncle, Thomas Wicksteed, was a famous waterworks engineer. At the age of 14 he was sent to the University College School in London, and two years later he was articled to the engineer Edward Filliter, with whom he remained for ten years. During this time he was employed on various water supply and sewerage projects.

On arrival in Port Elizabeth Wicksteed immediately set to work on the necessary surveys for the pipe track. He drafted the specifications for the project contracts (seven in all) in consultation with Gamble, and construction of the scheme started early in 1878. The pipes for the project were imported from Europe. During transport from the ship to the beach many of the pipes cracked and the damaged pieces had to be removed by council workers with hammer and chisel.

The first water was delivered to the Market Square in September 1880. This was probably the first significant interbasin transfer scheme to be implemented in South Africa.

The most challenging part of the scheme, however, was undoubtedly the pipeline route. About a third of the pipes had to be brought down a steep incline on a narrow path. Various methods had to be adopted to get the pipes to their positions from using oxen to drag the pipes to manoeuvring them while tied to sledges. At one point it was suggested that the workers should be attached to the ropes by which they controlled the sledges, with the view of 'giving them a feeling of personal involvement in the fate of the pipes' (this idea did not sit well with the workers, however, and it was never put into practice). Despite the difficulties experienced, there were few casualties.

Young Wicksteed remained unfazed by it all. He is described as strict and meticulous, yet he had a way with people and applied his good humour to overcome many difficulties. Once, when plodding along in the rain and mud to set out the pipe route, he came across one of the European workers, who loudly announced his intention of going home as he found the work to be not 'fit to turn a dog to'. Wicksteed answered that the man was right, that men were wanted and not dogs and that if the worker did not feel himself as good a man as the rest, he had better go home. That day the man accomplished more than all the others labourers. The project was successfully completed and the first water delivered to the Market Square in September 1880. This was probably the first significant interbasin transfer scheme to be implemented in South Africa.

With the successful completion of this project Wicksteed could look forward to a long and successful career ahead of him. Unfortunately, this was not to be. In his last letter to his mother dated 11 August 1881, Wicksteed complained of feeling ill. He had resigned his appointment as Town Engineer due to 'overwork'. A few days after he wrote the letter, on 16 August, Wicksteed simply left the office one day and was never

***Right**: Construction of the Bulk River Dam showing the curve of the wall, in 1906.*

***Far right**: Workers at the bottom of the Bulk River Dam.*


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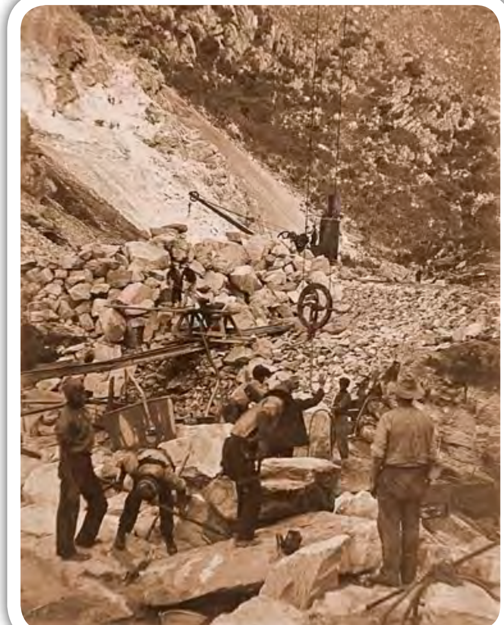
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seen alive again. A manhunt ensued and a search party found his body on 23 August close to the bush in Happy Valley. He had shot himself, the revolver still gripped in his right hand. It appears that Wicksteed suffered from depression. He was buried in the cemetery at St George's Park. Large masses of rock were brought down from the Van Staden's River gorge and laid on his grave.

A mere four years after the completion of the first weir on the Van Stadens River another water scheme had to be constructed to stem the growing water demand. This time Thomas Stewart was asked to oversee the project. This project involved the construction of a 15,2 m-high masonry-faced gravity dam, known as the Upper Van Stadens River Dam. This scheme was completed in 1893.

In March 1899, exploration started to establish a water supply scheme in the Sand, Palmiet and Bulk rivers. The outbreak of the South African War during that year prevented the scheme from developing further, but in 1903, hydraulic engineer William Ingham arrived from Britain to carry out the work. Excavation for the Sand River Dam started in January 1904, and the dam was completed in December, 1905. A monolithic concrete structure the dam had a total height of 20 m. The wall was 121,2 m long and 11,2 m wide. The valve control tower was incorporated into the structure to enhance the overall architectural effect.

Construction of the Bulk River Dam followed soon thereafter in 1906. The site selected for this dam was about 46 m upstream from a waterfall, 37 m high. The dam's foundations were carried down to a maximum depth of 4,3 m into the quartzite formation. During excavations, small springs were discovered and subsequently diverted to the downstream face. The 26 m-high Bulk River Dam was probably the first arch/gravity dam to be constructed in South Africa. It was

The Sand River Dam close to completion.

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completed in 1907. Both of these dams were raised in subsequent years and are still in operation today.

DURBAN

Europeans first settled in Port Natal following the arrival of the brig *Salisbury* in 1824. In June 1835, the resulting town was named D'urban after the Governor of the Cape, Sir Benjamin D'Urban. The settlers originally lived in dwellings made of wattle, drawing their water from streams, shallow wells in their backyards and off roofs in old wooden wine casks (the latter resulting in the water having an unpleasant spirit flavour).

In Durban, the problem was not so much the quantity of water as experienced in other parts of the country, but rather the quality of it. In 1855, CW Holden writes: "Africa has been described as a land of rivers without water, flowers without fragrance and birds without a song, but such a description does not apply to Natal... Of water [in Durban] there is abundance but often not of the best quality, except if it can be fetched from the uMgeni River, a mode of supply which is both troublesome and expensive." (Holden, 1855)

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A view of the Umgeni River in 1880.

Just a year earlier newly-arrived Rev John William Colenso described the water in Durban as the 'greater evil'. "The water is taken usually from wells that are not sunk deep enough and, consequently abounds with decaying vegetable, if not animal, matter, and innumerable animalcules and worms. The effect is by no means favourable to the health of the residents, more especially, that of the children, who have no refuge, I suppose, as their parents have, in stronger beverages...At present the remedy is to drink rain water, or the water from the Umgeni River...which is excellent." (Nichols, 1991).

Durban's first town council was established in 1854, and one of its first tasks was to establish a series of public wells. By 1877, there were 18 of these wells established, supplying about 214 kℓ a day to some 5 000 (European) people. Unfortunately, the drought experienced between 1878 and 1881 severely reduced the yields available from these groundwater sources. In 1879, the need for water became so acute that water was railed in special tanks from the uMgeni River about 6 km away. A special siding for this purpose was laid down in Pine Street, and the water sold to town residents for one penny a bucketful. Serious investigations into the possibility of surface water supply via dams started at this time.

Meanwhile boring operations by Councillor HW Currie at the foot of the Botanic Gardens resulted in the establishment of Currie's Fountain. This artesian well was the principal source of water to Durban until 1886. It allowed the town council to, for the first time, pipe water to hydrants in West Street and provide a few private water connections.

In 1882, Durban appointed town engineer JFE Barnes. He established some more wells, and in 1883 reported on three possible water schemes in the uMbilo, uMhlatuzana and uMlaas Rivers, each capable of delivering 0,9 Mℓ a day to the citizens of Durban. All of the schemes depended on weirs and essentially 'run-of-river' supplies. The town council selected the Umbilo project and Barnes was instructed to proceed with the necessary surveys and preparation of documents to allow the scheme to go ahead. The Durban Corporation Waterworks Law was passed in 1884. This allowed the town council to construct waterworks, acquire lands in connection therewith, levy a water rate not exceeding one halfpenny on immovable property, and frame bylaws in connection with water supply.

The municipality also managed to secure a loan of £50 000 from quite an unusual source. The town council received a letter on 18 September 1885 from one Mr Harry Escombe. In this letter he stated that he had to find investments for a considerable sum of money and could offer Durban £15 000 that year, £10 000 the following year, and £10 000 the year thereafter at an interest rate of 5%. The municipality promptly accepted and the project went ahead. Local firm Messrs Smith and Shepherd was contracted to undertake the earthworks.

The site chosen for the Umbilo headwords lies in the present Paradise Valley Nature Reserve in Pinetown, some 14,5 km from Durban. The dam wall was a conventional well-compacted earth embankment, about 91 m long at the crest and some 14 m high. The fill comprised weathered sandstone consolidated in about 300 mm-thick layers with a red clay core. A side channel spillway (or by-wash) 20 m wide and 3 m deep was constructed on the southern bank and rejoined the river after 250 m at a point below the waterworks, but immediately above the Umbilo Falls. The dam conserved 169 000 m^3 of water when full. Water was drawn off by means of a control tower constructed of dressed stone positioned in the upper embankment slope with access provided from the top of the dam wall by a single span lattice girder bridge.

The scheme was officially opened by Durban Mayoress WE Robarts on 21 July 1887. With the completion of this scheme the municipality thought its water woes were at an end, but it did not factor in the effect a steady water supply would have on the residents of Durban. With water now regularly piped directly to their homes rather than having to be carried by the bucketful, town inhabitants started using more water. Per capita consumption increased exponentially from around 90 ℓ per person a day (for all purposes) prior to the construction of the scheme to 290 ℓ per person a day. This huge increase was blamed largely on the introduction of in-door baths

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A public well in Berea, Durban, 1880.

and the town's first sewerage system. The Umbilo waterworks was taxed to the utmost, made worse when drought struck again a few years later.

In 1889, the town council decided to construct a temporary relief scheme on the Umlaas River. This scheme was completed in 1890, followed shortly thereafter by the Umlaas gravitation scheme in 1894. The outbreak of the South African War in 1899 led to a huge influx of people into Durban, and by 1900 town water consumption had grown to about 8 million litres per day. This forced the town to give permission to build a temporary dam at Camperdown in 1900. The concrete and earthen embankment was completed in only five months. The wall was 128 m wide and 12 m high. The dam proved its value during the summer of 1902 and 1903 when Durban again experienced drought.

Disaster struck in June 1905 when 450 mm of rain was recorded in 24 hours on 1 June in the Upper Umbilo catchment. The waterway opening of the railway bridge, situated 2,4 km above the Umbilo Dam wall became partially blocked with debris. One span of the bridge collapsed, and a wall of water rushed down the river. The storm surge could not be attenuated and swept over the dam wall, causing a breach 30 m wide and 2 m deep. Within 13 hours the wall was gone, along with the settling dam. The dam was never rebuilt and the scheme was closed.

It was rather decided to turn the Camperdown temporary dam into a permanent structure. Construction started in 1906 and in 1908 the retaining wall was laid. The resulting body of water was the largest in Natal. The lake was 3 km long, and 700 m at some points. Unfortunately the dam had completely silted up by 1926 and in 1943 it was destroyed by a flood.

GRAAFF-REINET

The fourth-oldest western settlement in South Africa, Graaff-Reinet was established by the Dutch occupiers of the Cape in 1786. As was common with many colonial settlements at that time, the site, on a loan farm belonging to Dirk Coetsee, was selected mainly for its defensive potential, being surrounded by the Sundays River on three sides. The town was named after Governor Cornelis Jacob van de Graaff and his wife Cornelia Reynet.

Despite its proximity to the river, the problem of water supply remained a dominating theme in the life of Graaff-Reinet for centuries. In 1797, John Barrow found the appearance of the town 'as miserable as that of the poorest village in England'. In the decades after Barrow's visit circumstances got a little better. As Graaff-Reinet grew into a bustling trading centre a temporary dam of driftsand and brushwood was constructed in the Sundays River. From this dam a furrow was led to the outskirts of town, where it was channelled into a number of canals for distribution to the gardens of the town's inhabitants. As noted before these erfholders used the water to grow produce, particularly vines.

In 1820, another dam and furrow, which became known as the upper dam and furrow, were constructed. The original works then became the lower dam and furrow. The making of a dam higher up in the river would reduce the flow of water into the lower dam so to compensate lower furrow users, a proportion of the water of the upper furrow was turned over the district mill located at the top end of town and into the lower furrow. However, the volume of water from the upper furrow that should be turned over the mill was a contentious issue and conflict over water between upper and lower sections of the town continued for decades.

The very system by which Graaff-Reinet was supplied with water also became an increasing source of dissatisfaction to the people in town. The two temporary dams in the Sundays River were washed away every time the river came down in flood, and both furrows became choked with mud. This meant that there was no water going into town until the dams were reconstructed and the furrows cleaned. This could take between a few days to a few weeks.

For those inhabitants who did not have wells or rainwater tanks on their properties, this was quite a concern. They had to rely on so-called *branddams* or fire-dams for their drinking water. These dams were formed simply by a widening of the furrows into squares of 3 m to 4 m and served, to a certain extent, as drains. According to *the Herald* newspaper when these dams were cleaned "the accumulated filth which is exposed and thrown out was sufficient to turn the stomach of even a municipal commissioner" (Smith, 1976).

Decades of financial difficulty prevented the municipality from improving the situation until 1873 when the municipal board decided

Graaff-Reinet Museum

The Graaff-Reinet Municipal Board at the new town water scheme in 1884.

to test the water from a groundwater source known as Mackie's Pit. Unfortunately tests revealed that the underground water was connected with the Sundays River. This meant that the municipal board could not use this water without consent of the erfholders, who were entitled to all the water in the river above the two dams.

During November and December 1874, heavy rains not only washed away the dams, but almost completely destroyed the lower furrow. The damage was considered to be permanent. Graaff-Reinet applied to Parliament for a loan of £12 000 to improve its water supply and, in December 1875, Gamble met with the municipal board to investigate possible schemes.

After many investigations and much discussion a plan was construed to sink two wells at Mackie's Pit and construct a concrete culvert to carry the water by gravitation to the mill; here the water would be divided between the upper and lower furrows. The fall from the upper to the lower furrow would be used to drive a turbine to pump 227 kℓ of water a day to a service reservoir. Water from this reservoir would be used for household purposes as well as in the case of fires.

At a town council meeting in 1881, it was decided to carry out only part of Gamble's scheme – that wells be sunk at Mackie's Pit and a furrow constructed to the upper furrow. The works were completed in November 1882. A decision was then made to continue the works a little further so that they would be secure against a flooding of the river (however, the in-fighting became so bad that these plans were never completed).

By 1908, people were thinking in terms of a weir across the Sundays River and it was in this direction that further attempts were made to improve the water supply of Graaff-Reinet, which culminated in the Nqweba Dam in 1924 (described elsewhere). The wells of Mackie's Pit were subsequently covered by the dam.

BEAUFORT WEST

When Lord Charles Somerset, then Governor at the Cape, wanted a site for a new town and magisterial seat he settled on the farm *Hooyvlakte*, and the district of Beaufort was proclaimed in 1818, named after Somerset's nobel family in England. It comprised the eastern portion of the Tulbagh district and the western portion of

The town of Beaufort West as it looked in 1901 with the dam in the background.


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Graaff-Reinet district. (The town was later named Beaufort West to distinguish it from Port Beaufort and Fort Beaufort).

There were many strong fountains on the farm selected and the owner, Abraham de Clercq, had already built a dam and a series of furrows. It is suspected that this could have been one of the main reasons why this particular site was selected. The new settlement started with 43 erven, with De Clercq being one of the first home owners. The original farm house became the first drostdy and later a prison. Just like in Graaff-Reinet water was led directly from the source into a series of furrows to irrigate town properties. For drinking purposes the inhabitants dug their own wells. These wells made use of a *wip* (literally 'whip') lever – a long pole that leaned horizontally over a prop or forked crutch. The pole was used as a lever to pull the full bucket from the well.

By 1839, this method of water supply was no longer sufficient and local surveyor CL Stretch was approached to come up with plans for the construction of a dam that would suit the town council's pocket. At that time there were 53 erven. Stretch could not come up with anything suitable and so the situation remained precarious until a small dam was constructed in a wetland next to the Kuils River in 1851. This supply was strengthened in 1859 with an additional furrow from the Gamka fountain. This furrow was extremely deep (up to 1,8 m in places), and when a Mrs Bees

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The outflow from the Beaufort West Dam. Swimming near the dam wall was prohibited so as to protect the reputation of 'respectable ladies'.

fell in and died in 1866, it was decided to cover the furrow with masonry stonework.

The town took its water supply very seriously. Anyone seen dumping waste or washing their hands (or anything else) in the furrows were seriously reprimanded. In 1874 washing laundry in the two rivers feeding the furrows was prohibited. Since inhabitants had no other place to do their washing concrete basins were erected in two rows on the banks of the river. This not only prevented pollution of the rivers but provided an additional income for the municipality. The basins were numbered from 1 to 51 and tickets were sold to the public for using a specific basin on a specific day. (This system remained in place until 1937 when a laundry was created in the old power station).

The idea for a larger dam was first suggested by Avon Bruce-Brand, a former bodyguard to the Queen of England who had settled in Beaufort West. He recommended the construction of a dam in the Soutrivierpoort, about 48 km northeast of town. But it was only two years after Bruce-Brand's recommendations that the town council pondered the construction of a permanent water storage dam. The necessary loans were requested from Parliament and approved in 1866, and the local magistrate was given instructions to provide as many convicts as possible for labour purposes. The convicts were housed in an old hospital building just north of the erstwhile *Hooyvlakte* farmhouse, belonging to JC Molteno.

The Springfontein Dam was constructed on Kuils River, on the side of a hill at the upper side of town. It had capacity of 2,6 million m^3 and the wall was 12 m high. The work was overseen by Municipal Commissioner DG Villiers and the dam was practically completed by 1868. In 1869, on recommendations from Bruce-Brand, the dam wall was strengthened and the outlet widened and deepened. Despite the increase in water supply many inhabitants of Beaufort West were unhappy with the proximity of the dam to the town. On 23 March 1869, the town council received a letter signed by 23 town's folk warning of a possible breach should heavy rains cause the river to flood. This letter led to a special town council meeting on 14 April and it was decided to widen and deepen the southern outlet as well. This work was completed on 6 July.

Despite all these precautions disaster came to Beaufort West in 1869. On 23 October of that year after severe rains and flooding upstream of the river catchment, three breaches appeared in the dam wall. Two of these breaches could be mended in time, but the third proved unstoppable. One brave man, Roelof JJ Eybers, was lowered down the dam wall with a bag of sand and did his utmost to close the hole in the wall. He was washed away bag and all, but luckily survived his ordeal.

By 12:00 there was 7,6 m of water in the dam, the water kept rising and the breach kept getting larger. At around 13:00, while the horrified townsfolk watched helplessly from a safe distance 76 m of the wall gave way and 2,6 million m^3 of muddy water at once rushed through the town. Streets turned into rivers and countless buildings were washed away or severely damaged. Thankfully no lives were lost, probably because the flood occurred during the day. The deluge lasted for two and a half hours until the dam was empty. It was later discovered that the dam


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suffered from some severe engineering faults. The town council, who had been forewarned about the disaster, was severely criticised, and several town council members resigned in shame.

Four years later the dam was rebuilt, this time under the direction of Bruce-Brand. Convict labour was again used and the new dam was completed in 1880. When Bruce-Brand, who was now a Municipal Commissioner, complained about men swimming in the dam, which prevented 'respectable ladies' from walking on the wall, swimming was prohibited within 400 paces.

By the end of the century the dam was facing a new crisis – it was not flooding but sedimentation that now threatened the water supply of Beaufort West. Four scotch carts were used in October 1902 to reduce the sediment, but this effort was abandoned after a week or two for being too expensive. In this time an average of 134 loads a day of sediment was carted away.

After much deliberation it was decided to raise the dam wall in 1913. During heavy flooding in 1918 town inhabitants had to flee for their lives again as the dam wall threatened to burst. While it remained intact this time the town council pleaded for government assistance to safeguard the dam against future flooding. The Irrigation Department sent engineer Patterson and the two damaged outlets were repaired. This work was completed in 1919.

Siltation has since reduced the dam's capacity significantly, and now when the dam fills it is scarcely 3 m deep. Today, it only plays a role in the social life of the town, and it is said to be a bird watcher's paradise.

Above: *Beaufort West Dam in 1955.*

Right: *An aerial view of Bongolo Dam, which was originally completed in 1908.*

QUEENSTOWN

Unlike the other towns mentioned Queenstown did not have its foundation in farming. Rather it was established in 1853 as a frontier town on the banks of the Komani River, one of a line of such towns founded in the Eastern Cape to protect European settlers from skirmishes with the


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Xhosa people. By March that year, the first 50 erven were sold, and by the time the Eighth Frontier War ended, the town comprised 154 erven. Queenstown was granted municipal status in 1855.

The newly-elected Board's first task was to secure the inhabitants' water supply and a series of weirs and furrows were constructed to bring water from the Komani River. This water was mainly for irrigating the erven. Drinking water had to be stored in tanks fed from roofs, or drawn from wells. Those who had neither bought their water from the 'water boys' – men who went about with poles thrown across their shoulders from which two buckets hang.

In 1862, owing to the severe drought, the town council sunk four boreholes to relieve water shortages. Twenty years later a 350 000 m^3 earthfill dam was constructed to the north of town. It was named Berry Reservoir after the Mayor, Dr Bisset Berry. In addition to furrows, pipelines were now laid to supply the local hospital, shops and houses.

Unfortunately, supply remained erratic in times of drought and it soon became clear that the storage capacity of Berry Reservoir was wholly inadequate to meet the growing demands of the town. Although the town population numbered only 1 200 (Europeans), the municipality decided to construct a grand water storage scheme with a large dam in the Bongolo Poort as its centre. This was quite a bold move for a small municipality.

The town council engaged the services of young engineer JTB Gellatly, who proceeded to set up an office and design the whole project, prepare plans, estimates and reports. The first preliminary reports were completed in February 1903, and a year later the Queenstown municipality placed the scheme before Parliament in search of the required funding. The estimated cost of the engineering work was £70 000. Parliament duly approved the project, and the funds, in 1905.

While the dam filled quickly, its continued large storage capability was threatened by siltation due to erosion in the catchment.

Rather than contracting out the work the Queenstown municipality decided that it would do the work itself, with Gellatly acting as Resident Engineer. He duly proceeded to East London, Cape Town and Johannesburg to obtain the necessary equipment, many of it second hand. This included a stone breaker, concrete mixer, cableway, tip trucks, platform wagons and concrete trucks. The original dam wall was a 23 m high, all concrete arch/gravity structure. Bongolo was one of the earliest dams where formwork was used to form the faces of the dam instead of the traditional stone masonry facings of the time.

The wall of the Bongolo Dam was completed on 9 December, 1908. A big crowd attended the official opening with entertainment provided by the Queenstown Rifle Volunteer band. Contained in Gellatly's final report is the first and only reference to what appears to be his renumeration for this grand project. He writes: "...added to the price, together with my salary of £3 240" (Crawford and Dachs, 1980). This appears to have been his total salary over the four-year construction period.

While the dam filled quickly its continued large storage capability was threatened by siltation due to erosion in the catchment. Doomsayers criticised the Bongolo scheme, saying it was money wasted as the dam would soon silt up. Gellatly was proud and confident, and he acted strongly against this criticism. In 1910, having since moved to Cala, he writes to the Town Clerk: "in this connection I was informed, solemnly, by a stranger travelling with me some weeks ago that the Bongolo Dam had silted up some 30 feet. He was a smaller man than myself so I simply said 'liar'." Despite Gellatly's vehement denial in this respect, siltation did occur to some extent, and the town council took steps to combat this by attempting to address erosion problems in the area.

In 1917, a flood occurred which reached a height of 1,3 m over the wall. A few years later, in 1924, consulting engineers submitted a report to the town council recommending that the dam wall be raised by 1,2 m. This work was, however, only undertaken in 1934. In addition to being raised, the dam was provided with three siphon spillways. This system of 18 siphons was the first of its kind in South Africa. Interestingly, the siphons all operated at the same time only in 1976 when continued heavy rain caused the dam to overflow.

WAR AND RECONSTRUCTION

One of the worst armed conflicts ever experienced by the country broke out in South Africa in 1899. In that year Great Britain provoked the Zuid-Afrikaansche Republiek (ZAR), led by Paul Kruger and supported by the Orange Free State into war. Many reasons are given for the conflict, but fundamentally the British coveted the goldfields on the Witwatersrand and wished to expand the Empire at the tip of Africa through the inclusion of the two Boer republics. What Imperial authorities thought would be a 'quick' and 'easy' campaign, turned out to be a difficult and dirty affair, which lasted until 1902. The war left behind a trail of destruction which was felt in the country for decades afterwards. Particularly devastating was the Scorched Earth campaign resorted to by British authorities in the last months of the war. In order to cut off the Boer guerrillas from supplies farm houses and crops were burnt throughout the countryside, farm animals destroyed and women, children and servants rounded up and placed in concentration camps.

We will not go into details of the South African War here, except to say that it cost the lives of about 30 000 troops on both sides. The number of armed black participants who perished remains unknown, but at least 20 000 black people died in concentration camps, mainly from

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***Top**: A Boer concentration camp at Irene, Transvaal.*

***Above**: British soldiers set fire to a Boer farm house in the Free State.*

***Left**: British soldiers doing laundry at a Pretoria railway camp during the South African War.*

The Boer Dam at Ladysmith

Not all dams constructed in South Africa had benign applications. During the South African War the town of Ladysmith made headline news when it was besieged by Boer forces from November 1899 to February 1900. The town was severely damaged before it was relieved after 119 days by British reinforcements under General Buller.

In mid-January 1900, the Boer forces started constructing a wall of sandbags across the Klip River with the aid of 1 200 black workers. It was hoped that the dammed water would flood the plain in which Ladysmith was situated and so force the British garrison to capitulate. The project ran out of time and the dam was never completed.

Ladysmith Siege Museum/Africa Media Online

Sir Alfred Milner

epidemic diseases. Some 28 000 Boers died in concentration camps, largely from measles, dysentery and pneumonia. Almost all of the victims were women and young children.

Following the war the resettlement of thousands of displaced people and reconstruction of the economy of the now unified country proved an enormous task for British High Commissioner Sir Alfred Milner. One of the most significant challenges was returning home the estimated 31 000 Boer prisoners of war, along with 116 000 white and 115 000 black inmates of concentration camps.

British authorities were convinced that agricultural development held the key to lifting the country from the ashes and so, even before the war ended they called on British engineer William Willcocks to investigate possible areas for irrigation in the Cape Colony, the Free State and the Transvaal. Born in 1852 in India at the side of an irrigation canal, some say Willcocks was destined to be involved in the field of irrigation engineering. Before he came to South Africa he worked extensively on irrigation projects in India and Egypt, and later became known for planning and constructing the first Aswan Dam on the Nile.

After travelling across the country Willcocks presented his report to the British government in 1901. It is clear that he was not at all impressed with the state of progress thus far. "Except in the extreme south-western corner of the Cape Colony, agriculture has scarcely been attempted, except on the most primitive lines, and in the most insignificant areas," he writes. "Farmers today trek from the high veld to the low veld and back again with the seasons, just as the wandering Arabs of the desert have done for centuries."

The only solution, according to Willcocks was for the State to become more involved in irrigation, and especially in the construction of large dams to store sufficient water. "The permanent development of agriculture in South Africa will depend on irrigation and on irrigation alone." He also thought the construction of irrigation infrastructure could be a good way of providing work to 'poor whites', a concept which had been raised since the late nineteenth century. These white labourers, he believed, could then be settled on the land with occupancy rights.

WHITE RIVER

Milner took Willcocks' words to heart and soon after his report sought to settle an irrigation community in the White River valley. It was thought that the area could be developed principally for citrus and the government availed £60 000 for irrigation infrastructure for what was to become known as the Milner Settlement. In 1903, a canal of about 28 km was constructed to supply water from the White River via a weir, and land on both sides of the river was divided into farms. Along with farming infrastructure a small town was established complete with police station, school and a house for the scheme manager.

The task of scheme manager and guidance councillor was taken on by Tom Lawrence, a farmer from Hilltop, 12 km outside Nelspruit. The Settlers Bridge was constructed over the White River to provide access to farms across town while an access road was provided to Nelspruit. A brochure advertised the farms. Most of the prospective farmers were former British soldiers. They were provided with wood and tin houses, wagons, oxen, ploughs and other farming implements. Since the new settlers would not be able to generate an income from the land immediately they would be paid a weekly allowance of £86s 8d in the interim.

The White River Farmers Association was established in March 1905 with 21 members. They farmed with tobacco, maize and vegetables and market was held in town on Saturdays. After two years the government was of the view that the settlers could now well take care of themselves, and the allowance was ceased. But the settlers had grown use to this 'money for nothing' and most had not really done much to expand their production. When the lease contracts for the land had to be renewed in 1909, many of the settlers had already left the White River settlement. By 1911, there was only one farmer left, Mac MacDonald, who had established a citrus orchard, which became known as Mac's Grove.

During 1909, a number of farmers, under leadership of FT Glynn, the founder of Sabie town, formed a syndicate known as White River Estates. In 1914, Government sold the Milner settlement, including the water infrastructure and the town to this syndicate under condition that 60 000 citrus trees be planted. Much of their work was disrupted by the outbreak of the First World War, but in 1916 the syndicate was registered as a private company with Glynn as its first chairman. The company went on to expand the original irrigation infrastructure, and after the war the plots were sold to returning soldiers.

THE FIRST IRRIGATION DEPARTMENTS

Further to Willcocks' recommendations 1904 saw the forerunners of today's Department of Water Affairs being established in the Cape and Transvaal. The first engineers to serve in these departments of irrigation were all recruited from abroad, many of them sent to South Africa 'on loan' from the Indian Irrigation Service. This included the first Directors of Irrigation WL Strange (Transvaal) and WB Gordon (Cape). Despite their vast knowledge of dams and irrigation works many of these engineers were disillusioned about the conditions they found in South Africa. No two districts were alike in their conditions and the enormous irrigation schemes that had been constructed in countries such as India, Egypt and the USA found no place in the Union.

The Transvaal Irrigation Department chose not to pursue small, 'piece-meal' irrigation works, but rather to gather extensive information about the rivers under its command. Up to that time no significant irrigation works has been undertaken in the Transvaal, mainly as a result of the sparse population density and the lack of legislation to encourage cooperative irrigation as existed in the Cape. Huge surveys were undertaken, among others along the Vaal and Olifants rivers, and an Irrigation Act was passed in 1908. Most of the early survey work was undertaken by Frederick Arthur Hurley who would go on to succeed Strange as Director of Irrigation in the Transvaal department. Hurley, who was recruited from the Egyptian Irrigation Service, identified many of the sites where some of South Africa's largest and most important dams would later be constructed, including the Vaal, Loskop, Middelburg and Bloemhof dams.

To appreciate the expanse of Hurley's undertakings one needs only take the example of the Olifants River survey. Between September 1905 and February 1906 Hurley, the surveyors GP Scott and CN Cook (along with their servants) covered more than 31 000 km^2 with nothing more than a mule wagon and their own feet. To make matters worse one night, when the party was camped on a hill outside Middelburg, lightning struck, killing one of the servants and five mules. These early engineers certainly had pioneering spirits. When the Union Department of Irrigation was established in 1912 Hurley became Deputy Director of Irrigation. Unfortunately the sector only had two more years of his good service. On 30 November 1914, Hurley died when his car crashed while he was one his way to inspect the Klipdrift irrigation works near Potchefstroom.

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The Vaal River in 1905.

Gordon arrived in South Africa on 23 October, 1903, and shortly after arriving embarked on an extensive tour with Commissioner Arthur Douglass to investigate the prevailing agricultural conditions of the Cape. The tour lasted until 8 December, and during this time he visited various districts, including the Harts River valley, Springfield (near Uitenhage), Sundays River irrigation settlement, the Gamtoos valley, Fish River valley, Beer vlei (Willowmore), Schoeman's Poort (Oudtshoorn) and Booysen's Poort (Graaff-Reinet). At this stage there were only three government irrigation settlements at the Cape, at Douglas, Vanwyksvlei and Nelskop (near Brandvlei).

Under Gordon's direction, the Cape Irrigation Department began detailed surveys of water resources, including underground

Smartt Syndicate Dam


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Thomas Smartt was an Irish-born medical practitioner, who established himself at Britstown, in the Northern Cape, where he could tend passing traffic on route to Kimberley (he later became a Member of Parliament). He fell in love with the stark beauty of the Karoo, and purchased his first farm in 1884. A decade later he formed the Smartt Syndicate, amassing holdings of about 100 000 ha. The syndicate was one of the first private enterprises to attempt large-scale irrigation in the area, mainly producing fodder crops for stud merino sheep and ostriches.

With the assistance of the newly-established Cape Irrigation Department, Smartt first constructed an earthen dam in the Ongers River valley. Up to 324 ha of land was irrigated from this dam annually. When the Great Houwater Dam, as it was called, washed away during floods in 1907 Smartt initiated construction of a new dam, this time with a concrete core. The project was again designed by the Cape Department of Irrigation, but it was overseen by William Ingham. The dam and associated canals was completed in 1912. It was initially constructed to a height of 16 m and was probably the largest private project undertaken in the Cape at that time. It was also the first dam in South Africa with an Ambursen-type spillway. The full capacity of the reservoir was 113 million m^3.

Siltation severely reduced the capacity of the dam, and it was consequently raised several times, reaching a height of 28 m in 1954. By this time the dam had a crest length of 2 082 m and a total volume of 387 000 m^3. After several decades of operation the harsh climate of the Karoo proved the better of the Smartt Syndicate, and it was liquidated in that year. The irrigable land under the dam was offered for sale to the public and was disposed of based on an undertaking that a statutory body would be established to administer the dam and the distribution of water. An irrigation district was established, and the ownership of the dam and canal infrastructure was transferred to the newly-elected Smartt Irrigation Board in 1961.

The new farmers were hardly settled in when heavy rains lashed the Northern Cape causing the Ongers River to come down in heavy flood in March 1961. As a result of weaknesses in the foundations, which rested on shale, the central spillway of the three concrete spillways washed away. On 28 March, the main earth embankment collapsed because of seepage near the crest. Thankfully the breaching of the dam did not cause much damage as the land below the dam was already under water. The dam was subsequently repaired by the Department of Water Affairs at a cost of R553 000.


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Above: Children stand on the wall of the old Houwater Dam ca1938.


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Left: The original sluices of the Smartt Syndicate Dam.


DWA/eWISA

The Smartt Syndicate Dam was severely damaged during floods in 1961.

water. Among the areas surveyed were the lower Orange River, and the Harts River valley, where significant schemes would be established decades later. The department also moved on legislation, with the Cape Irrigation Act being passed in 1906. This gave greater impetus to irrigation activities in the Cape not only to flood and diversion schemes, but to future storage prospects. It also established dedicated water courts that would adjudicate disputes. An administrative and executive body, rather than a judicial court, the water court could hear applications for a share of water and even decide on the construction of new works.

Under the 1906 Act, the Cape Department of Irrigation provided engineering assistance to farmers for the preparation of surveys, plans and estimates for irrigation works. The department's handful of engineering staff were overwhelmed by requests for assistance, and spent months on the road travelling from farm to farm dishing out advice. The tariff was fixed at £1 for every day spent undertaking the survey and excluded the time the engineer spent travelling to and from his headquarters. In matters regarding State irrigation policy and laws as well as general advice was provided to farmers free of charge. Commenting on this service, Gordon writes: "Under present conditions, it is the aim of the department to push irrigation as much as possible, and to do this close personal contact with the farmers is essential." By the end of 1906, 21 applications for loans for the construction of irrigation works had been referred to the Irrigation Department. In 1907, a year after the promulgation of the 1906 Act, dams storing a total of 138 million m^3 of water had been or was in the process of being constructed.

Gordon lamented the complete lack of engineering skill in South Africa (a challenge that remains to this day). To lead the department's divisions (called Circles) based in Cradock, Kimberley and Worcester, he required engineers with 'sufficient experience in irrigation engineering'. Gordon could not find these men (for they were all men) in South Africa. "It is hoped, however, that by effecting reasonably paid appointments for period of from three to five years, the right class of men will be attracted to this country," he writes in 1907. It was Gordon's wish that these engineers would eventually disseminate their knowledge to locally trained men.

One such a man was certainly found, and 1906 will forever be remembered as the year that Francis Edgar Kanthack arrived in South Africa. This formidable engineer would go on to become the head of the first Union Irrigation Department in 1912 and he would personally design many of the large dams still in use today, including Hartbeespoort, Kamanassie, Nqweba, Darlington, Bon Accord, and Clanwilliam dams. Kanthack understood the importance of growing local knowledge about water storage and irrigation matters and spent his life learning and teaching others on the subject. "In South Africa [the engineer] must learn that his works are merely aids to agricultural development," he wrote in 1907. "the agricultural requirements are paramount, and the irrigation works must be made to suite them and not vice versa...The vast experience gained in other great irrigation countries is of extreme importance to us, it should only form a foundation for development that is particularly suited to local conditions."

When the Union of South Africa was established in 1910 plans were made to amalgamate the two irrigation departments. On the eve of the establishment of the national Department of Irrigation there were nearly 24 000 dams (of all sizes) recorded in South Africa. ◈

Koppies irrigation settlement

One of the earliest irrigation settlements in the Free State was the one situated at Koppies, in the Vredefort district. Immediately following the South African War irrigation (and water storage) matters in the province were dealt with by the Orange Free State Department of Public Works. The preliminaries of this government scheme became to shape in about 1908. Work on the Koppies Dam on the Renoster River (a tributary of the Vaal) started in 1909, and it was carried out entirely by white labour. The dam had an original net capacity of 96 m^3. It was built as a composite structure comprising a curved concrete gravity wall 183 m long with an earth embankment 914 m long on the left flank. Two spillways were provided, the main or northern one consisting of a channel excavated in rock while a natural saddle at a higher level to the south of the wall was used for the subsidiary spillway. The dam filled for the first time in February, 1912.

To serve the settlers the township of Koppies was established in 1909. The main crops grown were lucerne, oats and wheat. By 1923 there were 531 people living in the settlement.

6

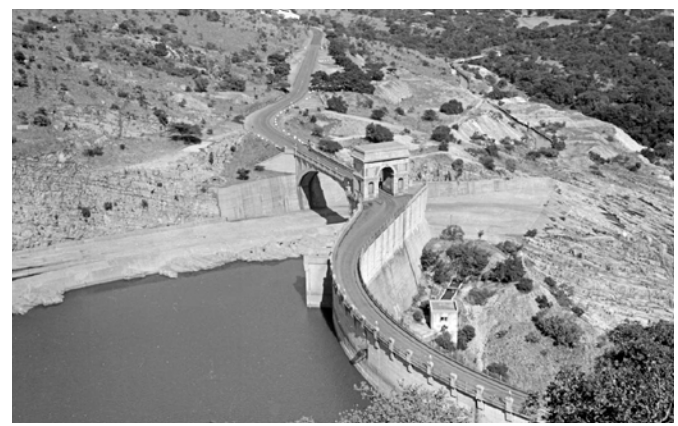
Department of Irrigation takes the lead (1912-1930)

The year 1912 signalled the beginning of large-scale State investment in water storage infrastructure and the start of South Africa's first dam-construction boom as disillusioned farmers moved away from the collapsed ostrich feather market and the government sought to grow the economy. With few exceptions almost all of the country's first large dams were for the exclusive use of irrigation farming.

Just prior to the establishment of the Union of South Africa every province had its own department dealing with water matters, each in its own unique way. In the Cape, the Irrigation Department was mainly a technical one attached to the Public Works Department headed by a Director of Irrigation, while in the Transvaal the Irrigation Department was under the professional control of the Chief Engineer for Irrigation, with administration work falling under the Secretary of Lands. In turn, in the Free State, irrigation matters were dealt with by the Director of Public Works, while in Natal, where for all practical purposes no irrigation had been carried out, irrigation matters fell under the Surveyor General.

And so in 1912, the Union Irrigation Department was born. Head of the Cape department, FE Kanthack was appointed Director, with head of the Transvaal department, FA Hurley, appointed his deputy. When Hurley was killed in a car accident in 1914 it took three years to fill his post, with GW Herdman eventually being transferred from the Public Works Department. The Department of Irrigation initially had a total permanent staff complement of only 34, including nine engineers and nine assistant engineers. From these humble beginnings, the department would eventually go on to design and construct 80% of the country's large dams and water schemes.

The department was led in its activities by the Union Irrigation and Conservation of Water Act, passed in 1912. It provided the national law regulating the use of water in public streams; special judicial machinery in the form of Water Courts for dealing with the definition of water rights along public streams; the settlement of disputes, granting of servitudes, permits etc, establishment of River and Irrigation Districts and Boards, as well as granting of loans to Boards and individuals for the purposes of constructing irrigation works. Importantly, the Act underlined government policy to foster private and cooperative enterprise rather than to undertake extensive State schemes. It also confirmed government's almost exclusive focus on water for agricultural use.



DWA/eWISA

The Hartbeespoort Dam, with its distinguishable miniature Arc de Triomphe feature, was one of the first major government settlement schemes to be constructed in South Africa.

Francis Edgar Kanthack

Of German heritage, Francis Edgar Kanthack was born on 15 January 1872 in Lancashire, Great Britain. He went to school in Liverpool until the age of 13 after which his father sent him to Luneburg in Germany. He completed his engineering degree at the Royal Indian Engineering College in 1894.

After serving his apprenticeship on the Cardiff Waterworks, Kanthack went to India where he worked as Assistant Engineer on the permanent staff in the Punjab of the Indian Irrigation Department. He was there for only two years before being approached by the Cape government. Cape Director of Irrigation WB Gordon's three-year contract was expiring and he personally recommended that Kanthack take his place. On 21 March 1907, 35-year-old Kanthack started his 22-month contract as Director of Irrigation at the Cape. At first, he was simply 'on loan' from the Indian government, and the idea was that he return to the country on the expiry of his South African contract.

However, the South African climate must have agreed with Kanthack (or perhaps it was South Africa's unique water challenges) because, in the end, he resigned his post in India and stayed on permanently. When the Union of South Africa was formed in 1910, Kanthack became the first Director of the new Union-wide Department of Irrigation.

During his early years at the Cape he studied hydrography and meteorology and, in 1912, he amalgamated the hydrographical and meteorological activities of all four provinces by establishing the country's first meteorological services. He was also responsible for the preparatory work that led to the publication in 1922 of hydrographic records.

He was the main drafter of the Irrigation Act of 1912. The Act opened the door to development of South Africa's first large water storage projects, including Bulshoek, Hartbeespoort, Grassridge, Darlington Dam (i.e. Lake Mentz), Nqweba (i.e. Van Rynevelds Pass), Bon Accord and Kamanassie. Kanthack was personally involved in the design and planning of most of these early projects, and he visited many of the sites personally. He was very energetic, travelling extensively, on average 24 000 km a year by car, train, wagon or even on foot. Interestingly, despite his intimate involvement in these large water storage projects Kanthack was rather of the opinion that small individual schemes rather that larger ones would hold the key to South Africa's development.

When the First World War broke out in 1914, Kanthack was called up to assist the South African government in its German South West African Campaign. Under his leadership water supplies were arranged all along the planned route of invasion. Kanthack endured much hardship, and for his efforts he was awarded the Most Distinguised Order of Saint Michael and Saint George.

When he returned to his seat at the Department of Irrigation in 1919 it was only to wrap up his affairs and hand in his resignation. In 1920, Kanthack launched his own consulting practice in Johannesburg, specialising in hydroelectric engineering. Among others, Kanthack's firm undertook projects for the South African Railways and Harbours, the Victoria Falls and Transvaal Company and the Electricity Supply Commission (Eskom). Despite his busy schedule, Kanthack still found time to lecture at the University of Cape Town.

He served on the council of many engineering societies in South Africa, served as President of the Civil Engineers, the Mechanical Engineers, the Association of Scientific and Technical Societies and the Geographical Society, and was nominated to sit on the first Council of the South African Bureau of Standards. In 1942, the University of Witwatersrand conferred on him an honorary degree of Doctor in Science, and in 1954 the Institution of Civil Engineers awarded him its first gold medal for his services to the profession.

SAICE

Kanthack was greatly respected for his self-discipline, his sense of duty, his integrity, judgement and power of endurance. He initiated many ventures which were carried out after his retirement, particularly the stream-gauging programme which he had extended throughout South Africa, and the water laws, which were not revised until 1956.

His long and distuinguished career ended with his retirement in 1958 at the age of 86! He died three years later in Johannesburg.

The importance of irrigation settlement to the State is best expressed by Kanthack when he wrote in 1920: "Agriculture in the broadest sense must take precedence over all other forms of development, and, as a matter of fact, industrial progress and development is impossible unless it is backed by agriculture in all its phases, more especially, those branches thereof which produce the main requirements of life" (Union, 1920).

Among the department's main functions were to collect and compile hydrographic data through the country and undertake systematic reconnaissance surveys, which together with the hydrographic statistics indicated where and how irrigation could best be developed. Arising out of these surveys the department would develop potential irrigation projects. The riparian owners (i.e. farmers) would then be encouraged to establish an irrigation district under the 1912 Act for the purpose of undertaking the scheme as a cooperative work financed under an irrigation loan. These loans were granted up to 30 years and could only be obtained from the Irrigation Department. At the date of Union there were already some 15 irrigation districts and boards established or under construction – all of them in the Cape. A decade later there were close to a 100 spread over almost every province. Interestingly, while considered 'private' enterprises, the Irrigation Department provided most of the resident engineers under whose guidance the irrigation schemes were constructed, and also conducted most of the surveys to select the dam sites.

General engineering advice was also dispensed to farmers at special rates. The latter was mostly undertaken by engineers from the department's so-called Circles or branches. By 1913, there were nine of these Circles, namely the Cape, Lower Orange, Midland, Central Karoo, Upper Orange River, Orange Free State, North Transvaal, South Transvaal and Natal circles. These circles were run as the real units of administration and 'connection with the Public'. The head of the Circle would always be an engineer. The department also maintained a water boring branch, which provided access to groundwater for farmers, settlements, schools and hospitals. Another important duty of the Irrigation Department was to administer the Union's existing government irrigation settlements.

WAR, DROUGHT AND FLOODS

The first few decades were an extremely busy and trying time for the Irrigation Department. One of the first challenges the department had to deal with was a severe drought raging over large parts of the country. At the government settlement at Douglas on the Vaal River, for example, the flow of the Vaal River into the reservoir ceased completely between November and December, 1912, leading to virtually all the stored water above the weir being exhausted. At the Vanwyksvlei government settlement the situation was equally dire, compounded by salinity problems experienced with the dam water. At many of these settlements the department's boring team had to come to the rescue, drilling emergency boreholes for drinking water supplies.

In 1913, irrigation loans could be obtained for the first time under the Irrigation Act. During that year 103 applications totalling £369 794 were granted

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Almost all of the Irrigation Department's young staff members participated in the First World War (1914-1919). The water boring branch, especially played an important role in providing much needed water points during South Africa's South West Africa campaign.

Dam construction in the 1920s

During the 1920s and 1930s most large dams constructed by the Irrigation Department were concrete gravity spillways set in earth or rockfill embankments for broad sites, and single- or double curvature arch dams wide side-channel or chute spillways for canyon sites.

While mechanised means of construction was available, scotch carts, oxen and donkeys, along with the use of picks, shovels and sheer brawn feature very prominently in almost all of the project reports of the time, especially during and immediately after the war when machinery became extremely expensive and nearly impossible to obtain (most equipment was still imported from Europe at the time). Many sites had to make do with second-hand machines bought from gold-mines in Johannesburg.

An interesting aspect, and a phenomenon that continued almost right up to the time that South Africa became a Republic, is the lack of expense spared on leisure activities at these sites, especially those that were far from towns and cities. Even in the 'lean' years of the post-war period it was not unusual for construction villages to feature tennis courts, soccer, rugby and cricket fields, and even boxing rings and cinemas. Also striking, and indicative of the political milieu of the time, was the separation of class and race. While construction staff usually received multi-bedroom, brick houses, unskilled labour (mostly black) had to sleep in single-quarter compounds with far less amenities. At Kamanassie, for example, the white labour camp was constructed on the one side of the river, while the black labour camp was constructed on the other side. All the houses in the white village had 457 mm-thick masonry walls, however, while single men's, married gangers' and some of the artisans' quarters had flat roofs, the first class artisans', foremen and staff quarters all had pitched roofs with porches. On the other hand, the black labour camp comprised 24 *rondawels* (traditional thatched round huts), also with 457 mm-thick walls, 5,5 m in diameter and 2,4 m high to the eaves. The white labour camp also featured a school, a combined mess hall and recreation room and sports facilities, such as a tennis court and a rifle range. There were no such amenities available at the black labour camp. Black labourers were very rarely allowed to bring their families with them on site, as was usually the case with white labourers.

Despite challenges experienced at some of these sites, such as siltation (Darlington, Nqweba) and eutrophication (Hartbeespoort), many of these dams are remarkably intact and are still playing an important role in domestic and agricultural water supply.

DWA

for irrigation works. The great majority of the irrigation districts constituted during 1912-1913 was based on the success of the ostrich feather industry. Interestingly, when the market collapsed in 1914 these districts were not disbanded. Rather farmers increased their calls for water storage works as they returned to farming crops.

In the first *Annual Report of the Department of Irrigation* (Union of South Africa, 1912) there occurs a most familiar phrase which seems to run like a continuous thread through many annual reports: "The shortage of engineers was particularly badly felt." Right from the inception of the department there appears to have been a conflict between the public demands on the department and the capacity of the department to satisfy those demands. In Kanthack's report covering the period 1913-1917 a lot of space is devoted to the subject of the inadequacy of the engineers, and other staff, to carry out the investigations programmes demanded and the schemes for

A familiar phrase seems to run like a continuous thread through many annual reports: "The shortage of engineers was particularly badly felt."

which large sums of money were willingly voted by Parliament. He did not mince his words on the subject. "If the country wants to extend irrigation it demands a vigorous policy on the part of the government," Kanthack wrote. "The taxpayer must be prepared to agree to the inevitable increase in the establishment of the department. Nevertheless, while large sums of money are voted with enthusiasm, the addition of one unit to the regular establishment, be he office boy, clerk or engineer, is in some quarters considered a criminal offence."

In 1914, the First World War broke out leading to a period of uncertainty and stagnation. The disturbed political state of the country caused agricultural development to languish, and it was decided not to grant any further loans except in those cases where government, by virtue of promises or to safeguard the security of existing loans, had already committed funds. During 1914-1915 only 47 irrigation loans were granted totalling £109 710 and in the following year, this fell to 12 loans totalling £60 000. On existing schemes construction ground to a halt as workers went off to join the war and plant and materials became excessively scarce and expensive.

Almost all young staff members proceeded on active service work and the Irrigation Department was cut down to the smallest limits, leaving those left behind in the office to 'merely mark time'. The call was heaviest on staff of the water boring branch, and when the British government requested the South African government to invade German South West Africa (today Namibia) the men from the Irrigation Department in no small measure contributed to the success of the campaign. In total 114 boreholes were sunk in connection with military operations in German South West Africa. A number of employees were also on active services with South African forces during the Rebellion. Later 18 members of staff went on to join the water supply corps supporting South African military operations in East Africa. They were dispatched under the command of Major Ireland, Chief Boring Engineer. Not all of these men returned. All of the department's water boring equipment was used for these campaigns.

When the protracted drought was broken by excessive rains and floods during 1916, the government decided to resume an active irrigation policy.

Among the four senior employees who participated in war activities overseas was AD Lewis, who went on to succeed Kanthack as Director of the Irrigation Department after the war. He was badly wounded in France, but recovered sufficiently to proceed to Mesopotamia, where he oversaw military engineering works on the Tigris River. Kanthack himself oversaw water boring operations in the Kalahari and South West Africa and in December 1915 he was appointed Special Commissioner of Transport, Remounts and Mechanical Transport in the Defence Department, discharging those duties concurrently with those of Director of Irrigation until the end of January 1917.

When the protracted drought was broken by excessive rains and floods during 1916, the government decided to resume an active irrigation policy. Close to £9 000 was spent on reconnaissance surveys during that year, even though in many cases it had to be carried out with 'older men' as younger personnel were still on war duty. An additional amount of £5 000 was placed on the loan estimates of the 1916/17 financial year. Preference was given to applications according to the character of work to be undertaken, with loans for the restoration or repairs of works damaged by floods placed first in order of precedence, followed by water storage works second and distribution works based on storage works third. All applications which had been refused owing to the war were classified according to this order of preference, and the applicants were advised to re-submit their applications. By the end of March 1917, 76 loans totalling £177 075 were granted.

This policy of development led to what is known as the first golden era of dam building in South Africa, which saw the construction of a number of large dams with crest lengths in excess of 20 m above foundation level. Most of these early dams were constructed for irrigation boards in the Cape region. A description of some of the early projects and their unique challenges and characteristics follows.

BULSHOEK DAM

eWISA

Left: *A historical photograph of the Bulshoek Dam shortly after its completion in 1920.*

Below: *Bulshoek Dam was built with 15 hand-operated gates of the Ashford type, a feature incorporated by Irrigation Department Director FE Kanthack. Each gate is 4,6 m high and 6 m wide.*

Known today for its rooibos and wine, the hamlet of Clanwilliam lies at the foot of the Cederberg Mountains in the Western Cape. Regarded as one of the ten oldest towns in the country, Clanwilliam's beginnings go as far back as 1660 when a team of Dutch explorers sent out by Jan van Riebeeck first reached the Olifants River. The river was named by Jan Danckaert, the Dutch cadet in charge of the party, who, upon entering the valley, saw 300 elephants frolicking on the riverbank.

The first farm in the Olifants River valley was awarded to Pieter van Zyl in 1732 and, by the late eighteenth century, small-scale irrigation was well established. Originally known as Jan Disselsvlei (after Jan Dissel, a local pioneer), the area first formed part of the district of Stellenbosch, but was declared a sub-district of its own in 1808 by the Earl of Caledon, then Governor of the Cape. In 1814, Caledon's successor, Sir John Cradock, renamed the area after his father-in-law, the Earl of Clanwilliam. Originally, farmers planted crops in the fine alluvial deposits on the banks of the Olifants River. These crops would be irrigated every time the river overflowed (the first flood ever recorded occurred in the Olifants River in 1822). However, vast destruction of riparian vegetation caused the river's banks to widen and deepen, until after a while it rarely overflowed. Between 1822 and 1870 the river had widened from an average 29 m to about 38 m.

On 16 October, 1858, Patrick Fletcher left Cape Town for Clanwilliam on orders from the Colonial Secretary to undertake one of the first surveys for a potential large irrigation scheme in the Cape. He travelled to the Olifants River mouth and surveyed the latter upstream for about 37 km. His report, which included estimates for two possible dams, was submitted in 1860. Around 120 people were living around the irrigable portion of the Olifants River at that time. According to Fletcher, however, the farmers were not very successful: "The total income of the whole valley could not have exceeded £1 400 per annum during the last nine years. Except when the river overflows they scarcely grow sufficient bread for their own consumption."

DWA/eWISA

A full Bulshoek Dam in 2004. The weir was originally supposed to be constructed on a rocky rapid in the Olifants River known as Oshoek, but was later moved to the farm Bulshoek, a few kilometres downstream of the original site.

In 1883, John Gamble suggested the construction of a series of moderately-sized weirs to restore original conditions in the river i.e. resulting in floodwaters once again spilling over its banks. Despite petitions from farmers in the area to the government, Gamble's plans were rejected due to the prohibitive cost of the scheme. Not long after that the post of Hydraulic Engineer was abolished as a result of economic circumstances prevailing at the Cape, and Gamble returned to England.

Meanwhile, local farmers started their own irrigation initiatives, including the use of steam pumps, windmills and bucket pumps (*bakkiespompe*) to boost their production. During the following decades the farmers would appeal to government time and time again for assistance in various forms without success. Finally, in 1907, the Cape government asked Kanthack, who was then Cape Director of Irrigation, to determine the possibility of an irrigation scheme on the Olifants River. His brief was to investigate the possibility of introducing irrigation on a perennial basis by means of a canal system fed from a high weir with 'considerable storage capacity' as much land as possible on both banks of the Olifants River and along the lower reaches of the Doorn and Hol Rivers.

Kanthack was at first sceptical of the possibility of such a scheme. In his 1909 report he writes: "Local opinion as to the suitability of the land for irrigation was very conflicting and it was with some feeling of uncertainty that I authorised a traverse line of levels along the Olifants River...some 20 miles below Clanwillian down to the mouth." This was followed by a contour survey and a soil survey, and, in September 1908, Kanthack himself visited the district. He must have cut quite the scene in his motorcar, the first to visit the area. He visited the upper portion of the valley from Clanwilliam to the Hol River mouth during September 1908 to 'get a clear idea of the nature of the area'.

When the plans were sufficiently advanced, in June 1909, Kanthack laid down the final alignment for the main canal and branches, fixed the site of the headworks and designed the weir. This proved a difficult task as a result of the irrigable land being only available on the left bank with distributaries crossing over to the right bank. The headworks were thus designed to compensate for this fact. While it was the Director's original intention to keep the weir as low as possible (so as to save costs), to keep grades as steep as possible and allow for the irrigation of the greatest amount of irrigable land, it was decided to construct the weir with a maximum height of about 7 m above the riverbed.

In 1911, an irrigation district was proclaimed and Parliament approved the sum of £155 000 for the construction of the weir and the associated (unlined) irrigation canals, which were to extend down the Olifants River valley for about 80 km. The site originally selected for the weir and offtake was at the head of a rocky rapid named Oshoek, on the farm *Rondeberg*. The original design was for a solid masonry weir (in Roman style) with falling shutters, each 1,8 m wide and 0,9 m high. However, when the project was initially prepared little or nothing was known of the flow of the Olifants River at the proposed weir site. Observations by the Cape Irrigation Department between 1909 and 1912 indicated that if the original design was to be carried out, the flow would not be sufficient to fill the irrigation canals at periods of greatest demand. It also showed that storage above the solid weir crest originally proposed (about 1,8 m) would not be sufficient.

As a result it was decided to increase this storage by erecting gates 4,6 m high above the solid weir. These 15 hand-operated gates are of the Ashford type, which consists of gates sliding in cast-iron grooves of special construction with a patent system of anti-friction rollers. The gates, each 6 m wide, are capable of being raised clear of flood by lifting gear mounted on an overhead superstructure and is supported by 2 m wide sandstone masonry pillars. (Each gate has since been provided with a sand-filled counterweight to ease operation). A 16th gate of 6,9 m clear span, but 5,7 m high, was placed on the extreme left flank near the head gates of the canal to act as a scour, the sill being considerably lower than that of the other 15 gates. The final design was undertaken by the firm Glenfield & Kennedy of Scotland in cooperation with engineer WM Watt. The firm also oversaw the construction of the weir. The site selected was now on the farm *Bulshoek*, a few kilometres downstream of the original site.

Floods as well as an apparent lack of labour prevented construction of the weir and canals from starting until March 1913. The project mainly employed white workers, who earned two shillings and eight pennies a day. Cement was imported from England, while the sandstone was obtained from a nearby quarry. Work was disrupted again by the First

Spanish influenza

The year 1918 will forever be known as the year of the outbreak of one of the world's greatest pandemics of modern times. Spanish influenza is thought to have started in Asia in late 1917 or the beginning of 1918, quickly spreading to Europe and North America. It was called Spanish influenza because reports of its outbreaks in central Spain were not censored, as was the case in other countries participating in the war. The airborne disease spread like wildfire in troopships, on battlefields and prisoner-of-war camps where thousands of people were found in close proximity of each other. By November 1918, the whole of the inhabited world had been infected, eventually leading to the death of an estimated 100 million people.

Ships laden with infected soldiers landing at the Cape and Durban harbours were probably responsible for bringing the disease to South Africa. The disease was spread nationwide by rail, and eventually affected people in all corners of the Union. It was not uncommon for people working in urban areas to die on trains while on their way home to their families in rural areas, and many trains had hospital carriages during this time to care for sick and dying passengers. Densely populated areas were most susceptible, for example, black townships, mining compounds and military camps. Like H1N1 influenza (also known as swine flu) the disease primarily struck those in the prime of their lives (25-34 years of age) as well as pregnant women. Spanish influenza brought every dam construction site to a standstill as those left standing were left to take care of the ill. Many of these sites were very isolated and their hospital facilities primitive.

According to official statistics, around 140 000 people in South Africa died as a result of the epidemic. However, it is now thought that this number was probably grossly underreported and that at least 250 000 people succumbed to the disease in this country. This would make South Africa one of the five worst hit countries in the world.

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World War. Many labourers also left to join the war effort. During October 1918, construction halted for a third time as a result of an outbreak of Spanish Influenza.

By 1920, the canal on the left bank was completed up to Bakleiplaas and the masonry of the 143,3-m-long weir and headworks as well as the erection of the steel gates and superstructures were practically finished by 31 March of that year. The entire scheme was eventually completed in 1924 at a total cost of £601 569.

A historic photograph of Darlington Dam taken in 1936. First known as Lake Mentz, the dam was later renamed after a small township which was inundated when the dam was constructed.

DARLINGTON DAM (LAKE MENTZ)

The first farms in the Sundays River valley, today still a premier export orange producing region, were demarcated in 1781. In 1976, the farm *Slagboom* on the White River was occupied by a certain Scheepers who was related to the Scheepers family who founded Uitenhage. After 1803 and the development of Uitenhage, the area was colonised by white settlers, then Addo Drift between 1880 and 1812.

The initiative to establish large-scale irrigation in the Sundays River Valley can be traced back to the arrival of prominent Port Elizabeth auctioneer James Somers Kirkwood. Described as, 'a tall man of pleasing personality, flowing beard and smiling eyes', Kirkwood came to the valley in 1877 to oversee the auction of the farm *Gouwernements Belooning*. The story goes that on that particular day Kirkwood could not reach the farm as the Sundays River was in flood. So he climbed a hill (known today as the 'Lookout') from where he had a view of the entire valley. The view he saw inspired him, and shortly thereafter he bought *Gouwernements Belooning* himself and settled in the area.

In 1877, legislation was passed on irrigation which aimed to encourage, by means of financial assistance, settlement on farms and the development of private irrigation schemes. Kirkwood tried to convince his neighbours to combine to form an irrigation district, which would be entitled to assistance from the government. The majority of farmers, however, viewed the legislation with suspicion, and in the end Kirkwood bought up sufficient land on his own so as to float a company and so establish an irrigation scheme himself. In 1883, he owned 21 farms in all, totalling more than 29 984,5 ha of land. He introduced irrigation on a small scale on his farms through the years. In December 1883, Kirkwood founded the Sundays River Land and Irrigation Company. Despite all the publicity given to the enterprise when the lists closed in January 1884, not a single share was taken up.

A river of many names

Like many rivers in South Africa, the Sundays River is known by many names. One of these names is *Nqweba* River meaning 'the river of thorn trees'. The Khoi name for the river was *Nukakamma* meaning 'grassy water'. The first record of Europeans crossing the Sundays River in the east is in 1702 although it is thought that the name *Sundays* was given to the river long before that date.

Kirkwood could not have picked a worse time to start his venture. At that time South Africa was in the grips of a depression, and those who had money preferred to invest in ostrich farming or the newly established diamond mines at Kimberley where returns were not only quick but certain and adequate. Kirkwood died a broke and bitter man in 1889.

In 1887, Kirkwood's insolvent estate was taken over by the Guardian Assurance and Trust Company of Port Elizabeth, and in 1903 it was sold to the Strathsomers Estate Company. The company employed engineer David Gerrard to bring more land, on both sides of the Sundays River, under irrigation, and in 1909 Gerrard, along with Ninham Shand (who became the company engineer in charge of this work) inspected the site of the Korhaan's Drift scheme. The scheme entailed the construction of a diversion weir across the Sundays River at Korhaans Drift where the river leaves the Zuurberg Mountains and enters the Sundays River Valley. The scheme was delayed for some years by litigation as other irrigators contested the company's water rights. In the end, the court ruled in favour of Strathsomers Estate and construction of the Korhaans Drift weir got underway in 1911.

At its completion in November 1913, Korhaans Drift was the largest irrigation scheme in South Africa, designed to irrigate 4 176,4 ha of land. The weir was 87,2 m wide, with two abutments 9,1 m high from the crest of the weir. Water for irrigation was released through seven sluice gates built at right angles to the river, and emptied into the main canal, 812,8 mm wide. Kirkwood's vision eventually attracted others to the idea of using the water of the Sundays River to irrigate large tracts of land. By 1913, there were three irrigation companies in the area: the Strathsomers Estate, Addo Land and Irrigation Company, and Cleveland Estate, who all had weirs on the Sundays River.

Famed author and businessman Sir Percy Fitzpatrick visited the Sundays River Valley to view the irrigation schemes in 1913. Soon thereafter he purchased a block of farms surrounding Addo. Fitzpatrick was always keenly interested in land settlement. In February 1914, negotiations were opened with the Cleveland Estate, which was experiencing financial difficulties. This resulted in the birth of the Cape Sundays River Settlements Company, of which Fitzpatrick was chairman. Fitzpatrick committed himself to citrus as a core crop. Port Elizabeth provided a major market and port nearby, and exports to Europe had already begun, taking advantage of South Africa's reverse season. Citrus production, however, required a sustainable water supply.

At the time of its construction in the early 1920s Darlington Dam was the second-biggest in South Africa, after Hartbeespoort Dam.

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The droughts of 1913-1915, coupled with the collapse of the ostrich feather industry (which forced farmers to look at other income possibilities) made it perfectly clear that any permanent extension of irrigation, coupled with settlement operations on a large scale, would be impossible unless large storage works were undertaken and the entire system of irrigation altered from flood irrigation to irrigation based on the storage of flood water. A flood

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Sir Percy Fitzpatrick was keenly interested in land settlement in the Sundays River valley.

in 1916 reinforced the argument that 'large volumes of water were being lost', which could only be rectified with a large storage scheme. The irrigation companies decided to work together and approached the Union government with a view of establishing a large storage dam at the head of the valley which would ensure adequate and perennial supplies of irrigation. Minister of Lands, Col Hendrik Mentz, and Kanthack, supported this idea. Not long after, the project was approved by Parliament.

In 1917, the Sundays River Irrigation Board was established with the sole purpose of constructing what was soon named Lake Mentz after the Minister of Lands. A loan was provided by the State to construct the dam and the repayment of the loan was the responsibility of the irrigators by the imposition of a canal levy by the irrigation board. The Sundays River Project, as it was then known, was considered unique by virtue of the fact that almost the entire area of irrigable land was controlled by companies and not by private individuals, and that the existing irrigation works, weirs, canals etc had been constructed by the companies themselves. Lake Mentz would be the second-largest dam after the Hartbeespoort, which was also being constructed at the time.

Kanthack made a personal examination of the entire length of the Sundays River Poort, 'one of the most imposing bits of mountain scenery in South Africa', rejecting as impractical both provisional sites which had been previously surveyed. He selected a new site a short distance upstream, in the Jansenville district. In a report for 1917/18 Kanthack writes: "The project itself is, in my opinion, one of the soundest and most promising ones I have ever been associated with in South Africa, and paves the way for one of the most favourable closer settlement schemes which the Union is ever likely to produce. Soil, topography, climate, communications and market conditions are all of the most favourable, and I have no hesitation whatever in strongly recommending that the works should be financed by the State."

Field and preliminary work were completed in the middle of 1917 and, in March 1918, the Sundays River Irrigation Board took over direct control of the project from the Irrigation Department. Initial impoundment of the lake was scheduled for 1919. The mass concrete-type gravity section was to have a concrete wall 304,8 m in length and 25,6 m high. In the wall six sluice gates, each 9,1 m wide and 7,6 m high, worked by hydraulic pressure, would regulate the flow and be capable of dealing with the biggest known flood.

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Minister of Lands, Col H Mentz, after whom the Darlington Dam was initially named.

When full, the original dam held 142 million m^3 of Sundays River water.

In April 1918, RW Newman was appointed Resident Engineer on the project, with AG Bridgman as his assistant. According to Kanthack 'the Board could certainly not have made a better choice'. Had Newman but known what a difficult project Lake Mentz would turn out to be, however, he might have thought otherwise than to take on the project! Firstly, the site selected for the dam was in the heart of the barren Noorsveld 40 km from the nearest station. Before any work could get underway a new road had to be constructed, around 30 km long, through mountainous country, from Wolwefontein to the site of the dam, as only 8 km of divisional road existed. At the same time a telegraph link from the works to the station was constructed. The road, telegraph line and all required buildings were completed by the end of 1918.

There was still the matter of transporting the materials from the station to the site. Carts drawn by donkeys were used to haul the total estimated 28 000 t of material to site. With no natural vegetation for the animals to feed on the wagons also had to carry sufficient food for the journey there and back. It became necessary to place outspans at 13 km intervals with supplies of drinking water for the donkeys. At one stage during construction, 30 wagons and 500 donkeys were being continuously employed. Newman, writing his report for 1922 stated that a team of 16 donkeys, drawing 3 175 kg, made an average ten trips a month, 30 km in each direction. "Experience has shown that when compared to mechanical [transport], this form of transport offers advantages despite its primitive nature," he said. Construction of the dam was not by completely primitive methods, however. The project did, for the first time in South Africa, make use of steel shuttering for the laying of the concrete rather than timber boxes.

Like many engineering projects of the time, construction was marred by the conditions created by the First World War. Not only was it difficult to recruit labour (very few men wanted to undertake the two-day journey on foot from the nearest railway siding), but the importation of suitable plant was practically impossible. In sheer desperation obsolete and often second-hand material and machinery had to be purchased at prohibitive prices. About 800 workers were employed on the dam, recruited mainly from the Transkei area. Following the war ex-soldiers were recruited, however this resulted in several difficulties. Not only were most of these men unaccustomed to the work required of them, but many suffered from relapses of malaria contracted in German South West Africa. The 1918 influenza epidemic reduced labour to a pitiful handful.

Matters were made worse by an outbreak of Bubonic plague and protracted drought, which cut down water supplies for domestic as well as construction purposes. Newman estimated that the demand for the works as well as for domestic use was often as much as 454 m^3 a day. In December 1921, the pumping plant placed on the bank of the river was washed away by floods. In the end, the dam was only completed in 1922. The most ironic part of the dam's completion was that it was followed by a drought, and the dam only filled in 1928.

This delay in completion of Lake Mentz proved the death knell in the dreams of many settlers who invested too early in the scheme. Kanthack had warned prospective British settlers that they needed £2 000 in capital and enough money to tide them over for four years. Even this proved optimistic. Early settlers survived by farming chickens and lucerne; a number had to live and work in Port Elizabeth and Uitenhage. The Cape Sundays River Settlement Company ran into financial difficulty and was eventually liquidated in 1923. Mounting financial demands on the Irrigation Department led the State to take over the scheme in 1925. By 1934 all outstanding monies owed by the irrigators to the State, totalling some £2 350 000 had to be written off.

Kanthack had anticipated that the dam would experience a problem with siltation. The solution he proposed was the provision of a number of large scouring

Darlington Dam boasts two spillways with control gates – the main spillway and an auxiliary spillway. Near the left abutment is the river outlet system with a number of release valves.

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sluices with their sills 7,6 m below full supply. Despite this measure, excessive siltation resulted in the dam wall having to be raised in 1935 by 1,5 m to restore its original capacity. The wall had to be raised again in 1951, this time by 5,8 m. After the second raising of the dam the Irrigation Board embarked on what was termed the Betterment Programme, which entailed the concrete lining of some 70 km of main canal and some 155 km of subsidiary distribution canals. This project was completed in 1962. Between 1922 and 1966 more than 103 million m^3 silt entered the dam (88% of its original capacity).

Engineering statistics of Darlington Dam

Dam type: Gravity
Height above lowest foundation: 48 m
Length of crest: 418 m
Volume content of dam: 0,209 million m^3
Original gross capacity of reservoir: 251,890 million m^3 (since severely reduced by siltation)

NQWEBA DAM (VAN RYNEVELD'S PASS DAM)

The idea of constructing a dam across the poort at the Van Rynevelds Pass on the Sunday's River outside Graaff-Reinet was discussed among eager irrigators and thirsty townsfolk for many years. But it was not until 1918 that any attempt was made to investigate the possibilities of a storage scheme here. In that year, a preliminary survey of the basin was made under the supervision of CH Warren, an engineer with the Cradock branch of the Irrigation Department. The results of this survey showed that a scheme was feasible and a detailed survey followed. In 1919, an Irrigation District was proclaimed under the Irrigation Act of 1912.

Irrigation Department engineer KR Shand was promptly seconded to the site as Resident Engineer. The scheme was to comprise a concrete storage dam a little less than two kilometres north-west of Graaff-Reinet, three pick-up weirs and about 97 km of canals.

The Van Ryneveld's Pass Irrigation Board was eager to start construction, however, the First World War had just ended, and obtaining plant and materials proved excessively difficult and expensive. The Irrigation Department, who at that time had quite a few big water schemes under construction, decided to tighten its belt and loans were held back for new schemes. The lack of funds meant that from November 1920 to July 1921 the only construction that could be done at Van Rynevelds Pass was the erection of quarters for staff and employees, installation of water supply and construction of works roads.

Unlike many other large dam sites at the time, the Van Rynevelds Pass Dam site was quite close to a town, "a 20 minute walk" as Shand put it in an Irrigation Department magazine article in 1924. As a result not nearly as many amenities were required as at other dam construction sites. As was typical of that time, one's position and one's race very much dictated what lodgings one would be afforded on site. All white (skilled) quarters were constructed of brick under an iron roof. The married quarters consisted of pairs of semi-detached cottages with flat roofs while single quarters comprised single rooms with small kitchen attached. The staff (mainly engineers) lived in single cottages with


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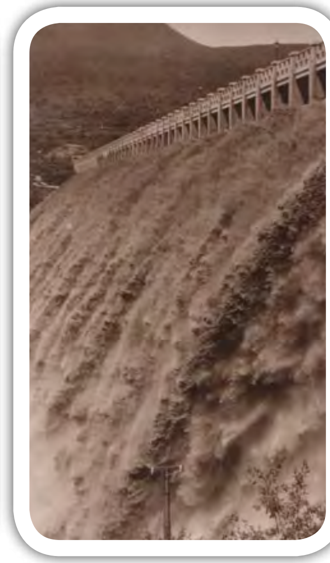
Left: Nqweba Dam (formerly known as Van Rynevelds Pass Dam) is a mass concrete wall of gravity section.

Right: In March 2008, the Nqweba Dam spilled for the first time in 22 years.

Camdeboo Municipality



Graaff-Reinet Museum

From left to right:

The dam under construction in 1923. More than 700 men worked to construct the dam in less than four years, quite an achievement for the time.

The Nqweba Dam project was quite modern for its time, with almost all plant on site being electrically driven.

Donkeys pulling cocopans were used to haul material on site.

Nqweba Dam spilling for the first time. The downstream face is made up of staggered steps, which break up the mass of floodwater spilling over the crest.

pitched roofs. All the houses had water laid on to near the kitchen door and were supplied with electric light.

Black employees, who made up the whole of the unskilled work contingent, were housed in two brick compounds, each capable of accommodating 200 men. When the number of black staff rose to 700 between July-November 1923 the extra men had to be accommodated in huts made of cement bags. All white employees paid rent and contributed to a special medical fund. Black employees did not pay rent but did contribute to the medical fund. Water was obtained from a 136 kl service reservoir above the camp supplied by a small pumping plant on the riverbank. A sanitary service removed sanitary buckets and rubbish twice weekly.

A start was made on the foundations of the dam in July 1921. Excavation work was carried out in four sections: left flank, base excavation, river section and right flank. About 27 432 m of soil were taken out by means of donkeys and scrapers. "This method proved very economical as long as the scrapers could be worked at right angles to the wall of the dam, which meant that a load was taken out going and coming, dumping both up and downstream," wrote Shand. After going down 3 m the pull up became too steep; a cut was then made in the riverbank, scrapers taken through this and dumped in the riverbed. This meant a long haul and an empty trip back, so this method was confined to that portion of the excavation close to the riverbank. At the far end, inclines and light track were put down and cocopans hauled up the inclines by means of donkeys and then pushed out through the cut in the riverbank.

The riverbed did offer some resistance in the form of large boulders, up to about a cubic metre in size, which had to be removed with pick and shovel as the purchase of a steam shovel proved too inhibitive. The donkeys were later replaced with large mechanical plant. Practically all the machinery on the works were electrically driven, the power being generated at a central power station located alongside the railway siding for easy handling of coal. Excavation was completed at the end of September 1923.

Concrete work started in November 1922 and by November

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Left: *The vertical upstream face of the Nqweba Dam.*

Top right: *The three main irrigation outlet valves were placed on the downstream side of the dam wall.*

Bottom right: *In total, nearly a quarter of a million bags of cement were used in the construction of the Nqweba Dam wall and over 80 km of steel rods were cut, bent and assembled and placed in the superstructure.*

Graaff-Reinet Museum

Graaff-Reinet Museum

Engineering features of Nqweba Dam

Dam type: Mass concrete gravity section overspill type
Maximum height of concrete wall above riverbed: 33 m
Length of dam at crest: 356,6 m
Crest width (overall): 3 m
Footway: 2 m
Maximum excavation depth: 14,4 m
(Original) gross capacity at full supply level: 78 843 Mℓ
Quantity of concrete in main wall: 99 392 m^3

1923, 52 754 m^3 of concrete had been placed. The great part of this concrete was placed by means of tip trucks; when work was below ground surface level, the trucks were run out on the side of the excavation, and concrete tipped down chutes into trucks at a lower level.

These trucks ran on rails resting on gum poles which, in turn, were carried by the shuttering: a day's work was shuttered off in pockets 4,2 m by 5,5 m wide by 1,4 m high. Once the wall reached ground surface level, the trucks were run out directly on the shuttering. The steel shuttering was built into panels 6 m by 3 m and 4,6 m by 3 m for the upstream and downstream faces respectively and was used only on these faces. The upstream panels weighed about 227 kg and were handled by cranes. When a crane was unavailable these panels had to be lifted by 'sheer legs and chain blocks.'

The dam was completed towards the end of 1924. In total, nearly a quarter of a million bags of cement were used in the construction of the wall and over 80 km of steel rods were cut, bent and assembled and placed in the

Today, Nqweba Dam is owned by Camdeboo Municipality and is still a major source of water to the town of Graaff-Reinet.

superstructure. Work on the canal structure was kicked off early in 1924 and supervised from the dam. The scheme was constructed for around £400 000, the costs of the canals being a fifth of the total cost of the scheme.

The dam consists of a mass concrete wall of gravity section, straight in plan of the overspill type. The upstream face is vertical and the downstream face stepped (a novel feature at the time). These steps are staggered to break up water coming over the crest in case of high floods and so reduce the pounding action on the toe of the dam and foundation. No special provision was made to form a water cushion as it was anticipated that a natural water cushion would be formed with a certain amount of surface material being scoured away, leaving a standing pool at the toe.

The spillway over the main wall is 169 m long and an auxiliary spillway on the left flank 69 m long. A removable reinforced concrete superstructure, 381 m long with a pedestrian walkway around 2 m wide, extends over the entire length of the top of the wall. The main irrigation outlet valves are placed on the downstream side of the wall, and discharges into the riverbed. As the dam also serves as a storage reservoir for Graaff-Reinet, a valve tower on the upstream side of the wall draws off the water for the town. Initially three pipelines served the town's requirements.

Like other dams in the area, Nqweba Dam has lost much of its capacity due to excessive siltation. This, in addition to an increase in soil salinity, has made irrigated agriculture a high-risk activity in the catchment, and over the years many farmers have gone out of business. However, the dam still provides much needed water to Graaff-Reinet, and when the Van Ryneveld's Pass Irrigation Board was dissolved in 2001/02 the ownership of Nqweba Dam passed on to Camdeboo Municipality. The dam now forms part of the Camdeboo National Park, and these days it is also noted as a tourist attraction as well as a main supply of water.

A hero's burial

One famous name connected with the Nqweba Dam is that of Gideon Scheepers. Among others, the Boer Commandant participated in the battle of Magersfontein and escaped when General Piet Cronje surrendered at Paardeberg. He further led a commando of 150 men to take on British forces in the Cape Colony during the South African War. Becoming seriously ill he was captured on a farm in Prince Albert in October 1901 and sentenced to death by firing squad in Graaff-Reinet. Scheepers was executed on 18 January, 1902, and buried in an undisclosed location. Legend has it that his remains now lie under the waters of the Nqweba Dam.

KAMANASSIE DAM

It might be known today as the ostrich capital of the world, but long before the domestication of the 'golden camel bird' Oudtshoorn was renowned, at least in South Africa, for its irrigation. The town originally grew around the Dutch Reformed Church established near the Grobbelaar's River in 1839 to serve farmers in the area. Almost a decade later a number of erven irrigated by furrows led from the river were surveyed and sold. It is thought that the town got its name from Geesje Ernestina Johanna van Oudtshoorn, wife of the first Civil Commissioner of George, Egbertus Bergh.

Like many towns in the Little Karoo the young Oudtshoorn struggled to thrive. In the 1860s drought threatened the existence of the town and drinking water had to be delivered to erfholders with carts. Then the drought was broken by floods that washed away large parts of town.

It was the domestication of the ostrich with the invention of the incubator that saved the town from ruin. Ostriches thrived at Oudtshoorn; the climate was dry and warm, the soil with its salt and lime agreed with the birds and the well watered valleys were ideal for lucerne fields, which was introduced as a fodder crop by Oudtshoorn magistrate Mr Scholtz. He imported the seeds and planted a small plot to feed his ostriches. The birds thrived on this diet and soon all the farmers started planting lucerne followed by the construction of irrigation schemes to water ever greater fields of crops. In 1875 the district possessed only about 2 160 ostriches, by 1893 this figure had risen to 27 000.

The Oudtshoorn district was reportedly streaks ahead of other areas in South Africa as far as irrigation was concerned. In his 1901 report on irrigation possibilities in South Africa, William


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__Above:__ After the domestication of ostriches in the 1860s Oudtshoorn became the world's ostrich feather capital.

__Top left:__ The farm Armoud outside Oudtshoorn in 1899. At this stage the district was at the forefront of irrigation farming in South Africa, largely as a result of the international demand for ostrich plumes.

__Middle left:__ Machinery used to crush rock for the Kamanassie Dam.

__Bottom left:__ Construction at the Kamanassie site progressed according to a strict programme set up by the Resident Engineer. Due to the inaccessibility of plant, mostly second-hand machinery was used.

Willcocks describes Oudtshoorn as the Cape's "Garden". At that stage, at least 971 ha of land was being cultivated with water from the Grobbelaars River. Most irrigation was done through diversion weirs In addition to lucerne, farmers in the area produced tobacco, potatoes, with orange groves, vineyards and fruit gardens in abundance.

While the ostrich feather sector grew, the need for water deepened. At the turn of the century, the Cape Colony's neighbours were preparing to engage in a destructive war with England, but the southern colony was experiencing one of the greatest periods of affluence in its known history. Next to gold, diamonds and wool, ostrich feathers became the Cape's largest export product. By the end of the century nearly 500 000 pounds of ostrich feathers were exported a year. But there was no abundance of water in the Little Karoo. The year 1896 was one of the driest on record and, by 1899, the Oudtshoorn municipality had to collect water from 18 km away. This water was sold to residents at over sixpence a bucket. To alleviate the problem Danie Nel, owner of the farm *Rust-en-Vrede* was persuaded to sell his water rights and work began immediately to pipe water to town.

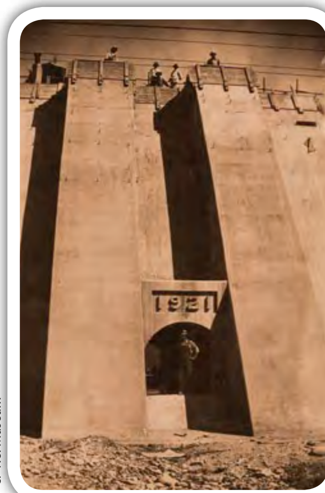
It was during this time that the first serious proposal was made to construct a storage dam on one of the rivers outside Oudtshoorn. ETL Edmeades, owner of the farm *Kamanassie*, proposed an irrigation dam to be constructed on the Kamanassie River, a tributary of the Olifants River. But while the ostrich palaces were being constructed in town nothing came of the idea.

In 1913 the ostrich feather industry reached its climax only to be followed by a complete collapse of the sector with the outbreak of the First World War. Farmers who had pulled out their tobacco crops and orange trees to make room for ostriches now had to return to their crops. With the emphasis on lucerne the need for irrigation had become more apparent, and so the Kamanassie irrigation scheme was again revived.

In 1916 an irrigation district was established and the Irrigation Department was approached with the view of preparing a suitable irrigation scheme. The irrigation board subsequently accepted the project proposed by the department and FT Patterson was appointed Resident Engineer to carry out the work with a loan granted by Parliament.

Construction of Kamanassie Dam only started in June 1919 due to the First World War. Work on the canals was carried out simultaneously. The design called for a mass concrete gravity section dam with a crest height of 44 m above deepest foundation and 35 m above riverbed. The dam wall was to be 386 m long. The main spillway was to be on the right flank and 91 m wide with a waste weir wall 183 m long. An emergency spillway was to be constructed on the right flank. This spillway was to be 91 m long and was to discharge into a channel 46 m wide.

Patterson worked according to a strict programme that called for the storage of water to start by December 1921. Work and finances were controlled from a central office at the Kamanassie Dam and sub-offices on the canals. The work schedule was set down in detail in a diagram, a copy of which was supplied to each member of staff so that responsibility and control could be clearly defined. It is interesting



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Right: The Kamanassie Dam shortly after its completion.

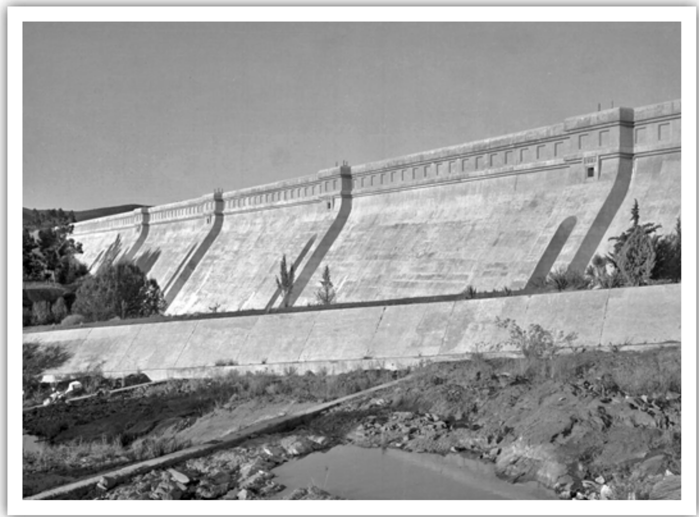
Below: Kamanassie Dam at an advanced stage of construction. Note the use of donkey carts and cocopans.

CP Nel Museum

to note that CJ Langenhoven, author of *Die Stem*, acted as legal advisor to the Kamanassie Irrigation Board (he set up practice as an attorney in Oudtshoorn in 1902), while famed water engineer Ninham Shand was Assistant Engineer on the project.

The board capped plant expenditure at £25 000. As construction was started at a time when it was impossible to obtain machinery from either Europe or America promptly and at reasonable prices the irrigation board decided to purchase second-hand engines and machinery and only import what could not be located in South Africa. This included concrete mixers and an air compressor. A three-ton capacity, 335 m-span cableway was obtained from Calitzdorp Dam (which had just been completed), together with a 40 HP suction gas engine, a few small crushers and other odd plant. In addition, three five-ton locomotive cranes were required from a mine in Johannesburg.

While all the machinery was finding its way to site, workers set about throwing an earthen coffer dam around the right half of the foundation on the riverbed. Excavation for the foundations was done entirely by hand. Interestingly, it was decided that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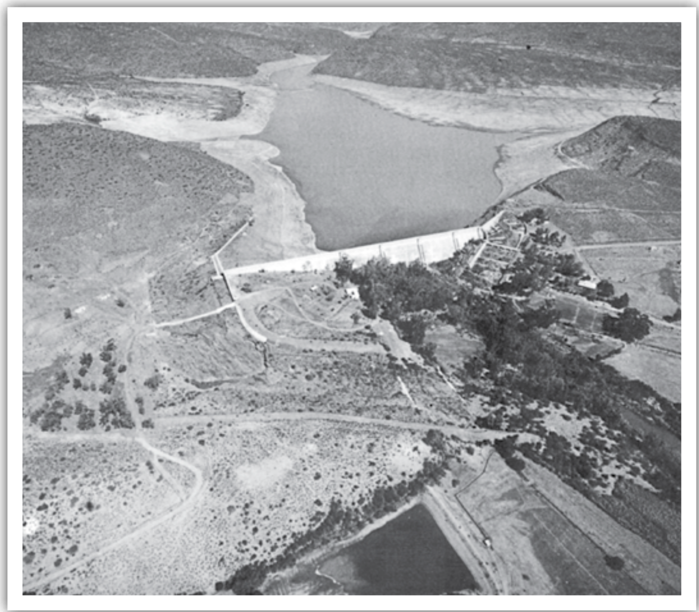
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Top left: *This photograph of Kamanassie Dam was taken in 1936.*

Bottom left: *Kamanassie Dam as seen from the air.*

all staff appointments should be advertised. There were 15 staff members in all. All white employees were to be recruited from the Oudtshoorn district and housing was provided for 30 single men and 30 families. Unskilled (black) labour was recruited from the Eastern Cape.

The white labour camp was constructed on the left or south bank of the river while the black labour camp was situated on the right or north bank. Apart from the conventional recreation and educational facilities, there was also a post office. At the height of construction there were 1 800 men working on the scheme.

By the end of November, 1919, 43 580 m^3 of concrete had been placed in the dam and earthworks of 48 km of canals had been completed. And on 6 May 1920, the first concrete was poured for the dam wall. The event was marked by a ceremony in which all staff and children attending the works school dropped small stone ‘plums’ into the first concrete placed in the foundation. Despite the good start the rate of construction was hampered severely by the curtailment of funds, and in the end the project was only completed towards the end of 1925.

GREAT FISH RIVER SCHEMES

Kamanassie Dam is not the only large dam in the Little Karoo that owes its existence to the ostrich feather boom of the early 1900s. With ostrich farmers supplementing their prized birds' feed with lucerne small diversion weirs starting to appear across large stretches of the Great Fish River after the South African War. These weirs and associated canals depended for success on summer floods and freshets that came down the rivers at uncertain intervals and run for a few hours or days depending on the intensity of the storm event that produced them. At other times water flow was quite negligible from an irrigation point of view.

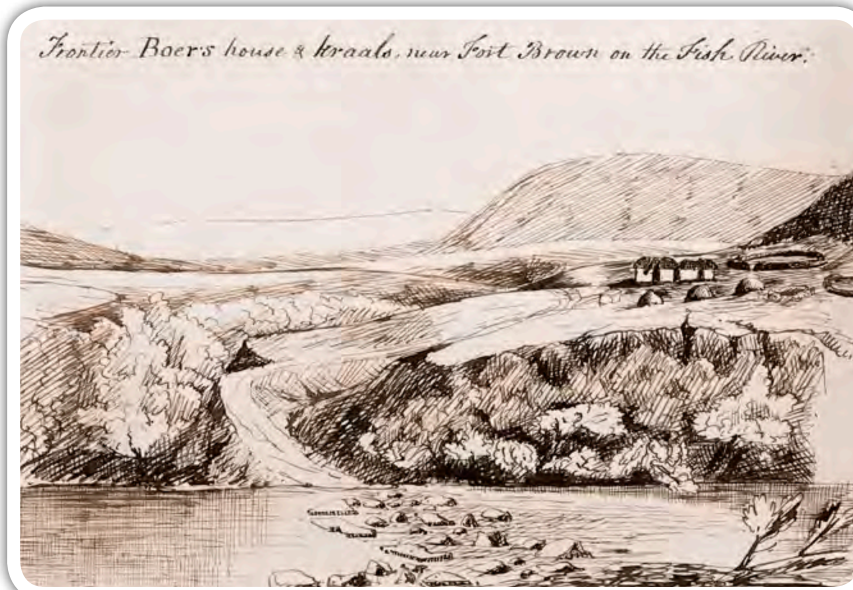
White settlers first started arriving in the Fish River valley in the 17th century. These trekboers were part of the second wave of European settlers advancing inland from the Cape to find suitable grazing for their livestock. In the beginning, these settlers met with great resistance from the Khoi and Xhosa communities settled in the area, and many skirmishes followed. As a result many white families left the area in the early 1800s.

One of the few farmers who stayed in the Fish River valley was Hendrik Janse van Rensburg. He took up residence on *Van Staden's Dam* farm in about June 1803. When new Governor at the Cape, Sir John Cradock, later surveyed the land for a suitable site to establish a fort (one of many to be built along the Fish River in an effort to 'restore order') his decision fell on *Van Staden's Dam* farm. Cradock also wanted to establish a settlement and military protection for a population he hoped to settle in the area between the Sundays and Fish rivers. However, Andries Stockenström, who was appointed to set up this drostdy as it was called, did not appreciate the fort site and opted for another 19 km north.

The farm, called *Buffelskloof*, which was eventually decided upon, belonged to Piet van Heerden and his brother. They were paid compensation of 3 500 Rix-dollars, and the government immediately set out to build the settlement, which later became the town of Cradock. There were already a few buildings on the farm and these were overhauled as government buildings to save on capital outlay. So, for instance, the original farmhouse served as the first gaol. The first title deeds on town erven were sold in 1918 and Cradock was granted municipal status in 1837.

The ostrich feather industry and the associated lucerne market, really propelled development in the region, and between 1815 and 1874 several irrigation works were established. The rich basin of the Fish River also produced enough cereals, not only for the area's population itself, but also for export to the rest of the Cape. Surveys towards the construction of water storage works was first carried out in the Cradock region in 1905 by WB Leane of the Cape Irrigation Department following a visit from the Commissioner. The site initially identified and consequently investigated was situated at the poort at Strydom's Kraal, however, this site was later rejected for being uneconomical.

The survey itself turned out to be particularly dangerous for Leane and his team as they found themselves confronted by flocks of breeding ostriches. "It was neither safe for us, nor good for the birds to work through the camps without the assistance of the owners," Leane wrote in his



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An 1884 illustration of a frontier farmer's house and kraals on the banks of the Fish River.

Water supply in Cradock

While Cradock is situated on the banks of the Great Fish River, the flow of the river never proved sufficiently constant to supply the town adequately. The first inhabitants built a weir and diverted the water of the river down an irrigation canal into the town in 1816. As the town grew, which it began to do rapidly as ostrich farming developed, this source of supply proved wholly inadequate and the problem of water supply was once again propelled to the forefront.

After considerable investigations into potential new sources, it was decided to purchase the farm *Holtzhuisbaken* situated about 12 miles from the town where there was a strong permanent fountain. Dams were built to store water from this fountain and pipes laid to a storage reservoir in town. The first supplies of water were received in 1866 at the rate of 391 m³/day.

By the late 19th century, Cradock again found itself in dire straits where its water supply was concerned and, after the South African War, the Tarka Irrigation Scheme was constructed, which was also to supply the thirsty townsfolk with water. This scheme was completed in 1909.

1906 report. "Considerable time was wasted in obtaining this protection and even then we were repeatedly chased and work abandoned for the time, when within the areas in which particularly savage birds were kept." No major water storage schemes came from these investigations, and it was not until farmers could no longer make their fortune from ostrich plumes that the attention turned back to large-scale irrigation.

After the global ostrich feather market crash in 1914 it was decided to investigate the possibility of providing storage on the Great Fish River and, to this end, several storage sites were investigated in 1917 by surveyor JF Weedon on the Brak and Tarka Rivers, both tributaries of the Great Fish River. Two sites were later selected, one at Tarka River about 24 km above its junction with the Great Fish River on the farms *Tekefontein* and *Vrishgewaagd* (Lake Arthur) and the other on the Great Brak River, situated on the farm *Grassridge* (Grassridge Dam).

In 1920, with preliminary work having been completed the Great Fish River Irrigation Board was formed, comprising nine members representing the different flood irrigation schemes already in existence, namely Tarka Bridge, Mortimer, Klipfontein, Hougham, Abrahamson and Middleton. Both water storage schemes were to be constructed simultaneously with funds procured from government. RJ Garratt was seconded from the Irrigation Department to act as Resident Engineer on the Lake Arthur scheme while AJ Wells-Jones acted as Resident Engineer on the Grassridge scheme. When Garratt resigned in 1922 he was replaced by AM Greathead.

Grassridge Dam

Grassridge Dam is essentially an earthen structure with a concrete core carried up to 1,5 m below the crest level. The height of the crest is 24 m above the riverbed (it is 366 m long). The dam features two concrete spillways, both 366 m long, situated 3 m below the crest of the dam. Around 366 986 m³ of earth was used to construct the dam. Discharge was controlled by a valve tower built at the entrance to a tunnel, which was constructed on the western side of the wall to deal with heavy floods during construction. Access to the operating valves was obtained by means of a footbridge. The dam had an original capacity of 72,8 million m³.

Construction was originally due to start in 1920, however, due to the limited funds available from the Irrigation Department, progress was rather slow. That year was spent clearing the site, making roads and putting down trials pits to test the foundation. The latter turned out to be the saving grace of the project. The original site of the dam was formed by a chain of dolerite koppies running east and west and at right angles to the Great Brak River. At the eastern side, the foundation was found to be of extremely poor quality, and it was thus decided to move the location of the dam 15 m upstream.

Restricted funds only allowed a small amount of work to be done during 1921/22, including the erection of living quarters and offices, digging out and concreting of core foundations. When funding came through in 1923 the project proceeded at full steam. At the height of construction about 1 200 workers were employed on the project. Most of the work was done using oxen, scrapers and scotch carts. Basically all the soil was brought in on cocopans, which was then tipped and the soil distributed by drag-scrapers drawn by four oxen. A total of 936 oxen were used for this purpose. These were divided into two shifts – working one day and resting one – and changing over each mid-day. Apart from the 6 854 ha of veldt the oxen had to graze on, they were also fed small portions of lucerne. During 1923 severe drought caused many of these animals to perish. The dam was completed in December 1923 at a cost of £160 000.

Lake Arthur

Lake Arthur, or Tarka Dam, as it was known before 1923, is essentially a concrete dam of ordinary gravity section type, except that the face is vertical and the back stepped instead of battered. About 149 088 m^3 of concrete was cast in the construction of the dam wall which has a crest length of 500 m and a crest width of 3 m. The spillway is 303 m long.

Save for two short bays marking the spillway the steps are broken into 4,6 m lengths and arranged in such a manner that the spill, which is over the wall, may be thrown from side to side, as well as checked, in its descent. It was believed that a maximum of energy would be dissipated this way before the water reached the toe of the dam. The dam was constructed without an apron, but it was expected that the spill would form a water cushion by piling up soil and boulders downstream. The steps were designed in such a way that they form a convenient footing should the dam ever be raised (which did happen in later years). The dam had an original capacity of 86 million m^3.

To allow for the contraction of concrete, the dam was divided into blocks, around 28 m in length. These blocks were brought up individually from a point 27 m below non-overspill crest level on the right bank, and 30 m below on the left, the difference being due to the lie of the foundation rock. They were then connected by a copper sheet and bitumen joint. The dam discharged to riverbed, and no additional canals were constructed, the water finding its way down the river to the existing diversion weirs.

Preliminary work started in 1921, including the building of 11 km of road connecting the dam site with Cradock as well as works buildings and accommodation for staff and labourers, however, construction only truly got underway in 1923 when the necessary funds were released by government. By October of that year preparations had been far enough advanced to start concreting from the layout on the left bank of the river, with the right bank following in January, 1924. The cement was obtained locally, and transported from

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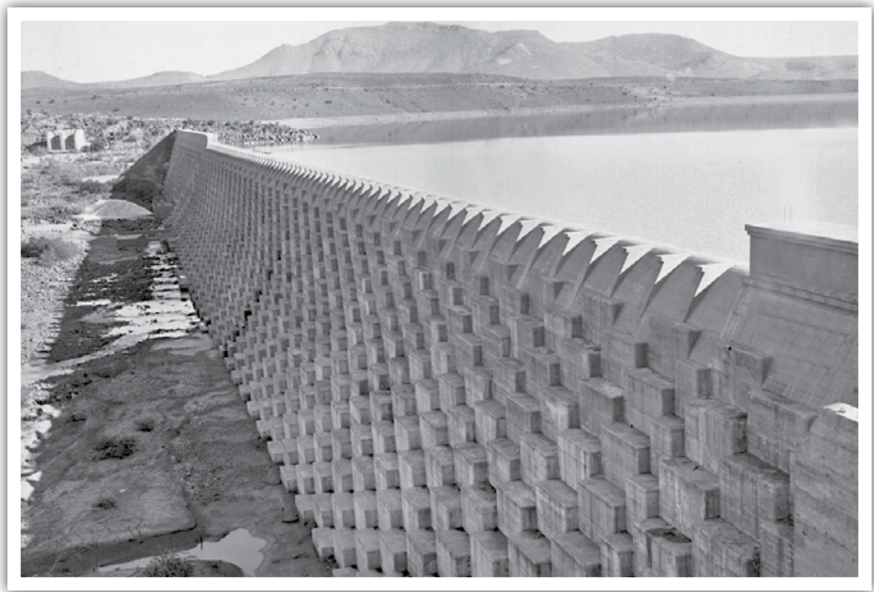
Lake Arthur owes its name to former Governor-General of the Union, Prince Arthur of Connaught, who laid a stone in the foundations of the dam on 3 November, 1923.



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Lake Arthur (also known as Tarka Dam). Close to 150 000 m^3 of concrete was used in the dam wall.

Cradock using mainly donkey wagons. At times as many as 80 donkey wagons were used for this purpose. Around 1 000 bags (90 tons) were used a day.

All the water from the works had to be piped from wells about 3,2 km away as there was not enough water in the river to cope with the demand. The river water also contained a lot of silt, which made it unfit for drinking and for use in the on-site power station which was bought over from the Hartbeespoort Dam, which had just been completed.

Sand for concrete was collected from the river channel upstream of the site using cocopans hauled by mules. The pans were taken to dumps near the river, and from these dumps other mules hauled the sand up tracks, piling it in reserve near the mixing stations. The mules were also used to remove the material during excavation, which was undertaken entirely by hand. At the height of construction nearly 2 000 men worked on site. The dam was basically completed in 1925 at a cost of £550 000.

Siltation reduced the capacity of both dams considerably over the years, but until recently the dams still fed large tracts of irrigation land.

BRANDVLEI DAM (LAKE MARAIS)

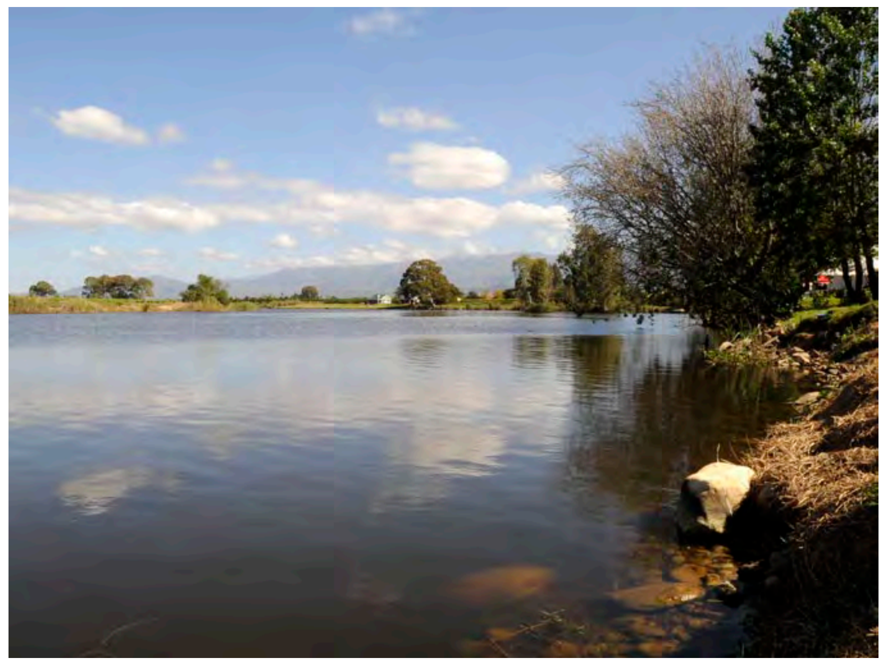
With a total catchment area of 12 600 km² the Breede River (also called Breë, meaning 'broad') is one of the largest rivers in the Western Cape. The river lies on the East Coast of the Western Cape and originates in the Ceres valley, from where it drains in a south-easterly direction, cutting through Mitchell's Pass and meeting the Indian Ocean at Witsand (Sebastian Bay). The river supports a key agriculture region, known for its wines, fruits and vegetables.

White farmers had settled most of the Breede River valley by the beginning of the 18th century, although large-scale development only took place following the cutting of passes through the mountains a century later. The valley was one of the first areas in South Africa where modern irrigation practices were applied – the earliest known irrigation works on the Breede River date back to 1864. By 1918, several irrigation boards had been proclaimed, such as Breede River (Robertson) in 1898, the first in the country. Other included Zanddrift Irrigation Board (proclaimed in 1909), Le Chasseur and Goree Irrigation Board (1910), and Angora Irrigation Board (1917). By the end of the second decade of the 1900s several small weirs and canal schemes had been constructed to abstract water from the river at various points.

Farmers frequently found themselves without adequate water supplies, especially during the dry summer months (the region being dependent on winter rainfall). As far back as 1906 proposals were put forward for the construction of a storage dam at Gerberspoort near Wolseley, together with a high-level canal known as the Ashton Scheme. The scheme appears in various reports of the Cape Irrigation Department until 1909, after which it seems to have fallen off the radar, mainly due to the difficulty in obtaining suitable foundations for a dam.

Following the establishment of the Union Irrigation Department, the development of water storage works in the Breede River valley again came to the fore.

The Breede River in the Western Cape.



Robertson Wine Valley

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Top: Before it became a dam, Brandvlei was a wetland fed by a hotwater spring.

Middle: Brandvlei Dam in 1955, prior to its augmentation.

Bottom: A dry Brandvlei Dam, also known as Lake Marais, during the drought of the 1930s.

At this time about 7 710 ha of land lay under irrigation in the valley. The department investigated several possible locations along the river and eventually settled for a site situated about 10 km from the town of Worcester. Here the surveyors found a natural vlei (*Brandvlei*, meaning 'burning wetland') about 6 miles in extent and fed by natural hot springs. The vlei was located close to the Breede River. At times of flood the Breede River backed up into Brandvlei through a gap 550 m in width between the hills flanking the river and formed a large expanse of water. As the river fell, this water receded back through the gap. The department's engineers conceived the idea of placing a dam across this gap, and filling the reservoir thus formed from the Holsloot River, a tributary of the Breede.

The original design was for a concrete dam, however, test borings revealed layers of sandy clay, sand and gravel, rock bottom being reached only at a depth of about 25 m, in the centre of the gap. Since this would make the cost of a concrete dam prohibitive, the designers instead opted for an earthen embankment without a core wall. Instead a puddle clay apron was to be constructed on the upstream face. This apron extended to a width of 34 m opposite the highest part of the embankment, decreasing in width as it approached the flanks. The original storage capacity of the dam was 45,8 million m^3 and the area of water surface extended 15,5 km^2 (at full supply level).

The Breede River Conservation Board was proclaimed in 1918 to take ownership of the project, and Edmund Burrows was appointed Resident Engineer. Work started in March 1920 under contract with Messrs JW Wilson and Company from Johannesburg. The embankment was pitched on the downstream side as well as upstream to protect it from Breede River floods.

In addition, five (hand-operated) regulating sluices, 1,8 m by 0,9 m, with steel gates were installed for the dual purpose of discharging the required water into the river for the numerous irrigation works downstream, and of allowing through floodwater. The total length of the dam wall was 990 m and it had a maximum height of 7 m.

Since the dam would submerge the original road from Worcester to Villiersdorp, it had to be diverted

The Robertson district in the Western Cape is especially known for its viticulture and wines. Farmers here are still very dependent on the water from the Greater Brandvlei Dam.

Robertson Wine Valley

to pass along the crest of the dam, which was built wide enough to accommodate a 6 m roadway. Along the upstream edge of the crest, a metre high masonry wall was built to protect the surface of the roadway and the travelling public from the north-westerly gales which prevailed during winter months. These winds caused a great deal of inconvenience to the construction team.

Halfway through the project severe floods caused serious damage to the works, however, the project was eventually completed in 1922. The total amount of material in the structure of the dam, including apron, pitching and masonry amounted to 172 025 m^3, and the total cost of the project (including roads) was £47 570.

Like many other dams in South Africa, Brandvlei Dam is plagued by sedimentation, and in 1950 it became necessary to increase the capacity of the dam to 84 million m^3. By 1972, this capacity had diminished to 76 million m^3. During that time the Department of Water Affairs began investigations into suitable off-channel storage sites for a dam to control the runoff of the Breede River. At first it appeared that a dam at the northern exit of the Slanghoek Valley would be most suitable.

The department's engineers had reservations about constructing a major high dam at Brandvlei, mainly on account of the difficulties and high cost expected in the sealing of the pervious foundations at the sight. However, a technology had been developed overseas involving the excavation of a deep and narrow cut-off trench and then filling it with impervious slurry material. Engineers were confident that the method could be replicated successfully at the Brandvlei site.

So, instead the Brandvlei-Kwaggaskloof basin was selected as the site of the new main storage unit in place of the Slanghoek Valley. The project consisted of raising Brandvlei Dam together with the corresponding raising of the adjacent Kwaggaskloof Dam, which was under construction at the time. Several embankments were also built between some of the surrounding hills. These two storage units then became an integrated off-channel storage unit. The storage capacity of the combined rolled earthfill dam, completed in 1981, was 460 million m^3. Today, the Great Brandvlei Dam as it is known is still a major water supplier to agricultural activities in the area, specifically the wine farms around Robertson.

HARTBEESPOORT DAM

It was Boer General Hendrik J Schoeman who first saw the potential for a dam on the Crocodile River, 30 km west of Pretoria. In 1898, he completed the construction of a dam on his farm *Hartbeespoort*, and named it Sophia Dam, after his wife. The stone and concrete dam, constructed by engineer Emil Kunst, was about 9 m high. This dam did not impound any water, but was used for the leading out of water and the irrigation of adjacent land.

At the opening ceremony of the dam on 28 May 1898, General Schoeman made a pledge to President Paul Kruger to build a dam using government funds. The purpose of such a project would be to irrigate a few plots of land on which poor whites could be settled. On 1 April 1899, General Schoeman wrote a letter in which he stated that he was willing to sell a portion of his farm for the above-mentioned project. President Kruger reportedly welcomed this idea. The outbreak of the South African War in October 1899 put a hold on the implementation of the project, however.

When the war ended in 1902, the total reconstruction of South

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Top: *Hartbeespoort Dam early during its construction in 1921.*

Middle: *More than a million bags of cement went into the original 59 m-high Hartbeespoort Dam wall.*

Bottom: *For many years Hartbeespoort Dam carried the main road between Rustenburg and Pretoria. The road was opened to traffic for the first time in September, 1923. From the Pretoria side the road goes through a short tunnel.*

Tygerpoort Dam

Situated about 35 km south of Bloemfontein the Tygerpoort (or Tierpoort) Dam was designed by the Irrigation Department for the then Kaffir River Irrigation Board soon after the First World War. Following investigations into the project, including a geological investigation by well-known geologist Alex L du Toit, construction of the dam started under contract in 1920.

Nearly the entire project was constructed by hand. In addition to the 70 labourers, there were 12 scotch carts, 90 oxen and two horses on site. The scotch carts were used to bring the earthwork to the embankment, while consolidation was by means of tramping of oxen assisted by a roller. The relatively small amount of concrete required was hand-mixed throughout. On the canals (which had a total length of 30 km), all excavation in soil was done by pick and shovel while excavation in rock was undertaken through drilling and blasting.

Tygerpoort Dam featured quite an unusual design for the time. It was constructed of earth with a core wall. This core wall was not on the centre line of the dam, but well upstream of this. The face of the dam above the core wall was protected by a reinforced concrete slab monolith in the lower portions with the core wall. The dam had a capacity of 34 million m^3 with a maximum wall height of 19 m and a crest length of 120 m. At 183 m long the main spillway was designed to discharge a flood 1,5 m in depth over the spillway crest (1:50-year flood event). An auxiliary spillway, 32 m in length was constructed across a neck between the abutment wall and a small koppie, the latter separating the auxiliary spillway from the main spillway. The waterway channel of the two spillways led overflowing water well away from the toe of the embankment and the channel was formed by mostly unweathered dolerite. The dam was completed in 1923.

In February 1988, central parts of the Free State and the Northern Cape were subject to severe rainfall. The flood peak at Tygerpoort Dam reached 1 100 m^3/s (1:200-year flood), causing water to overtop the embankment, rising 300 mm above the crest. On Sunday, 21 February, the Tygerpoort Dam failed, sending a rush of water downstream. Ironically a delegation from the Department of Water Affairs had visited the dam just a month earlier to discuss the requirements for the dam safety inspection with the irrigation board. They had found the upstream slab cracked in places and, while it had been repaired with mortar, it was no longer watertight. Bushes were growing on the downstream slope although no erosion was noted, and both spillways were found to be in excellent condition.

Thankfully no lives were lost as people living downstream of the wall had already been evacuated, but the incident did flood parts of the N1 highway, washing away the approaches to a road bridge as well as the approaches to the main railway line downstream of the dam. Considerable erosion damage was caused to farmland while many houses and other buildings were inundated.

At the dam itself all the embankment material had been removed from abutment to abutment. The inlet tower, which was located upstream of the embankment, was also removed by the force of the flowing water, indicating the high flow velocity. The foundation block for the tower , the upstream control valve and the outlet pipe encased in concrete remained intact. In addition, the concrete core wall was still intact except for the central part, which could not withstand the force of the fast flowing water.

Tygerpoort Dam was the third-largest dam ever to fail in South Africa.

Africa got underway and investigations into a possible dam on the Crocodile River resumed. Unfortunately, General Schoeman would never witness his vision become reality. In May 1902, he died violently when a lyddite bomb used as an ashtray exploded in his house in Pretoria. There was much speculation that his death was not an accident, but rather a result of his participation in the South African War. Schoeman's son, Johan Hendrik, revived plans for the building of a dam, and he put 2 000 ha of farmland under irrigation through a series of unlined furrows with water from Sophia Dam to prove the viability of such a scheme.

Following its establishment after the war the Transvaal Irrigation Department surveyed rivers for possible dam sites, including the Crocodile River. In 1905, Swedish engineer August Karlson also recommended to the government that a dam should be built. Following its own investigations, the Transvaal Irrigation Department proposed a 43 m-high

The scheme would be the largest government irrigation settlement scheme of its kind constructed in South Africa at that time.

gravity dam. Unfortunately, Sophia Dam was washed away during floods in January 1909, and the establishment of the Union of South Africa in 1910 postponed any further work on the scheme until 1914.

That year increased interest resulted in the promulgation of the Hartbeestpoort Irrigation Scheme (Crocodile River) Act, which authorised the construction of the Hartbeespoort Dam and associated canals. The scheme would be the largest government irrigation settlement scheme of its kind constructed in South Africa at that time. The estimated cost of the scheme was £605 000. This sudden flare-up of interest in the project is ascribed to various factors, such as the political occurrences of 1913 and 1914 (for example, the miners' strike and uprisings on the Witwatersrand). It is said that the government could have passed the project to appease the white electorate.

Construction was to start concurrently on the dam and irrigation canals at the end of 1915. However, South Africa's involvement in the First World War meant that the project was sidelined once again. In the meantime, a detailed survey was undertaken of the irrigable area, while the sight provisionally selected for the dam was minutely surveyed in order to determine the final alignment of the dam and spillway. After these investigations, it was decided to move the dam a short distance below the site originally selected. The dam was to be located in a poort in the Magaliesberg Range through which the Crocodile River cuts its course.

As is the case with many dams constructed in South Africa, Hartbeespoort Dam was named for the farm on which the wall was constructed. Or so it was thought. Actually, the site was located on the farm *Hartebeesfontein, Hartebeespoort* being its next-door neighbour. It is thought that the difficulty in locating the boundary between these two farms was responsible for the naming mistake.

The implementation of the scheme did not go as planned. The war put a huge damper on the project as State funding to a number of government departments was slashed. As a result, preliminary steps to get ready for construction only started in August 1916. This included building of a light railway siding starting from Brits West Siding to site, a distance of about 16 km. Using the railway line cement, stone and sand would be transported to site by cocopans drawn by oxen, horses and mules. The Irrigation Department also purchased a second-hand electric power plant along with all necessary electrical accessories to drive the machinery on site. Until the end of the war the labour contingent was kept busy by undertaking preliminary work, including constructing roads and a footbridge, staff quarters, sheds etc.

Just as work started to get underway, in January 1917, a serious dispute was declared with AC van Maareseveen, the owner of the farm *Hartebeestfontein* on which most of the dam wall was to be located. The farmer applied for an interdict restraining the government from building the dam and expropriating his land. He also claimed damages for trespassing, and during the court case all work on site was suspended and construction camps removed. In total eight farms were affected by the construction of the dam. The Irrigation Department generally experienced great trouble in acquiring this land. Maareseveen eventually lost the case, and in 1918 the Hartbeestpoort Irrigation Scheme (Acquisition of Land) Act was passed, authorising the government to expropriate certain land for any matter relating to the construction of the scheme. In the end, most of the land required was expropriated through this piece of legislation.

Interestingly, the project also required the relocation of a large black community established on a number of farms (about 12 500 ha in total). These farms were registered in the names of the chiefs, Jacobus Mare Mamogale;


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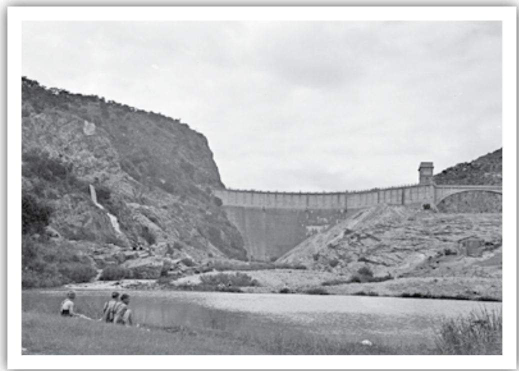
***Top:** The original jetty on Hartbeespoort Dam in 1927.*

***Bottom:** A historic photograph of the Crocodile River downstream from the Hartbeespoort Dam.*

***Top left**: Bathers relax on the banks of the Crocodile River downstream of the Hartbeespoort Dam in 1936.*

***Middle left**: Floods rush through the Hartbeespoort Dam in 1941.*

***Bottom left:** A 1950s photograph of the Hartbeespoort Dam depicting the original side-channel spillway, which was erected on the left flank.*



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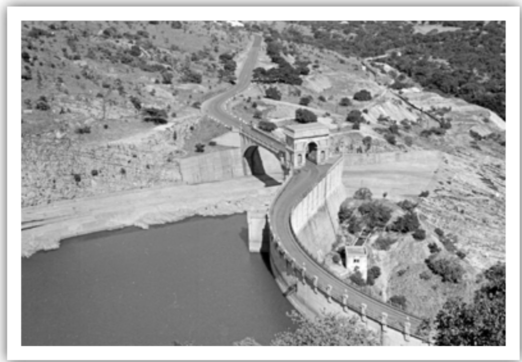

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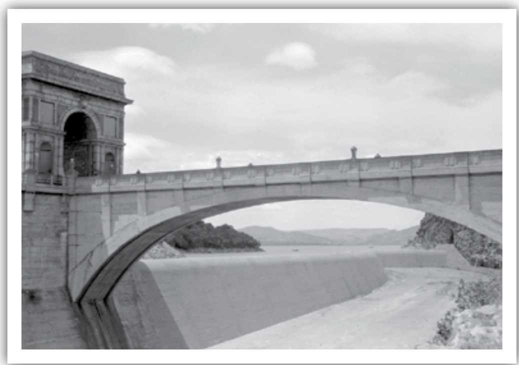

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Johannes Mare Mamogale and Darius Mogale. The land belonging to the two Mamogales adjoined Bethanie Mission properties belonging to the Hermansbrug Mission. Early in the Hartbeespoort Dam project an arrangement was come to with the chiefs, in which they agreed to give the government certain farms required for the scheme, taking in exchange an area 10% in excess of the area ceded, lying to the west of the farms held by them, and including the Hermansburg Mission farms.

The Irrigation Department was also not prepared for the rising costs of the project due to the difficult terrain through which the canals had to be constructed.

In 1913, however, the Native Land Act was passed (Act No 27 of 1913). The law, which incorporated territorial segregation into legislation for the first time since Union, created reserves for black people and prohibited the sale of white territory to blacks and vice versa. However, since the arrangement with the Mamogale and Mogale chiefs were made prior to the promulgation of this Act, government allowed this transaction to occur.

Difficulties kept plaguing the Hartbeespoort scheme. During construction there were no less than four Resident Engineers, GT Richie (August 1918), W Cooper (September 1918 to March 1921), FW Scott (March 1921 to 1922) and BT Twycross (September 1922 to 1923). In October 1918, Spanish Influenza broke out in the construction camp and spread rapidly. In all, nearly 240 people were taken ill. Work stopped completely and only resumed again in January 1919. The Irrigation Department was also not prepared for the rising costs of the project due to the difficult terrain through which the canals had to be constructed. Some of the rock foundations on which the dam wall itself was constructed also had to be excavated deeper than was thought previously.

When public criticism against the slow progress of construction began to grow, especially when the First World War ended, greater provision was made to push ahead

Dams have traditionally been named after the farms on which they are constructed, however, Hartbeespoort Dam was actually built on the farm Hartebeestfontein.

Lani van Vuuren

Chapter 6

Lani van Vuuren

the building of the scheme.

The dam design was adapted from a gravity structure to a varying radius arch structure 59 m high. This allowed for much less cement to be used. Nevertheless, more than a quarter of a million bags of Portland cement were used in the wall. The foundation could be completed in one dry season. By May 1921, the river was diverted, and excavation of the foundation completed by July, which enabled concrete to be placed.

The dam features a side channel spillway on its left flank. Two outlets, one of each bank, were provided to supply water to a canal system which would eventually stretch 64 km along both sides of the Crocodile River valley. The main canal (East) is 48 km long and the main canal (West) is 56 km long. Both canals have a carrying capacity of 8,5 m^3/s. The north canal, which is an extension of the east canal, is 30 km long. The total length of the branch canals is 532 km.

At that stage, Hartbeespoort was the largest dam under construction in the country and the State decided to use the project as a job creation scheme for whites. At first, men especially selected were sent from government headquarters in Pretoria, but later as demand grew they simply arrived 'en masse'. In 1921, LLR Buckland writes in a department magazine: "Mob is now a descriptive word. For about five weeks the air seemed filled with the rush of passing strangers. The docks at Liverpool or perhaps Antwerp during the advance of the Germans through Belgium in the early days of the war might supply a parallel."

Left: The Hartbeespoort Dam sluices as they look today.

But while the labour force was eager to arrive, many also seemed too eager to leave. Many of these men were not accustomed to hard labour, and some suffered from diseases such as malaria contracted during the war. According to Buckland, the situation got so bad that "one day 33 men would turn up" and the next day "30 would start to walk back to Johannesburg". These labour troubles set back work tremendously, and finally, permission was asked to employ additional black labour.

At the peak of construction, some 3 300 men were employed at the dam, including 19 engineers. The men also brought their families along with them so that at one stage there were about 10 000 people living on site. All of these people needed basic services, such as water, sanitation and electricity supplied to them.

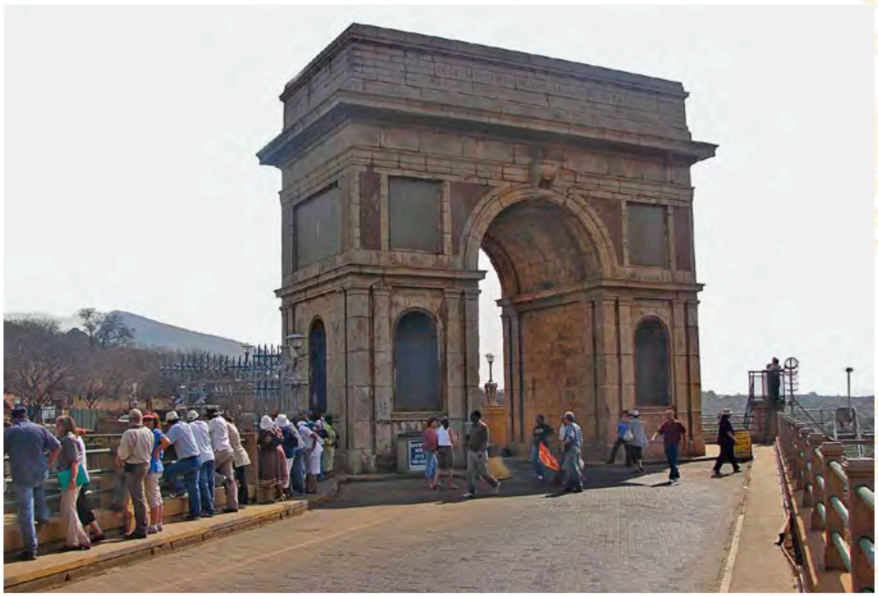
Hansie Pretorius

Hartbeespoort Dam overflowing in 1967.

The more experienced workers were used at the dam itself, while others were used on the canals. The workers were accommodated on-site in houses, semi-detached houses and housing blocks with four living quarters. The site also had an office block, store, blacksmith, and a small hydropower station. While the site was more mechanised then other dam construction sites of the time, much of the work was still done using pickaxes, spades and wheelbarrows.

By April 1923, the wall was completed, and only the finishing of the parapets and crest road remained. During the construction phase the dam impounded the floods of 1922/23. The whole scheme, including the canals, was completed in 1925. The dam was filled on 11 March 1925, and a maximum flood of 2 700 cusecs passed down the spillway on 26 March of that year. After completion, 97 farmers and 65 lessees

Drinie van Rensburg


Drinie van Rensburg

***Top**: One of the two Latin inscriptions on the arch on the dam wall.*

***Above**: The replica 'arc de triomphe' on the Hartbeespoort Dam wall. The outside of the 12,4-m high arch was done in pre-cast concrete. To brighten up the exterior work, an experiment was made of applying bold colour effects by means of mosaic tiles. Few of the original tiles remain.*

made use of the water from the Hartbeespoort Dam.

The west end of the dam wall sports an unusual feature, an arch built as a replica of the Arc de Triomphe. This was not just an aesthetic embellishment, but serves a very structural function. The spillway trough of the side

Engineering statistics of Hartbeespoort Dam

Year of completion	1923 (raised 1970)
Type	Variable arch wall of mass concrete
Gross storage capacity	194,6 million m^3
Wall height above lowest foundation	59,43 m
Crest length	100,6 m
Type of spillway	Controlled, crest gates
Capacity of spillway	2 322 m^3/s
Material content of dam wall	68 000 m^3 concrete
Surface area of dam at full supply level	2 062 ha

The dam has unfortunately become famous not for its aesthetics or water storage ability. Rather it is cited as one of the worst examples of eutrophication.

channel spillway is located on the left (western) bank and the arch ends at this point. Normally an arch dam has contact with both flanks of the valley to distribute the water and other loads. The Irrigation Department engineers overcame this problem of supporting the 'free standing' upper portion of the arch on the left flank by the construction of the miniature Arc de Triomphe. There are two inscriptions on the arch. The inscription on the eastern side reads *Dedi in deserto aquas, flumina in invio* which means 'I give waters in the wilderness and rivers in the desert (Isaiah 43:20). The inscription on the western side reads *Sine aqua arida ac misera agri cultura* which means 'Without water it is arid and miserable in agriculture'.

Johan Schoeman, son of General Schoeman, laid out the towns of Schoemansville, Meerhof, and Kosmos on the shores of the Hartbeespoort Dam in 1923. He also erected a café and built a jetty for boats. In 1928, the Brits magisterial district was proclaimed. This was as a direct consequence of the increased activity in the Hartbeespoort area, and rapid development that took place under the scheme.

In 1964, the Department of Water Affairs proposed that the dam be raised to increase its capacity and to make a larger volume of water available for irrigation purposes. The raising of the dam was done by means of ten 2,74 m radial crest sluices on the spillway raising the full supply level by 2,4 m. The dam has a crest length of 140 m and a capacity of more than 200 million m^3. Today, the dam still irrigates almost 14 000 ha of land. During the raising project all the old canals were lined with concrete.

The dam has unfortunately become famous not for its aesthetics or water storage ability. Rather it is cited as one of the worst examples of eutrophication, resulting from high levels of phosphates and nitrates washing into the dam.

This had had a negative affect on the water quality, the fish life, use of the dam and the environment. The Department of Water Affairs has initiated a remediation programme called Harties Metsi a Me (meaning 'Harties, my water'), which is working towards improving the situation at the dam. Rand Water is the implementing agent for the programme.

VAAL BARRAGE

'Gold fever' first hit the Transvaal in the 1870s, first near Pietersburg (today Polokwane) and later in the Eastern Transvaal, close to Pilgrim's Rest, Lydenburg and De Kaap. However, these discoveries were mere dress rehearsals for the mineral revolution which followed when gold was discovered on the Witwatersrand in the 1860s. The latter resource was so huge that the ZAR became the biggest gold producer within 12 years of its discovery.

The discovery led to the establishment of Johannesburg as people from all over the world drifted to the area to seek their fortunes. But while there was plenty of gold, water was scarce. No major rivers flow here and, at first, people had to depend on small rivers, streams and springs. This included the Jukskei River, Natalspruit, the springs of Doornfontein and Braamfontein, as well as the wetlands of Bertrams and Fordsburg. Residents also captured rainwater. Water shortages were first reported in 1887, and water was sold at exorbitant prices. In times of drought residents had to do their washing with ammonia and lavender water, with soda water being used to prepare food. The rich citizens of Johannesburg even used soda water to bathe in (early soft drink and beer manufacturers did very good business during these times), leaving the poor to disguise the smell of their

A smelly and dusty place

In its early days Johannesburg hardly conjured up the glitzy, glamorous images it does today. In 1897, James Bruce wrote the following about the town: "The streets and road alternate between mud for the two wet months and dust in the rest of the year, and in the dry months not only the streets but the air is full of dust, for there is usually wind blowing. But for this dust, and for the want of proper drainage and a proper water supply, the place would be healthy, for the air is dry and bracing. But there had been up to the end of 1895 a good deal of typhoid fever, and a great deal of pneumonia, often fatal. In the latter part of 1896 the mortality was as high as 58 per thousand."

NLSA

A dust storm hits the Johannesburg streets in 1895.

Bon Accord Dam

Farmers first established a river board to control the distribution of irrigation water from the Apies River for farms between Pretoria and the Pienaars River under the Transvaal Irrigation Act of 1908. In 1917, the river board approached the Irrigation Department with a view to investigating the possibility of establishing storage works on the river. Circle Engineer CDH Braine visited the area in August of that year looking at various potential sites. Several promising sites were selected and the department was asked to have detailed surveys made. In the meantime, the owners of five farms organised themselves into the Bon Accord Irrigation Board.

Early in 1918 the Irrigation Department sent out surveyors to undertake a reconnaissance survey, and they identified a possible dam site on the farm *Onderstepoort*, near Bon Accord Siding. However, after investigating the merits of the scheme, followed by a personal site visit on 24 December, 1918, Irrigation Director FE Kanthack rejected the initial site, instead calling for an alternative dam site higher up in the valley to be investigated. He visited the scheme again in 1920 and, after reviewing the merits of both sites, chose the upper one.

Construction of the dam started towards the end of 1920. Initially a contract of £45 000 was awarded to a private contractor, however, work did not progress as desired, and in 1922 the Irrigation Department took over the project. The dam was designed to be of earth with a puddle core. The upstream face was protected by dry-stone pitching, while the downstream face was planted with grass. Two feet gauge, 20 lb rail track were brought on to the works, and small second-hand locomotives were purchased to haul material in cocopans. Scotch carts were also used to bring material found in small pockets near the dam. As at many other dam sites of the time consolidation was done by scrapers and the tramping of oxen. Water was laid onto the bank for the purpose of wetting during consolidation. At the height of construction in July 1923, 600 labourers were employed on the project.

The spillway is situated on the left flank, and consists partly of a masonry overfall weir, with a maximum height of 1,5 m. A channel was excavated for a considerable distance from the actual weir, the spoil forming a bank on the downstream side, protected by a wide dumped rock facing, to divert floods from the toe of the dam. The outlet, which is on the right bank, consists of a 0,9 m diameter concrete culvert with concrete tower, reinforced concrete foot bridge and soil approach bank. The Water Court determined that the irrigation board was only allowed to dam water above normal flow, so as to not cut off water supplies to the City of Pretoria. This was built into the design of the dam. The culvert was to discharge water into three stilling and distribution chambers, with the normal flow of the Apies River passing down the middle chamber, and supply to the right and left bank canals passing through the other chambers. Measuring notches were fixed on all three chambers to measure the supply discharge.

By October 1923, the general level of the dam was safe against potential floods, and by 1924 the project was complete. The dam wall eventually had a crest length of 1 067 m and a maximum height above riverbed of 18 m. The height above spillway level was 2,4 m. Bon Accord Dam had an original maximum full supply storage capacity of 11,8-million m^3.

The first appreciable flood to reach the dam occurred on 17 December, 1923, and the first water for irrigation was let out of the dam on 24 August, 1924. Unfortunately, the 1926 Irrigation Finance Commission found that the scheme was a failure. In its Third and Final Report, on a number of private, small and government irrigation schemes, the Commission noted that: “In many respects this is the most unsatisfactory scheme which we visited.” They found that the water supply for the Bon Accord irrigation project was inadequate, and that the promoters of the scheme and government “were in so great a hurry to get the scheme launched that no opportunity was afforded the technical advisors to collect the relative hydrographic data.”

unwashed bodies with toilet water and perfumes. Water carts, selling a bucket full for as much as two shillings and sixpence were a common feature of the Johannesburg landscape by the 1890s. During 1895, the *AmaWasha*, Zulu men making a living out of doing laundry, were compelled to board trains and wash their customers' clothing as far away as Witbank.

Matters were made worse by the enormous population growth, the town swelled to 102 000 in 1896 from only 25 000 in 1889. By the end of 1901, Johannesburg was home to an estimated 150 000 people. The Republic government, use to leading an economy based on agriculture, neither had the know-how nor the budget to deal with the water deficits in Johannesburg, and it had no choice but to let free market initiatives take the lead. Water concessions began springing up as a result, the first being granted to James Sivewright in December 1887. He was previously instrumental in the founding of Kimberley. Interestingly, the firm of Barnato Brothers was one of the founding members of the new company. In 1888, the Johannesburg Waterworks, Estate and Exploration Company, as it became known, constructed a reservoir and made the first piped water available to the city's residents. Households were charged a minimum of 30 shillings a month, an exorbitant fee in those days. Thereafter, a number of small companies and syndicates followed.

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Mining magnate Barney Barnato also owned one of the first water supply syndicates in Johannesburg.

The syndicates did little to alleviate water shortages, and after a series of governmental commissions of enquiry the Rand Water Board was constituted by legislation in 1903. The Board immediately set out to consolidate all the available water resources under its authority. One of the most significant early policy decisions of the Board was that there would be a fixed rate per thousand gallons, irrespective of the point on the trunk lines from which the supply was drawn. This meant that the Witwatersrand could develop independently of where the source water lay. Another important decision was that the rate of water was not to yield any profit, but was calculated to cover working costs. The Board charged around a tenth of the price compared to the independent syndicates.

When the Rand Water Board was established, the current water sources were used to supply Johannesburg: two or three springs in the Doornfontein area; a well near the corner of Market and Strait streets; a spring at Berea; water from the dolomites at Zuurbekom; a spring in Parktown, and a supply in the Klip River valley. The actual quantity of water that came under control of the Board was in the order of 11 000 m^3/day.

As described in the previous chapter, the Vaal had received considerable attention from hydraulic engineers since the early 1900s. ZAR President Paul Kruger had even proposed the Vaal River as a potential source of supply in the Volksraad back in 1889. One possible reason why the river was perhaps not considered before is that it was at one stage an 'international' river, serving as the

NLSA

Johannesburg residents rush out to buy water during the severe drought of 1895/96.

Vierfontein Dam

One of the first attempts to augment water supply to Johannesburg through the construction of a dam was undertaken by the Vierfontein Syndicate. In 1893, the syndicate proposed a scheme to dam a stream south of Johannesburg, flowing through the valley of the farms *Vierfontein* and *Ormonde*, to the south of Crown Mines. This dam was to provide much needed water to the mines. With financial backing from some of the largest gold-mining companies of the time, the syndicate soon has hundreds of men working on the dam site. Foundations for the dam wall were dug to 15,24 m and crest blocks were cut out of a neighbouring quarry. These were carried by cabling to the site. The dam was planned to store around 4 million m³ of water. By 1899, wall height had reached 13 m. Unfortunately the outbreak of the South African War that year halted any further progress, and the work was never again resumed.

The official opening of the Vaal Barrage in on 27 July, 1923. Governor-general of South Africa, Prince Arthur of Connaught, was an honoured guest.

Rand Water/Johann Tempelhoff

border between the Transvaal and Orange Free State.

Shortly after its establishment the Transvaal Irrigation Department undertook the first comprehensive survey on the river in 1904/5. This survey identified several possible dam sites, which formed the basis of all subsequent work. Ironically, however, the first water storage scheme to be constructed on the river was not for irrigation purposes, as originally envisioned, but for domestic and industrial supply.

Shortly after South Africa became a Union in 1910, drought set in exposing the unstable foundations upon which the Witwatersrand's rapid expansion and growing prosperity was based. By 1911, the mines were the largest water consumers in the area. At the same time, the number of municipal authorities had increased considerably. Together these consumers required a water supply of 40 million m³/day. Rand Water instructed its chief engineer, William Ingham, to launch an investigation to find the most suitable water catchments within a radius of 80 km of Johannesburg to expand the board's sources of supply. As many as 21 different sites and schemes were scrutinised before Lindeque's Drift, on the Vaal River, some 70 km from Johannesburg was settled on as the best solution. Among the other schemes investigated were the Kuilfontein scheme on the Zuikerboschrand River in the Heidelberg district; the Mount Arabel scheme just below the confluence of the Zuikerboschrand River and the Blesbokspruit; and the Koppiesfontein scheme on the Vaal River, 75,2 km upstream from Vereeniging.

The Vaal Barrage scheme was approved by the Board of Rand Water on 26 September 1913. As originally conceived the potential yield of water from the Vaal River and the four tributaries flowing into the barrage was estimated at 91 million m³/day, 45 million m³/day of which could be tapped. It was estimated that costs for the project would not exceed £1,3-million. Ingham wrote in a report in February 1913: "The Lindeque's Falls site is situated about 24 miles below Vereeniging, and, by building a dam 30 feet [9 m] high at the Fall, the water would be backed up the river to Engelbrecht's Drift above Vereeniging for a distance of 44 miles [70 km], and a pumping station could be erected at Vereeniging in the neighbourhood of the collieries." The plan was essentially to dam up the Vaal River over a distance of 60 to 70 km. The water would then be extracted at a point well above the site where the major storage source was located. The deep river banks were to be used as a longitudinal storage passage extending from above Vereeniging, at Engelbrecht's Drift, to the barrage.

In March 1916, the Board approved a plan to expand the capacity of the scheme further by 23 million m³/day. A further £758 000 was earmarked for the project. Interestingly, upon completion in 1923 it transpired that the construction of the barrage only cost £1,5-milion, much less than anticipated. Johann Tempelhoff writes of the project: "In many respects the Vaal Barrage was part of a novel and pioneering

Vaal Barrage from the air. Here the 36 sluice gates can clearly be seen. Each gate measures 7,5 m by 9,6 m and weighs about 26 tons.

endeavour of farsighted engineers who were cognisant of the leisure and aesthetic value significance of the (Vaal) river. It was one of the most ambitious water projects of its kind in South Africa at the start of the twentieth century" (Tempelhoff, 2001).

The project was based on the latest technological developments in engineering. Before plans were drawn up for the barrage, Ingham and Donald Simpson, a member of the Rand Water Board, visited large dam projects in Egypt and Europe to become acquainted with the latest engineering technology. Leading British engineering firms were contracted to supply the necessary mechanical equipment to be used for the barrage.

It was originally anticipated that construction of the Vaal Barrage would start in 1914. However, the First World War broke out that year hampering not only the construction of the barrage, but all of Rand Water's operations. Firstly, this was due to financial reasons. Up until the 1950s South Africa had no domestic capital market, and had to raise all its loans overseas. As a result of the outbreak of war and the diversion of all financial and other resources to the war effort, Rand Water was unable to raise the necessary loan capital to finance the barrage. This would only become available in 1916.

Secondly, the Rand Water Board at that time had a distinctly British character, with practically all of its senior employees being either British or English speaking. As a result the water board lost the services of a substantial number of its employees as they enlisted in the war. In fact, between 1914 and 1918, 75% of head office staff, 57% of the officials of the Chief Engineer's Department and 33% of the ordinary employees of the Chief Engineer's Department enlisted in one or other war-related activity (on the understanding that their posts would be kept open until they returned). Inevitably, all aspects of the work of Rand Water slowed down.

In the end work on the barrage started in June 1916, and overnight the site took on the appearance of a small village. Between 1916 and 1923 the scheme employed about 300 black workers and 40 to 50 white workers. While many white workers comprised carpenters and other skilled trades, about 25 unskilled whites were employed as gangers in charge of squads of black labourers. Interestingly, when construction work started the white employees were accommodated at a cooperative mess established by the Rand Water Board. Later the mess was dissolved and most of the men then took up residence with storekeepers and farmers situated close to the site. On the other hand, the black workers were housed in a compound with their own cooking house. Most were former mine workers. To accommodate the children of construction workers a school was opened briefly on site in 1917. One Miss Tyrer was the first teacher and 22 children at first attended school. However, these numbers proved intermittent as workers came and left the site. Following the December holidays of 1917, the school did not reopen, and Miss Tyrer left to join the war effort.


Lani van Vuuren

The Vaal River, with the Barrage in the distance. Completed by Rand Water Board in 1923, it was the first large structure to be built on the Vaal River.

Construction reports of that time indicate that labour shortages was an intermittent feature of the early years of construction of the Vaal Barrage. In November 1916, 50 black workers left the site to plough their lands. This was a common practice among migrant mine workers, and their return was confidently expected in January the following year. Again in June 1917 an abundant harvest in the African reserves prompted a significant drop in the number of black workers on site. Efforts were now made to attract new recruits from uMzimkhulu in Natal and also from Herschel and Klerksdorp district. It is said that management even urged workers on site to write letters to their families asking the men to come work on the project.

Further delays in construction were experienced in late 1917 when major floods struck the Vaal. Water levels in January 1918 were recorded as shooting up to six to seven metres. Even once the floods had passed their peak, water levels remained high and it was recorded in May 1919 that since concreting had begun, it had been possible to work on the river bed for only 193 days due to its flooded state. Next to strike was Spanish Influenza. A total of 38% of Rand Water's white and 83% of the board's black employees were temporarily disabled by this debilitating disease. Of the 402 workers at the Vaal Barrage project 98% were incapacitated and nearly 10% died. Other health problems experienced included food poisoning, and an outbreak of scarlet fever. Many of the war veterans who joined the project after the First World War also suffered from malaria relapses.

The Vaal Barrage was finally completed in 1923. Spanning the Vaal River over a distance of about 400 m, it is described as 'a veritable monument of engineering skill'. More than 275 000 m^3 had been excavated in rock of which 43 000 m^3 had been cast in concrete. By making use of the Duff Abrams method of steel-reinforced concrete the structure was strong and capable of withstanding all types of flooding conditions. It was constructed in a blend of art nouveau and classical styles. There were 36 sluice gates creating a storage capacity of nearly 70 000 million litres of water. The gear for operating the gates was placed on a platform above the piers, which were in turn supported by concrete columns. An intake station was constructed upstream of the Barrage from where water was pumped to the main pumping and purification works at Vereeniging. The pumps at this station were driven by steam turbines. The turbines also powered alternators to provide electric current for driving the river intake pumps.

The completion of this scheme brought to an end the era of uncertainty and extreme difficulty the Rand Water Board had faced in meeting the demands of its consumers. With water supply from the Vaal River being assured, the Board was able to close down several of its smaller sources, such as the wells at Doornfontein and Braamfontein. In grand style the Vaal Barrage was officially opened on 27 July 1923 by the then Governor-general of South Africa, Prince Arthur of Connaught. A train was chartered to convey guests from Johannesburg to Vereeniging whence they were conveyed to the site by buses and cars.

Irrigation water storage works completed under the direction of the Irrigation Department by 1924

Dam	District	Total storage million m^3
Witpoort	Wolmaransstad	0,9
Klerksdorp	Klerksdorp	5,3
Klipdrift	Potchefstroom	12,5
Calitzdorp	Oudtshoorn	5,8
Laughing Waters	Willowmore	0,4
Krugerspoort	Bloemfontein	5
Prins River	Ladismith	135
Rooikraal	Middelburg	3,8
Leeuw Gamka	Prince Albert	10
Bulshoek	Clanwilliam	6,5
Brandvlei	Worcester	46
Kaffir River	Bloemfontein	38
Stolz River	Beaufort West	1,6
Lake Mentz	Uitenhage	116
Kamanassie	Oudtshoorn	38
Rooipoort	Potgietersrust	0,4
Hartbeespoort	Pretoria	152
Blyde River	Pearston	2,3
Bon Accord	Pretoria	11,8
Grassridge	Cradock	50
Van Ryneveld's Pass	Graaff-Reinet	79
Lake Arthur	Cradock	86

END OF AN ERA

The first golden era of dam building was of short duration. In the aftermath of the First World War the South African economy entered a perilous phase. Between 1920 and 1932 the gross domestic product declined in monetary terms, with almost no increase in industrial output. Factories tightened their belts and terminated employment. The Irrigation Department was, once again, forced to cut its activities, with some schemes having to proceed at a greatly reduced rate of expenditure, with others being cut out entirely. This latter was the fate of practically every proposal in which construction had not actually started by the end of the war.

Another problem that had started to rear its ugly head was the arrears in loan repayment by the irrigation boards. In 1922 legislation was introduced to make it possible to lessen the repayment charges on irrigation loans during the early years after the completion of new irrigation schemes. At the Fourth Irrigation Congress held in Johannesburg, in 1923, Minister of Lands, Deneys Reitz, made reference to the issue. He regarded irrigation and settlement matters as 'one of the great problems of the country', being exceeded in importance only by 'native matters and the poor white question'.

Many blamed the irrigation scheme infrastructure. New Director of Irrigation, AD Lewis, responded to this by saying: "People are apt to overlook [agricultural, financial, political and social] considerations and assume that it is only necessary to construct an irrigation works as perfectly as engineering skills will allow and success is bound to follow as the night the day. In South Africa we are learning the same lessons [as in Italy, the USA and Australia] and we cannot shut our eyes to the fact that many schemes which were initiated with the brightest hopes of success are today struggling against extraordinary difficulties not, as some people have alleged, entirely due to faulty engineering, but chiefly owing to far wider causes." (Lewis, 1923). These wider causes, according to Lewis, included factors such as transportation and marketing of produce and the slow rate of increase of the agricultural population possessing the necessary capital and experience to make a success of irrigation farming.

Also receiving increased attention was the poor white (*armblanke*) issue. The government strongly believed that agriculture, particularly irrigation, had a strong role to play in providing employment and income to the mainly-Afrikaans speaking poor-white community. In the mid-1920s the Irrigation Department received its first instructions to construct large State-driven irrigation schemes employing predominantly white labour. This would constitute the second wave of dam building in South Africa. ◈

7

Depression spurs on development (1930-1950)

The great economic depression and coincident drought over large parts of South Africa would provide impetus to the construction of several large labour-intensive State irrigation schemes during the 1930s and 1940s. In this period subsidies would also be introduced to accelerate the development of private irrigation schemes.

The period between the two great wars was one of uncertainty for world economies. Internationally, many countries were rebuilding themselves after the First World War, and in South Africa the 'poor white' problem was becoming a political quagmire. By 1925, South Africa had a gross domestic product of only R537-million, with agriculture contributing 21% and mining 16%. In 1929, the economy received a hammer blow when the crash of the New York Stock Exchange signalled the start of the Great Depression. South African exports plummeted and a crisis in economic confidence developed on a scale never experienced before.

The country was simultaneously in the grips of one of the worst droughts in its recorded history. By the mid-1930s, Depression and drought had reduced sheep flocks by 15 million head. The price of maize, which was the major agricultural export dropped by half between 1929 and 1935. This compounded the 'poor white' problem in South Africa, and the government of the day responded by announcing the construction of large State infrastructure schemes (including dams and canals), which would set out to employ large numbers of white labour. At the height of the State's intervention, relief measures made up around 16% of the national budget. Public works

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***Top**: A 1932 photograph of the Marico-Bosveld Dam showing the upstream face of the embankment. Note the team of oxen in the distance.*

***Bottom**: Olifantsnek Dam outside Rustenburg shortly after its completion in 1936.*

schemes provided some training for unskilled labourers, educated and trained their children and provided free housing and medical services.

A number of irrigation projects that had been considered for many years without action were suddenly fast-tracked, including the Buchuberg irrigation scheme, the Loskop irrigation scheme, and the Vaal River Development Scheme, which would lead to the development of the largest irrigation scheme in the country (Vaalharts) and the country's strategically most important dam (Vaal Dam). The Irrigation Department, which was responsible for designing and constructing these schemes, found itself shoulder-deep in work, and additional staff had to be added hastily to cope with all the additional projects. Its role was slowly expanding, driven by increasing pressure on water resources and the need for more

By the mid-1930s, Depression and drought had reduced sheep flocks by 15 million head. The price of maize, which was the major agricultural export dropped by half between 1929 and 1935.

Poor, white and Afrikaans

The term 'poor white' was originally derived from the southern states of the US. The term was first used in 1890 although the problem is believed to have existed long before then, intensified by natural as well as manmade disasters. At that time the majority of the white Afrikaans-speaking population were still engaged in subsistence farming, which required a relatively low level of education.

From mid-1895 to late 1896 a severe drought raged over large parts of South Africa. At the same time rinderpest, a fatal cattle disease, swept through southern Africa. In the Transvaal alone, half of the farmers' cattle herds were wiped out. Then the South African War broke out in 1899. Apart from killing thousands of people, mostly civilians, the war finally crushed the farming community through Britain's Scorched Earth Policy, which saw an estimated 30 000 farmsteads being destroyed in the Transvaal and the Orange Free State. Most of the herds in the Boer republics were decimated, with crops and implements destroyed.

Thousands of families were unable to be resettled on their farms, and they flocked to urban areas in search of work. By 1926, 41% of the white Afrikaans-speaking population lived in towns and cities, compared to only 2% in 1890. Because of their low levels of education (a 1930s survey found that one in ten was totally illiterate) employment was hard to find. Girls found work at hand laundries or as cleaners, boys as messengers or newspaper sellers. Many white Afrikaans-speaking men worked as trolley or cab drivers; brick makers or mineworkers. Others turned to prostitution and crime.

A 'poor white' girl or Armblanke photographed outside the door of a house in 1890. Girls from poor families were often sent to cities ahead of their families to find employment as nursemaids or cleaners.

Another problem was the centuries-old heritage practices of the Boer community. Once a farmer died his land would be divided equally among his sons. Since these families were usually large (in the early twentieth century more than 50% of white families still had more than four children) the sons would all end up with very small lots on which they could not make a living. In many cases, they became *bywoners,* labourers who provided their services in exchange for privileges such as housing and grazing. Malnutrition and stunted growth was common among these families.

In 1929/30, the poor white problem became the subject of a report published by the Dutch Reformed Church and funded by the Carnegie Commission. The commission found that 17% of the white community could be considered 'poor' (about 300 000 people). The vast majority were Afrikaans speaking. At the start of the Great Depression the white poverty issue hit crisis proportions.

Interestingly, it was recognised that black poverty was just as acute as white poverty. However, to justify a focus on whites only, it was suggested that solving the poverty of whites would also benefit other communities.

centralised control in their allocation and development.

By 1938, expenditure on departmental works had increased ten-fold over that in 1928. The Loskop and Vaal schemes together would see an expenditure of over £5-million in six years. In many cases only preliminary surveys had been done on these schemes, and survey and design parties had to set out hastily to survey sites and draw up engineering plans. In many cases design would take place after construction teams had already started preliminary work. Other measures implemented to provide relief included reducing interest of small irrigation loans (up to £500) to 3½ % and the implementation of a 'no water, no cost' principle for Union boring operations. By the end of the 1930s, the Irrigation Department had a large staff component and many resources associated with a rapid growth in construction.

Workers for these projects were provided by the Department of Labour, ensuring that the objective of employment of destitute whites, especially single white men, met with as much success as possible. Interestingly, accommodation, amenities and even loans differed significantly depending on which project the men found themselves working on. For example, at the Pongola irrigation scheme in Zululand white labourers earned five shillings a day and were housed in wooden structures, while at Vaal Dam they earned two shillings a day, with a bonus of 1 shilling sixpence for every day worked. Here the men lived in electrified zinc huts. At Vioolsdrif on the Lower Orange River, workers were housed in bell tents and earned four shillings eightpence a day. In many cases, the use of white labour turned out to be less than ideal. Many of the men were inexperienced and unaccustomed to such hard, physical labour in often hostile terrains. In 1934, Director of Irrigation, AD Lewis, writes in his annual report for that year: "The experience of this department is that where white labour is being used expenditure is relatively high, for example, to keep an average workforce of 360 [such as on the Rust-de-Winter irrigation scheme] requires recruitment of more than 1 550 workers." It was found that in cases where labourers were well fed, their output improved. At many sites meals were initially provided at low cost (around one shilling) and later supplied for free.

South Africa's economic resurgence preceding the Second World War created an acute labour shortage, sharply increasing project costs. On insistence of the Irrigation Department, who feared that projects would not be completed in time, the Department of Labour had to hire great numbers of black and coloured workers, which was contrary to the original intent of the fast-tracked projects. This situation was greatly exacerbated by a diminished white workforce

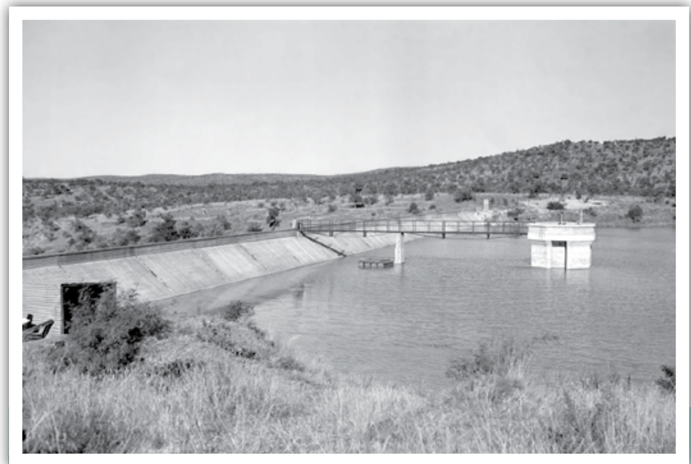
DWA

Unemployed whites were put to work, and later settled, on many labour-intensive State irrigation schemes.

Of cats and men

Few people know that during the 1930s, the Irrigation Department also had a cat on its payroll. At that time the department owned large warehouses in Pretoria from where food such as maize meal was sent to the different infrastructure sites. The warehouses were often plagued by rats and mice and when a cat found his way into one of the warehouses the manager did not complain. However, the cat could not live on rats and mice alone, and the manager could not afford to supplement the cat's diet. So a letter was written to the department's headquarters in this regard. The cat was promptly placed on the payroll, his payment being a monthly quota of milk.

DWA/eWISA



DWA/eWISA

DWA

and drastically reduced funding during the war. Of course, as was the norm at the time, black workers earned far less than their white counterparts for performing the same work.

BUCHUBERG DAM

One of the first projects to kick off during the Depression years was the Buchuberg scheme on the Orange River. The idea of constructing a dam and canal in the lower reaches of the Orange River to irrigate the narrow strip of alluvial soil which lies across the south bank of the river to the west of the Buchuberg range (so named for the

Top left: *This photograph taken in 1931 shows the sand-washing apparatus used at the Marico-Bosveld construction site.*

Top right: *Rust-der-Winter Dam on the Elands River was completed in 1934. It was one of the few construction sites in the 1930s where mechanical equipment was used extensively.*

Right: *Buchuberg Dam on the lower Orange River as seen from the air. Despite siltation problems the dam still provides water to a number of irrigators in the region.*

AD Lewis

Alfred Dale Lewis was the second Director of Irrigation of the Union of South Africa and the first South African-born engineer to hold this post. The son of Dr and Mrs CE Lewis, he was born in Cape Town on 24 September 1881, and obtained his BSc Degree at the University of Cape Town. He then went on to study at Cambridge University, where he obtained his Masters Degree and AMICE qualification in 1904.

From the very beginning, Lewis was interested in the subject of irrigation engineering, a subject which he was later to become a world authority on. After a year's practical training under WH Hunter and H Congreave he started his career with the Manchester Ship Canal engaged in construction of new coal hoists and deepening a waterway. He also inspected irrigation works in Egypt. A year later young Lewis went to become Engineer in the Government of India Irrigation Department, working on irrigation canals in the Punjab.

Two years later, Lewis came back to his home country, taking on the post of Circle Engineer of the Lower Orange River, stationed in Kimberley for the then Cape Irrigation Department. Lewis supervised the construction of numerous irrigation schemes in the Cape Province and the Free State while he was Circle Engineer. He was first appointed on a five-year contract, but his professional skill was soon noted, and he was later transferred to the newly established Union's department's head office.

He had an unmatched quest for knowledge and would endure much hardship in his search to learn more about South Africa's water resources. Lewis was particularly fascinated by the country's largest river, the Orange, and on 24 November 1912, he set off on an epic journey to explore its lower reaches for the possibilities of irrigation. "There can hardly be a true South African and certainly no irrigation engineer, with a soul so dead that he can contemplate our greatest river tearing down to the ocean through a vast area of country which is thirsty for water, without feeling that some great effort should be made to design and carry out irrigation works for the Orange River which would rival those famous works of other great rivers of the world," he said in his report following his expedition.


DWA

***Below**: A graphic representation of the 400 km journey undertaken by Dr Alfred Lewis along the Lower Orange River in 1912.*

Ralf Broemer

He first travelled by horse-drawn cart from Kenhardt to Pella mission station. It was one of the hottest years on record and the country was suffering from a great drought. By the time Lewis reached Pella on 27 November two of his horses had died. From this point onwards it turned out to be impossible to follow the river even on horseback, so Lewis decided to complete the journey – a distance of over 400 km – on foot. For 16 days he travelled alone beside the river, over rough terrain, carrying all his gear. Temperatures reached 41°C in the shade in some places. He sometimes managed to procure the services of carriers from Khoi villages dotted along the landscape to help him with his load (in his final report Lewis writes how he had to bribe these men with tea and tobacco). When his food ran out he procured goats for slaughter from the passing villages. Through all of this he kept his sense of humour. Managing to procure a riding ox for a while, Lewis writes how comfortable it is to ride "the only body part tiring being the arm from slogging." He reached the Orange River Mouth on 12 December, and the detailed report he prepared shortly thereafter served as the main information source for planning for many years.

Lewis' travels were not limited to South Africa. He inspected irrigation works in England, Spain, Egypt, Australia, New Zealand, India, Kenya, the USA and Canada, later writing books on his findings. While investigating the original source of South African water law, which has its roots in Roman law, he was informed that the Italian government suffered fewer bad debts in recovering loan repayments and rates for the construction of State water works than was the case in South Africa. So Lewis decided that study of the matter required him to read and speak Italian, which he learned in his spare time. This came in handy when he eventually visited the country in 1927.

During the First World War, Lewis served first with the SA Infantry, then with a commission in the Royal Engineers with the 67th Field Company. He was seriously wounded in France, but was later sent as Staff Major to Mesopotamia, in charge of the Tigris River Conservancy. Here he supervised, among others, the closing of the Chalala and Major Cabir branches of the Tigris River to conserve navigation in the main channel.

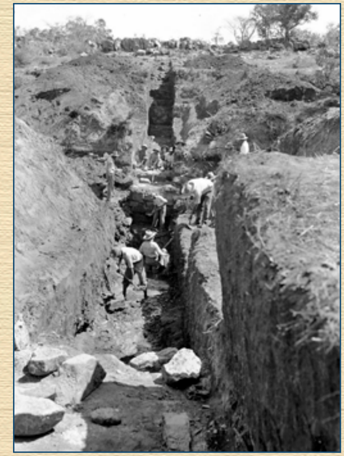
Upon his return to South Africa he succeeded FE Kanthack as Director of Irrigation in 1921. He was only 33 years old. The post-war recession was imminent and, believing that the full implementation of irrigation schemes in settlement areas would alleviate the anticipated unemployment, he prevailed on the government to set up a permanent Irrigation Commission and to take control of a number of existing irrigation schemes. As a result of this policy, thousands of workers found employment through irrigation schemes.

Realising that some time in the future the Depression would be followed by a period of growth, Lewis intensified the study of South Africa's water resources. Under his leadership reconnaissance and major surveys were undertaken in various catchments. In 1924, he delegated three survey parties to investigate the possibility of the Vaalharts Irrigation Scheme. He also laid down the broad outline of the Orange River Project. Lewis' ambitions for this river, however, were way ahead of their time, and in 1928 he shifted his sights on South Africa's second-largest river, the Vaal. He was extremely dedicated in his work. In the 1930s, when the Bon Accord Dam outside Pretoria was at the point of breaching, Lewis himself worked to solve the problem, labouring almost continually for 72 hours until the crisis was passed.

Some of the country's largest water development schemes were completed during his tenure, including the Vaal Dam, Vaalharts, and Loskop schemes. Interestingly, one of his greatest achievements was not in the field of irrigation engineering. For years Lewis had pressed various government departments and officials for a complete topographical map of the country, without which he found himself unable to calculate the actual catchment areas of rivers in South Africa. He was told it would take between 30 and 50 years to produce the maps he requested.

With advances in aviation and the support of the South African Air force, which was likewise in need of good maps, Lewis convinced the government to authorise him to do the work. He achieved his goal in two-and-a-half years, employing 12 field surveys parties, a team of draftsmen and a number of land surveyors to carry out the work. The area of land covered was nearly 1 295 000 km^2. These maps were of inestimable value for water development planners throughout the Second World War and for many years afterwards.

During the early years of the Second World War, Lewis took on an advisory role to the Department of Defence. He retired in 1941.



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Left: Men at work excavating a trench for the Marico siphon, part of the Marico-Bosveld scheme, circa 1932. Construction of the scheme started in 1930.

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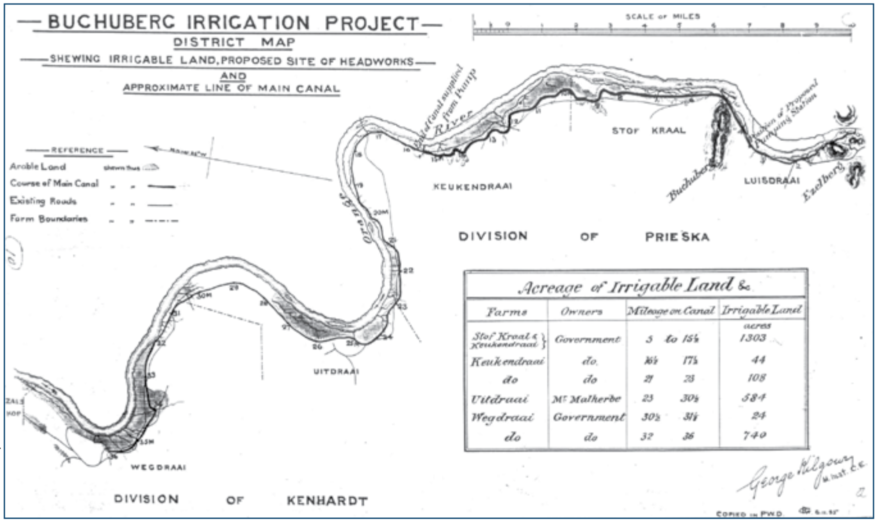
Below: Oukloof Dam, one of the large dams completed in the 1930s under the leadership of AD Lewis.



Lokkie van Zyl

Buchu plant – a medicinal herb – which grew wildly there) was considered as far back as 1872, shortly after the discovery of the first diamonds in the Northern Cape. The government owned a series of farms along the river front, which had been reserved for irrigation.

The first definite scheme for the irrigation of any portion of these farms was prepared in 1895. During that time private irrigators had started using water from the Orange River through the construction of small weirs. The Cape government organised a survey and estimates were prepared for a canal 58 km long, to irrigate about 1 133 ha, on four farms. It was to take off at a point on the Orange River, about 8 km above the Buchuberg Range, from above a masonry weir, about 4 m high. The scheme was discussed in the Cape Parliament by Cecil John Rhodes, John X Merriman and Jan Smuts. However, the calculated cost of the scheme at £40 per acre was considered prohibitive and the scheme was placed on the backburner.

During the next decade the scheme would come up in Parliamentary discussions often, and various changes were proposed to the original design in efforts to come up with a cheaper solution. MPs expressed their concern over the fact that the Colony's water resources were allowed to flow "useless into the sea," and pleaded that the waters of the Orange River should rather be used for irrigation.

In 1906, it was proposed that the Buchuberg Irrigation Project be brought back on line. Director of Irrigation at the Cape, WB Gordon, proposed the construction of a smaller canal to irrigate

***Top**: The original plans drawn up for the Buchuberg irrigation scheme in 1895.*

***Top right**: At Buchuberg, excavation teams typically comprised 14 men, who then selected their own team leader.*

***Bottom right**: The dam wall at the start of construction in 1930.*

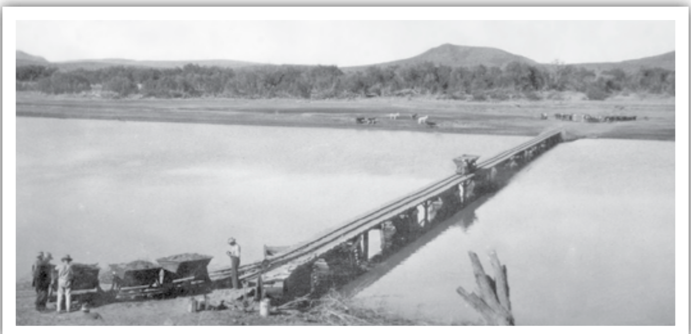

DWA


Lokkie van Zyl

Without bread, without beer

O Boegoeberg broodloos,
Boegoeberg bierloos,
Seeploos, lampolieloos,
Skeerlem-, papierloos,
Laat geskied'nis bewys
Ons betaal 'n hoë prys
Om Oranje te dwing
Haar waters te bring
Aan akker en wingerd
en huis

(Poem written by anonymous staff member of Irrigation Department)



Lokkie van Zyl

Lokkie van Zyl

Lokkie van Zyl

***Top left**: The temporary bridge over the Orange River providing access to the sand island. Sand was brought to site on cocopans.*

***Middle left**: The sand and rock mixers used at Buchuberg Dam.*

***Bottom left**: A close-up of the Buchuberg sluices during construction.*

567 ha at a cost of about £20 an acre. The canal would be about 27 km long instead of 58 km as originally planned. Gordon suggested that a weir would not be needed because the inlet of the canal would be above the rapids. The entire project would cost £34 000. In his report, laid before Parliament in 1907, Gordon states: "An irrigation scheme is urgently needed for the development of this backward part of the country."

Initial work started on the scheme in September 1906. Interestingly, initial work was carried out by black labourers as white labour was considered 'too scarce' in the area. They also proved 'unsteady workers'. WN Kelley was appointed Resident Engineer with Cyril Crowther as Assistant Engineer. By August 1907 about 610 m of canal had been completed and a start had been made with quarrying and dressing stone for the weir. However, on 10 September 1907, it was indicated in Parliament that work on the project had been abandoned due to the unexpectedly high construction costs. Commissioner of Irrigation, Dr Thomas Smartt, said that £7 650 had already been spent on the works. He also stated that: "As soon as the financial position of the country improved, it was the intention of the government to resume operations." However, this was not to be for nearly two more decades.

In 1929 Lewis received sudden instructions to organise and start with construction of irrigation works at Buchuberg. He was told to "start construction as soon as possible to provide employment for white people who were suffering from the effects of drought." Funds were to be provided by the Department of Labour, with construction led by the Department of Irrigation.

This was in spite of Lewis' caution against the implementation of large water resource development schemes in the Orange River. He stated that, because of the steep gradient of the river and the magnitude of floods, storage works for the purpose of irrigation would be "very expensive". Lewis wrote in 1929: "The Orange River will never provide a solution to the problem of water conservation, because large storage facilities will be subjected to siltation." These words proved to be prophetic as siltation would significantly reduce Buchuberg Dam's storage capacity in later years.

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Lokkie van Zyl

***Top left**: The Buchuberg Dam shortly after its completion in 1936. This was the first large water storage infrastructure to be thrown across the Orange River.*

***Bottom left**: During the drought of 1966, the Orange River stopped flowing.*

Lewis was quite taken aback by this sudden decision. In his annual report of 1929/1930 he writes of how there was no previous indication that government would be renewing this project, and how no engineering designs or project schedules had been drawn up. When the engineers and workers arrived on site there was still no specific scheme in mind, and it was only once

A poem for Buchuberg

Canal Construction Engineer W Lingnau wrote the following poem of his experience of building the Buchuberg Canal in August 1933:

Have I Loved These

Rotten roads and windy days
Flapping tents torn many ways
Dusty plates and gritty food
A rattling car without a hood

Sacks for carpets on muddy floors
Vacant spaces where should be doors
A stretcher with a mattress thin
Where warm goes out and cold comes in

A stagnant pool the pump does stand
Disinfectant used by liberal hand
Dead donkeys in the river sand
Tasty water to beat the band

Yapping dogs and donkeys bray
Troubled callers every day
Tattered clothes in bright array
Does the pay car come this way?

Families large and still they grow
Ag sister kom kyk tog na my vrou
Always ready their ails to show
Are they happy for all we know?

Here we meet something so rare
Surely not found everywhere
Dust and wind for all to share
Few trees and shrubs but here and there

Have I loved these say it not
Rather would I place a dot
For Buchuberg although you're hot
You still remain a lovely spot

(Source: Van Zyl, 1997)

preliminary work had started that a decision was made to build a storage dam. The design was only finalised in 1930.

The Buchuberg Dam and canal would be tackled as two separate construction projects. Resident Engineer DF Kokot oversaw works at the dam, and the dam's construction camp was to be sited on the farm *Seeikoeibaart*. Adolf Aslaken was the Resident Engineer in charge of work on the canal, and the main canal construction camp (out of a total of 13) was at Sternham, which was later renamed Groblershoop. Work on the dam and construction camp started concurrently in 1929.

Willa Cloete was one of the first workers on site in May of that year. He describes the area that greeted these first 18 men as "a wasteland". Cloete told Lokkie van Zyl, author of *Boegoebergdam se Mense*, that there was no cement at the start of the project, and labourers started by collecting sand needed for the concrete. Level areas were chiselled from the mountain to create space for the stone crusher. Tip-trucks were hauled up the mountain by machine to bring the rock to the bottom.

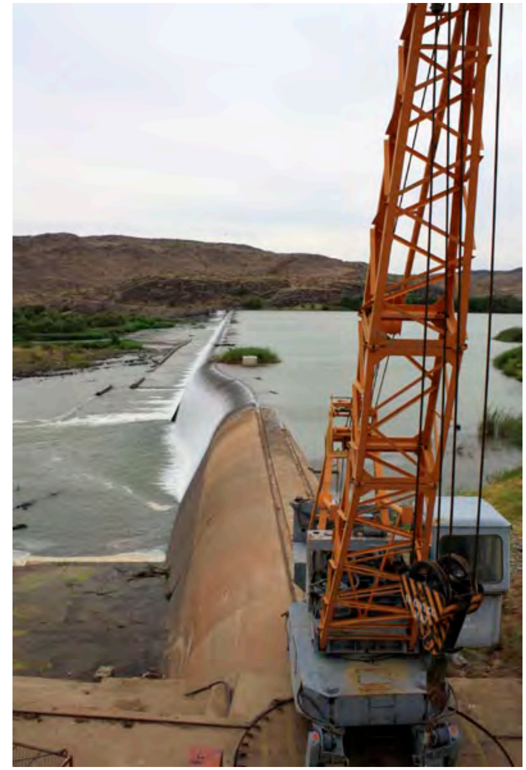
Children as young as nine worked for a sixpence hauling stone in an effort to help their families put food on the table. It is reported that at one time as many as 30 children between the ages of nine and fourteen were working on the dam site.

All work was done by hand, with pick, shovel and wheelbarrow, with the assistance of donkeys and mules. Even the holes for the explosives (some as deep as two metres) were drilled by hand. The coffer dams were built on sand bags which the workers carried on their backs. Work was carried out by day under the 40°C heat and at night by oil lamp to tame the mighty Orange River by hand. Tales are told of hardened men reduced to tears at the site of their bleeding hands.

An average 350 men worked on the construction of the dam. They came in hordes, from the closed diamond mines and the insolvent farms to earn seven shillings and sixpence a day. Only white men were employed on the project. The only work people of colour could hope for was to cut firewood for a few scraps of food. Children as young as nine worked for a sixpence hauling stone in an effort to help their families put food on the table. It is reported that at one time as many as 30 children between the ages of nine and fourteen were working on the dam site.

Initially, the labourers and engineers stayed together in tents. Kokot had a strict rule: no liquor and no women! However, liquor was easily smuggled in and the workers' wives soon started arriving on site, living in makeshift shelters. Later these shelters were replaced by wooden units with sink roofs and clay floors for the use of families. Unmarried men remained in the tents, the so-called "bachelor's camp". At the height of construction, there were over 3 000 people living on site. Each camp had two shops where basic amenities such as maize flour and dried peaches could be bought. Meat was mainly in the form of mutton. One day a farmer drove his cattle over the newly completed dam wall to take them to Draghoender station. One unfortunate animal fell off and drowned. The farmer donated the beast to the people of Buchuberg and it was immediately slaughtered and cooked with huge celebration. Unfortunately, the people were not used to eating beef, and many landed up in hospital with upset stomachs as a result.

Everything, from labourers to equipment, sluices and even the stone crusher was initially transported piece by piece by donkey cart from the nearest train station at Draghoender, more than 60 km



Lani van Vuuren

Buchuberg Dam was initially constructed with 68 sluices designed to allow sediment to pass through the structure. In this photograph the crane used to open the sluices can clearly be seen.


Lani van Vuuren

Buchuberg Dam features a wall of mass concrete gravity section overspill type, 10,7 m high. The crest is 622 m long.

away. Such a round trip could not be done in a day. Thus the hotel, the liquor and grocery stores at Draghoender became very popular during the construction of Buchuberg Dam. The donkeys were later replaced by trucks, rented from richer farmers in the region. Once excavation was done all available transport was used to bring cement from Draghoender. As a result the people of Buchuberg often had to do without everyday products such as soap, bread, paraffin, matches, and writing paper. There was no radio and the people's only entertainment was the roving bioscope which visited once every three weeks.

In June, 1930, a school was opened (although the pioneer teacher, Koos de Beer, initially taught children under the trees with no books and no desks). Although the camp later boasted a hospital with a medical officer paid for by the Department of Labour, these were tough times, and around 50 people (including 38 children) died during the construction of the dam. In 1933, the river stopped flowing, causing an outbreak of diarrhoea. The camp was also plagued by malaria when the river was in flood.

By 1932, construction of the dam had advanced enough for water to flow into the canal for the first time. The dam wall was constructed to a final height of 10,7 m and is 622 m long. The dam was initially equipped with 68 sluices designed to allow sediment to pass through the structure. Workers on the site not only used these sluices to let out water, but also fish, such as barbel. The fish were killed with picks and shovels and then pickled or curried.

Shortly before the completion of the dam, three inspectors arrived at site in suit and tie to investigate conditions. On the morning of their arrival it was already 40°C. When they heard that the day would become even hotter, they politely declined a tour of the works, and without further ado, got into their vehicle and left. One can only imagine what they wrote in their report (if there ever was one).

The completion of the 121 km canal in 1934 was celebrated with big fanfare. Dignitaries walked ahead of the water in the canal and at the canal's end a prayer of thanks was held. All present had to pick up a stone along the way which was to be used later to construct a monument in honour of those who constructed the dam. The monument did not materialise until some years later when a rebuilt ox wagon camped at this venue on its way to a commemoration ceremony of the Great Trek. The monument that was erected afterwards served a dual purpose (to commemorate the Great Trek and, with the inclusion of the stone collection, the pioneers of the Buchuberg Dam and canal).

Lani van Vuuren

Although the dam had an initial storage capacity of 40 million m³, this has been halved through sedimentation. The sediment sluices have been closed permanently and the structure is now effectively a concrete weir which supplies water into the canal on the left bank. Today, the Buchuberg canal supplies water to 7 560 ha of irrigated area, most of which is used for field crops and a small portion of fodder crops.

At present, the Buchuberg site is one of several sites being considered for a new larger dam along the lower Orange River to provide additional storage and regulation capacity below the Vanderkloof Dam. It is thought that a new weir will be constructed at a proposed construction site about 1,5 km downstream of Buchuberg Dam, although a final decision is still pending.

The Buchuberg main canal. Considering the geology of the region one gets a new respect for the pioneers who constructed the original canals by hand.

Vioolsdrift and Beenbreek

In 1933, after the Minister of Irrigation himself inspected the Lower Orange River, he gave the order to build the Vioolsdrift and Beenbreek schemes to provide work to labourers previously employed on road construction in the area. Once the canals were completed many of the labourers from Buchuberg were sent to the site. Engineers only had a limited amount of survey data to work with and designs were hastily drawn up. By the end of the 1933/34 financial year, £5 861 had been spent on Beenbreek and £19 916 on Vioolsdrift. The latter comprised a weir with an average height of 6 m and a main canal 34 km long, with about 14 km of secondary canals. Both white and black labour were used on the projects.

Today, the canal which is fed by Vioolsdrift Weir still supplies about 15 million m^3/year to various areas of irrigation, the main crops being lucerne and vegetables. The weir is also used for flow measurement as it is effectively the last point along the Orange River where a reasonable estimate of the river flow can be obtained. The possibility of a major dam at Vioolsdrift has been suggested and has been investigated by both Namibia and South Africa.

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Vioolsdrift Weir on the Lower Orange River.


Lani van Vuuren

The rogue islanders

In 1926, a group of land-hungry men seized Kanon Island on the Orange River, about 30 km from Upington. The settlers first lived in huts after the Khoi manner of saplings and reeds (these were, however, rectangular rather than oval). Later they made a weir and an irrigation canal, dug furrows and dams, chopped down trees and levelled the rough island fields for the first sowing. They were assisted in their irrigation infrastructure by the then 68-year-old Japie Lutz. All of these activities were illegal since the island was State property and a lone policeman, Sergeant Andries Coetzee, was sent to deal with the trespassers. He had to cross the river with his uniform on his head to get to the islanders, who greeted him joyously and invited him to join the colony (the story goes that he did, in fact, later settle there).

Not being able to evict the settlers, the authorities first granted them permission to remain for a year, and then gave them legal tenure. The settlers were even invited to draw up their own 'laws' for the administration of the island.

In 1934, floods swept down the Orange River, washing much of the infrastructure away on Kanon Island. By this time there were around 1 000 people living on the island. The settlers were marooned on the highest ridges, cut off from the outside world by raging waters. A telegram was hastily sent to Minister of Lands, Deneys Reitz, who at once commandeered an Air Force two-seater to take him to the island. An old motor launch manned by volunteers got him to the island and, after a dangerous crossing, he found the people bereft of houses and crops but otherwise not in immediate danger. The islanders were supplied from the air until the flood subsided and they then set to work to rebuild and replant. In 1937, the islanders were allowed to purchase their holdings.

__Left__: The Orange River at Kanon Island.

__Right:__ The canals at Kanon Island as they look today.


Lani van Vuuren

LOSKOP DAM

The history of the Loskop Dam can be traced back to the 1840s when the Voortrekkers settled in the Kruis River valley not far from the present dam site. The first farms in the Olifants River valley, including *Lagersdrift* and *Kalkfontein*, were pegged out as long ago as 1886. Back then, the farmers cultivated mainly wheat under dry-land conditions. Notwithstanding the establishment of these farms, due to malaria and cattle diseases like East Coast fever, initial development was slow until the turn of the nineteenth century. In the early twentieth century, many farmers trekked with their cattle from the Highveld to the Olifants River valley during the winter. Each winter they stayed a little longer until they eventually settled in the area in greater numbers. This was particularly during the years between 1917 to 1924.

The Olifants River was one of the main rivers surveyed by the Transvaal Irrigation Department following the South African War. Three main potential projects were identified, of which Loskop was the largest. Interestingly, FA Hurley, who led the surveys, recommended that the Middelburg Dam be constructed before Loskop Dam as the area in the vicinity of the dam site was more densely populated at the time and was closer to major infrastructure such as railways.

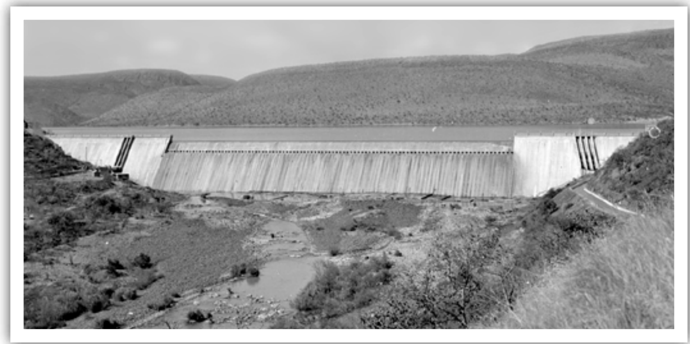
It was in 1917 that the first private dam in the area was completed on the farm *Rooikraal* with government assistance. Thanks to irrigation, the wheat crop on this farm increased from 150 to 8 000 bags a year. Around 1925, other small irrigation schemes were completed involving both weirs and pumping water from the river. This led to the establishment of the Hereford Irrigation Board to serve an area of about 2 140 ha which was situated about 10 km downstream of the present Loskop Dam.

Meanwhile, the Middelburg Irrigation Board made an application for the apportionment of the water of the Olifants River. The Water Court hearing under Judge Jeppe was held in Middelburg in 1926, and the normal stream of the Olifants River was apportioned down to the boundary of the Lydenburg district. Immediately after this the Hereford Irrigation Board applied for a loan. The proposed Hereford Scheme included an improvement of the diversion

***Top**: The original dam wall of the Loskop Dam, completed in 1938, was 45 m high.*

***Middle**: Loskop Dam comprises a mass concrete gravity wall with an ogee crest spillway.*

***Bottom**: Loskop Dam was the first in South Africa to incorporate the so-called Roberts' splitter design. The aim of the splitters is energy dissipation, which is obtained by means of a step in the spillway, placed beneath a row of projecting teeth or splitters.*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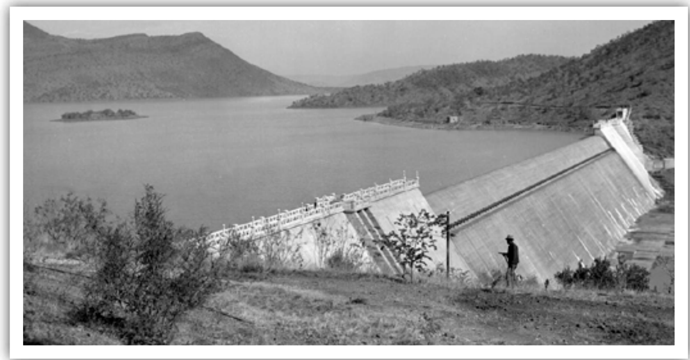
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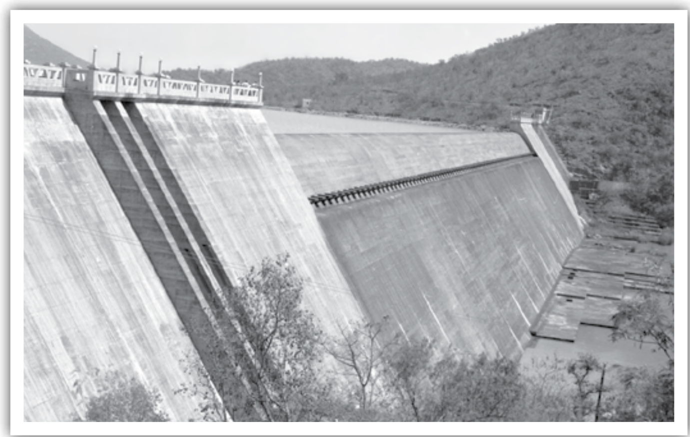
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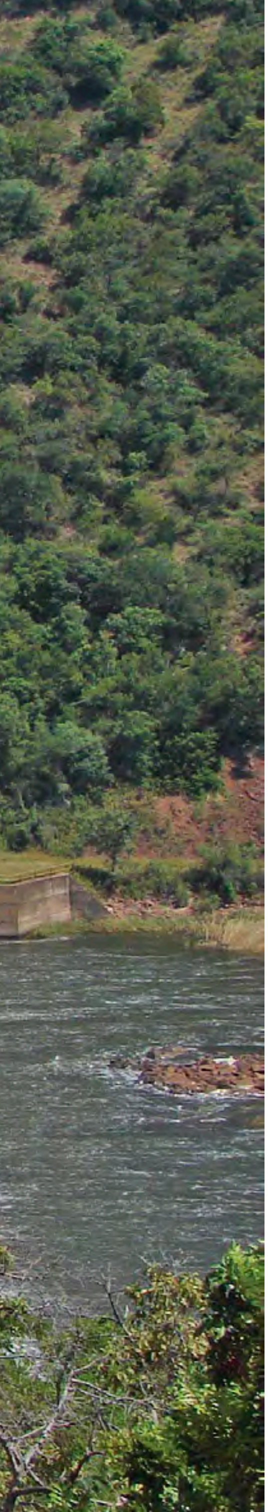


Lani van Vuuren

DWA/eWISA

***Left**: Loskop Dam is a majestic site when it spills.*

***Above**: A historical photograph of the main canal flowing from the Loskop Dam. The total length of the canals from the Loskop Irrigation Scheme is 480 km.*

weir at Kameeldoring, and a 41 km-long canal extending as far as the Moses River. After a loan of R70 000 was granted by the Land Bank, work started during 1928 under the supervision of the Irrigation Department's engineers BG Twycross and EGH Barry. The various contracts were completed in 1930.

The early success of this scheme gave rise to a petition by farmers for the establishment of the Loskop Irrigation District. In 1929, the Minister of Irrigation instructed the Irrigation Commission to investigate the possibility of the Loskop Irrigation Scheme. After studying the position, the Commission recommended that the Hereford Scheme, which was then under construction, be studied further together with other private schemes, which were developing, before approval was given to a larger scheme at Loskop. A topographical and soil survey of the dam basin was undertaken during 1933. Eventually the Irrigation Department and the Irrigation Commission brought out various reports on the success of agricultural crops under the Hereford Scheme and a

DF Roberts

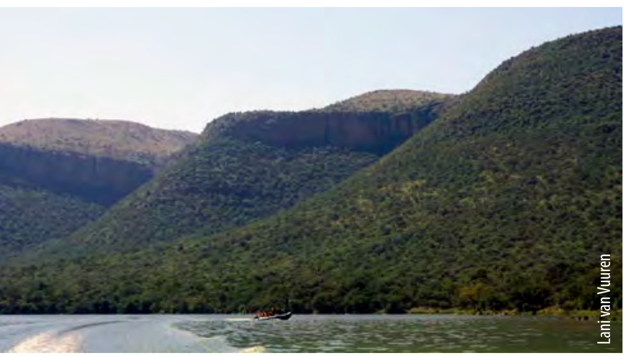
Inventive engineer Lieutenant Colonel Douglas Fletcher Roberts was born at Cradock on 6 April 1892. He completed his engineering degree at the University of Cape Town after initial studies at Rhodes. He did active duty overseas during the First World War, afterwards joining the Irrigation Department.

In the 1930s he oversaw some of the most important upliftment projects of the department, including Rust-der-Winter Dam on the Elands River, Longmere Dam on the White River and Loskop Dam on the Olifants River. Throughout his life he took a keen interest in the research side of engineering. It was while Roberts was stationed at Loskop that he became interested in the problems associated with the dispersion of energy of the water passing over the spillways of dams. He carried out research in this field in a makeshift laboratory on the banks of the Olifants River, eventually developing the Roberts' splitter. In subsequent years his design was emulated on some 32 dams both locally and abroad, including South Africa's largest dam, the Gariep, on the Orange River as well as the Vaal Dam. Following the Loskop project the Irrigation Department established a Research Division, led by Roberts.

During the Second World War, he was again involved in military affairs. In April 1940 he was seconded to the Department of Defence. In May he was released for full-time military service, assuming command of the military construction organisation known as the Directorate of Works. Here he earned the rank of Lieutenant Colonel.

Upon his formal retirement in 1952, Roberts rejoined the department in a temporary capacity. He was engaged on research work in the Division of Hydrological Research, where he remained until a few months before his death on 23 July, 1969. Roberts was never one for the limelight, preferring the engineering engine room, and he was never happier than when asked to solve some knotty problem involving advanced mathematics.

Upon his death, his ashes were buried on Hazel Island (the so-called 'los kop' from where the dam got its name), named after his wife, in the middle of Loskop Dam. However, when the dam wall was raised in the 1970s the ashes were reburied in the dam wall.



***Top**: Between 1974 and 1980 the Loskop dam wall was raised 9 m to a height of 54 m above the lowest foundation level.*

***Above**: Lake Loskop has become an important recreation and conservation area.*

special sub-committee of Cabinet decided to recommend the scheme to Parliament.

Interestingly, the scheme was placed on the government's Loan Estimates for the year 1934-35, without any recommendations of the Commission having been obtained as to whether it should be constructed or not. The estimated cost of the entire project was £1,5-million. Construction of the Loskop Dam on the farms *Loskop* and *Vergelegen* started in 1934. Again only white labour was used. Initially only married white men were employed on the Loskop Dam construction site. They were paid five shillings a day and provided with free accommodation, food and medical attention. Machinery and equipment were brought over from the Rust-der-Winter site. By 31 March 1935, there were 460 workers employed.

Interviewed during the 50-year anniversary of the dam, Japie Bosman and Alexander (Alkie) Bezuidenhout shared their experiences of working on the project with the Department of Water Affairs' communications team. They told of men coming from all over the country, mostly farmers who had lost everything due to drought and other hardships, working and living together on this remote site. The men lived together in temporary rondavels – 20 to a hut, and snakes were a regular nuisance. Malaria struck often, and at one stage as many as 60 cases were reported. Meals were swapped for tickets, and dinner consisted mainly of samp and meat. On Wednesdays, the men were treated to dessert in the form of custard and jelly.

The number of labourers employed at the end of March 1935 was 460 men. Throughout 1935 and 1936 the Director of Irrigation noted in his report that there was a shortage of labour, especially concerning the construction of the Loskop Dam. The department then asked the Department of Labour to allow it to employ single white men on the project as well. In total, about 7 000 men worked on the scheme. By the end of 1937 the dam was nearly complete, except for a number of minor tasks on the superstructure. Good rains fell in December 1937 and January 1938. This resulted in the dam being filled and it overflowed in January 1938.

In June 1935, a start was made on the canal system, which was eventually completed in 1948, after an interruption in the work as a result of the outbreak of the Second World War. When the war broke out labourers were told to sign up for active duty or risk losing their jobs. As the former also included better pay, many joined the war effort. The total length of the canals is 480 km. The Loskop Irrigation Scheme also resulted in the establishment of a town, Groblersdal, laid out on a farm owned by WJ Grobler. The town was proclaimed in 1938.

The Loskop Dam comprises a mass concrete gravity wall with an ogee crest spillway. The original wall was 45 m high. A total of 235 185 m^3 of concrete went into the original dam wall. The dam is well known in engineering circles as the first dam where the so-called Roberts splitter system – an energy-dissipating step and splitter system devised by Lt Col DF Roberts – was used. Lt Col Roberts was the Resident Engineer at the Department of Irrigation's very first hydraulics laboratory near the dam site. His splitter system was used on the downstream face of the Loskop Dam wall to dissipate the kinetic energy of the overflowing water. Following this successful application, this system has been widely adopted in South Africa, including on the Nagle and

Gariep dams. It has also been applied abroad, for example, on the Victoria Dam in Sri Lanka.

Development in the Witbank-Middelburg area necessitated the raising of the dam wall so that the portion of the assured yield which had in the meantime become affected as a result of the construction of upstream dams such as Rondebosch, Witbank and Doornpoort dams could be restored. By 1971, when the recommendation to raise the dam wall was made, the Loskop Dam system of canals served about 25 000 ha of farmlands.

Between 1974 and 1980 the dam wall was raised by nine metres to a height of 54 m above the lowest foundation level. The geographic formations found underneath the dam made for an interesting engineering project. The dam is underlain by rhyolitic lava of the Rooiberg Group. Excavation to competent foundation rock was shallow on the left flank and in the river section. However, on the right flank close fracturing and deep weathering had necessitated deep excavation for the old right-flank section.

It was not until the investigation for the raising that the presence of a wide fault zone just downstream of the right flank was discovered. To ensure stability of the right flank, the raised wall was kinked in a downstream direction to cross the fault zone in the shortest possible way. Excavation in the fault zone was up to 16 m deep, but the longer, upper end of the wall could be founded on competent rock at shallow depth. Today, the dam has a total crest length (of which the spillway section is 244 m long) of 506 m. In the design of the dam provision was made for crest gates in order to facilitate the raising of the dam wall by another four metres at a future stage. The full supply capacity of the dam is 362 million m^3. The dam has been constructed to accommodate a design flood of 2 886 m^3/s (a 1:200 year flood).

At present, the Loskop Water Scheme consists of 667 properties with an average scheduling of 25,7 ha each. Wheat, vegetables, tobacco, peanuts, cotton, and citrus fruit are cultivated. Furthermore, water from the dam supplies the Hereford Irrigation Board, the Olifants River Irrigation Board, as well as the Groblersdal and Marble Hall municipalities.

Engineering statistics of Loskop Dam

Year of completion	1938 (raised in 1979)
Purpose	Irrigation, domestic, industrial
River	Olifants River
Nearest town and province	Groblersdal, Mpumalanga
Type	Mass concrete
Net storage capacity	348 million m^3
Wall height above lowest foundation	54 m
Crest length	506 m
Material content of dam wall (original and raised)	415 000 m^3
Type of spillway	Uncontrolled
Capacity of spillway	7 750 m^3/s
Surface area of dam at full supply level	2 350 ha

Dam tragedy

Not all official dam opening functions were happy occasions. Louw's Creek Dam, situated at the confluence of the Shiyalongabo and Ugutugulo rivers, was one of the first dams to be constructed in the old Transvaal Lowveld. It was the brainchild of Bromley Dreyer and his neighbours Mike Bertaeso and Rudolph Dehrmann, who together established the Shiyalongabo Irrigation Board in 1932. The dam was completed in 1939. Member of Parliament and representative of the district, Colonel Deneys Reitz, was to be the guest of honour at the official opening of the dam on 7 April, 1940. However, shortly before the occasion was due to start the brakes of a parked

DWA/eWISA

vehicle, belonging to Harvey Brown, failed causing the car to plough into the waiting crowd. Two people were killed in the incident, one being Barberton Town Clerk CG Hurd, and several people were seriously injured, including the Mayor of Barberton's wife, Kate Tregoning. The opening was called off and the dam was never officially opened.

A dam for Pretoria

It is not only State irrigation schemes that were constructed during the Depression years. Between 1930 and 1934 the Pretoria municipality constructed the Rietvlei Dam in the Sesmylspruit, a tributary of the Hennops River. Prior to the construction of this dam, the only water supply to the town, which by 1928 had around 75 000 residents, came from dolomitic resources in the Fountains valley.

The dam was built on the farm *Rietvlei*, which is today managed as a nature reserve. Mainly white men were employed and most of the work was done by hand, including construction of the dam wall and all associated brick work. All the soil was carted away by mule carts and oxwagons (numerous horse shoes can still reportedly be found on the site). The dam wall, an earthen structure with a central concrete core and hand-packed rip -rap, was constructed to a height of 32 m, and a length of 350 m, and cost around £146 700. A concrete-lined chute spillway varying from 90 m wide at the crest to 47 m wide at the discharge end is located on the left flank. The concrete outlet tower feeds water to the adjacent purification plant through a concrete culvert beneath the wall.

Today, Rietvlei Dam still provides around 15% of the City of Tshwane's water requirements. In 1990, the spillway capacity was increased from 1 100 m^3/s to 2 500 m^3/s for the dam to meet modern safety requirements. In addition, dam wall stability and the security of the outlet works were improved.

Lani van Vuuren

THE VAAL RIVER DEVELOPMENT SCHEME

Situated at the confluence of the Harts and Vaal rivers on the border between North West and the Northern Cape, the Vaalharts irrigation scheme was first suggested by surveyor-general Francis HS Orpen. He surveyed the area, which then formed part of Griqualand-West after it was annexed by the British in 1871 for the establishment of settler farms. Orpen found that the Vaal River bed was higher than the Harts River valley floor, making irrigation through the use of gravity-fed canals possible. In his report dated 22 December, 1875 he wrote: "It is possible, by taking out the water of the Vaal River near Fourteen Streams, to irrigate about half a million of acres in the Harts River Valley."

The Griqualand-West war broke out before Orpen's idea could be investigated further. In 1882, statesman John X Merriman proposed in Parliament that a committee should be appointed to deal with irrigation matters, among others the proposed irrigation works at the Vaal and Harts rivers. The proposal was based on a report by Cape hydraulic engineer John Gamble. Merriman argued that the Vaalharts irrigation works would turn the 'desert into a garden.' Unfortunately the lack of funds prevented anything further to be done on the scheme.

Cecil John Rhodes advocated strongly for the proposed Vaalharts scheme (then known as the Harts River Valley Irrigation Scheme), possibly because of its proximity to the rich Kimberley diamond mines. In 1886, he had already carried a motion to get some land between the Harts and Vaal rivers for the purposes of irrigation. Government granted him the land; however, he was unable to raise the money to implement the irrigation works. Interestingly, it was Rhodes who first suggested that the land be made available to poor white farmers who had lost everything due to an outbreak of Rinderpest. He argued that the poor whites refused to work in the mines and would rather farm.

At that time the State was not prepared to pay for an irrigation scheme of that magnitude, however, it was decided that Crown Lands between the Harts and Vaal rivers would be granted to any company or individual prepared to implement such an irrigation scheme (at a cost not exceeding

Mine magnate and statesman Cecil John Rhodes originally wanted to develop the Vaalharts irrigation scheme to bring water and food to Kimberley.

£130 000). Unfortunately, no-one took up this offer. This despite the fact that some Tswana-speaking and Korana communities had already been displaced in the locality of the proposed irrigation scheme to make room for white settlers. Rhodes even persuaded the government to carry out the works when he was Prime Minister, to no avail. The government's argument was that other parts of the country also needed irrigation works.

In 1898, further efforts were launched to get the Vaalharts scheme off the ground when engineer HC Litchfield was appointed to investigate the possibility of an irrigation scheme in the Harts River valley. The South African War put a stop to investigations a year later. Following the war, the Directors of Irrigation of the Cape and Transvaal attempted to revive the Litchfield report. Each of them wrote a report recommending the construction of a dam in the Vaal River. Again, there were no funds available. The Vaalharts scheme was further put on the backburner by FE Kanthack, the first Director of the Irrigation Department established after the Union of South Africa in 1910. His argument was that the area in the Harts River valley to be irrigated was too widespread. He thought that the limited resources of the government should rather be devoted to the encouragement of a large number of smaller schemes throughout the country.

The Vaalharts irrigation scheme gained new impetus following the First World War as it became government policy to grant land to soldiers returning from the war. Reconnaissance parties began work on the Vaal River in 1921. Up to 1923 investigations dealt with the Vaal-Rhenoster Scheme, but in 1924/25 the lower Vaalharts area was investigated and preliminary investigations into the soils of that area made. A large number of holes were drilled to test the depth of the soil. Work was again renewed in 1929, coupled with aerial photography.

The scheme would include several large infrastructure components, including a storage dam, a weir, and associated canals.

In 1933 the Irrigation Department was given the order to go ahead with the Vaalharts irrigation scheme. The Vaal River Development Scheme Act was subsequently passed in 1934. The scheme would include several large infrastructure components, including a storage dam, a weir, and associated canals. Originally, the plan was to construct a dam on the Vaal River at Christiana to provide water for the scheme. However, following negotiations with the Rand Water Board (who desperately needed to augment its water resources for a growing Johannesburg) the decision was made to construct the Vaal Dam at the confluence of the Wilge and Vaal rivers near Vereeniging. The Rand Water Board agreed to pay a portion of the cost to construct the dam (£1,17-million of the estimated cost of £1,7-million). Water would flow from the Vaal Dam to a diversion weir 57 km downstream and then through the main canals to the scheme. Construction of the Vaal Dam and Vaalharts Weir and canals would be undertaken simultaneously. At the time, it was the largest engineering project ever undertaken in South Africa.

Vaalharts

In December 1933, construction teams started clearing land on the farm *Andalusia*, near Border Station, to make way for offices, accommodation and storage facilities. It was first thought that Warrenton would serve as the headquarters of the scheme, but when the town council refused, the project team had to find an alternative venue. In 1934, work started concurrently on the Vaal Dam, the Vaalharts weir (then known as Knoppiesfontein Dam) and the main canal. Initially only white men were employed on the scheme. Labourers had to be unmarried (although married men were later also employed), between the ages of 18 and 45 and medically fit. Due to the 'lack of white labour' experienced later on in the

A concrete barrage-type structure, the Vaalharts Weir has a height of 11 m and is 750 m long.

Courtesy Dana Grobler

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Top: Workers constructing the concrete arch bridge over the canal at Warrenton.

Bottom: Labourers worked in gangs of 10 to 20 men.

project, coloured and black workers were also employed on sections requiring only 'unskilled' labour.

The pay for white labourers was two shillings per day, with a bonus of one shilling 6d per day worked. These bonuses were paid into a Post Office Savings Bank and workers were only allowed to draw the money once they had completed their work. Money could be paid to dependents via a stop order. In the case of coloured labourers the greater of a man's wages was sent by cheque to his dependents and only a small part was paid out to the man himself for pocket money. If a labourer experienced a domestic emergency the Resident Engineer was empowered to allow a man to draw out a portion of his compulsory savings. In the early stages of the works a full-time welfare officer was employed to go round all the camps and keep in touch with the men. Any hardships were reported to the Resident Engineer.

For all jobs of a routine nature where the output could be accurately measured, payment was made on a piece-work basis. A gang of 10 to 20 men worked as a unit and at the end of the month their output was measured up and its value worked out. The total value of the job was then divided up among the members of the gang in proportion to the number of Mondays each one had worked during the month. If the members of a gang found that any particular member was not pulling his weight, they could throw him out and invite someone else to join their gang.

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The post office and staff houses at Andalusia. The head-quarters of the Vaalharts irrigation scheme later became a town on its own and in 1953 it was renamed Jan Kempdorp, after General Jan Kemp, former Minister of Agriculture.

Carl Sandrock

The man who oversaw construction at the Vaalharts irrigation scheme was Resident Engineer Carl Sandrock. He was known for his compassion and good treatment of labourers on the schemes where he worked, and it is reported that the welfare measures he implemented were well in advance of normal practice at the time. At Vaalharts the winters were especially cold, and one morning he noticed a construction worker wearing a woman's coat. When he asked the worker about it, it transpired that the worker and his wife only had one coat between them. "What does your wife do when you are wearing the coat?" Sandrock asked. "She has to stay in bed until it warms up," was the worker's reply. Upon hearing this, the Resident Engineer took off his own coat and handed it to the man.

Sandrock was not only a compassionate man, he was also a good engineer. His introduction of screeded concrete for lining canals represented a major advance which afterwards became standard technique for such work in South Africa. After the completion of the Vaalharts scheme Sandrock became Chief Engineer at the Irrigation Department's headoffice where he was responsible for all departmental construction work.

***Top right**: Excavation of the Vaalharts canals. Both manual and mechanical means were employed.*

***Middle right:** By 1936 the Vaalharts Weir was nearly completed.*

Vaalharts Water

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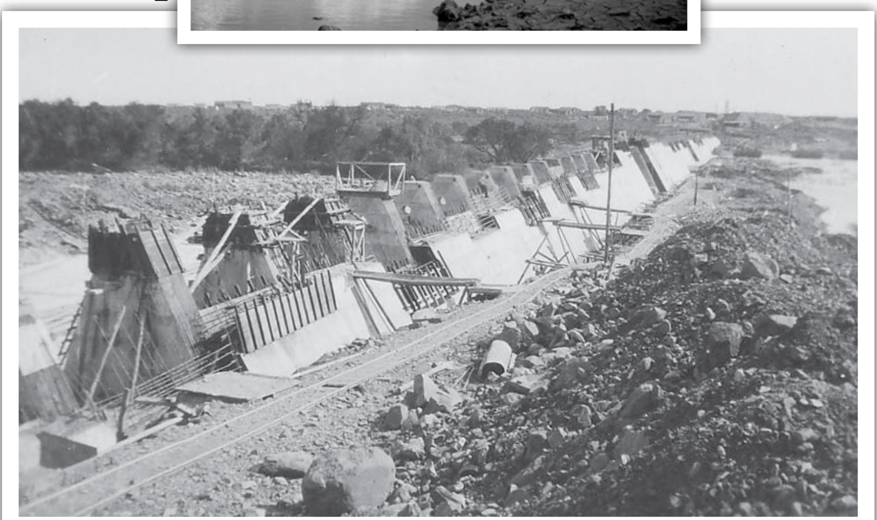
The Vaalharts Weir during construction.



Vaalharts Water

Labourers were not entitled to have their families with them on the works, but were accommodated in camps composed of a large number of wood and iron bunkhouses, each containing four double-deck bunks (dubbed *hoenderstellasies* or 'chicken coops'). The more skilled workers and office staff were allowed to have their wives and families with them on the works and were provided with houses at a reasonable rental. Interestingly, Vaalharts was one of the first schemes on which electric light was provided for the staff. In the early stages the power station closed down at 10 pm except when there was a special function on. Later, power was available throughout the night.

As the works were spread out over a linear distance of 80 km the job was divided into sections, each in charge of a section engineer, and all under the control of the Resident Engineer at the headquarters of the scheme. Each section had its own camp, number one being at the weir, near Fourteen Streams Station, section two being near Warrenton and section three next to the Headquarters Office near Border Station (this was later moved about a kilometre up the line and renamed Jan Kempdorp Station). Section four was started later near Pokwani – this job included the construction of two tunnels.

All meals were free, and large mess halls and kitchens were built and staffed. Contracts were given out for the supply of meat, vegetables and milk in large quantities. A dry-goods canteen was also supplied at each camp. Goods here were not sold for cash, but rather coupons and were generally cheaper than in town (the cancelled coupons were burnt in front of witnesses so as to prevent fraud). Recreational facilities were also provided, among others a large recreation hall which could house 600 people. This had a stage and two small dressing rooms for staging concerts and plays. The hall was also provided with a 35-mm cinematograph projector and films were shown twice a week. Rugby fields, tennis courts, a golf course and swimming pool were also provided. The works also had a small church, a school and a number of field hospitals. The latter could handle the ordinary run of medicines and provide first aid treatment, however, serious cases had to be sent to Kimberley. When there was an outbreak of epidemics (such as diphtheria or typhoid) mass immunisation was undertaken.

At Vaalharts both mechanical and manual labour were used. Workers were transported to site by truck where each one got an area of 3 m by 3 m to dig out. Digging was done mainly by pick and shovel. Workers used 6 kg hammers to break the rock, which was then placed in bags and hauled out of the steep sidewalls. In really rocky areas it could take months to reach canal depth. The area known as the 'blue canal' was notoriously difficult to penetrate. Once one team had completed the digging another took over to cast the concrete lining.

The weir, a concrete barrage-type structure, has a height of 11 m and is 750 m long. It was designed to accommodate a flow of 283,2 m³/s, with water 4 m deep flowing over the crest. Three sluice gates of 8 m by 6 m have been built into the weir. In 1967, the weir was raised by 1,2 m to

DWA/eWISA

***Left**: Water runs down the Vaalharts system in 1950. The first farmers were already settled on the scheme in 1938 even though the canal system was only completed in1946.*

DWA/eWISA

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***Top**: Apart from the main canal there are 180 km of secondary and 540 km of tertiary canals.*

***Middle**: The canal headgates consist of three 254 mm by 229 mm radial gates which control the flow into a three-channel covered aqueduct.*

***Below**: A historic view of the Vaalharts prior to its raising in 1976.*

***Below:** All the canals are concrete-lined and various shapes are used. With the exception of a length of the minor branch, the whole of the main canal has been built to a trapezoid section. In all cases the bed of the canal was cast in-situ, but for making the sides several methods were tried. The most satisfactory method turned out to be the use of precast side slabs.*

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From the earliest investigations it was realised that a large proportion of the best land suitable for irrigation lay in what was then known as the Taung Native Reserve. Two ministers (Lands and Native Affairs) and their advisors met with the heads of Taung ahead of the project whereby they reportedly agreed that half of their irrigable area in the south would be transferred on condition that the northern half be supplied with water free of charge to their lands. It was also agreed that the community of Taung would receive an equivalent area of grazing land adjoining the reserve to the north to compensate for the land lost.

Work on the feeder and distribution canals started in 1937. However, the Second World War brought construction to a screeching halt. At the start of the war, 186 men at the works were released for full-time military service, and the 34th Company of the SA Engineering Corps, formed towards the end of March 1940, was largely manned and officered by Vaalharts personnel. This unit served in Rhodesia (Zimbabwe), Kenya, British Somaliland (Somalia) and Abyssinia (Ethiopia and Eritrea). Those who remained on site were employed to build essential defence works at Kimberley and Bloemfontein. In 1944, it was decided to complete the scheme as soon as possible as insurance against post-war unemployment and food shortages. Workers were re-organised while large numbers of white, coloured and black ex-servicemen were recruited. A maximum of 2 465 workers raced to complete the project in 1946.

Today, the main canal, feeder and distribution canals total more than 800 km. Later 300 km of drainage canals were also constructed to improve soil conditions created by an increased surface runoff. Before the Vaalharts scheme began the soil was probably always dry and capable of absorbing all the rainfall. With irrigation, however, the soil is kept damp, and consequently, is not able to absorb much rain. Therefore, the engineers had to provide not merely a distribution system for delivering water but also a network of drains to deal with the surface runoff. All the canals are lined with concrete. To reduce pressure on the Vaal Dam, the Bloemhof Dam was constructed in the 1970s to feed the Vaalharts Weir.

The main canal runs parallel to the Vaal River for about 13 km. Here the Klipdam/Barkley canal (not included in the original design, but constructed later in 1946) is taken off and runs south to feed a system of minor canals. Interestingly, at the time of its construction, the Klipdam/Barkley canal

increase the storage capacity to 48,7 million m³. This was done by raising the Stoney sluices and installing crest gates in the form of fishbelly flaps on the river. Three hand-operated radial sluice gates of 3 m by 2,7 m make up the inlet sluices. These flow into a three-barrelled aqueduct, which controls the water flowing into the canal. Vaalharts comprises two main canals – A North Canal and a West Canal. By 1936, the first 40 km of the canals were completed and water first flowed into the canals on 15 December.

***Above**: Three hundred kilometres of drainage canal have been constructed at Vaalharts to improve soil conditions.*

***Right**: Taung Dam. In addition to commercial farmers, the Vaalharts scheme also supplies emerging farmers in the Taung area with irrigation water.*

Job X

Vaalharts also supplied water to Ganspan, a settlement in the heart of South Africa for aged and infirm persons managed by the Department of Social Welfare. Here, those who could manage only light work stayed on plots up to 1,6 ha in size, with free housing and medical services provided. In 1942, the Royal Navy selected Ganspan (now part of Jan Kempdorp) for an ammunition depot for their naval vessels because of its easy access from there to any coast in South Africa. It is said that the settlement was also too far for either German or Japanese planes to reach. Construction of the depot, which included 80 reinforced concrete magazines and elaborately protected stores, as well as accommodation for depot staff and guards and several kilometres of concrete roadway, was undertaken by the staff and workforce of the Vaalharts irrigation works at a cost of around £700 000. This project, dubbed 'Job X', was completed towards the end of 1943. After the war, the Union Defence Force opened an ammunition depot adjacent to the Royal Navy depot. The latter was taken over by South Africa when the Royal Navy left in 1958.

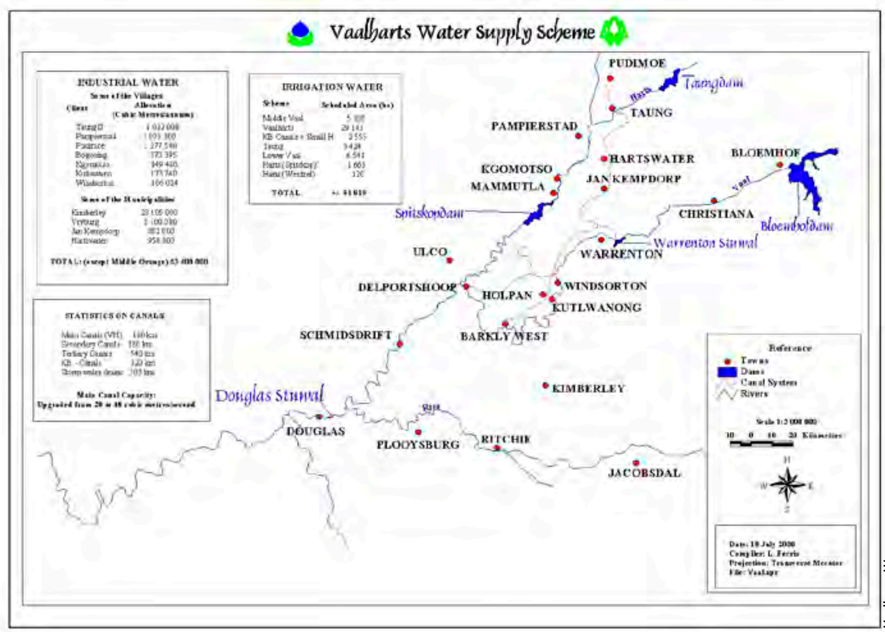
During the Second World War three internment camps were established in the region, one at Ganspan and two at Andalusia. Here, too, all infrastructure was overseen and built by the teams from the Vaalharts irrigation works. Internees were mostly German-speaking residents of South West Africa. At Andalusia, at least 2 000 internees lived in the camp, with 180 at Ganspan (nine of which made a daring escape through a hand-dug tunnel in October 1941).

was described as 'one of the most challenging projects' yet undertaken by the Irrigation Department because of the difficult terrain through which the canal had to be constructed. Long stretches of the canal had to be cut through solid rock up to 9 m deep. Much of the work was done by hand mainly employing coloured labour.

After the Klipdam-Barkley offtake, the main canal turns and cuts through a nek into the Harts Valley. On emerging from this cut, which is about 3 km long and 10 m deep, at the highest point of the nek the canal bifurcates. The major branch runs in a northerly direction until it crosses the Harts River some 64 km beyond the bifurcation. The minor branch continues in a westerly direction for about 8 km and then turns south and continues a further 13 km. The capacity of both canals, which are lined throughout, are gradually reduced, as water is drawn off the various blocks of land. Apart from the usual minor structures such as bridges, superpassages, outlets etc, there are a number of major structures including two tunnels and two large inverted siphons. The tunnels are concrete-lined and egg-shaped in section with an equivalent diameter of about 3 m. The lengths of the tunnels are 1 878 m and 1 428 m respectively a portion having been built on the cut-and-cover principle. From the main canal the water is fed into a system of secondary canals known as feeders which, in turn, supply the community furrows from which the irrigators draw their supplies.

By 1938, the first 80 lots were ready for occupation. A unique feature of the scheme is the regular layout of a large portion of the distribution system. This was made possible by the fact that the bulk of the irrigable area lies in a

A map shows the Vaalharts scheme as it looks today.



Vaalharts Water

Vaalharts remains the largest irrigation scheme in the country, with a scheduled area of 29 181 ha.

Lani van Vuuren

continuous block with a more or less uniform shape. This block is roughly 32 km long and varies in width from 6 km to 11 km. Applicants were selected by a special committee. Healthy persons under the age of 50 with dependent children were selected above unmarried applicants. Bona fide farmers, who lost farms due to circumstances 'beyond their control' were also preferred. Joblessness did not disadvantage applicants but could not be provided as the only reason why they should be allotted a piece of ground. Once an applicant had been selected he had to go to the offices of the Department of Lands at Andalusia where he randomly chose a plot by picking a piece of paper out of a box containing the numbers of all the available plots. By 1940 there were 304 settlers on the scheme. This grew to around 632 settlers and 147 probationary lessees by 1950.

Basic housing was provided comprising a brick three- or four-bedroomed house, with kitchen and bathroom, corrugated iron roof and wooden floors. Probationary lessees received livestock and production materials, for example a team of mules, dairy cows, a wagon, harnesses, a plough, harrow, small tools, seed and fertiliser. In the first 18 months of settlement, they also received a cash allowance, starting at around £7 and gradually diminishing to about a quarter of this amount. In exchange the lessee had to give the State a percentage of his harvest for the first four years. After the four years was up the lessee's probation was over and he had the choice to purchase his lot. Lessees did not pay for their water quota and were provided with a grant for the first 18 months, the amount depending on their marriage status and number of children. Initially, they were not allowed to hire labour and everyone had to pitch in, even the children. After the Second World War preference was given to ex-servicemen who wished to become farmers.

Due to the nature of the soil, a decision was made to establish an agricultural research station at Vaalharts in 1935. These early researchers knew just as little about which crops would be most suitable as the new farmers and farming really was by trial and error. In the early years, farmers mostly grew lucerne, ground nuts, potatoes, grains and vegetables. Today, farmers also grow pecan nuts, cotton, olives, citrus, apricots, grapes, watermelon and peaches. Wind was a considerable challenge and an early solution was to plant long rows of poplar trees along the hedges of fields. By 1945 about two million trees had been planted and, at one stage, Vaalharts had one of the longest hedgerows of poplars in the world. Today, few of these poplar hedges remain.

The Vaalharts Water User Association took over the government scheme in 2003. It remains the largest irrigation scheme in the country, with a scheduled area of 29 181 ha.

Vaal Dam

The outbreak of two World Wars saw massive bursts of secondary industrialisation taking place on the Witwatersrand, and with it an exponential growth in population. This resulted in an insatiable demand for water. Between 1915-16 and 1921-22 the number of industrial establishments in and around Johannesburg more than doubled from 862 to 1 760. With Johannesburg being one of the few large cities in the world not built on a large river, the Rand Water Board looked to the nearby Vaal River to meet the growing demand, constructing the Vaal Barrage in the early 1920s. Soon, however, this proved not to be enough to meet the users' growing water needs.

The Rand Water Board reached the limits of its abstraction rights in the early 1930s around the same time as the government was planning its Vaalharts irrigation scheme. After much debate, the government reached an agreement with the water board whereby a dam would be built at the confluence of the Wilge and Vaal rivers about 56 km south of Johannesburg, near Vereeniging. The dam was to be a mass gravity concrete structure 518,6 m long, with a height of 31,14 m above the mean river bed level and an earth embankment on the Transvaal (now Gauteng) side or right bank of the river, 1 890 m long. A novel feature of the overspill section of the dam, where floods were discharged, was the dissipation of destructive energy of the falling water through its contact with a step on the downstream face of the dam about 6 m below the crest and surmounted by a rock of brackets or 'splitters' so that the water would reach the riverbed largely in the form of spray. The lower capacity of the dam, 20%, as well as 10% of the increased capacity of the dam was placed at the exclusive use of the Rand Water Board. In addition, the board was given the right to develop any hydroelectrical power that would become available because of the release of water from the Vaal Dam.

The site of the Vaal Dam (then known as Vaalbank Dam) was first identified by FA Hurley during his extensive reconnaissance of the Vaal River in 1905. Government wavered between the Vaal-Wilge and Bloemhof (Krommellenboog) site, another potential site identified by Hurley, but in the end the upper site was selected. In his 1934 report Lewis explains why this particular site was selected: "There is a wide natural neck on the right bank at almost the exact level requirements to give the necessary storage, this obviating the necessity for passing the enormously high floods that can occur in the Vaal River over a high concrete dam and allowing for a comparatively cheap increase at a later stage by

Vaal Dam as seen from the air. It remains one of South Africa's biggest dams.

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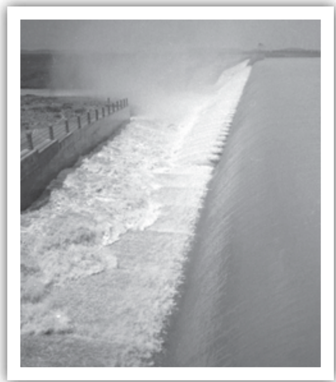

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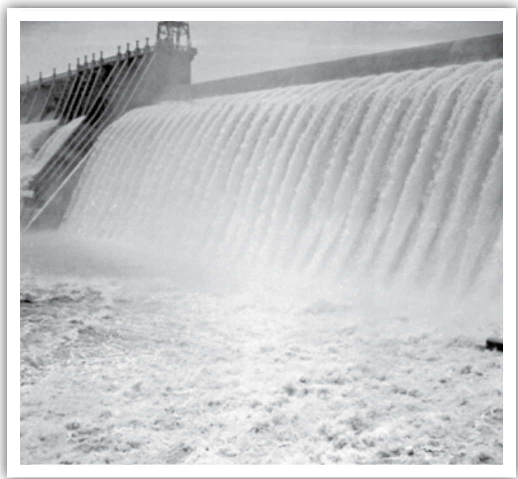
***Above**: The Vaal Dam construction site. About 800 men worked on the dam.*

***Above**: The Vaal Dam overflowing in 1939.*

***Below**: The Vaal Dam spilled for the first time on 13 December 1938. At that time the dam had a full supply capacity of 994 million m^3.*



DWA/eWISA

installing moveable gates in the spillway."

Work started on the dam in 1934. The government entered into an agreement with the Victoria Falls Power Company to convey power over 32 km to site, and camp and operating equipment was set up on the right bank. Initially only whites were employed. These labourers were between the ages of 18 and 45 and unmarried. The pay was two shillings per day, with a bonus of one shilling 6d per day worked. After six months the bonus was increased to one shilling 9 d and after 12 months to two shillings. Just like at other schemes, the workers' bonuses were paid into a Post Office Savings Bank account, and they were only allowed to draw the money after they left the work. Money could be paid to dependants via a stop order. Independent transport riders were employed to convey material from the train station at Viljoensdrift (on the Free State side) to site – a distance of about 30 km.

About 800 men worked on the construction of the dam. Housing, food, clothing and shoes were supplied for free. The men stayed in zinc huts with separate bathing facilities supplied. There was even a barbershop on site. A hospital was erected where a nurse tended to most injuries. Serious cases were sent to Vereeniging. In his annual report for 1934/35, Lewis writes how everything was done in the department's power to look after the social welfare of the workers, even so far as keeping them entertained after hours. Workers could amuse themselves in the recreation hall, where concerts and debate evenings were held regularly. A radio kept the men up to date on recent events, and they even had a boxing ring. Tennis courts and football fields were also laid out on site. No wonder then that the evening classes implemented were not very well attended!

Notwithstanding this, in 1935 the Department of Labour found it impossible to keep the white labour force "up to the required strength, and it became necessary to employ black workers on certain sections of the work." The reason for this, according to Lewis, was "the increased prosperity of the country and the consequent demand for labour." Around 300 black men were eventually employed. Work continued day and night, even in winter when the temperature sometimes dropped to -20°C.

In 1938, work on the superstructure of the Vaal Dam was completed, and a superintendent and small staff were appointed for maintenance purposes. On 13 December 1938, the dam overflowed for the first time. At that stage the dam had a full supply capacity of 994 million m^3. Lewis noted in his report for the period 1938/39 that "the dam's usefulness as a regulator of the Vaal River flow has now been amply demonstrated and, although the year was admittedly a good one as regards water supply, it is clear that the reach between the dam and the Vaalharz (sic)Weir will be vastly improved both in the increase of the winter minimum flow, and the reduction in the magnitude of floods."

During the construction of the Vaal Dam, a small village was

OF PLANES AND SECRET MEETINGS

Vaal Dam has its own island that was used for secret meetings during the old government days. For a time after the Second World War the dam was also established as a permanent flying boat base and port of entry for the British Overseas Airways Corporation service from Great Britain.

This service was instituted in December 1946. The overall flying time for the flying boat service was six days – definitely not for the fussing tourist or impatient businessman! The flight started in Southhampton, the first stop-over being Augusta, Sicily, where passengers spent the night. The next stops were Cairo and Luxor, where passengers were given the opportunity of visiting the historical relics. The flying boats then crossed to Anglo-Egyptian Sudan to Khartoum and made the third night's stop at Port Bell on Lake Victoria. From Port Bell the journey took them 2 000 km southwards over Lake Victoria, Tanganyika and Northern Rhodesia to the Zambezi just above the Victoria Falls, where the fourth and last night was spent. The final stage of the flight was the flight across Southern Rhodesia to the Vaal Dam.

The aeroplane used for the first flight was a Solent luxury flying boat, the *Southhampton*. Journalists and travel agents made up the bulk of the first flight. The commander of the Southhampton was Captain A le Roy Upton. According to him, the Vaal Dam was "the finest sheet of water" ever seen for landing flying boats.

Passengers who did not travel immediately to Johannesburg by luxury motor coach could stay at the Vaal Dam Hotel at Deneysville, while those who wanted to mail their families could do so at the old Vaal Dam Post Office.

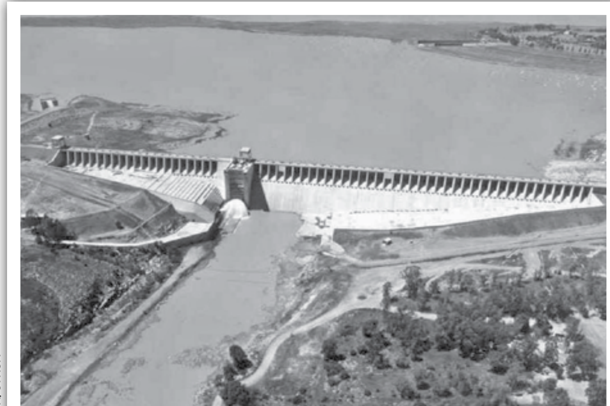
Sadly, the flying boat service was terminated as people began to discover that time was money and no-one could find the time to enjoy the feeling of an aeroplane's landing being cushioned by millions of cubic metres of water.

NLSA

founded named Deneysville after Deneys Reitz, who was Minister of Irrigation at the time of the dam's construction. Today, it is the centre of activity for the marinas and boating facilities that hug the shore of the dam. After the Second World War, because of the rapid expansion in industrial activity and development of the Free State goldfields, it was decided that the Vaal Dam be raised by 6,1 m to make additional supplies of water available. This comprised raising the concrete overspill crest by 3,05 m and installing 60 crest gates 2,05 m high on top of the concrete. The earth embankment was also raised. Work started in 1952 and was completed in 1956. The raising increased the storage capacity to 2 330-million m^3, which increased the dependable yield to 1 029-million m^3 a year. The cost of raising the dam was R2,9-million.

To better control floods, the gate height was increased by 1,82 m. This was done by adding a bottom extension to the existing gates. Furthermore, it was proposed that a pilot channel be provided through the saddle dam embankment. This saddle dam is situated on the Gauteng side of the Vaal River. If this pilot channel were not installed a flood could breach the saddle dam and cause extensive damage to the undeveloped valley below the dam. Provision was also made for foundation drainage to uplift the dam wall itself. This was to improve the stability of the concrete wall, and was done

The Vaal Dam was raised for the first time in the 1950s. The raising, completed in 1956, increased the dam's storage capacity to 2 330 million m^3.



DWA/eWISA

by providing a foundation drainage tunnel in the foundations below the dam wall. This tunnel is 600 m long and a vertical curtain of drainage holes was drilled between the tunnel and the foundation line.

The stability of the concrete wall was also improved. Tensile stresses on the upstream face were decreased through the installation of pre-stressed cables. A total of 320 cables along the crest, 2,8 m from the upstream face, were installed. Each cable reaches from the crest to a maximum of 25 m below foundation level. New hoisting structures and hoisting gear capable of raising the gates completely clear of the bridge deck were also installed.

In 1979, the Department of Water Affairs proposed to raise the dam wall to 3,05 m. This was to increase the capacity of the Vaal Dam by 1 033,5 million m^3 to 3 364-million m^3. It was proposed that 1,1 m of this raising be used for supply storage and the rest for flood storage. In this way, it was possible to store for consumption an addition 342 million m^3 of water. This second raising took place in 1985.

The flood attenuation properties of the dam were severely tested in February 1996 when the largest flood ever recorded at the Vaal Dam site was experienced. An inflow of over 4 700 m^3/s was measured into the Vaal Dam, which was already at full capacity due to good rains. Full supply capacity was reached on 19 February 1996, i.e. only 194 million m^3 of flood absorption capacity remained before the full inflow would have had to be released causing major damage. During the period from 15 December 1995 to 15 March 1996 the inflow volume to the dam was estimated at 7 605 million m^3 – enough the fill the dam three times over. The inflow peak was estimated to have a return period of 70 years, while the outflow peak was estimated to have a return period of only 20 years.

Engineering statistics of the Vaal Dam

Capacity: 2,54 billion m^3
Shoreline: 880 km
Dam surface area: 32 107 ha
Number of crest gates: 60, each capable of releasing 115 m^3/s. During high floods this can be increased to 202 m^3/s.
Number of provinces that make up the shorelines: Three (Free State, Mpumalanga and Gauteng)
Dam catchment area: 38 500 km^2

Lani van Vuuren

***Above**: The Vaal Dam is a concrete gravity structure with an earthfill section on the right flank. The dam has a current capacity of 2 536 million m^3.*

***Left**: Today, the dam has 60 crest gates, each capable of releasing 115 m^3/s.*

CLANWILLIAM DAM

Despite the construction of Bulshoek Dam in the Olifants River, in the Western Cape, in the 1920s, water demand soon again outstripped supply, especially during the hot summer months. In 1927, a start was made to line the canals with concrete, and by 1932 nearly £89 000 was spent on this endeavour. Meanwhile, the Union Irrigation Department undertook surveys along the Olifants River and its tributary, the Doorn River, in search of a suitable site for a new storage dam. It was hoped that this new dam would not only store enough water for the existing irrigation scheme, but allow for the expansion of agricultural activities.

A suitable site was found just outside Clanwilliam. Work started with the construction of staff housing and the erection of machinery in September 1932. Again only white workers were employed on the construction of the dam. However, as the new dam would inundate part of the Clanwilliam-Piketberg Road, a new bypass had to be created, and here use was made of coloured labour.

Lani van Vuuren

Lani van Vuuren

Left: *The Lower Olifants River has for centuries been the artery of life for one of the most important agricultural regions in the country.*

Top right: *The original Clanwilliam Dam shortly after its completion.*

Middle right: *The original outlets at Clanwilliam Dam, photographed in 1936.*

Bottom right: *Clanwilliam Dam spilling in 1961.*

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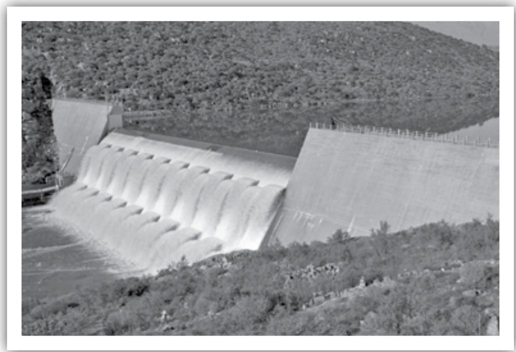

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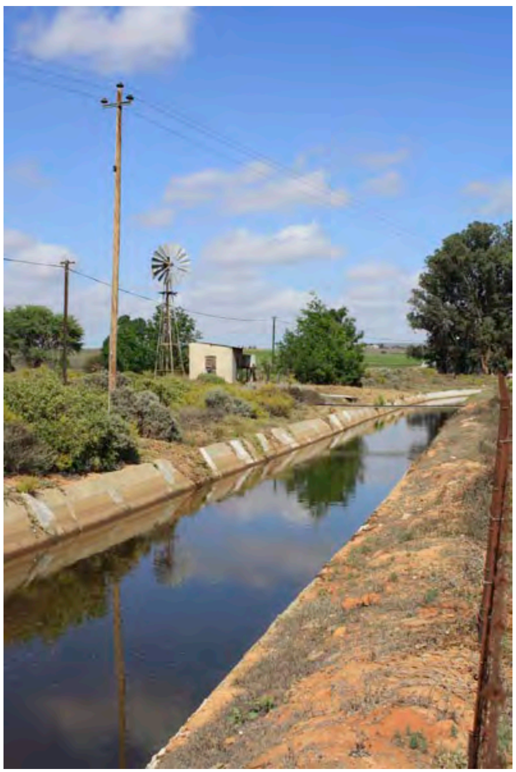
At the height of construction (1934) an average of 428 whites and 366 coloured workers were employed. White workers earned 4 shillings and eight pennies a day, while their coloured counterparts earned two shillings and 6 pennies a day. In his 1934 report, Director of Irrigation AD Lewis complained about the productivity of the white workers. Recruited by the Department of Labour, many of these workers probably had no construction skills (in subsequent reports the aversion of many of these workers to hard, physical labour is also noted). Staff housing comprised wood houses with tin roofs, along with a combined mess hall and entertainment area. Meals were supplied to workers daily at a cost of one shilling, and the mess hall was



Lani van Vuuren

***Right**: In the early 1960s Clanwilliam Dam was raised with the installation of 13 crest gates.*

***Left**: The Lower Olifants River main canal was clad with concrete in the 1960s.*

Lani van Vuuren

managed by the farmer on whose farm the dam was being built.

By December 1933, the foundations had been completed and placing of concrete started in January 1934. Clanwilliam Dam was completed in March, 1935. The original dam was a mass concrete gravity structure with a centrally situated overspill section, 117 m long.

By 1962 the Olifants River valley was inhabited by about 13 000 people. The ever increasing need for water resulted in the dam being raised between 1962 and 1964. The overspill crest was increased in length, remodelled and raised by the addition of 3,05 m of mass concrete on top of the crest, and the installation of 13 crest gates, each 7,77 m wide and 3,05 m high.

In addition, the non-overspill flanks were raised by 4,88 m by means of mass concrete. A bridge superstructure was constructed across the dam to provide access for the operation of the gates. For stability, the dam is tied to its foundations by means of post-tensioned cables positioned along the centre line of the dam. Clanwilliam Dam has a present height of 43 m, and a capacity of around 122 million m^3.

Water rushes through Clanwilliam Dam's crest gates. Plans are currently underfoot to raise the dam wall further.

Underground activities

When Dr JP Kriel, then Secretary of Water Affairs, visited Cradock in 1948 to investigate the proposed tunnel route of the Orange-Fish Tunnel, the biggest subject of discussion in town was the Ossewabrandwag, or Ox-wagon Sentinel, an anti-British and pro-German organisation, which opposed South Africa's participation in the war. When someone asked Dr Kriel whether he was also involved in these 'underground activities' his answer was an unequivocal: "Yes, on large scale!"

At present, plans are being finalised to raise the dam by another 13 m. This dual-purpose project will not only see the increase of storage capacity of the dam, but also aims to upgrade and strengthen the wall to ensure its safety and long-term viability, especially during flood events. This will entail increasing the width and height of the wall and spillway. A new multi-level outlet structure will also be constructed. A portion of the N7 national road will be affected by the raised water level and will be re-aligned by the South African National Roads Agency. Minor roads, property developments and cultivated land surrounding the dam basin will also be affected by the raised water level.

The raising of the dam will increase the yield of water supplied from the dam by 70 million m^3/year. This will stabilise the current irrigation development and provide an opportunity to establish resource poor farmers to promote food security and decent employment through inclusive economic growth. At least 75% of the additional water is earmarked for the development of resource poor farmers. The project has the potential to create about 3 800 jobs and provide tax revenue, including about R700-million on wine produced on the scheme.

In addition to the raising of the dam, the existing conveyance infrastructure needs to be improved and new conveyance infrastructure needs to be provided for land allocated to resource poor farmers. These actions, in parallel to construction work on the dam, will be required from the relevant agencies, such as the Lower Olifants River Water Users Association, and responsible government departments, such as the Western Cape Department of Agriculture.

THE WAR BRINGS A CHANGE OF FOCUS

The outbreak of the Second World War in 1939 yet again brought changes to the water resource development scene. The Irrigation Department, the driver behind most of these projects, had to release many of its staff for military service, most of whom joined the Mobile Field Force. In his annual report for 1939/1940 Lewis writes: "It was fortunate that at the outbreak of war we had a strong force of engineers and workmen and considerable construction materials in works which were nearing completion and we were, therefore, able to render immediate assistance to the Defence Department on a large scale." Lewis himself was seconded to a Technical Committee of Defence on War Supplies and as Advisory Engineer to the Department of Defence. He retired in 1941, ending a 20-year spell as Director of the Irrigation Department. He was eventually succeeded by LA Mackenzie.

Throughout the war, the department was severely handicapped in the prosecution of its work, both irrigation and other use. Over 50% of technical

Pongola Irrigation Scheme

The Pongola River has its source 12 km west of Wakkerstroom in Mpumalanga and flows for 170 km in an easterly direction and then north, reaching the sea at the Maputo River in Mozambique. The name 'Pongola' is derived from isiZulu meaning 'river of troughs' or 'great pools'.

Up until the 1800s, the river formed an informal boundary between Swaziland and Zululand. Then Swazi authorities requested Britain to demarcate formal boundaries between the two areas. President Paul Kruger of the ZAR, who saw the opportunity of establishing an alternative harbour for the republic at Kosi Bay, negotiated with Queen Victoria for a strip of land between Swaziland and Zululand to be allocated to the Transvaal. He then proclaimed it a nature reserve in 1894 – the first one on the continent.

Early white settlers planted cotton, but malaria and other diseases kept population numbers low.

The Irrigation Department was first requested to investigate the possibility of establishing an irrigation scheme on the Pongola River, in what was then known as Zululand, in 1925. The request was made by RA Rouillard, a French engineer who had settled in the area after working on the Vryheid coalfields. In the early 1930s the department undertook reconnaissance surveys along the river. These survey parties were badly plagued by malaria, and to cross the river the surveyors had to escape the snapping jaws of crocodiles. Despite the difficulties they faced, the surveyors successfully complete reconnaissance of the area, and construction of the scheme, comprising a weir and 64 km of earth canals, started in June, 1932 at an estimated cost of £200 000.

Initially only black labour was to be used, but because of the government's policies of the time an additional 250 white workers were also employed, mostly recruited from the Vryheid and Piet Retief districts. White workers were paid 5 shillings a day while black workers were paid 1 shilling 6d a day. Housing was provided for free, but a small fee (1 shilling) was charged for meals.

No machinery was used and everything was done by hand. The area was very remote and malaria was a real threat. Two hospitals, one for white workers and one for black workers, were erected to deal with cases of malaria and any other injuries or illness occurring on the site.

The scheme was completed in 1934, and during 1935/36 the first settlers – young, unmarried men arrived. They were initially housed in a specially constructed hostel. Each received a parcel of land for a probationary period of two years. Thereafter they were allowed to marry and settle permanently. The weir, a reinforced concrete overspill structure, was originally 305 m long and 6 m above the lowest foundation. However, it completely silted up. This, together with the remoteness of the area and other challenges, led to the scheme effectively being closed down by 1941, with the last few settlers being re-settled at the Loskop scheme.

During the Second World War the hostel was used as an internment camp for Italian prisoners who were set to work growing vegetables for convoys and military camps. To this end, some 1 713 ha of ground was cultivated, the main crops being potatoes, vegetables and maize.

Towards the end of the war investigations into improving the scheme began, and a fairly large area was subsequently put under sugarcane.

Bob Raymer/Wikipedia

personnel, together with a large proportion of administration and clerical staff, joined the war effort. A total of 22 departmental staff died during the war. The Irrigation Department was forced to curtail ordinary activities as all of its resources were put to the exposal of the Defence Department and, in fact, some branches almost ceased to function as such. Among the local defence infrastructure the department participated in were 14 military camps, aerodrome hangars, the naval storage depot at Ganspan and various smaller works.

During the war years no new infrastructure projects were embarked upon, and the completion of schemes which were under construction, as we have seen from the examples above, were considerably delayed. However, even while the hostilities raged overseas, the Irrigation Department was called on to prepare post-war irrigation projects which could gradually be put into operation as an avenue of employment for post-war years. Thus, the Reconnaissance and Surveys Branch was kept quite busy, with investigations for at least 28 potential projects being undertaken between 1939 and 1946. One of these was the Orange-Fish Tunnel.

After the war the Irrigation Department found itself increasingly becoming involved in municipal and industrial water schemes. Some of the dams completed soon after the war include Bronkhorstspruit, Laing, Witbank and Middelburg dams. Subsidies of up to a third of total project cost for domestic water schemes were introduced to improve the standards of supply, although these were soon subsequently modified to assist only smaller municipalities that would otherwise not have been in a position to carry out works on a satisfactory standard. In the first year after the subsidies were introduced, 13 municipal water schemes were approved by Parliament.

In 1946, a move towards the better planning of water resource development, a Research Branch was established under the leadership of former Loskop scheme Resident Engineer, DF Roberts. In addition, the Hydrographic Survey Branch, which was later to become a Hydrological Division, was expanded to organise, coordinate and increase the tempo of the investigations into and the evaluation of resources.

The department's surveyors were known for their skills and they were in high demand, and especially after the Second World War many left government service for better salaries in private practice. So many had resigned from the Irrigation Department that by 1957 there were only four surveyors left. ◈

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The Blyde River valley was among the areas surveyed during the war years.

Reconnaissance cowboys

One of the toughest jobs in the Irrigation Department was that of surveyor. These men spent months on end in the field with the stars as their ceiling and the veld as their beds. The only transport up to the 1960s were half ton trucks and horse-drawn carts, however, these were only used by those lucky enough to work further than 16 km from camp. The rest had to depend on their feet, usually accompanied by porters with guns to ward of any wild animals that might be encountered.

Supplies were usually transported to the survey parties by rail, and food was stored in home-made coolers. It was only in the 1950s that paraffin refrigerators started to be used. The instruments used were simple and using them was usually time-consuming and frustrating.

In the early days of the department young civil engineers had to spend six months in the field with surveying teams to brush up on their surveying skills. In this way strong bonds formed between the engineering and survey sections of the Irrigation Department.

8

Harnessing the rain on another plain (1950-1980)

The end of the Second World War signalled the end of the focus on irrigation and rising emphasis on water provision to cater for an increasingly industrialised and urbanised society. As South Africa's mines and factories were not always located in areas of ample water supply, the country started devising water transfer schemes on large scale to bring water to catchments in need from areas of plenty.


Lani van Vuuren

Today a playground for jet skis and motorboats, Bronkhorstspruit Dam, completed in 1950, was one of the first dams built after the Second World War.

The year 1945 brought a radical change in thinking on water management. During the previous 50 years, the department's emphasis had been on supplying water to irrigators who had used much of the water rather extravagantly. The ever-growing needs of expanding mines and industry and domestic use as well as the acceptance of the fact that the water resources were limited required a complete change in water legislation. Less and less of these water storage works were aimed exclusively at providing water for irrigation purposes, and the Irrigation Department found itself increasingly engaging in work out of touch with its original mandate under the 1912 Act. In his first post-war annual report in 1946, new Director of Irrigation, LA Mackenzie, writes: "During the past half century we have been chiefly concerned with the agricultural use of water, both domestic and irrigation, and have not kept pace with the ever increasing needs of our mining, urban and industrial development and the time is ripe for a complete revision of the Act to meet the present changed conditions."

By 1946 there were 147 river and irrigation districts, but concern was growing over the way in which these districts were applying their water. Even back then there was a strong realisation of the limits of the country's water resources. According to Mackenzie "a better and more economical use of South Africa's water" had to be given effect to. "Though unpalatable to the farming community it is a fact that much of the present day irrigation use of water is primitive, wasteful and uneconomical and recent surveys indicate that too large a percentage of our most fertile soil is being ruined over over-irrigation, unscientific farming methods and the growing of unsuitable crops," (Union of South Africa, 1948). Mackenzie was very much in favour of developing regional schemes that would serve multiple users. It was also his feeling that the department should play a leading role to ensure water resources were developed systematically and well ahead of demand (rather than haphazardly as it had been done in the past).


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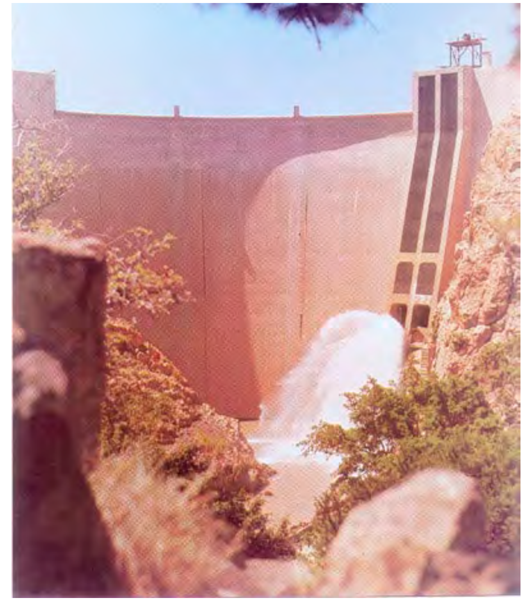
DWA-eWISA

The first major shift away from irrigation occurred when the Vaal River Development Act was amended to enable water to be supplied to the Orange Free State Goldfields, the first large regional scheme to be constructed. This scheme was authorised by Parliament in 1946 following the discovery of gold in the Odendaalsrus area. The scheme comprised the construction of an intake on the south bank of the Vaal River near Bothaville. From the river, low lift pumps raised the water to a nearby water treatment plant. Following treatment, water was


DWA

Top left: *Craigieburn Dam during construction in the early 1960s. This 35 m-high thin arch dam was completed in 1963, with the main aim of stabilising irrigation along the Mooi River, KwaZulu-Natal.*

Bottom left: *The 61 m-high Ebenezer Dam was completed in 1959 originally to provide water for irrigation down the Great Letaba River. Since 1973, Polokwane has also drawn water from the dam.*

Above: *Njelele Dam was originally completed in 1948 to stabilise the flow of the river and to make water available for irrigation in the Makhado (Louis Trichardt) district. The dam was raised by 6 m in 1967 to a current height of 43 m.*

lifted over 150 m in two stages to service reservoirs 66 km away built on a high point commanding the new goldfield and its satellite villages. Construction started in 1948 and by 1951 water was being delivered to the goldfields area, including Odendaalsrus, Welkom, Virginia, Riebeeckstad, Henneman, Wesselsbron, and Allanridge.

A NEW ACT AND A NEW NAME

In 1956, a new Water Act superseded the Irrigation and Conservation of Waters Act of 1912. With it the Irrigation Department now became the Department of Water Affairs (DWA) to reflect its expanding duties. A few years later, in 1961, the designation of the head of the department changed from Director to Secretary. In essence, the new Act vested the Minister and DWA with wider powers of control over the water resources of the country with a view to 'more efficient and equitable employment by agricultural, industrial and other interests'. This meant that riparian owners could still use the water resources on their private property, but that the State could also allocate water to industries and non-riparian users. The law also made it easier for industries to gain access to water resources.

Significantly, the Act gave power to the State President of the country to declare 'any area within which the use of water should be controlled in the public interest to be a government water control area'. Equally, a 'catchment control area' could be declared. In such control areas the State would be allowed to expropriate any land required and would obtain all the water rights within the area. Director of Water Affairs, JM Jordaan, wrote of the new Act in 1956/57: "The Water Act contains much that is without precedent and in the administration of its provisions the department will in many respects be breaking new ground and have to feel its way. The benefits to be derived by the country as a whole will become apparent when the department has, by experience, learnt how the new provisions can most advantageously be applied in practice and when the necessary administrative machinery has achieved the required proficiency," (Union(c), 1960).

The functions of DWA in 1956

- The **Research Branch** of the Planning and Research Division undertook preliminary investigations into the water resources of South Africa and their possible utilisation. If a scheme appeared feasible, the planning branch, with the assistance of the reconnaissance section, made detailed investigations. This branch also prepared detailed designs for construction purposes and drew up estimates of costs for parliamentary approval.
- The **Construction Division** organised and carried out construction work.
- Once completed, the administration of a scheme rested with an Irrigation Board or the **Superintending Division**. In addition to the national office, there were eight Circles – basically regional offices of the Superintending Division.
- The **Mechanical Division** solved all mechanical and electrical problems.
- The **Boring Branch** developed water supplies from underground sources for farmers. This branch also undertook exploratory drilling for dam sites.
- The **Hydrological Division** collected and correlated data on rainfall, river flow, evaporation, transpiration, underground water, the water requirement of crops and spring flow and return seepage.
- The **General Administration Division** dealt with legal and administrative matters.
- The **Servitudes Branch** attended to the acquisition of servitudes for storage, abutment, aqueduct and drainage in connection with government water schemes.
- Other departments included Accounts, Stores, the Staff Branch, Registry, Drawing Offices and Plant Reproduction Section.

IRRIGATION WATER SUPPLY

The shift in focus onto large industrial and mining users of water did not mean that further dams for irrigation development would be precluded from the department's portfolio after the war. In fact, a large number of dams were constructed particularly to satisfy the ruling party's large rural electorate, especially in the run-up to the second golden era of dam-building in the 1960s and 1970s. Most of these so-called Government Water Schemes were constructed in the old Transvaal (now North West, Mpumalanga and Limpopo provinces) and the Orange Free State. Preparation of these schemes had taken place either during or immediately after the war. Among these schemes built in the 1950s were the Bronkhorstspruit, Levubu (later renamed Albasini), Ohrigstad, Tarka River, Elands River, Koster River, Groot Letaba, Lindleyspoort, Modder River, Mogalakweni, Njelele and Sand-Vet Government Water Schemes. However, in contrast to the schemes built before the war, most of these schemes were no longer exclusively for irrigation use. Rather, they were multipurpose dams, providing water for irrigation as well as domestic or other uses. The development of a couple of these schemes is related in more detail below.

IRRIGATION IN THE GAMTOOS VALLEY

Situated between winter and summer rainfall areas the Gamtoos valley is known for its rich, fertile soils, its fresh water, and its subsequent agricultural bounty. The main river running through the valley is the Kouga River. Rising at Avontuur at a height of 1 500 m above sea level, the Kouga River flows through the Langkloof Valley, lying between the Tsitsikamma, Kouga and Winterhoek mountains. After joining up with its tributary, the Baviaanskloof River, it flows through a narrow gorge, the Kougapoort, to its confluence with the Groot River. After the confluence, the name of the river changes to Gamtoos.

The valley was originally populated by Khoisan communities. Trekboers first settled in the Gamtoos valley with their livestock in the era of Dutch occupation, and by 1770 the Gamtoos River was declared the eastern boundary of the Cape settlement. This remained so until 1804 when the area became part of the newly proclaimed Uitenhage district. Between 1816 and 1818 the first farms of around 1 713 ha each were officially handed over to European farmers. Irrigation in the valley started in the 1840s and gained momentum after the introduction of lucerne to bolster the production of ostrich feathers. Storage weirs and distribution canals were constructed by several farmers in the district who wanted a share of one of South Africa's most lucrative export products at the time. Where weirs were impractical steam and oil pumps were used to bring water from the river to the field.

Following a visit to the valley an agricultural assistant to the Cape government wrote in 1904: "Some help is needed to simplify the present complicated system of distribution...The present system of using the water is wasteful to extreme. The temporary dams are inefficient and constantly being broken by floods. The water leading canals are small and long, badly laid out and far too numerous, owing to a lack of combination among the proprietors and it only requires organisation and a reader outlet for the produce to bring great prosperity.

"Should the government undertake the work of regulating

Albasini Dam


DWA/eWISA

An early aerial photograph of Albasini Dam.

João Albasini was born in Lisbon, Portugal, in 1813. When his ship was stranded on the east coast of Africa nearly two decades later, he set up a trading store in Delagoa Bay. It was here that he met Voortrekker leader Carel Trichardt in 1838, with whom he formed a hunting partnership. He later settled on the Sabie River, and in 1845 became the first Portuguese trader to do business with the Voortrekkers under the leadership of Andries Ohrigstad. Perhaps an indication of his roving spirit Albasini would move around quite frequently in his lifetime, leaving Ohrigstad for Lydenburg and then later settling in the Soutpansberg. Eventually he settled on the farm *Goedewensch*, where he died in 1888.

The Levubu Irrigation Settlement was established on the banks of the Luvuvhu River in the 1940s, and shortly after the Second World War it was decided to improve water supply to this scheme by constructing a dam. This site identified was on Albasini's farm *Goedewensch*, and thus would later carry his name.

Completed in 1953, the original dam was a concrete structure with earth flanks, 30 m high and 622 m long. In 1970/71, the full supply level of the dam was increased by the installation of radial crest gates 3 m high.

and conserving the water supply of the Gamtoos valley the scheme that would meet the most general approval on the part of the inhabitants would be one for the construction of a series of dams in the bed of the river itself, from which the water might be brought on the land either by gravitation or by pumping" (Malan, 1970).

These unorganised and primitive methods of extracting water led to numerous requests by community leaders and the farmers themselves for intervention by the State through the development of proper irrigation schemes. In 1910, the Cape Director of Irrigation, FE Kanthack, visited the valley. He called it "the most favourable part of the Union." Following the promulgation of the Irrigation and Conservation of Waters Act of 1912 several Irrigation Boards were established in the Gamtoos valley, including the Kougapoort, Reenen and Rademeyer Irrigation Boards. By the 1950s, there were some 4 798 ha of land under irrigation in the valley. The main crops under irrigation at that time were citrus, tobacco, vegetables, potatoes, wheat, maize and lucerne, with Port Elizabeth proving a convenient market.

The boards immediately set to work improving irrigation infrastructure with significant loans from the government. One of these schemes, Reenen, was completed in 1916 and included a weir, 29 km-long canal and a tunnel of 163 m to irrigate 1 285 ha of land. Periodical floods were the enemy of irrigation farmers in the Gamtoos valley. In May 1916, such an extreme event led to the death of 24 people. The Gamtoos River destroyed everything in its path, including the newly constructed irrigation infrastructure as well as 514 ha of scheduled irrigation land. Many of the farmers also lost their crops. More loans had to be made to rebuild the works. Extreme measures were taken to protect the structures from further flood damage, including surrounding them with thorny branches and gabions of rock and steel. These were often simply washed away when the river came down. In long stretches of the river, no large rocks could later be found.

Another notable flood hit the region in 1932, this time destroying 932 ha of land and washing away weirs and canals. Thankfully the arrival of a telephone service years earlier meant that people could be forewarned and no loss of life occurred. At Hankey, known at that time for the quality of its apples and other fruit, most of the trees were lost. Following the flood the Irrigation Commission surveyed the damage in the valley and recommended the construction of dams to control these periodical floods. When the farmers were not tormented by floods they had to contend with droughts. Available flow in the Kouga and Gamtoos rivers was insufficient for around a third of the time. Farmers upstream were better positioned than their downstream neighbours, especially in times of deficit.

A number of sites for storage dams in the Kouga River catchment had been investigated from time to time. As early as 1931 a site on the farm *Kruisrivier*, immediately below the confluence of the Kouga and Baviaanskloof rivers was surveyed, while in 1947 and 1953 further topographical surveys were made of alternative sites near Guerna, a short distance below the infall of the Witteklip River in the Kouga, and on the farm *Tweerivieren* in Kougapoort. The latter site, located about 5 km upstream of the Kouga/Gamtoos confluence, was eventually selected, and the dam was initially known as Tweerivieren Dam. Topographical surveys were carried out of the Gamtoos valley in 1952/1953. In 1956, the Department of Agriculture commissioned an investigation into the suitability of the soil in the valley for the expansion of irrigation.

BEERVLEI DAM

In 1946, the Union government rather unexpectedly decided to first construct a flood control at Beervlei on the Groot River near Willowmore, before making a final decision on a dam in the Gamtoos valley. The site, situated about 5 km below the confluence of the Groot River with the South and Kariega rivers, was first recognised in the early 1920s. Considered one of the best storage basins in the country, irrigators along the Groot River agitated for this dam for many years. However, because of the extremely irregular flow, high

The Beervlei Dam is a bit of an oddity on the landscape, since it is mostly completely empty.

Cedric Nunn/Africa Media Online


DWA-eWISA

The Beervlei Dam's distinctive multiple arch structure comprises 15 cylindrical arches with gravity sections on its flanks.

mineral content and silt load of the rivers, the government was at first reluctant until it was decided to use Beervlei mainly for flood control instead. Only around 2 190 ha of irrigated area would be regulated from this dam.

Construction of the multiple arch dam started in 1953. At that time it was government policy to make use of black convict labour on large public works projects and so a large prison labour camp was constructed at the site. Around 400 prisoners eventually worked on the dam. Excavations for foundations started in July 1954, and the first concrete was placed in May, 1955. Due to the high mineral content of the water, a super sulphated cement was imported from Belgium and used in the preparation of concrete for the dam. The spillway was originally at two levels, the upper level was 1,8 m above the full supply level and reached over three of the dam's 15 cylindrical arches.

The project was finally completed in September, 1957. In 1967, the full supply level of the dam was raised to the level of the upper spillway to increase the capacity of the dam from 52 208 million m^3 to 92 850 million m^3. The dam wall has a height above lowest foundation of 31 m, and a crest length of 348 m. The volume content of the dam is 0,042 million m^3 and it has a gross capacity of 100 731 million m^3.

The dam is a bit of an oddity on the landscape. Being a flood attenuation dam it is kept mostly empty, prompting passersby to think that it is decommissioned. The dam is indeed 'alive and well' in its empty state – since it is a flood attenuation dam the dam is always kept purposefully empty so as to ensure it can retain as much floodwater as possible. In addition, it has been found that lengthy storage of the Karoo water results in high water salinity. Thus any floodwater is used as quickly as possible by downstream irrigators.

KOUGA DAM

In 1955, Paul Sauer, then Minister of Lands, stated that once the Beervlei Dam was completed, a start would be made with a dam on the Kouga River. A White Paper proposing the building of the Kouga Dam was submitted to Parliament in 1957, and not long thereafter a construction team moved onto site. The DWA team selected was the same one that had constructed the Beervlei Dam.

The original objectives of the project as stated in the document was to ensure a more assured


Gamtoos Irrigation Board

supply of water to the existing lands under irrigation, permit the development under irrigation of an additional 3 770 ha of land for the purposes of government settlement, and to alleviate serious flood hazards in the Gamtoos valley. Later it was realised that the dam also had the potential to supply water to Port Elizabeth and renowned water engineer Ninham Shand was appointed by the town council to report on this possibility. The town council resolved to proceed with the Kouga scheme on the basis of a supply drawn from the end of a canal system at Loerie. In 1963, Council negotiated an agreement with government for a water supply from the scheme which was redefined as dual purpose, namely irrigation and urban usage. The agreement provided for the supply by government to council at Loerie of a quantity of water not exceeding an annual average of 140 000 m^3/day.

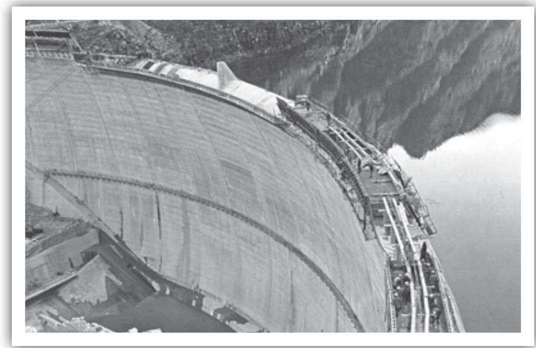
Original design and estimates were based on a concrete gravity dam, however, it was later decided to construct the dam as a double curvature thin ('cupola') arch instead as this would be less

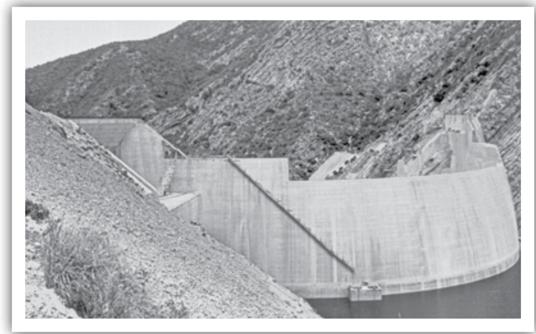
Left: *Kouga Dam is located near the downstream end of the Gamtoos valley in a narrow gorge.*

Top right: *The Kouga Dam wall during construction. Cocopans were used to bring concrete to the top of the wall. Here the rail can clearly be seen.*

Middle right: *Kouga Dam was the first double curvature thin ('cupola') arch dam to be constructed in South Africa. This was a triumph for the Department of Water Affairs which was responsible for both the design and construction of the dam.*

Bottom right: *A close-up of the overspill section of the Kouga Dam during construction.*


Gamtoos Irrigation Board


Gamtoos Irrigation Board


Gamtoos Irrigation Board

expensive. This was the first dam of its kind to be constructed in South Africa. The DWA project team developed a mathematical mesh model to obtain the optimal shape of the dam and ensure minimum bending within the shell. Solid model laboratory tests were also undertaken – another 'first' for the department.

The geological conditions at the site provided many challenges, and a number of measures had to be provided to safeguard the dam and its foundations. Among others, three tunnels, each 145 m long, were constructed in the right flank for drainage and pressure alleviation. In addition, a thick reinforced concrete slab was built against the downstream right abutment.

This was post-stressed with cables extending to a depth of 40 m into the mountain. Lastly, a comprehensive set of observation points and instruments were incorporated on and inside the dam wall. The latter led to even more sophisticated instrumentation in other cupola dams such as the Pongolapoort Dam. Huge volumes of water had to be diverted from the construction area, resulting in the construction of a substantial coffer dam. The dam was 302 m long and varied from 5 m to 9 m in height.

Excavation for the main wall started in August, 1958. Little over a year later the placing of concrete started. The wall was constructed to a maximum height of 94,5 m above the lowest foundation level. The maximum thickness of the shell is 10,2 m tapering down to 4,8 m at the non-overspill spill. A small hydroelectric power station was constructed on the right bank (it was later found to be non-economical).

In order for the dam to fulfil its flood control function, a radial gate-controlled chute spillway was installed on the left flank, making it possible to drawn down to the level in the reservoir before a flood arrived and so alleviate the

Kouga Dam engineering features

Dam type: Double curvature arch dam
Maximum height above lowest foundation: 94,5 m
Crest length: 204 m
Maximum water depth: 53 m
Gross storage capacity: 133 million m^3
Surface area (at full supply level): 555 ha
Total quantity of concrete in wall: 268 000 m^3
Maximum thickness of wall: 10,2 m
Design flood (1:200 year): 4 249 m^3/s


Wayne Erlank

__Below:__ A 2,4 m-diameter pipe being offloaded to distribute water from the Kouga Dam. The dam not only supplies water to irrigators in the Gamtoos valley, but also supplements water supply to Port Elizabeth.

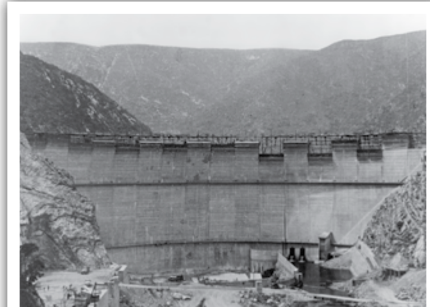
__Below right:__ A downstream view of Kouga Dam during construction.

__Above:__ Kouga Dam spilling in 2006.

__Right:__ A historical photograph of Kouga Dam as seen from the right bank.


Gamtoos Irrigation Board


Gamtoos Irrigation Board



The use of convict labour

In the early 1950s the South African government started employing prisoners on its public works projects. Water infrastructure schemes were considered especially suitable for the use of convict labour. Only black prisoners were employed, and only those serving long-term sentences (i.e. two years or longer).

While they received no salaries, the convicts had to be housed and fed, and huge, highly-secured prison camps were constructed at various dam sites for this purpose. For example, at Ohrigstad and Floriskraal dams 200 and 300 prisoners were employed respectively, while at Beervlei and Kouga dams 400 prisoners were employed at each site. While the Department of Water Affairs carried the cost of housing and transporting the prisoners, they were fed and clothed (and guarded) by the Department of Correctional Services, with additional wardens being employed specifically for this purpose.

Unfortunately for the State the prisoners tended to be far less productive than their free counterparts. They even had a tendency to deliberately injure themselves on site so as to avoid the hard, physical work. In the 1954/55 report of the department, Director DF Marais writes: "Measured over a long period these prisoners do from 50% to 60% of what hired Native labourers (sic) do under the same conditions and from the State's point of view such work must be recorded in credit side (i.e. they work for free). From a departmental point of view, purely from cost angle, such work is not an asset. In modern construction where a large number of machined and trained operators and maintenance staff are used overheads can become a very material factor if the time spent on the work is unduly protracted. It must therefore be our aim to influence the prisoner into producing more work per shift."

Various methods of motivating the prisoners to improve their work output were applied, including providing a ration of tobacco to those who reached a certain quota each day. This does not seem to have made much difference and the idea was abandoned a few years later.


Gamtoos Irrigation Board

The prison camp at the Kouga Dam construction site housed 400 inmates.


DWA-eWISA

Floriskraal Dam during construction. Partially built by convict labour the dam was completed in 1957.

flood peak. The dam also features an uncontrolled spillway 64 m above apron level. The hydraulics of the dissipation of energy of the water passing over the spillway down to the apron gave rise to a number of problems. The impact forces on the apron were measured through a series of hydraulic model tests and reduced as far as possible using a deep water cushion. The apron was built to be a minimum of 3 m thick, and is heavily reinforced and anchored to the rock. The dam was eventually completed in 1969. Today, several decades later, it still provides a valuable water supply function in this region.

WAGENDRIFT DAM

Sites for possible water storage in the Upper Thukela River and its tributaries were first investigated by the Irrigation Department after the Second World War. The resultant report, published in 1948, sited the Bushmans River above Estcourt as a particularly good spot to build a dam to stabilise water supply to the town and irrigation farmers in the area. Estcourt, which began its life as a modest trading store established by its first inhabitant

Clem Heeley in 1847, had by then flourished into the largest industrial and commercial centre in the Midlands region. It was thought that by providing additional water resources, these enterprises could be expanded.

The potential of the Upper Thukela as a potential stimulator of the economy was noticed even then. "It [is] apparent that the rivers of Northern Natal, properly regulated, represent extremely important water resources in the national economy which, in point in fact, exceed the requirements of all possible agricultural development in their valleys and reasonable industrial use," wrote Mackenzie in his 1948 report. Of course, the Thukela River would later become one of South Africa's strategically most important river systems with the construction of the Thukela-Vaal Transfer Scheme to supply water to Gauteng.

The 1948 report recommended that initial operations be focused on establishing a dam on the Bushmans River above Estcourt and so work was undertaken in this regard by DWA. Various possibilities were investigated, including establishing the dam on the farm *Groot Mielietuin*, but the department eventually settled for a dam site on the farm

Roodeplaat Dam

Farmers in the Pienaars River Valley started irrigating their fields as far back as the late-1800s. Irrigation infrastructure was not sophisticated, and comprised mainly short unlined furrows dug in the alluvial soils on the banks of the Pienaars River into which water from the river was diverted by small low weirs. It was beyond the financial means of the irrigators themselves to provide storage in the river, and representations for the construction of a dam were made during the first years of the twentieth century. Possible dam sites were surveyed back in 1909, but it was only in 1955 that construction of a dam in the Pienaars River actually started.

Known as the Pienaars River Government Water Scheme, the scheme originally consisted of small plots of about 13 ha each, totalling about 1 700 ha of irrigable land (these plots were later found to be uneconomical to run and the government bought them out in 1969). The dam, situated about 25 km northeast of Pretoria, was constructed on the farm *Roodeplaat* at the confluence of the Pienaars River, Hartebees Spruit and Edendal Spruit by DWA.

A concrete arch dam with a marked vertical curvature, the dam was constructed to a wall height of 54,3 m, and a spillway section of 143 m long. The dam has a storage capacity of 40 million m^3. On completion in 1959, it was the highest dam of its type in the country.

In the construction of the dam, a blend of ordinary Portland cement and milled granulated blast furnace slag was used for the first time by DWA. This pozzolan, or cement extender, is a blast furnace waste product which usually comprises between 50% and 70% of the total cementitious material content. The use of this so-called slagment, makes it possible to reduce the quantity of ordinary Portland cement in concrete, reducing the heat produced by the chemical reaction of the cement setting.

Today, the main purpose of the dam is to supply water for urban use. In 2006, two new layers of outlets were added to create a five-level abstraction facility under full operational head.


DWA-eWISA

Above: *A historic photograph of Roodeplaat Dam shortly after its completion in 1959.*

Below: *Roodeplaat Dam has a crest length of 351 m and a wall height above lowest foundation of 54,3 m.*


Tony Moore

DWA-eWISA

Wagendrift – some 6 km upstream and south west of Estcourt. The farm takes its name from the drift through the Bushmans River used by transport wagons on their way from Port Natal to the goldfields of the Witwatersrand. This site was thought to have good storage characteristics and be well placed in respect of the water resources available. In addition, it would inundate relatively undeveloped areas. The primary objective of the dam according to the White Paper, would be to 'stabilise the flow of the Bushmans River to overcome the seasonal shortages experienced by irrigators lower down the valley at Weenen and to provide an assured supply for municipal and industrial use in Estcourt'.

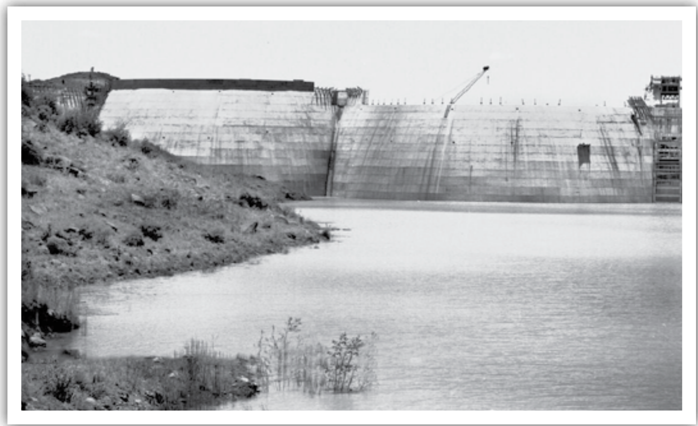
The proposed scheme was approved by Parliament in 1959, and work on the construction camp began that same year. The department had managed to obtain 20 railway construction houses in Estcourt for housing a large proportion of its employees, and so only 19 houses had to be erected at the dam site. By the end of March, 1960, the camp and works buildings had been completed and a start was made on excavation – 6 116 m^3 of excavation was done that first year.

In total, some 96 000 m^3 of soil was excavated and 73 00 m^3 of rock, while some 54 000 m^3 of concrete went into the dam wall. By the end of July, 1960, it was possible to cast the first concrete in the central buttress and a year later the river was brought under control of the structure – the concrete work having been completed for the full bed width of the river section. The dam was eventually completed in 1963 and

***Above:** The main domes at Wagendrift Dam (spanning 63 m between the buttresses) are made up of solid skins generated by a series of ellipses and circles superimposed so that the centres of the ellipses and circles follow loci defined in a vertical plane.*

***Right:** Wagendrift Dam from the air. It was the first structure of significance to be constructed in the Upper Thukela River system.*

DWA-eWISA



DWA-eWISA

DWA-eWISA

DWA-eWISA

WRP

Top left: *Wagendrift Dam rises in the Bushmans River. The dam had an original maximum capacity 58,4-million m³.*

Bottom left: *Wagendrift's unusual design was selected to retain the economics of an arch structure while fitting a wide-bottomed site. The dam wall is 281 m long from flank to flank.*

Top right: *Wagendrift Dam nearing completion. Some of the shuttering can still be seen. The dam used the same type of shuttering as that applied on the construction of Kariba Dam.*

Bottom right: *Wagendrift Dam spilling. Today, the dam makes a magnificent site for motorists passing on the N3 highway.*

officially opened on 14 March, 1964 amidst great fanfare. The final dam is a 40 m-high multiple double-curvature arch dam – believed to be the first of its kind in the world. The design retained the economics of an arch structure while fitting a wide-bottomed site at the same time. Wagendrift had an initial storage capacity of some 58,4 million m^3. Like many other South African dams, this dam was also designed in such a way to allow for future raising.

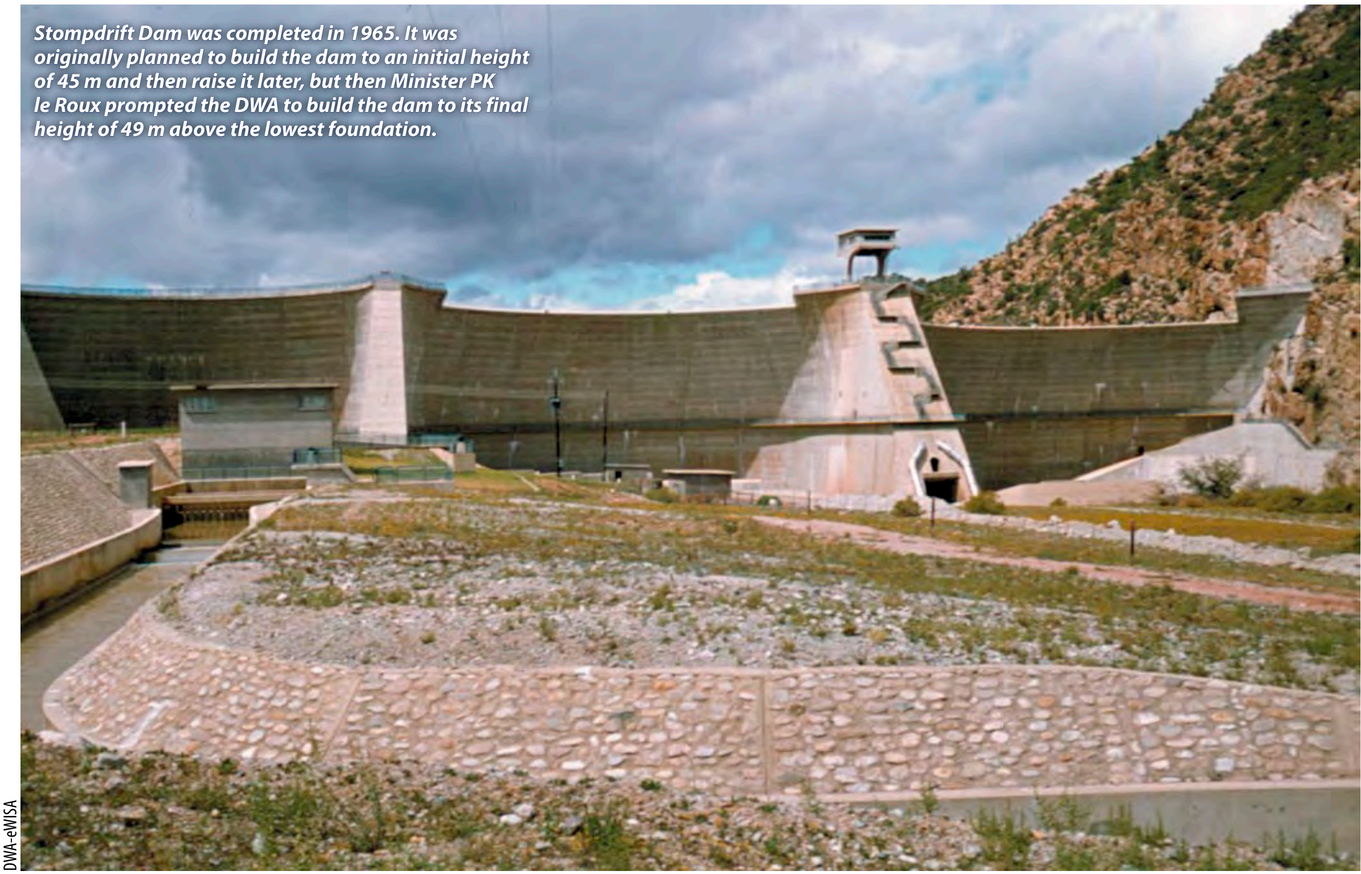
During the final design stage the initial arches were modified to domes – the latter being more economical than arches and also offering the added possibility of simplification of the outlet and scouring arrangements. The final structure has four domes supported by five buttresses spanning the major section of the river. The flanks have been closed off by means of half-domes with the crown thrust from the half-domes carried to the foundation and flanks by means of pre-stressed cantilever thrust blocks. One of the greatest challenges of the project was the shuttering – while the type of shuttering used at Kariba Dam was applied it took a considerable time before proficiency in application of a flat plane to a warped or curved surface was achieved.

DWA designers had to design a dam that would be able to withstand extremely variable flow, from as little as about 0,1 m^3/s to in excess of 28 m^3/s. High flood discharge is carried over the two central domes which provide a spillway length of 107 m, but low floods and service requirements are accommodated by the outlet works contained in the central buttress. The whole structure is symmetrical about the central buttress which has been split on its centre line to provide for the outlet works. The buttress is virtually a mass gravity structure but has been reinforced near the upstream face by means of post-tensioned stressing cables. A 2,7 m by 3 m radial gate was installed for desilting purposes. This was originally operated by means of an electrically driven rack-and-pinion winch. The normal service openings were provided in the form of three sets of 0,9 m-diameter pipes so connected that they are able to discharge water through one set of outlets.

STOMPDRIFT DAM

As we saw in Chapter 6, farmers in the Oudtshoorn district were among the first in South Africa to establish irrigation works, initially for their tobacco fields and later to produce lucerne for their ostriches. The first large dam to be constructed in the district was Kamanassie Dam, and despite several investigations into additional possibilities from 1877 another dam was yet to be established in this part of the Little Karoo. Potential sites were investigated (and dismissed) in the Grobbelaars and Groot rivers, after which attention turned to the Traka River, a major tributary of the Olifants River in its upper reaches.

The first investigations into the possibility of establishing a dam in the Traka River date back to 1908 when a site at Toorwaterspoort was surveyed.

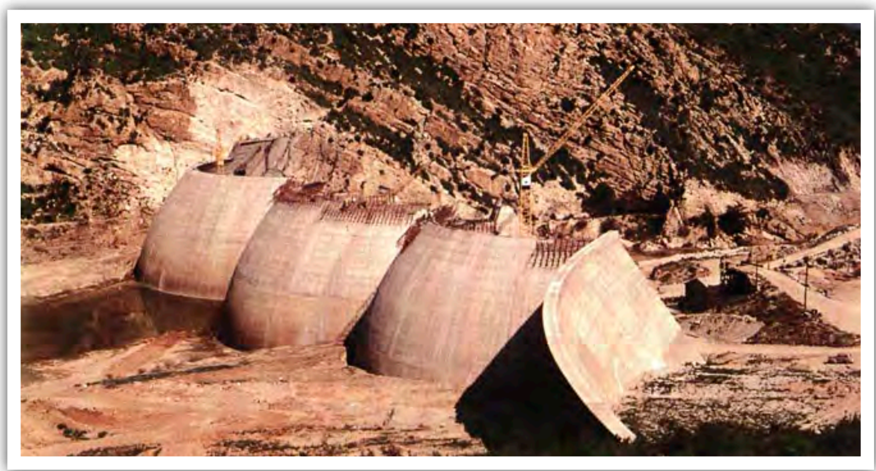


Stompdrift Dam was completed in 1965. It was originally planned to build the dam to an initial height of 45 m and then raise it later, but then Minister PK le Roux prompted the DWA to build the dam to its final height of 49 m above the lowest foundation.

DWA-eWISA

Unfortunately both the runoff and the available dam sites left a great deal to be desired. Moreover, building a dam here would require long deviations of the railway line between Uniondale Road and Willowmore, resulting in such a scheme being rejected on economic grounds. In 1947, consideration was given to a proposal to build a dam in the Upper Olifants River, on the farm *Bakkie*, but this too was eventually rejected for being uneconomical. Also, such a scheme would benefit a limited number of farmers in the Upper Olifants valley to the detriment of their downstream neighbours. The Irrigation Department even considered diverting water from other catchments, such as the Gamka, and transporting it to the Olifants River valley, but again costs proved prohibitive. Meanwhile rising lucerne prices had encouraged increased development in the upper valley, with the result that the interests of the downstream farmers, insofar as water supplies during times of shortage were concerned, were seriously prejudiced. It seemed that when these farmers did not have too little water, they had too much. Periodical flooding along the Olifants River caused considerable damage to infrastructure and livelihoods from time to time.

DWA-eWISA



DWA-eWISA

***Left**: Stompdrift Dam has a full storage capacity of some 49,6 million m^3.*

***Below**: The multiple domes of Stompdrift Dam taking shape during construction.*

Thus effort was rather put into finding a suitable site below the junction of the Olifants and Traka rivers where the flow was boosted by a number of mountain tributaries. Reconnaissance by the DWA, followed by detailed surveys around 1954, revealed that only two sites were suitable for the construction of a dam: one near the Stompdrift railway line siding on the farms *Doornkraal* and *Fonteinskloof* near De Rust, and the other located on the farm *Rooikrans*, 3 miles downstream of Uniondale Road station. Drilling to explore foundation conditions resulted in the latter site to be rejected, and so all eyes turned to the Stompdrift site.

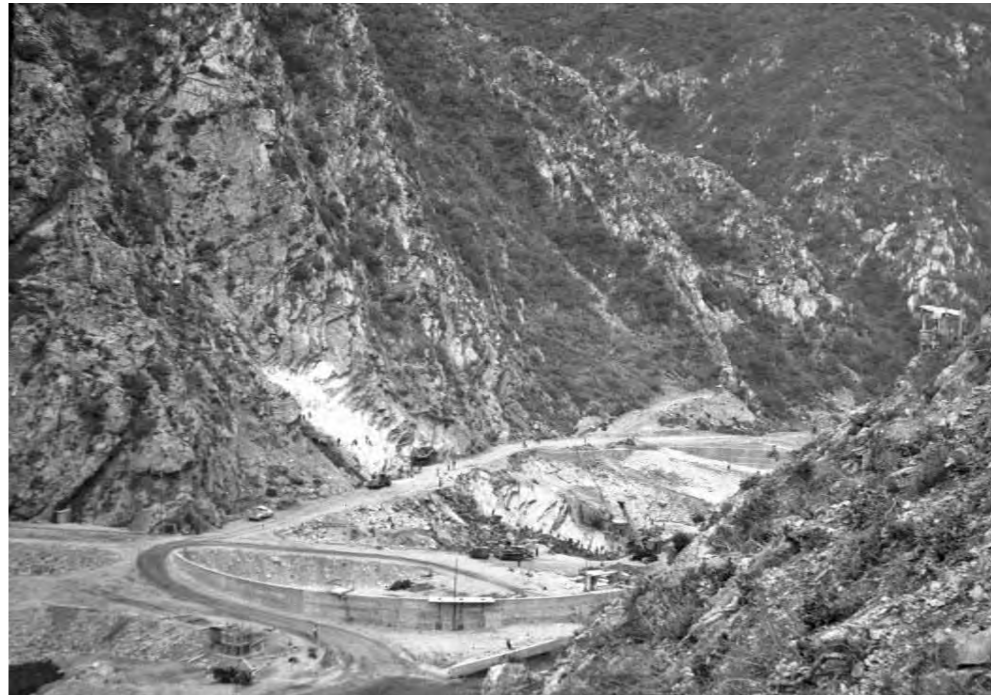
A White Paper was prepared in 1959, and upon receiving Parliamentary approval the DWA moved its construction teams onto site. The main aim of Stompdrift Dam was to regulate the flow of the Olifants River to provide increased and more assured water supplies for existing irrigation development in the valley downstream, however, it was also to function as a flood control works. Initial preparations included constructing housing for staff, roads, electricity supply, sewage disposal, offices, workshops, a concrete testing laboratory and a clinic.

Interestingly, the dam was constructed on the property of then Water Affairs Minister PK le Roux. This led to rumours that he was profiting from the construction of the dam, however, it is maintained that this just happened to be the best site available. The only money the minister made was by selling stone and sand in the riverbed on his farm.

The works initially drew its water supply from one of the boreholes sunk to test foundations, which yielded around 8 m³/hour. Later five boreholes yielding from 20 m³ to 36 m³/hour were sunk.

Theo Hooper was appointed Resident Engineer. The dam was designed as a multiple dome structure supported by a left rock flank and three buttresses. An earth flank on the right bank completed the picture. By the end of January, 1960, sufficient labour was available to make a start on stripping the surface material from the cliff slopes and, with the help of a bulldozer, the excavation of river gravel down to solid rock for the building of the upstream coffer dam. Excavations were later sped up with the arrival of a Lorain excavator. More than 400 people were employed on the construction of the dam.

A considerable complication of the site was the fact that the railway line from Oudtshoorn to Klipplaat ran straight through the site and had to be relocated by South African Railways. This caused great difficulties for the dam construction team as the rail service had to be kept running and a gap left in the dam to be filled later. The rail deviation was finally completed by May, 1962. Once the old railway track was removed the work could be spread over the whole of the secondary arch. This was not the only challenge the project was to face. Scarcely had the excavations of the dam been completed in 1962 when a large flood originating in the Great Karoo overflowed the coffer dam and filled the excavations to the brim with slimy sludge. This proved most difficult to remove.



The Stompdrift Dam site in 1959 prior to the construction of the dam. The dam is located on the farm of former Water Affairs Minister PK le Roux.

Interestingly, the dam was constructed on the property of then Water Affairs Minister PK le Roux. This led to rumours that he was profiting from the construction of the dam, however, it is maintained that this just happened to be the best site available. The only money the minister made was by selling stone and sand in the riverbed on his farm. He did exercise his power, however, by inducing the department to complete the dam, which would originally have been built in two phases, in one go. Stompdrift Dam was finally completed in 1965 with a maximum capacity of 49,6 million m³. The height of the dam above the lowest foundation level is 49 m and the total crest length is 364 m.

Era of apartheid

The victory of the National Party in the 1948 national elections signalled a new era in South Africa – that of the implementation of apartheid on a grand scale.

While discrimination of other races was already entrenched in the national psyche through legislation such as the 1913 Land Act, the government would now establish total control over people's movements, where they lived and worked, what work they did, whom they could have relationships with – even as far as where they could sit on the train and which entrance they could use at the post office.

One of the government's most significant policies was the creation of a series of semi-independent states (also called 'homelands' or 'bantustans') mainly for black communities. The idea behind the creation of these territories, which started with the Black Authorities Act, promulgated in 1951, was that the Republic would become the exclusive home of white people while black people and people of other races would become citizens of particular 'homelands' based on their ethnic and linguistic origin. The subsequent Promotion of Black Self Government Act of 1959 made provision for these entities to gain self-governing status (the idea being that they would eventually become completely independent from South Africa). With the adoption of the Black States Constitution Act in 1971 the machinery was created whereby the constitutional development of these states could be accelerated. The Transkei was first to gain independence in 1976. Other subsequent entities included Bophuthatswana, KaNgwane, KwaZulu, Lebowa, Qwaqwa, South Ndebele, Venda, Ciskei and Gazankulu.

The creation of these states made the management of water resources in South Africa much more complex as several river systems were now deemed 'international' by virtue of being shared between South Africa and the homelands. In 1973, a special Interdepartmental Committee was established to enquire into, report on and make recommendations on a way to 'fairly divide' these common resources between the black states and the remainder of the Republic. The Committee report, published in 1979, made several recommendations, including:

- That the Helsinki rules of 1966 for international water courses be applied for the division of water;
- That initial allocations of water from common rivers be made to every state within the limits of which development of water can take place freely;
- That on common rivers existing development (including planned projects and those under construction) receive preference for the allocation of water between states; and
- That in every agreement between a black state and the Republic, provision be made for the institution of a Permanent Technical Water Commission with equal representation of each state concerned to deal with the administrative and technical tasks resulting from agreements.

The Department of Bantu Administration (later renamed the Department of Plural Relations and Administration) was responsible for the provision of water to these homelands. Agriculture was the mainstay of these areas, and several dams were constructed either by the Department of Water Affairs or through contractors in the 1970s, including Lubisi, Umtata, and Ncora dams.

Black resistance to the restrictive laws of apartheid often led to violent clashes between communities and the police. In 1960, the Pan Africanist Congress (PAC) announced a campaign against the pass laws. On 21 March of that year residents of Sharpeville on the Witwatersrand marched to the police station. Shots were fired into the crowd and 69 people were killed.

The killings were condemned internationally, and panicky investors started extracting their capital. The Stock Exchange plummeted. The State reacted by calling a state of emergency on 30 March and detaining 18 000 people over the next few weeks. It also banned the PAC and the African National Congress (ANC). To curb the mass outflow of capital, the government imposed strict controls on the repatriation of profits. Foreign firms were left with little option but to reinvest in South Africa.

But the government needed to restore confidence in the country's economy. Shortly after that the announcement came that South Africa would see the construction of its biggest engineering feat yet: the Orange River Development Project (ORDP), of which the Gariep Dam (then known as the Ruigte Valley and later Hendrik Verwoerd Dam) formed the main storage unit. On 23 March 1962, Minister of Water Affairs, PK le Roux, announced in Parliament the commencement of the construction of the ORDP. During his announcement, Le Roux said that "the government has therefore decided to undertake the biggest, most important and most spectacular water supply project ever initiated in the history of our country's water affairs. Not only is it the biggest in Africa, when seen as a whole, but it will be one of the biggest projects of its kind in the world."

"In the history of all young civilised countries the time arrives when big and imaginative water development projects must be launched to promote the growth of areas of development, the formation of industries and the generation of electric power, and to create a means of coping with the future population increase, so as to maintain the rate of progress for the country as a whole. That is the principal aim of the Orange River Project," said Le Roux.

PONGOLAPOORT DAM

The Pongola River passes between the Lebombo and Ubombo ranges through a narrow gorge (known as Pongolapoort) and the lower reaches of the river lie on the Maputuland coastal plain east of the mountains in northern KwaZulu-Natal. Here, the river has a slope of 1 in 3 000; the abrupt change in gradient stems the flow rate of the river on the plain, causing a deposition of part of the sediment load and the flooding of extensive areas adjacent to the river course. This broad alluvial plain, known as the Pongola floodplain, extends from the gorge to the confluence of the Pongola and the Usutu rivers, close to the border with Mozambique.

The Pongola floodplain is one of the most biologically diverse ecosystems in South Africa. The complex of lagoons, oxbow lakes, marshes, forests, levees and flood-plain grassland provide habitat for a very wide variety of birds, fish and animals. Importantly, the area is home to thousands of people from the amaThonga culture, who have lived adjacent to the floodplain and subsisted off the resources it provided for hundreds of years.

Pongolapoort Dam's 183 m-long spillway is situated in the centre of the arch.

DWA/eWISA

Prior to construction of the dam, summer flooding inundated the floodplain creating a diverse set of environmental conditions and when these floodwaters receded, rich soils were exposed. These soils were cultivated as they dried, providing a wide range of crops to local inhabit-ants. In addition to cropping, the natural resources of the forests adjoining the floodplain provided a variety of products for food, fuel, construction and traditional medicines. In winter, the flood-plain provided grazing for live-stock. But it was the agriculture potential of the adjacent Makatini flats rather than the value of the floodplain ecosystem services that drew the attention of the National Party government. Long before the decision was uttered to build the Pongolapoort Dam in 1960, the area to the east of the gorge was earmarked for white farmer upliftment, particularly through sugarcane production.

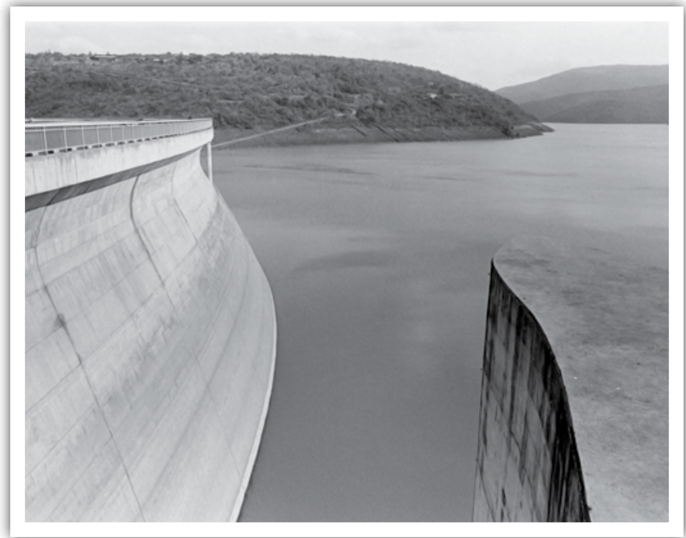
By 1955, plans were well advanced for the construction of a dam in the Pongolapoort. The dam was to be big enough to support 40 000 to 50 000 ha of irrigation on the Makatini Flats, a highly fertile area adjacent to the floodplain on both sides of the river. Apart from boosting commercial farming, the government also hoped to 'stabilise the frontier' bordering Mozambique and Swaziland. At the time, it was believed that development would automatically follow impoundment and so not much consideration was given to alternative development options. Interestingly, merits of the scheme were a subject of debate even after construction started. One of the main grounds of criticism was that intensive soil and other tests, which would determine suitable land usage, were only undertaken after the project was given the go ahead.

After the scheme was announced it took three more years of preliminary work before construction of the actual dam started in 1963. Four suitable sites were investigated. Siting was complicated by the underlying geological conditions. The dam is founded mainly on good-quality dacite of the Lebombo Group, but the presence of deeply weathered breccia dykes crossing the river at almost right angles strongly influenced the founding conditions. In order to avoid crossing the two largest breccias dykes, the dam had to be sited so far downstream that the upper flanks could not make optimum use of the site topography. The dam was eventually located at the eastern end of Pongolapoort.

Prior to the construction of Pongolapoort Dam, the area was fairly isolated. There were no communications or services of any sort and, according to media reports at the time, Resident Engineer RF Phélines spent the early years of construction sleeping in a tent. Before building of the dam itself could start, a heavy-duty road was constructed over the Lebombo Mountains to the railhead around 30 km away. A village was also erected to house staff and their families (with a hostel for bachelors), and a compound for the estimated 1 400 black workers employed on the project.

Until work started on the Gariep Dam in 1966, Pongolapoort was the largest dam under construction in South Africa. It is a medium thin, double curvature

__Right__: Pongolapoort Dam (formerly known as JG Strydom Dam after a former Prime Minister) was the largest dam in South Africa prior to the construction of Gariep Dam on the Orange River.



Cedric Nunn/Africa Media Online

__Below__: Pongolapoort Dam as seen from the air. The dam has gross capacity of 2 500 million m³- twice the mean annual runoff of the river.

Kevin Rogers

Kevin Rogers

Fish was an important source of food for people of the floodplain. Traditionally fish were caught using weaved baskets known as isifonyo.

arch dam with a gradual transition towards a gravity thrust block on the left flank. It has a maximum height of 89 m and a crest length of 515 m. The dam has a controlled and an uncontrolled spillway. The gross capacity of the reservoir is 2 500 million m^3, which is more than twice the mean annual runoff. The chute spillways have a combined capacity of 2 010 m^3 at high flood level. The thickness of the wall above the cushion is 18,3 m tapering to 8,2 m at the spillway and then flowing to 11 m to carry a double carriageway across it.

A crucial element of the design aspect was determining the most efficient shape of the arch. This was achieved using an analogue mesh model of a series of strings where the foundation shape (boundary condition) was determined and the loads in three-dimensions were applied by weighted strings. Dr Paul Roberts, who worked in the design office at DWA at the time explains the process: "We had huge sheets of tables to do all of the hand calculations. At the time we were very proud of our electro-mechanical calculators which could add, subtract, multiply and divide. Once we had determined the shape we had the Hydraulics Laboratory perform a solid model, test where the model was cast in plaster of paris, loaded with mercury and strains measured with strain gauges – a long and tedious process. The advent of the electronic computer years later replaced all of this activity and it is now so much easier to undertake finite element analyses quickly and cheaply."

The foundations and abutments of the dam presented a number of challenges. During excavation for the foundation, great difficulty was experienced as a result of the sensitivity of the brittle dacite to blasting and stress relief and its reaction to changes in temperature. In the SANCOLD publication *Large Dams and Water Systems in South Africa* it is written: "Whole layers of what appeared to be sound rock scaled off with a noise like a pistol shot and necessitated the use of 30 m-long rock anchors, line drilling and the use of hydraulic wedging for final excavations." Work on the dam was on a 24-hour basis, requiring up to 764 m^3 of concrete a day. The aggregate came from a site 20 km upstream, some two million tons had been stockpiled at the start of the project.

It has to be noted that the envisaged large-scale irrigation development never occurred following the completion of the dam.

Another significant challenge was the high average air temperatures on the site. This was overcome by pre-cooling the aggregate with controlled amounts of crushed ice. Pongolapoort Dam was the first dam in South Africa where this artificial cooling method was used. FA Venter wrote about it in 1970: "The conveyor with its load of snow in the depths of the warm valley is a prime example of Western science and technology and the use of water for the progress for Africa."

At a later stage, piped cooling systems, which gave better control, were used in the construction of the Gariep and Vanderkloof dams. The dam went up in 1,8 m sections, the curvature of each one having to be separately calculated, taking about 30 hours on a manual calculation. Some 563 000 m^3 of concrete and rock went into the dam wall. Each vertical section is independent of the other. The gravity sections on the flanks induced blasting of some 500 000 t of rock. The dam was eventually completed in 1973.

It has to be noted that the envisaged large-scale irrigation development never occurred following the completion of the dam. This was due to, among others, a significant drop in the price of sugar. Today, only about 3 000 ha of irrigation has been created.

The building of the dam and planned irrigation developments of the area focused attention on the unique floodplain ecosystem downstream of the scheme and the plight of the AmaTonga people dependent on the ecosystem services it provided. The completion of the dam resulted in the flow of the river to the floodplain being regulated. Strong voices were heard from the research community for releases from the dam to stimulate the natural flow regime and thus maintain the floodplain integrity.

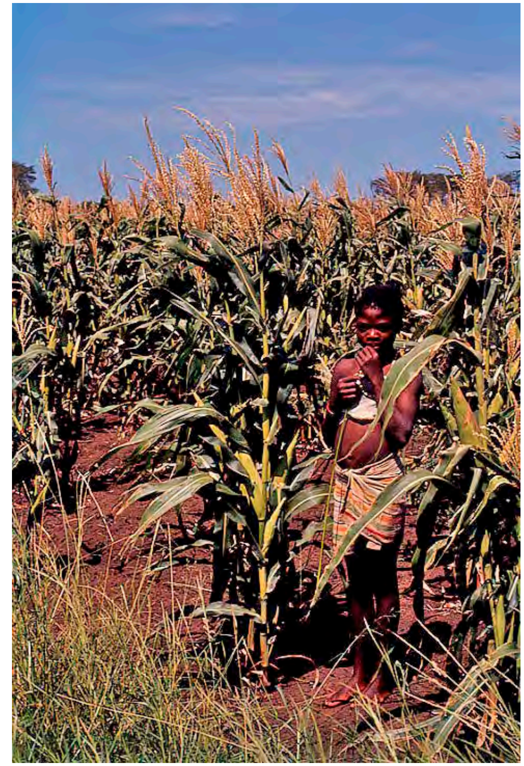
A multidisciplinary research programme was initiated by Prof Charles Breen and Jan Heeg of the University of Natal in the 1970s with the aim to understand the floodplain as a social-ecological system. Even today this would be considered an unparalleled exercise in environmental flow determination because it had the express objective to deliver both social and environmental justice. The research was the first in this country, and arguably internationally, to propose flow releases from a dam to maintain ecosystem services delivery to people, and as such was an important precursor to our current concept of the Ecological Reserve, which has the same purpose. The government of the time was sympathetic to a concept of 'water for ecosystem maintenance' but needed much convincing that the Pongolo floodplain should take preference over agricultural development.

An ingenious cost/benefit analysis by Breen and Heeg, however, clearly demonstrated that using 14,6% of mean assured yield to inundate the floodplain should generate the required ecosystem services which would be of much greater economic and social benefit than if that water were used to grow sugarcane under irrigation. The government was convinced and preparations then began to implement flow management in the 1980s.

However, in the early years following its completion Pongolapoort Dam could not be filled as it would inundate part of Swaziland. While negotiations with Great Britain prior to the independence of Swaziland had solved the problem of inundation, these decisions were withdrawn by Swazi authorities following the country's independence. During this time floodwater had to be discharged through the scour outlets. These outlets were not designed for that purpose, however, and were subsequently damaged. These damages necessitated the replacement of the sleeve valves which, in turn, reduced the capacity of the scour outlets by 36%.

Both the political and engineering problems were overcome by 1982. This was none too soon because in 1984 the area was hit by tropical cyclone Domoina. A 1985 DWA report on the effects of the cyclone describes that in January when Domoina hit, the catchment of the dam received more than 700 mm of rainfall (a record to this day). A peak inflow of 1 600 m^3/s occurred into the Pongolapoort Dam on 31 January 1984. This peak was 18 times higher than the previous highest recorded peak. At the time the dam was only 13% full. The total inflow as a result of the cyclone was 2 000 million m^3 or 87% of the total capacity of the dam.

During the 1970s social, ecological and hydrological scientists funded by the Cooperative Scientific Programme gained a detailed understanding of the Pongolo social-ecological system. It was clear that unless water was delivered to the floodplain at particular times of the year, for particular durations and to achieve a certain level of flooding, water quality would decline, organisms would not complete their lifecycles and people's livelihoods would be in jeopardy as


Kevin Rogers

The rich soils of the Pongola floodplain yielded good-quality crops.

ecological service provision was disrupted.

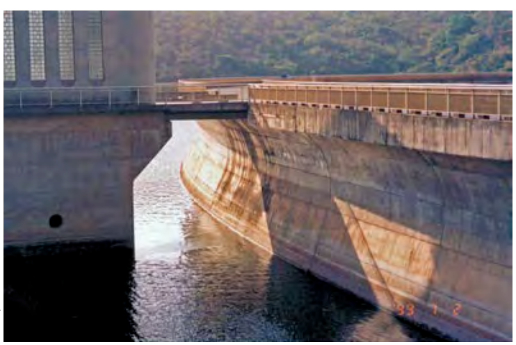
The scientists proposed a flow regime that should maintain the integrity of the ecosystem, and ecological services to the people, yet have minimal effect on irrigation potential. Winter flows in the Pongolo River were set to be around 2 m^3/s to meet the requirements of local people, but also those stipulated by

Mozambique. Periodic increases in flows (about 80 m^3/s) in early summer (November to January) would replenish the water in most floodplain pans, and a large flow (600 to 800 m^3/s) sometime in February would inundate the floodplain to high flood level. The early summer flows were planned to flush out saline water and refresh water available to people and livestock at the end of the dry winter. The February flow would provide the cue for fish migration and breeding, and the plant growth that followed the receding water provided grazing during the winter months when grazing of the floodplain was limited.

Relative to the detailed flow regimes of current day Ecological Reserves that for the Pongolo was simple, yet more than 25 years later none of its components, let alone the regime, have been implemented. While many issues have clouded decision making over this time, one of the main problems has been confusion between whether flow releases from the dam should be for the delivery of ecological services or agriculture on the floodplain.

Pongolapoort Dam engineering statistics

Type of dam: Double-curvature single-arch
Height above lowest foundation: 89 m
Length of crest: 515 m
Gross capacity: 2 500 million m^3
Volume content of dam: 575 000 m^3



DWA/eWISA

In this photograph the arch of Pongolapoort Dam is clearly visible.

Once the research process had delivered the proposed flow regime funding dried up and the hydrological and ecological researchers moved on to other projects. During the final years of the programme, however, social scientists had suggested that traditional farmers switch from their usual multi-coloured maize to white maize, which had the potential to give a higher yield. Within a few years white maize became the main crop, but since it had a much longer growing period than the traditional variety, fields were sometimes destroyed by floods that arrived before the grain was mature. Farmers, with the assistance of ex-social researchers, therefore persuaded dam operators that the proposed between-flood periods should be extended to allow the maize to mature.

This began an unstructured process of so-called 'negotiated' releases that has essentially ignored the regime proposed by the original research team and its purpose of generating ecosystem services. Between 1984 and 2005 some 25 releases were made from the dam. In some years there were no releases, in others two or three, and they came at any time of the year. Consequences of this unstructured decision making in a policy vacuum were soon felt throughout the social and ecological system. Fish stocks declined rapidly as adults were not ready to spawn in the cold of July or water levels fell too fast for juveniles to establish in the population. When floods were far apart evapo-transpiration losses of water resulted in many of the channels and oxbow lakes of the floodplain drying up, killing many aquatic organisms.

Traditionally, people had not fenced their fields on the floodplain because these water bodies prevented cattle from accessing them during the growing season. Now that they were drying up the cattle had easy access to the diverse crop lands that had fed the people for centuries. Serious conflict was reported between the agriculturists, graziers and fishermen within a community that no longer had the surety of food supply they had been used to under the natural flow regimes.

Almost 40 years after the construction of the Pongolapoort Dam, management of its waters is still the subject of contention. What future does this seemingly large white elephant hold under South Africa's new legislation? Government authorities have not written off the Pongolapoort Dam. Utilisation plans have been drawn up for the dam, focusing on its potential as an eco-tourism draw card and its potential as a water resource for domestic water supply in the area. The area around the dam certainly has a high conservation value, and today much of it is protected, either as a public nature reserve, private game farm of communal protected area. It is said that the dam could play a particularly important role in the Lebombo Spatial Initiative, an ambitious project that involves the regional interests of South Africa, Swaziland and Mozambique.

BLYDERIVIERSPOORT DAM

A significant tributary of the Olifants River, the Blyde River rises on the western slopes of the Drakensberg, near Sabie in Mpumalanga. It flows northwards past the town of Pilgrim's Rest for more than 100 km through a region of extraordinary beauty along the eastern escarpment and through the Blyderivierspoort. Here the Blyde River cascades down a steep series of rapids to its lower reaches, where it again flows northwards to join the Olifants River north of Hoedspruit.

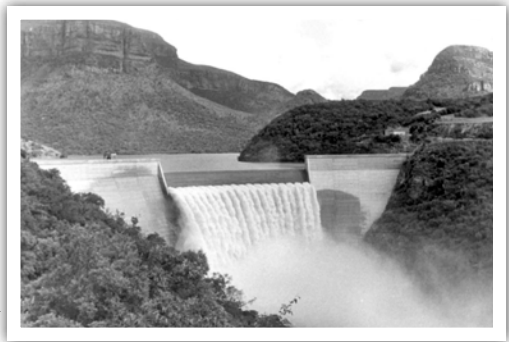
Modern irrigation started in the Lower Blyde River Valley in the late 1800s following the settlement of Voortrekkers in the area. However, Tsetse fly and malaria as well as skirmishes with local populations kept irrigation development to a minimum. Only after the introduction of DDT in the 1930s and 1940s did permanent crop farming take off. The first investigations towards the establishment of a large irrigation scheme were undertaken prior to the Second World War. In the subsequent Irrigation Department report published in 1936, Circle Engineer MA Kean proposed the construction of a dam on the farm *Rietvley 25* in the Lower Breede River Valley with a capacity of 333 million m^3.

Chris Kirchhoff/MediaclubSouthAfrica.com

Blyderivierspoort Dam has a maximum capacity of 54 million mʷ.

The outbreak of the Second World War stemmed any further development, and it was only in 1948 that the Irrigation Department again investigated the possibility of establishing a dam and bulk irrigation infrastructure here. The only irrigation of consequence could be found on the farm *Moriah*, where an irrigation furrow taking water directly from the Blyde River had been established. At this stage there were still only around 200 whites living in the valley (the population of 5 000 black people were not considered), of whom only 31 were farm owners. This proved not motivation enough to warrant such significant expenditure. The Irrigation Department was also demotivated by the results of soil studies, which indicated that soil conditions were mostly not conducive for irrigation. It was consequently decided that, until such time that the (white) farming community had increased considerably and had become experienced in local farming and irrigation methods, no large irrigation scheme would be contemplated by the government.

The Phalaborwa mining complex was established in the 1950s, and subsequently the Phalaborwa Barrage was constructed in 1966



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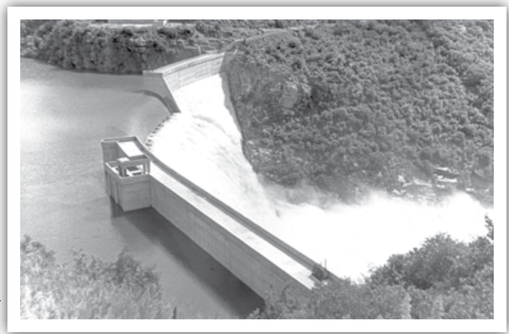

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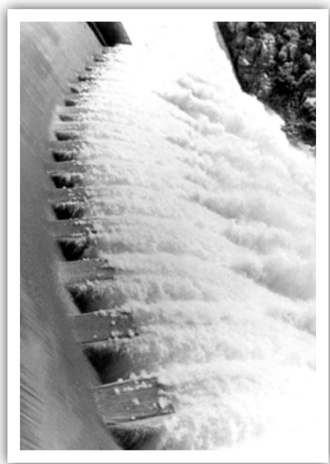


DWA/eWISA

***Right**: A close-up view of the Blyde-rivierspoort Dam overspill section. The steps built in to dissipate the energy of the falling water can clearly be seen.*

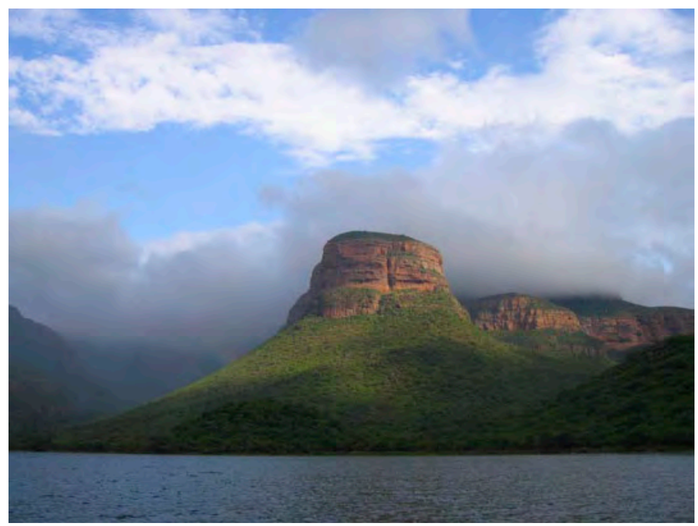
***Top left**: Blyderiviers-poort Dam is a concrete gravity arch dam. It was one of the first dams in the country where computers were used in the design calculations.*

***Middle left**: In total, about 220 000 m³ of concrete was used in the construction of the 71 m-high wall of the Blyderiviers-poort Dam.*

***Right**: Blyde-rivierspoort Dam is situated in one of the most scenic areas in the country and, in addition to its original purpose, has become a significant tourist attraction.*

to supplement water to the complex. The supply from this 235 m long concrete structure was controlled by the Phalaborwa Water Board, which had the right to abstract 28 127 290 m^3/day from the Olifants River. However, upstream developments, such as the raising of the Middelburg and Loskop dams later caused the water supply to the mines to fall short. This pushed the idea of a dam on the Blyde River back onto the table. The 1969 White Paper suggested the construction of a dam on the farm *Blyde River Poort* in the district of Pilgrim's Rest with the purpose of stabilising the supply of water to irrigators in the Blyde River irrigation district while, at the same time, increasing the quantity of water available to the Phalaborwa Water Board.

The proposal was approved by Parliament and preliminary work on the dam site just below the confluence of the Blyde and Ohrigstad rivers started in April 1970 with the establishment of roads and houses by the DWA. Excavation blasting started a year later in April 1971. By June, construction of the cofferdam started. This was completed in April 1972, despite setbacks caused by unprecedented floods (1 200 m^3/s). In August 1972, the first concrete was placed via cableway, and two years later the river diversion gap through the wall was



Robert van de Bijl

In 1972, history was made when the DWA's first female engineer to work on a construction site, A Mouton, joined the team at Blyde-rivierspoort Dam.

closed and the crusher removed out of the reservoir basin.

Originally it was thought that a double curvature dam could be constructed, but later this was changed to a concrete gravity arch. This was decided as the most suitable type of structure because the massive but weathered and jointed condition of the foundation necessitated a good distribution of load over a wide area. The maximum height of the dam is 71 m, with a crest length of 240 m and a maximum wall thickness of 30 m. Blyderivierspoort Dam has a maximum capacity of 54 million m^3.

The availability of alluvial deposits allowed the crusher to be located inside the dam basin, thus avoiding unnecessary scarring of the natural area. An aerial ropeway transported the aggregate from the crusher to the batching plant. Aggregate was stockpiled in the works area to facilitate early withdrawal of the crusher from the basin. The batching plant comprised aggregate bins into which the ropeway buckets discharged their loads, recovery tunnel and conveyor belts leading up to the top of the 30 m-high batching and mixing tower. The dam was completed in 1975, and spilled for the first time a year later.

URBAN WATER SUPPLY

The Second World War provided major stimulus for the diversification of the South African economy. Europe's post-war reconstruction triggered two decades of strong economic growth which only came to an end with the oil crisis of the 1970s. South Africa also benefited from this and during the 1960s managed to maintain one of the highest growth rates in the world. New opportunities opened up as the war virtually halted the flow of imported manufactured goods from Britain. People started pouring into towns and cities. Between 1936 and 1946 the proportion of urbanised people rose from around 48% to 53%. This rapid influx stretched the already inadequate infrastructure to breaking point.

Water demand in towns and cities rose sharply, and municipalities found themselves having to look further and further to bring water to their constituents. Apart from population growth, the increased introduction of waterborne sewerage in towns hitherto using the bucket system or pit latrines also pushed up demand. Spurred on by the government subsidies introduced after the First World War local governments, with the aid of consultants and the DWA, constructed an array of dams, many of which still play a crucial role in water supply today. Unlike the dams constructed in previous decades, these were often big, bold projects, a few examples of which appear below. Unfortunately, many of these projects were a haphazard and chaotic response to the experienced water shortage. Planned water development would only improve in later years.

WEMMERSHOEK DAM

Cape Town's modernisation accelerated after the First World War and so did the population. Between 1913 and 1945 the total number of people calling the Mother City home grew from around 152 000 to 370 000. While Cape Town had all the makings

The intake tower of Wemmershoek Dam is 7,3 m in diameter and 55 m high. Water is drawn from the intake tower through penstocks at various levels.

eWisa/Dirk van Driel

of a modern city by 1949, it was lacking one thing – water.

Today, the Wemmershoek Dam still plays a critical role in the bulk water supply to Cape Town and surrounds. But it took several decades from the time the engineering project was first contemplated to being executed by the City of Cape Town, to whom the dam still belongs. In a report dated 1882 the hydrographic surveyor to what was then known as the Cape Colony drew attention for the first time to the possibility of developing the Wemmershoek catchment. The relatively small, mountainous catchment area, surrounded by spectacular peaks, drew attention particularly due to its abundant winter rainfall.

Water shortages have been an occurring theme throughout the history of the Cape. No sooner had one crisis been averted than the next scheme had to be implemented to meet rising demand. This was again the situation following the South African War.

In 1899, the Woodstock Municipal Council, following investigations by consulting engineer Thomas Stewart, already started buying up properties in what was then known as Oliphants Hoek (Wemmershoek) with the view of constructing a reservoir there with a capacity of 13 638 m³. In 1904, Cape Town City Engineer, J Cook, submitted a report on various water supply schemes, among others, Steenbras, Palmiet, Twenty-Four Rivers, Wemmershoek and Franschhoek (today known as the Berg Water Project). However, with Woodstock having already 'claimed' the Wemmershoek

Top right: *Wemmershoek has a gate-controlled discharge spillway with a chute. The spillway has a maximum discharge of 1 065 m³/s (controlled).*

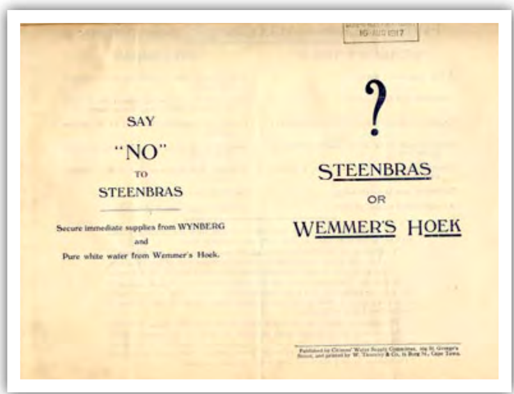
Bottom right: *Another view of the Wemmershoek Dam spillway. Here the radial control gates can clearly be seen.*

City of Cape Town

eWisa/Dirk van Driel

Right: *In 1916 there was huge rivalry between those supporting the development of the Steenbras scheme and those supporting the Wemmershoek scheme. In the end a referendum was held, resulting in Steenbras Dam being constructed in 1921.*

Left: *Wemmershoek Dam was initially designed to be a mass concrete dam, but later a design incorporating a rockfill embankment with a clay core and filters was proposed, saving some half million pounds in foundation costs.*



SAY
"NO"
TO
STEENBRAS

Secure immediate supplies from WYNBERG
and
Pure white water from Wemmer's Hoek.

?

STEENBRAS
OR
WEMMER'S HOEK

NLSA

City of Cape Town

scheme, Cape Town's attention turned first to Franschhoek and then to Steenbras after it became clear that Table Mountain, from which it was receiving its main water supply at the time, had reached its limits.

In 1907, Woodstock and three other municipalities, Mowbray, Claremont and Rondebosch successfully promoted a Private Bill, which gave them the right to construct a relatively small reservoir in the Wemmershoek catchment. Initial investigations kicked off with rainfall and river gauging, and a series of trial pits were dug at the present dam site. The project, however, was beyond the financial capacity of the interested local authorities. In 1913 the rights to the scheme devolved on the Municipality of Cape Town when it amalgamated with eight surrounding municipalities, including the four Councils that had promoted the original Bill.

At the time of unification recurrent water shortages were already posing a serious problem. Detailed investigations of possible new sources were undertaken as a matter of urgency not only at Wemmershoek but also at Steenbras, which had emerged as its most serious rival as the new source of supply. In 1916, the Board of Engineers recommended that Steenbras be developed. A referendum among ratepayers between Steenbras and Wemmershoek followed. Steenbras won the poll and the Council of Cape Town adopted the Steenbras Scheme in 1917. This dam was eventually completed in 1921.

The Wemmershoek Scheme remained on the backburner until after the Second World War when it became apparent that a new water supply would soon be necessary for Cape Town. Investigation of several possible schemes showed that Wemmershoek would be the most economical source of supply except perhaps Riviersonderend. Since, however, the latter was to be pursued by National Government as an irrigation scheme, it was decided to pursue the Wemmershoek Scheme instead. Cape Town started taking steps to obtain, through Parliament, amplification of the powers it had originally been granted so as to permit development of the catchment's full potential yield. The Private Bill promoted for this purpose was finally passed by Parliament in 1951. An important requirement of the Act was that the City was not to construct the dam in stages, but was to build it immediately to full height.

A Board of Engineers were appointed to control the project. The Board comprised recently appointed City Engineer Solly Morris and renowned consulting engineer Ninham Shand, assisted by Technical Secretary BD Kark. At the invitation of Shand former head of the US Bureau of Reclamation, Dr John Savage, became the third member of the Board. Construction of large earth dams had not been customary practice in South Africa at the time, with traditional mass concrete construction being commonly employed. Initially Wemmershoek Dam was designed to be a mass concrete dam, but Shand proposed a rockfill embankment with a clay core and filters – an engineering design that had taken off

At the time of construction in the 1950s, Wemmershoek Dam was the largest of its kind in South Africa.

More than 50 years after its construction, Wemmershoek continues to be a crucial source of bulk water to the residents of Cape Town and surrounding towns.

SAICE

South African consulting engineering legend Ninham Shand and Dr John Savage, head of the US Bureau of Reclamation, who helped design the Wemmershoek Dam.

in the US. Dr Savage supported Shand's proposal, and the design was implemented accordingly, saving some half million pounds in foundation costs. Morris had this to say about the design: "With the tremendous advances in earthmoving equipment and the increased knowledge made available from intensive studies in soil mechanics, there is little doubt that construction of dams in earth will be extended." (Morris, 1959)

Interestingly the amount of material handled was more than twice that contained in the Great Pyramid of Egypt. At the time of its construction, the Wemmershoek Dam was the largest dam of its kind in southern Africa.

The raising of Steenbras Dam during the early 1950s bought Cape Town some time, but it was still a race against time to complete Wemmershoek Dam to avert a major water crisis. The main contract for construction was awarded to George Wimpey & Co of London in April 1953, and work on the site commenced in June of that year. Nearly all the construction plant – to a value of £784 000 – was purchased new for the project. Most of it was delivered to the site before, or during the first summer of construction. JG Welsh was appointed Resident Engineer on Wemmershoek Dam, while JA Shaw was the Resident Engineer on the Wemmershoek Pipeline, which formed an important part of the overall scheme.

At the peak of construction 1 286 peoples were employed on the dam site. Work proceeded day and night in two shifts. Face shovels were used for excavation, except in places where access was unduly difficult; in these areas draglines were used. Work on the dam was dealt a significant blow when on 19 May, 1954, the Wemmers River Valley experienced one of its highest floods ever. The peak flow was assessed at about 453 m^3/s. Direct losses were covered by all-risk insurance, but the resulting delay – which was not insurable, was far more serious. The flood also led to a reconsideration of spillway design capacity. The dam was finally completed in 1957.

The dam wall consists of an embankment-type structure composed of river gravel and boulders with sloping clay core, rising 55 m above original ground level. The length along the top of the embankment is 518 m and the maximum width at the bottom is 335 m. Interestingly the amount of material handled was more than twice that contained in the Great Pyramid of Egypt. At the time of its construction, the Wemmershoek Dam was the largest dam of its kind in southern Africa.

The central clay core totals a quarter of the volume of the dam and was placed in layers 152 mm thick and rolled ten times with 37-t rubber-tyred rollers drawn by tractors. Before placement of the clay could start, it was necessary to prepare a foundation sufficiently strong enough to prevent percolation of water under pressure through the ground. This engineering problem was solved by excavating a trench more than 18 m deep through river alluvium until sound rock was reached. Holes were then drilled to a depth of a further 30 m or more and grout was pumped into them. The cement grout percolated into the surrounding rock and set solid. The rock foundation of the site was thus rendered practically impervious. This screen grouting was also extended to each flank of the dam.

The spillway comprises three radial gates, each 8,5 m wide by 8,2 m high, which discharge into a chute channel 30 m wide, 4,6 m deep and 396 m long. At the base of the chute channel is a specially designed bucket which disperses the water through a ski jump during big floods. The spillway gates were originally designed to be hoisted by electric motors, with standby petrol engines provided for each hoist in the event of power failure. The intake tower is 7,3 m in diameter and 55 m high. Water is drawn from the intake tower through penstocks at various levels and supplied to a treatment plant situated at the base of the Wemmershoek Dam through twin pipelines laid in a diversion culvert underneath the dam.

When Wemmershoek Dam was constructed a compensation agreement involving an exchange of water rights for agricultural use, between Wemmershoek Dam and the Riviersonderend/Berg River Government Water Scheme (constructed in the 1980s) was made, and a 10 million m^3 annual release is made into the Berg River from the Riviersonderend Scheme in lieu of that from the Wemmershoek Dam. More than 50 years after its construction, Wemmershoek continues to be a crucial source of bulk water to the residents of Cape Town and surrounding towns.

View over the Lower Steenbras reservoir.

Steenbras Dam

The Steenbras River was first investigated for the possible construction of a dam in the late 1800s by consulting engineer Thomas Stewart for the municipalities of Mowbray and Rondebosch. The municipalities purchased a set of farms in 1899 for this purpose, but when it was realised that three more farms would be submerged by the resulting reservoir and that it would cost a further £23 000 (a lot of money at that time), the scheme was put on the backburner.

In 1904, the scheme was again investigated by the municipality of Cape Town to augment its water supplies. In 1913, seven municipalities around Cape Town combined with the Mother City to form the Greater Cape Town. Under the guidance of City Engineer DE Lloyed-Davis the Steenbras Dam, 50 km outside the city, was at last constructed in 1921. Built on the slopes of the Hottentots-Holland mountains, the first Steenbras Dam was a modest masonry structure (by today's standards) in the manner of the Table Mountain dams, and impounded 27 000 m^3 behind an 8 m-high wall. A pipeline of 76 km transported the water to the Greater Cape Town. Construction of the dam was

City of Cape Town

The two Steenbras dams as seen from the air.

originally given out on contract, but due to disruptions as a result of the First World War work did not proceed satisfactorily resulting in the municipality taking over the project.

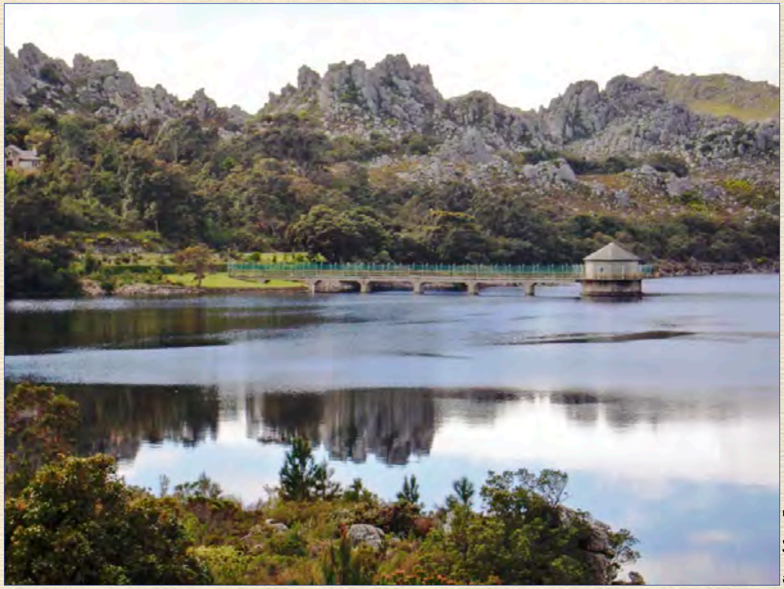
Unfortunately the dam soon proved inadequate to meet Cape Town's growing water demand, and it was raised in 1926 by 13 m to provide for an increased capacity. Jack Hawkins was appointed Resident Engineer on this project, with Ninham Shand as the second-in-charge. The work was rather more than a simple raising of the dam wall. The entire original structure was enveloped by the new construction and the capacity of the reservoir was increased ten-fold.

After the Second World War the dam wall was raised again, this time by pinning a two-metre high extension onto the old dam which increased the capacity of the reservoir by some 60%.

In the early 1970s, Cape Town began to experience shortages in peak electric power. A report had earlier been compiled on the potential for pumped storage in the Western Cape, and it was realised that the Steenbras Dam would offer possibilities for such a scheme. Cape Town took the bold decision to construction the first pumped storage scheme in the country. The work was contracted to Murray & Stewart, with RUC Mining Contracting handling tunnelling

***Top right**: The intake tower of the Lower Steenbras Dam. The dam has a capacity 2 million m³.*

***Top right**: Lower Steenbras overflowing in 2007.*



City of Cape Town

City of Cape Town

operations. The consulting engineers on the project were Ninham Shand.

At first the existing Steenbras Dam was to be used for the upper reservoir, but later investigations found the structure unsuitable for further raising to provide the optimum head required for the reversible pump turbines. Instead the decision was made to construct a separate embankment dam within the reservoir.

As Tony Murray explains, this upper dam serves a dual purpose in that it not only increased the head available for the generating system but also augmented the total water supply to Cape Town by doubling the effective capacity of the original Steenbras reservoir (Murray, 2010). The 30 m-high receiving dam is sited below the power station on the western slopes of the Hottentots-Holland Mountains, about 300 m below the upper dam, and is also an embankment dam. All the rock removed from the power station excavations as well as from the reservoir basin and the tunnels were used to form the reservoir wall, which is about 1,5 km long. The Lower Steenbras Dam has a capacity of 2 million m^3.

The scheme required 430 m of concrete-lined tunnels and shafts 3,6 m and 6,4 m diameter, 350 m of 3,6 m diameter steel penstock and a surface power station located above the twin machine shafts. Construction was made difficult by the poor geological conditions uncovered.

The project was completed in 1978 and won an award for excellence from the South African Association of Consulting Engineers.

STETTYNSKLOOF DAM

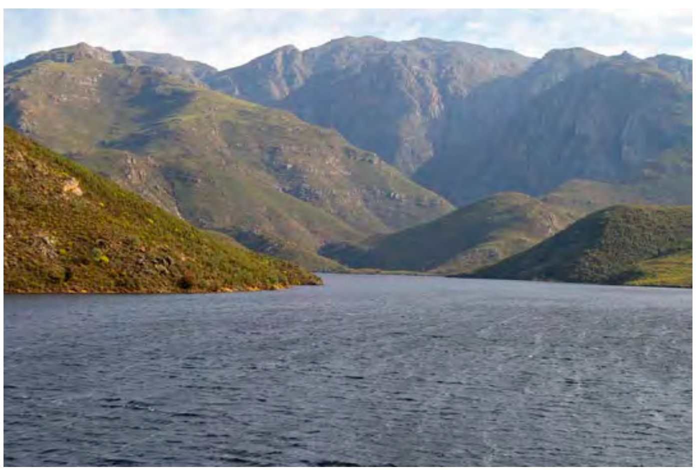
Situated in the heart of the Breede River valley, Worcester was initially established as a sub-drostdy of Tulbagh in 1819 at around the same time as the Franschhoek Mountain Pass – one of the first mountain passes in the country – was built. The town was laid out on the farms *Langerug* and *Roodewal*, and initially there were 144 properties. The town was named after the eldest brother of Lord Charles Somerset, the Marquis of Worcester, and achieved municipal status in 1842. Originally, the town drew its water directly from the Hex River through a series of open furrows flowing through the town from which erfholders drew their share. It was not until the mid-1870s that the town contemplated building its first reservoir and water distribution pipelines to improve its water supply situation. The reservoir or 'old water house' was completed in 1875. Each property owner was entitled to 0,9 m^3/day from these distribution pipes and it was the duty of Worcester's first water bailiff, Jannie de Wit, to ensure that no-one took more than their fair share.

The townsfolk of Worcester shared the water in the Hex River with farmers upstream, and dwindling supplies due to growing farming activity resulted in the town having to look elsewhere to augment supplies. In 1910, a diversion and storage dam was constructed in the Brandwagkloof (later known as Fairy Glen) and water supply brought down in a pipeline to the service reservoir above town. This supply proved adequate for the Worcester's water needs until the arrival of textile mills and other industries.

In 1946, the municipality acquired the services of Ninham Shand to end their water woes. The town had a large storage dam in mind, and there were at least 17 possible storage sites to choose from. The famed water engineer took to his aeroplane in search of the most suitable site, and spotted one such a possible location in a the Holsloot River (a tributary of the Breede River) as it flowed through a deep valley known as Stettynskloof. Further reconnaissance and detailed surveys confirmed Shand's suspicions that the kloof would make a good place for a dam.

Worcester was one of the first local authorities to take advantage of the State's subsidies for municipal water supply implemented after the Second World War, and once the ratepayers approved the project, development of the scheme could begin. Tenders were called and won by a German firm, Beton und Monierbau Aktiengesellshaft (while very competent builders the Germans did have some challenges in communicating with the Xhosa workforce and the expertise of an ex-policeman was later acquired to act as translator between the two). Shand again called on his friend Dr John Savage to finalise the design of the dam.

Preliminary construction started in September 1952 with the first concrete being poured in May 1953. Heavy plant had to be manhandled over difficult mountain track to site. Electricity was generated on site and a huge crusher, fed with stone from the riverbed, produced all the required sand and stone aggregate, which eliminated transportation. About 5 million m^3 of concrete was eventually poured to form the dam wall. Stettynskloof is a concrete gravity dam featuring a rockfill face with a clay core against its downstream face. In a souvenir brochure printed by the municipality for the official opening of the dam in 1955 it is written: "[Stettynskloof Dam] represents one of the most ambitious and courageous enterprises of its kind ever undertaken by a community of the platteland."



Elkarine Rossouw/eWISA

Stettynskloof Dam, which supplies water to Worcester, is sited in one of the most beautiful locations in the country.

Bridle Drift Dam

Also known as the Konka or Buffels River by early communities the Buffalo River Mouth had attracted the attention of the British as a possible port from the 1830s. In 1835, Colonel Harry Smith, then Chief of Staff to the Governor, led a special expedition of 600 men to the river mouth, and in 1836 a fully-laden brig, the *Knysna*, was sent there as an experiment. The ship managed to offload its cargo successfully, however, skirmishes between the British and the Xhosa led to the land being relinquished to the latter.

In 1846, war between the two parties again led the British to occupy the Buffalo River Mouth to land troops and stores. This military settlement became known as 'Cape Point'. A year later, after again visiting the site – now as Governor of the Cape – Sir Harry Smith gave orders that a town be laid out on the West bank of the river, as well as barracks to house 300 men. The settlement was officially dubbed East London on 14 January, 1848. The British garrison was later joined by members of the Anglo-German Legion, with the population being further boosted by the arrival of the *Lady Kennedy* carrying 151 Irish girls, 21 Englishmen and their wives and 33 children sent to boost the white population on the Frontier. More than 2 300 Germans were also settled there.

The first water supply came from a spring discovered by Captain William Baker below the Hood Point Lighthouse. After the spring was dammed up in 1879, it became known as Baker's Wells. However, as East London grew from a small army barracks into a bona fide village, so the need for a reliable freshwater supply became more urgent. The economy of the town was especially boosted by the growth of the wool trade, the discovery of diamonds at Kimberley as well as the South African War, which saw an influx of people and led to an increase in commerce. A dam constructed on the Amalinda River augmented supply from 1885. This scheme was first suggested by JG Gamble, Hydraulic Engineer to the Cape Colony.

In 1899, the first of three Buffalo River pumping schemes designed by Town Engineer John Powell was started. The Amalinda Dam remained the main storage reservoir in both the first and second schemes. The third scheme was completed in 1922, and involved the construction of a dam at Umzoniana. Five years after the completion of this scheme the Border area suffered one of the worst droughts in written history, leaving East London's water supplies all but exhausted. Water flow was restricted to an hour a day, and had to be collected from standpipes in the street. In 1945/46 similar circumstances led to water again being restricted to an hour a day.

To ease these shortages, the Laing Dam was constructed on the Buffalo River in 1950. After extensive surveys, in the early 1960s the municipality decided to construct another dam on the Buffalo River at Bridle Drift 18 km west of East London to augment existing supplies. The contract for the construction of the dam was awarded to Concor-Grinaker while Ninham Shand and Partners were the consulting engineers. Work on the site started that same year. Immediately the construction team encountered their first challenge. The site was characterised by densely wooded hills, and bushclearing proved tricky. Ten percent of the area to be cleared lay at slopes steeper than 60°, which meant that the clearing had to be done by hand using power saws, axes and handsaws. The gentler slopes were cleared using machinery.

The site selected was on a narrow pass where the river left the flat, wide valleys in the sandstone and shale areas and entered a deep gorge confined by dolerite shapes. It was decided to construct a rockfill embankment dam with a sloping impervious clay core to eventually impound 77 million m^3 of water. This was an interesting project as it was the first rockfill structure to be built in South Africa without any major flood diversion works. Instead a unique system was designed to allow any exceptional floodwaters to pour over the partly complete rockfill without damaging the structure. In addition, a 2 m-diameter tunnel was driven to bypass normal flow and smaller floods.

At the height of construction around 400 people worked on the project. Shortly before completion in 1970, an extremely heavy flood (one of the biggest on record) overtopped the partially-completed embankment and created considerable damage. In the early 1980s it was decided to raise the dam wall by 6,8 m by placing earthfill against the downstream rockfill face. This would increase the storage capacity to 100 000 m^3. In addition, a new ogee-shaped concrete overflow spillway was constructed, which involved some 7 000 m^3 of concrete. The engineers had to pay close attention to environmental aspects, as the dam lies within a nature reserve. As a result, every effort was made to blend the embankment and spillway into the surrounds as much as possible. This project was completed in 1985.

NLSA

The concrete gravity Laing Dam under construction in the Buffalo River. The dam was completed in 1950 to supply water to East London.

DWA/eWISA

Bridle Drift Dam from the air. The original earth and rockfill dam wall was 518 m long at the crest and 52 m high.

UMGENI RIVER DAMS

Like nearly all of South Africa's large towns and cities, Durban had to look further and further away to meet its growing demand for water. The uMgeni River was considered as a potential source of water for the residents of Durban since the founding of the settlement, and in 1861 such a scheme was actually initiated. However, it would only be a century later that a significant dam would be constructed on the river. Not long after the inauguration of the Shongweni Dam, the relentless increase in demand for water prompted the town council to again cast its eyes towards the uMgeni River.

In his 1931 report town water engineer Walter Campbell recommended that a scheme be developed on the river. However, the municipal cogs turned rather slowly, because it was only in 1935 that the town council gave the go-ahead for such a scheme, including a dam in the Valley of a Thousand Hills, to be developed. By the time the South African government approved plans for the project, the Second World War had broken out, severely delaying progress. Durban's water demand could not wait for the scheme to be completed, and in 1940 an emergency scheme to pump water directly from the uMgeni River to the Durban Heights Water Treatment Plant was completed (the scheme was abandoned after Nagle Dam was constructed).

The company Dougall & Munro was contracted to undertake the building of Nagle Dam, as it would eventually be called (the dam was named after W Nagle, a councillor of Durban municipality). Construction of the main wall was eventually started in January, 1943. Later that year unusually high rains led to the floods that washed away the Camperdown Dam wall. Debris and sediment was swept downstream into the Shongweni Dam, and within a day the latter's capacity was markedly decreased. It now became imperative for Durban that the Nagle Dam and associated pipelines be completed as a matter of urgency. Still the challenges brought on by the war meant it would be several more years before the dam would be finished. Nagle Dam was officially opened on 11 January, 1950. At completion, the dam was 393 m long and 45 m high and had a capacity of 24 million m^3.

Nagle Dam, officially opened in 1950, was the first dam constructed on the uMgeni River to supply water to Durban. Around 200 300 m^3 of concrete went into the dam wall.

WRC

Midmar Dam

Merely seven years on Durban again looked to uMgeni River to augment its water supply. By that time water demand in the town had reached 273 000 m^3 a day in summer and was still growing in leaps and bounds. The municipality identified several potential storage sites, one being on the farm *Midmar*, just above Howick. However, Durban was not the only one which had set its sights on developing a dam here. Neighbouring town, Pietermaritzburg, at that stage still dependent on Henley Dam (constructed in 1942 on the uMsinduzi River and raised in 1960), had actually gone so far as surveying the Midmar site in detail, and was already preparing plans for constructing a dam there. Then it transpired that the government itself was interested in building a dam at Midmar. In the end, it was decided that the DWA would construct a dam big enough to

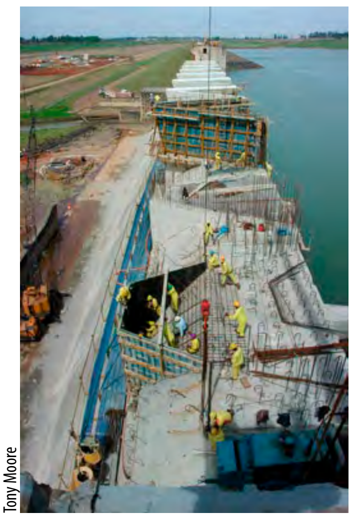
Right: *A close-up of the labyrinth structure at Midmar Dam, which effectively increased the spillway length from 140 m to 235 m.*

Right insert: *Midmar Dam spilling in 2005.*

Tony Moore

Tony Moore

Tony Moore



Tony Moore

Above: *Midmar Dam was the second dam to be constructed on the uMgeni River. The dam had an original capacity of 175 million m³, but was raised by 3,5 m in the early 2000s to increase its storage capacity to 235 million m³.*

Right: *A bird's eye view of Midmar's concrete labyrinth spillway under construction.*

supply water to both towns as well as for agricultural use.

The uMgeni Government Water Scheme was approved by Parliament in 1961, and that same year the DWA construction team moved onto site. The original dam wall was of the composite type, having a mass gravity concrete overspill section with earth flank walls. At the height of construction, more than 600 people laboured on the project. The dam was eventually completed in 1964.

In the early 2000s a decision was made to increase the capacity of the dam by raising the spillway. The original design made provision for the raising of the dam with radial gates, however, the DWA decided against this as the gates would require people to operate them. As a result, engineers came up with an innovative fixed concrete labyrinth design, which blended in with the existing spillway. This labyrinth consists of a concrete wall 4,4 m high and 0,75 m thick, and was constructed in a zig-zag pattern with ten and a half cycles. In addition to the construction of the labyrinth, a 2,5 m wide by 2,9 m high sluice gate was incorporated into the spillway on the right bank to augment releases to meet future inflow river requirements. The gate was designed to release up to 22 m³/s.

Albert Falls Dam

Another dam was established in the uMgeni River near Albert Falls in the early 1970s to provide additional water to the Pietermaritzburg-Durban complex. This is after Durban experienced a huge increase in demand for water due to increased activities at its port brought on by the closure of the Suez Canal in 1967/68. Construction started on the Albert Falls Dam in 1972 and was completed in 1976. The dam features a concrete overspill section with earth embankments (similar to the original Midmar Dam). The maximum height of the concrete section is 25 m above riverbed level and the dam had an original storage capacity of 287 million m³.

Today, raw water is supplied from Midmar Dam under gravity to the DV Harris Water Treatment Plant, and under pumping to the Midmar Water Treatment Plant. Water is released from Albert Falls Dam to Nagle Dam from where it is supplied under gravity to the Durban Heights Water Treatment Plant.

BOTHA'S BABIES

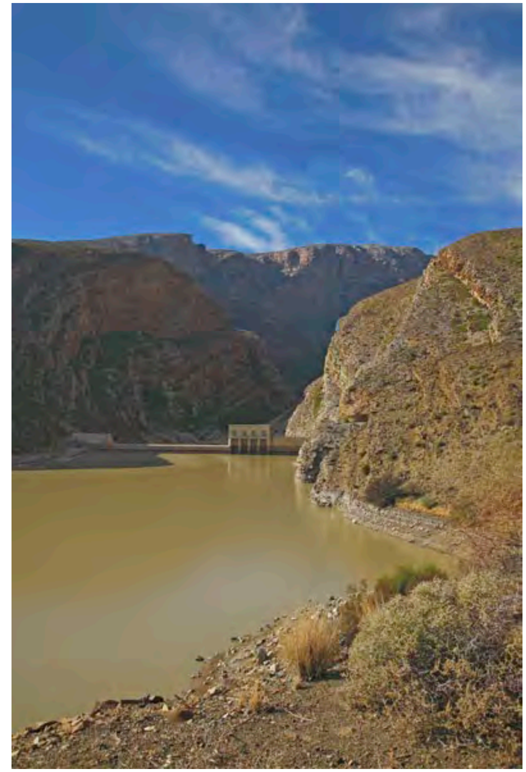
The global dam-building era reached its height in the post-war period, and despite its economic and political isolation South Africa was no exception. By 1970, South Africa's dams had a total storage capacity of around 20 000 million m³ (storing 40% of the country's total runoff). The country now had 104 dams with a capacity of more than 5 000 million m³ and 250 000 smaller dams with capacity averaging about 5 million m³.

In those days departmental construction teams were literally moved from one site to the next, often times in totally different parts of the country. On average, DWA staff prepared 20 White Papers each year (including new dams and raising of existing dams) with the Reconnaissance Branch surveying dozens more projects. This would be underlined by hundreds of preliminary and final designs for proposed dam projects (onerous work considering all calculations were done by hand in the early years). It was an exciting time for youngsters in the department. Theo van Robbroeck, who joined the department after completing his studies in 1957 explains: "Most young engineers working for the DWA wanted to be on construction. We were given major responsibilities at an early age and did the most interesting work imaginable following the drudgery of study."

To take on these volumes of work required lots of people. DWA's construction department alone employed more than 20 000 people (excluding department officials). Still this wasn't enough. Consulting engineers started taking on increasingly more work as DWA engineers ran out of capacity, and increasingly private companies were appointed to construct public projects. Acute staff shortages are reported throughout this period. In 1967/68 and 1968/69, for example, engineering shortages of up to 50% are reported. Departmental missions were sent to the UK and certain European countries in 1963 to recruit additional engineers and technicians, and in 1968, a comprehensive recruitment campaign was launched nationally. This latter campaign was mainly concentrated on recruiting and training 'young men with the necessary potential and ambition'. These engineers became known as 'Botha's babies' (Fanie Botha being the Water Minister at the time). Some of the most formidable men of the department, including Johan van Rooyen, Fred van Zyl and Niel van Wyk, were recruited this way, and have served DWA for many years (many have now reached retirement age). A number of refugees from Eastern Bloc countries, such as Hungary and Czechoslovakia, joined the DWA engineering team in the 1960s, although the language barrier initially hampered communication somewhat. On construction sites shortages of tradesmen were also often encountered (no doubt fuelled by government's job reservation policies of the time).

Due to the shortage in capacity a strategic decision was also made to invest in technology, and in 1967 DWA became the proud owner of an IBM 1130 computer (it was one of the first South African government departments to own one and had to consequently share it with other departments). Before the advent of computers, engineering calculations were carried out by slide rule or by seven figure logarithms, read from a very thick book. The advent of the computer age greatly simplified this work. The Kat River Dam, near Fort Beaufort in the Eastern Cape, completed in 1970, was the first DWA designed and constructed dam where design calculations were undertaken using a computer.

Gone were the labour-intensive projects of the 1930s. Building dams still required hundreds of employees, but engineers now continually sought ways of making construction faster and cheaper by introducing new designs and an increasing number of modern mechanical plant and equipment. As good dam-building sites became increasingly scarcer dam engineers had to come up with new and different ways of constructing dams in challenging places. In 1960, South Africa became a member of the International Committee on Large Dams (ICOLD), which enabled its engineers to share in the experiences of the world and gain a lot of knowledge about the latest designs and materials used (although at time, due to the country's politics South Africans were not allowed entry into some of the countries where the conferences were held).
The 1960s are especially known for the use of thin-shell arch dams in South Africa, and it is described as a decade 'rich in innovation and design' (SANCOLD, 1994). These dams are essentially concrete shells, very thin in cross-section and highly sophisticated in design. Head of the design office at DWA, Robbie Myburgh, was an apparent expert in the design of concrete arch dams, having completed his Masters degree on the topic. He is described as a meticulous engineer. Apart from Stompdrift, Wagendrift and Pongolapoort dams which were described above, other thin-shell arch dams include Hluhluwe River Dam in KwaZulu-Natal.



Chris Marais/Karoospace

Gamkapoort Dam near Prince Albert in the Western Cape was completed in 1969. The dam is 42 m high and 231 m long, with a maximum capacity of 37-million m^3.

Rose among the thorns

Civil engineers might be responsible for establishing dams, but they require a whole host of information in order to select the most suitable site, design, size, and so on. Knowledge of the hydrology of a catchment is pertinent to the construction of a dam.

The years following the Second World War saw an explosive proliferation of research on the occurrence and use of water in many State departments and universities. DWA expanded its network of hydrometric stations, gradually substituting automatic recorders for visual observations. It also maintained a network of rainfall and evaporation stations independently of the Weather Bureau, and like the Geological Survey also operated a network of groundwater stations.

This caused much duplication of efforts and waste of expenditure, and a resultant interdepartmental commission to address the problem recommended the appointment of an Interdepartmental Coordinating Committee for Hydrological Research. The committee also suggested the establishment of a Division of Hydrological Research within an existing department to give a lead and impetus to hydrological research as a whole, to initiate new research, amplify work already in progress as well as eliminate gaps in the field.

DWA

Joan Whitmore at the official opening of the HRI offices with Water Minister Fanie Botha (left).

It was decided that DWA would be the best home for such a division, which was duly established in 1958 (this despite the fact that the department employed no scientists at the time). In that year the new division was joined by a remarkable woman – Joan Sydney Whitmore. Remarkable that at that stage she was the only woman not employed at the department in an administrative position, but rather as a scientist and a researcher (and a senior one at that!), and remarkable for what she would achieve in the decades to come.

Born in 1922, Whitmore matriculated at Rondebosch Girls' High School and became a teacher after graduating from Rhodes University with a MA (Geography) Degree in 1944. In 1946, she joined the Department of Agriculture where she initiated the Agroclimatological Research Unit, which she headed until 1958.

Whitmore felt strongly that the new research unit required its own separate research facilities and in her own words pursued it with 'zealous and unquenchable' fervour. She fought many obstacles in this regard – not the least the hierarchical and patriarchical system that is the administrative system – but through her relentless pursuit the Hydrological Research Institute (HRI) officially opened its doors at Roodeplaat Dam on 20 October 1972, with Whitmore at its helm. At that stage it was the highest post attained by a woman in the public service (excluding the judiciary). The institute initially comprised seven sections: hydrometeorology, surface water hydrology, groundwater hydrology, water quality, catchment management, hydrological techniques and multidisciplinary research. The latter's main function was to liaise with bodies such as the Weather Bureau, the Department of Agriculture, CSIR and various universities and so forth on joint research and matters of common concern. (Today that division of the department is known as RQS – Resource Quality Services)

In her lifetime Whitmore published more than 60 scientific publications and was a member of a countless number of societies and associations. In 1967 she developed a mathematical model to determine the influence of land use on rainfall runoff. Her seminal book, *Drought Management on Farmlands* is about the management of all aspects of drought, culminating in defining cardinal principles of its management. She also led many research projects on the way to reduce evaporation in large dams, more specifically a project to reduce evaporation from Vaal Dam during the drought years of the 1960s. At that time it was the largest project of its kind in the world.

DWA

In 1977, Whitmore retired from the HRI and established her own consultancy, Climatique, an advisory and analytical consultancy in applied climatology/hydrology. She felt strongly about the advancement of women, and in 1988 initiated the International Convention on Women, Leadership and Development, which was held at the University of Pretoria. The event was attended by about 500 delegates from Lesotho, Zambia, Zimbabwe, the USA and Austria, and focused on the development and advancement of women. In 1999, she initiated the International Conference on Drought Management, sponsored by UNESCO, which was held in Pretoria.

Whitmore passed away in 2002, and in 2003, she received a posthumous Women in Water Award. Other awards included the Chancellors Medal bestowed on her by the University of Pretoria.

Drought and the Commission of Enquiry

In the early 1960s South Africa experienced a tremendous countrywide drought, in some areas the worst seen in a century. The storage in many dams dropped to less than a third of their total capacity. Water restrictions were at the order of the day, the most dramatic being these applied to consumers dependent on the Vaal Dam which, at its lowest, was less than 27% full. In 1963/64, for example, drought conditions in the Orange and Vaal river catchments necessitated the regulation of flow of the Vaal River to supplement water supplies for irrigators along the Lower Orange River. The situation was so severe that for a period in October 1963 the Lower Orange River practically stopped flowing in places. The drought further fuelled the dam-building frenzy, with many demands for the raising of existing dams and construction of new dams.

There was an increased realisation that the country had been rather cavalier in the management of its water resources, and in 1966 a Commission of Enquiry into Water Matters was appointed under the leadership of Prof SP du Toit Viljoen to investigate the current situation and make recommendations regarding the management of water resources across all sectors. The resultant report was published in 1970, and to this day is one of the most important documents in the South African water sector.

The Commission confirmed the country's worst fears – that it was on a severely unsustainable path as far as its water use was concerned. If demand increased at the levels it had reached in 1967, South Africa's total water use would have been 80 240 million m^3/day by 2000 – nearly double the country's available surface water resources. South Africa's salvation lay in three critical aspects: it needed to better plan future developments; it needed to improve the way in which it was using water; and it needed to find alternative sources of supply (such as desalination of seawater and the reuse of effluents). The Commission was particularly critical of the irrigation industry, which at that stage was using more than 83% of the country's water. If existing irrigation water infrastructure could be improved to reduce leakage and better irrigation management practices applied, the irrigation sector could save as much as 25% of water used, the Commission found.

People in all sectors needed to start paying for the water they used. In many municipal areas proper metering had not yet commenced, while larger water users were paying far too little for the water they consumed. According to the Commission, these low prices contributed to the reckless wastage of the country's scarce water resources. It recommended that water tariffs be set higher so that people could start appreciating water more. Industry, mining and power generating users were to be encouraged to find ways of improving water use and reusing wastewater.

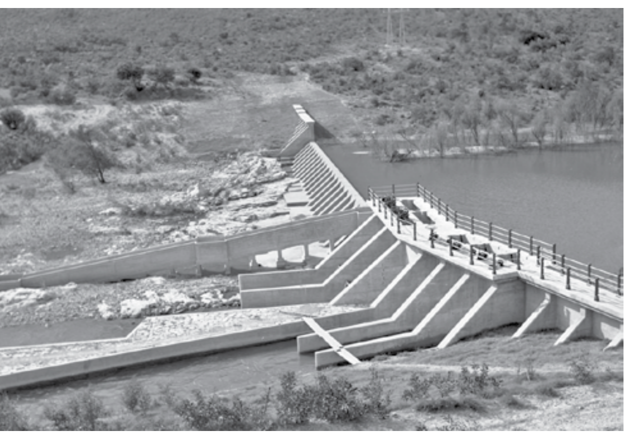
As far as dams were concerned, development up to that time had been far too ad hoc, many times as an emergency measure rather than as a result of proper long-term planning. "There is too often no rational basis for the determination of priorities and the optimal scale, time scale and development pattern of water projects. In some cases water schemes were commanded by individual organisations too focused on local demands, and not in a position to realise national needs and requirements," the Commission said. Much more control was needed over the country's thousands of farm dams, which in many cases were merely 'evaporating water'.

HARNESSING THE RAIN FROM ANOTHER PLAIN

The post-war period signalled the start of the construction of major governmental water transfer schemes in South Africa. The vast majority of these schemes were to meet the water demand of power generation and other industrial activities, however, one of the first water transfer schemes to be constructed was the small Saldanha Regional Water Supply Project built in 1943. The project, constructed as a war measure to increase water supply to the town of Saldanha Bay and defence installations at Langebaan, included a pump station in the Malmesbury district to pump water out of the Great Berg River. At that stage, legislation limited abstraction from the river to a 4 546 m^3/day.

After the war, several local towns and industrial areas on the West Coast requested to be supplied from the scheme. There was not enough water in the Great Berg River catchment to supply the required volume of water throughout the year, and so the Irrigation Department decided to construct a dam on the upper reaches of the river so as to store winter rainfall for supply in the dry summer months.

The proposed site was a small, natural lake known as Vogel Vley near the town of Gouda. Interestingly, the site was first investigated for the possible construction of a dam by Thomas Bain in 1886. Records show that Vogel Vley was known as early as 1702, at one time serving as a military post for the VOC. Between 1948 and 1952 the marsh was enlarged into a storage reservoir. A canal was also constructed to Voëlvlei Dam, as it became known, from a diversion dam on the Klein Berg River.


DWA/eWISA

Voëlvlei Dam was the first large water supply scheme to be constructed in the Berg River catchment. The dam has a capacity of 16 million m³ and the dam wall is 17,7 m high.

NGAGANE DAM

While not a transfer scheme, the Ntshingwayo (formerly Chelmsford Dam) is still an important symbol of the teamwork between DWA and Eskom to keep up with the country's rampant demands for electricity. By the end of the 1950s, Eskom had three power stations operational in KwaZulu-Natal – Umgeni, Colenso, and Congella. However, the latter two power stations had already operated for more than 30 years and had become less effective. This, in addition to the rising demand for electricity, prompted the power generator to seek alternative sites to establish a new power station. Power stations require ample supplies of coal and water, and three sites were consequently surveyed in the Dundee, Newcastle and Balangeich areas, in the northern part of the province.

Following negotiations with DWA regarding the supply of water, the area of Newcastle was selected for the new power station. The original intention was for the new power station to be located at Colenso, supplemented with water from the Thukela River; however coal would have to be transported by rail to this site, making it uneconomical. For this reason, Eskom settled on a location close to Ngagane Station.

A dam would have to be built, and DWA surveyed three sites along the Ngagane River for this purpose. The site chosen for the dam was situated on the farms *Chelmsford* and *River Bend* some 24 km south of Newcastle. The dam was one of the first to be constructed by the department not for irrigation purposes. Its sole duty would be to supply water to the new Ingagane Power Station. It was estimated that the power station, which would have an ultimate installed capacity of 500 MW, would require 45 400 m³/day of water. The dam would be constructed large enough to meet this demand with additional yield used to improve river quality and provide water for industrial and domestic use in the vicinity.

A White Paper was put forward to Parliament in 1958/59, and upon its acceptance, construction began. Chelmsford Dam was constructed as an earth embankment 994 m long with a central gravity section concrete overspill section 15 m long and 16 m above normal river bed level. A short distance away on

Why the need for transfer schemes?

South Africa's water resources are extremely unevenly distributed. The driest 70% of the country's surface area has only 11% of the usable water available. In addition, runoff varies greatly from season to season and year to year, which is why large volumes of water have to be stored to bridge the long periods of drought. Unfortunately, for South Africa, this is where most of its mineral riches are located, with the result that cities such as Johannesburg have developed nowhere near a reliable water source.

To overcome this problem the country's engineers have devised a series of transfer schemes to bring water from those catchments with plenty to those where more water is needed. Today, South Africa is a world leader in the field of water transfer schemes, the most notable being the Lesotho Highlands Water Project and the Orange River Development Project. By the 1980s South Africa had a water transfer map so complex it 'resembled a wiring diagram for a computer motherboard' (Davies & Day, 1998).

Eskom

DWA/eWISA

***Top**: At the time of its construction, Ingagane was the largest and most economical power station in KwaZulu-Natal. The power station was mothballed in the 1980s.*

***Bottom**: The original Ntshingwayo Dam (previously Chelmsford), prior to being raised.*

the left flank an auxiliary earth embankment of 588 m was located. This embankment had a maximum height of 6 m above ground level and was constructed to close a low neck or saddle. The dam was completed in 1961. The original design did permit the raising of the crest, and this was done in 1982. The dam was raised by 4,57 m and raising of the spillway crest was accomplished by the addition of 3 m of concrete on the crest and two fishbelly flaps 1,5 m high, each with a length of 61 m. The earth embankments were also raised with 126 000 m^3 of material. To prevent damage to the wall by waves during the design flood (1:500 years), a concrete parapet 1 m high was constructed on the earth embankment. The dam now has a maximum capacity of 194,6 million m^3.

The power station came on line in 1963. Water was gravity fed from Chelmsford Dam to Ingagane Power Station via a 16 km-long pipeline. Coal reached the power station from the nearby Kilbarchan colliery via overland coal conveyors, capable of transporting 435,5 t/hour. A decrease in demand saw Ingagane being mothballed in the 1980s, and it was finally shut down in 1990. In 2000, Chelmsford Dam was renamed Ntshingwayo Dam after Inkosi Ntshingwayo KaMahale Khoza, a senior general in King Cetswayo's army. The dam remains an important source of supply to the town of Newcastle.

KOMATI WATER TRANSFER SCHEME

South Africa's first large-scale water transfer schemes were undertaken almost exclusively to meet the growing need for electricity. Eskom saw its power stations double in capacity between 1954 and 1955. New power stations had to be constructed to meet the country's insatiable hunger for electricity and Eskom initially focused on the Eastern Transvaal (Mpumalanga) because of its rich coal reserves. However, electricity generation requires water in addition to coal, and so Eskom also started consulting with the DWA to gain access to the necessary water supplies.

Nooitgedacht Dam was originally constructed to supply water almost exclusively to Komati Power Station, the first unit of which was commissioned in 1961. The power station was mothballed in 1990, but has recently been recommissioned.

Eskom

Lani van Vuuren

The 450 km-long Komati River is shared between South Africa, Swaziland and Mozambique.

Top right: *Nooitgedacht Dam wall taking shape in 1960.*

Middle right: *The Nooitgedacht Dam construction site from the dam wall looking downstream in 1961.*

Bottom right: *Nooitgedacht Dam as it looked during construction in September 1961. The outlet structure consists of a reinforced concrete tower housing the valve controls from which water is led through the embankment by means of a conduit for release to Eskom and other users downstream.*

DWA/eWISA

DWA/eWISA

DWA/eWISA

At first Eskom wanted to establish a 480 MW power station in the Witbank area which had known coal reserves. It was suggested that the 50 000 m³/day of water the power station needed would be drawn from either the Vaal River or the Olifants River near Witbank itself. However, neither of these resources proved suitable due to the expected rise in demand from existing users and so engineers turned their sights further east to the Upper Komati River, at that point a relatively untapped resource. The only catch was that the dam site had to be located close to suitable coal deposits.

Reconnaissance identified three possible sites, the lowest or furthest downstream situated on the farm *Waterval No 97*; the second or middle site on *Doornkop No*

168 and the uppermost site near the boundary of the farm *Nooitgedacht*. From an engineering perspective the Nooitgedacht site was found to be the most suitable and a White Paper in this regard was consequently prepared and approved by Parliament in 1957.

The Komati River is an international river, shared between South Africa, Swaziland and Mozambique. The 450 km-long river originates west of the town of Carolina, then passes through northern Swaziland before flowing back to South Africa and joining the Crocodile River at the border with Mozambique. Negotiations over the utilisation of shared rivers were held with neighbouring countries from time to time, and DWA it seemed had confidence that it would have no resistance regarding the construction of Nooitgedacht Dam. "Negotiations will, in due course, also be initiated with the Swazi government in regard to the construction of the Nooitgedacht Dam, but in view of the runoff position...it is not anticipated that any objectives can possibly be raised against the proposed scheme that would affect its planned construction or the planned use of its water by the Union government," wrote the Secretary for Water Affairs in his 1957/58 *Annual Report*.

Water flows below the Nooitgedacht Dam through a conduit to users downstream.

Lani van Vuuren

Engineering features of Nooitgedacht Dam

Dam type: Earthfill with concrete trough spillway
Gross storage capacity: 79 million m^3
Wall height above lowest foundation: 44 m
Crest length: 1 021 m
Type of spillway: Uncontrolled
Surface area of dam at full supply level: 761 ha
Main spillway capacity: 1 590 m^3/s

The dam was completed in 1962. Nooitgedacht Dam is an earthfill dam with an uncontrolled concrete trough spillway. Interestingly, the dam features a unique structure incorporated into the central section of the dam, intended to counteract silting of the basin by discharging silt-laden water instead of clearer stored water over the spillway during times of flood. This is meant to increase the period before silt accumulation renders it necessary to raise the dam wall. From the dam water is pumped 250 m to the watershed of the Olifants River to Komati Power Station. In 1967, the dam supplied 72 000 m^3/day of water to the Komati Power Station (up from an initial 18 200 m^3/day in 1961).

In the mid-1960s, Eskom decided to build the Hendrina and Arnot power stations. The two power stations would have a combined water demand of close to 300 000 m^3 a day. With Nooitgedacht Dam being incapable of meeting this water requirement on its own, it was decided to construct another dam in the Komati River catchment. Investigations for this new dam started in about 1964, and sites on the farms *Racebaan*, *Boekenhoutrand* and *Kafferskraal* received particular attention. The latter site, situated about 50 km downstream from Nooitgedacht Dam, was eventually decided upon and the White Paper was laid before Parliament in 1967. Investigations also indicated that water could be supplied to the Hendrina and Arnot power stations more economically from the Komati than from the Usutu River system. Another reason for the construction of more dams was that more power stations were envisaged in the future.

Construction of the Vygeboom Dam, as it would become known, started shortly thereafter and the dam was completed in 1971. The yield of the Vygeboom Dam was later supplemented through the construction of the Gemsbokhoek Weir on the adjacent

Engineering features of Vygeboom Dam

Dam type: Earthfill with concrete side-channel spillway
Gross storage capacity: 78,4 million m^3
Wall height above lowest foundation: 48 m
Crest length: 1 220 m
Type of spillway: Uncontrolled
Surface area of dam at full supply level: 671 ha
Main spillway capacity: 2 617 m^3/s

Gladdespruit. Water is diverted from the weir into a canal with a capacity of 3,8 m^3/s which flowed into the Vygeboom Dam. From Vygeboom Dam the water is pumped to a height of 469 m into the Nooitgedacht Dam. By 1986, 131 million m^3 of water was transferred annually from the Komati River basin to the Olifants River catchment area.

Nooitgedacht Dam as it looks today. The concrete trough spillway features built-in outlet pipes that can discharge silt when necessary.

Lani van Vuuren

Surveying in the 1950s and '60s

All young engineers at DWA were required to do a stint with the Reconnaissance division. Soon after joining the department a young Theo van Robbroeck joined the team surveying the Chelmsford Dam site and basin. They were led by Mike Basson, known for his strict discipline. Van Robbroeck's experience, related here, is typical of what surveying entailed a half century ago.

"We were housed in a tented camp at the Ngagane River – although I was lucky enough to be assigned a caravan. Meals, prepared by a cook, were served in a large military tent. Various teams were formed, each consisting of a surveyor (or an engineer), a learner to enter the survey readings and to observe the process, and some ten labourers with Sopwith staves – long staves graduated in feet and tenths of feet. These formed a row, with each man some 1,5 to 2 m from the next one. The surveyor, having mounted his tacheometer above a peg with a known position, would read distance, horizontal and vertical angle to each of the staves, readings which were written down by the 'booker'.

"The labourer would then take a step or two back until all ten were again in a straight line. The process would then be repeated until sufficient 'spot shots' had been taken to cover the area from the surveyor's position, who then moved his instrument to a new position. In this way the whole site and basin was covered by these spot shots. After a while, one became so dexterous with the instrument that the booker could hardly keep up with writing the readings down.

"In the evening, the readings were 'reduced' by means of a Cox stadia computer. This consisted of a plastic disc which could be turned over a square plastic plate, also graduated. In this way the precise position and height of each spot shot could be determined and plotted. Contours could then be drawn by interpolating between these spots.

"Mike Basson, in the meantime, had determined the exact positions of the pegs over which our tacheometers were mounted. This he did by surveying the position of flags over these pegs from the survey beacons of the Trigonometric Survey Division of the State by means of a single second theodolite."

Surveying was hard work, with the teams spending all day outdoors and then doing their paperwork in the evenings. "The only time we could get out of the camp was when the GG Lorry went to Newcastle to do the shopping. At one stage it was so cold that some 30 cm of snow had fallen during the night. Never mind the number of blankets on top, the cold came from the bottom!" relates Van Robbroeck.

USUTU SCHEMES

Usutu River Government Water Scheme

Five years after the completion of Nooitgedacht Dam, demand for water from new power stations and other industrial users on the Highveld (such as Sasol) had grown to such a degree that DWA had to look for another large water source from where to transfer water to the Olifants River system. As a result, it started tapping the hence largely unused Usutu River system. The resultant Usutu River Government Water Scheme was built in five phases between 1964 and 1990.

First, the Jericho Dam was constructed in the Mpama Spruit, one of the tributaries of the Usutu River. The dam, situated near the town of Amsterdam, has a composite wall with earth flanks and a central mass gravity overspill section. The dam is ideally sited to receive augmentation water from other rivers in the Usutu basin. Also constructed in the first phase (1964-1966) was a pumping station below the dam wall and a single rising main from the pumping station to two balancing reservoirs on the farm *Onverwacht* on the watershed between the Usutu and the Vaal River catchment areas. In addition, DWA built the first gravity pipeline from the Onverwacht reservoirs to the Camden Power Station as well as terminal reservoirs at the power station.

During the second phase (1966-1968), Jericho Dam was raised by means of five radial gates, each 4 m high and 11 m wide to give the dam a gross storage capacity of 59,3 million m^3. Also the Westoe Dam was constructed on the Usutu River from where water is conveyed to the Jericho Dam by means of the 1,6 km-long Westoe Tunnel and a 15 km-long gravity pipeline from the tunnel outlet. From there runoff of both rivers is pumped to the Onverwacht reservoirs on the watershed between the Usutu and Vaal rivers. Westoe Dam comprises a composite wall with earth flanks and a central mass gravity overspill section.

Phase 3 (1969-1971) saw the raising of Westoe Dam by means of two fishbelly flap gates, each 4,57 m high and 45,4 m wide to raise the gross storage capacity to 60 million m^3. (Incidentally, a fishbelly flap is lowered to allow the water to flow over the gate, whereas a radial gate is raised to allow the water to flow underneath the gate). DWA also doubled the pipeline from the Jericho Dam to the Camden Power Station. A third reservoir was also added at Onverwacht.

Phase 4 lasted from 1974 to 1981. This phase saw the construction of a pipeline from the Camden to the Kriel Power Station and a third pipeline between Onverwacht and Camden as well as the construction of a third reservoir at the power station. Most notably, it was during this phase that the Morgenstond Dam on the Ngwempisi River was constructed to supplement the power station complex with water. A pumping station at the Morgenstond Dam pumps the water nearly 9 km to Jericho from where it is distributed to the various power stations.

During the last phase (1985-1990) the Churchill Weir was built on the Bonnie Brook along with a 9 km-long canal to divert water from the Bonnie Brook to the Westoe Dam. DWA also constructed a fourth gravity pipeline between Onverwacht and Camden and raised Morgenstond Dam by means of three radial crest gates, each 8 m high and 9 m wide. This increased the capacity of the dam to 100,7-million m^3. An uncontrolled spillway was also constructed to cope with a flood with a return period of 20 years without having to operate the gates. In order to protect the main wall against larger floods, an emergency spillway was built between the radial gates and the uncontrolled spillway.

***Top right**: Duvha Power Station near Witbank is one of the myriad of power stations on the Highveld for which water transfer schemes were constructed by DWA.*

Eskom

***Bottom right**: Morgenstond Dam on the Ngwempisi River was constructed during phase four of the Usutu-River Government Water Scheme.*

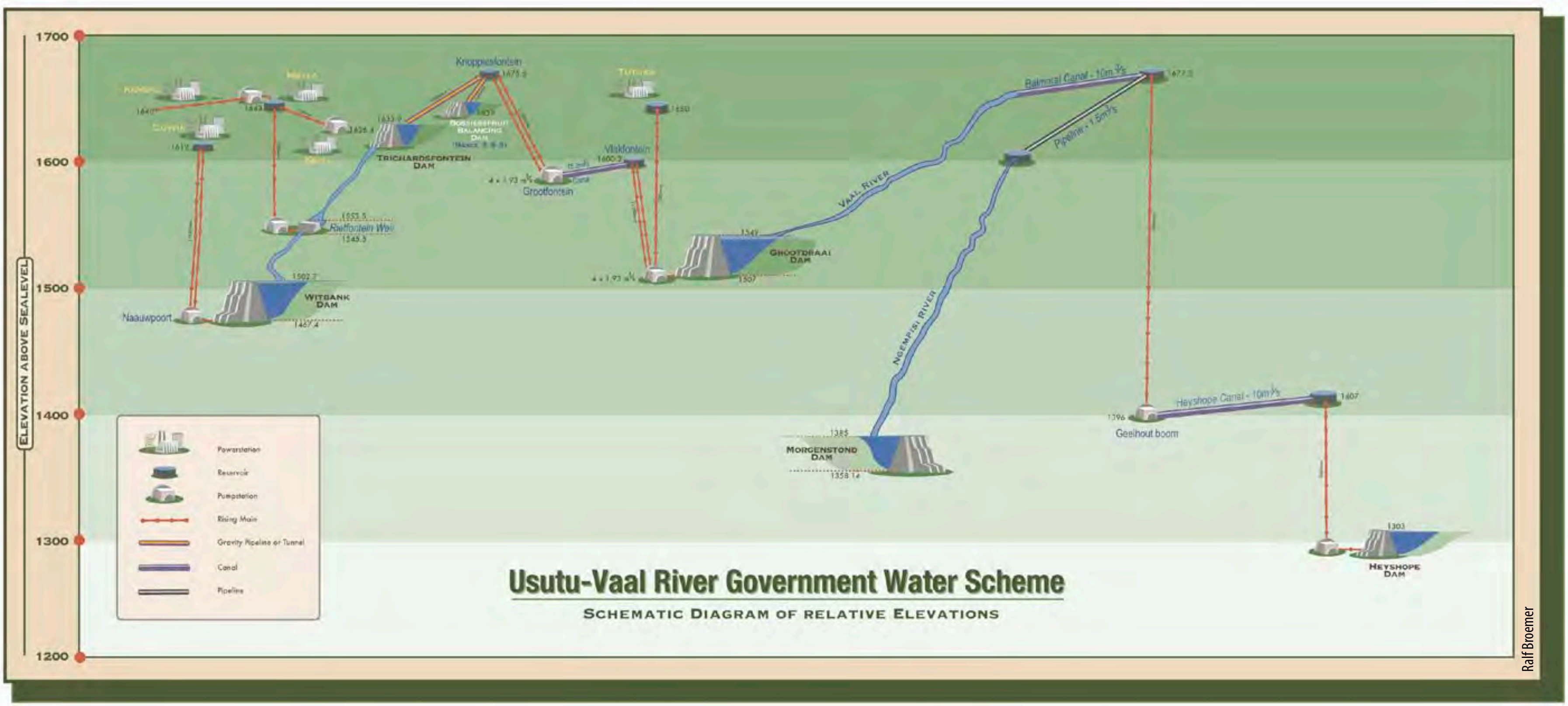
DWA/eWISA

Usutu-Vaal River Government Water Scheme

In 1975, the new Sasol oil-from-coal plant was announced. The plant was to be located in Trichardt, on the watershed between the Vaal and Olifants rivers. Enough water had to be provided for the new plant, as well as for the Tutuka Power Station (which was then in the planning stage), as well as for the balance of the Matla and Duvha power stations' needs. Later it was announced that Sasol III was also to be situated here.

To meet this rising demand for water, DWA started exploiting the headwaters of the Vaal River. The ensuing Usutu-Vaal River Government Water Scheme was constructed in two phases: first utilising the headwaters of the Vaal River and the second supplementing these headwaters with water from the Assegaai River, a tributary of the Usutu River, near Piet Retief.

Grootdraai Dam was constructed on the Upper Vaal River near Standerton between 1977 and 1981. More than 1 000 departmental workers were employed on different aspects of the project. It was not possible for DWA to carry out all the work itself and therefore various consultants and contractors were appointed, for example, for the construction of the pipelines, supply and installation of



Ralf Broemer

***Left**: Grootdraai Dam from the air. At full supply level the dam has a surface area of 5 500 ha.*

pumps, supply and installation of mechanical equipment and various other small contracts.

The dam is a composite structure comprising a central concrete gravity section 360 m long and two earthfill flanks giving a total crest length of 2 180 m and a maximum wall height of 42 m above lowest foundation level. In addition to supplying water to power station and industry, Grootdraai Dam also provides some flood attenuation for Standerton.

From Grootdraai, a combination of pumping stations, pipelines and canals, take the water to the Sasol plant and further to the watershed between the Vaal and Olifants rivers. From there it flows down in the Steenkoolspruit, a tributary of the Olifants River, to the Matla and Duvha power stations. In addition a pumping station and pipeline was constructed between Matla and the Kriel power stations. This serves the dual purpose of being able to supply Matla Power Station with water from the Usutu River Government Water Scheme and the Kriel Power Station with water from the Usutu-Vaal Government Water Scheme, should a shortage of water occur in any of these two systems.

Between 1982 and 1988 the Heyshope Dam was constructed in the Assegaai River. This scheme enables DWA to pump 100 million m^3/year into the Vaal River system. It supplements the water in the Grootdraai Dam. Due to the severe drought which prevailed in the Vaal River system in the early 1980s, the construction of this phase was expedited to bring it into operation six months earlier than originally scheduled.

DWA

***Below**: The Grootdraai Dam on the Upper Vaal River was completed in 1981.*

Engineering features of the Grootdraai Dam

Dam type: Concrete gravity overspill section with earthfill embankments on both flanks
Height of non-overspill crest above lowest foundation: 43 m
Design flood: 4 600 m^3/s
Crest length: 1 970 (total)
Concrete section: 360 m
Earthfill section: 1 970 m
Gross storage capacity: 364 million m^3
Surface area at full supply area: 5 500 ha

Engineering features of Heyshope Dam

Dam type: Earthfill
Wall height above lowest foundation: 26,5 m
Crest length: 1 030 m
Type of spillway: Tunnel outlet and uncontrolled chute spillway
Gross storage capacity: 364 million m^3
Surface area at full supply level: 4 500 ha

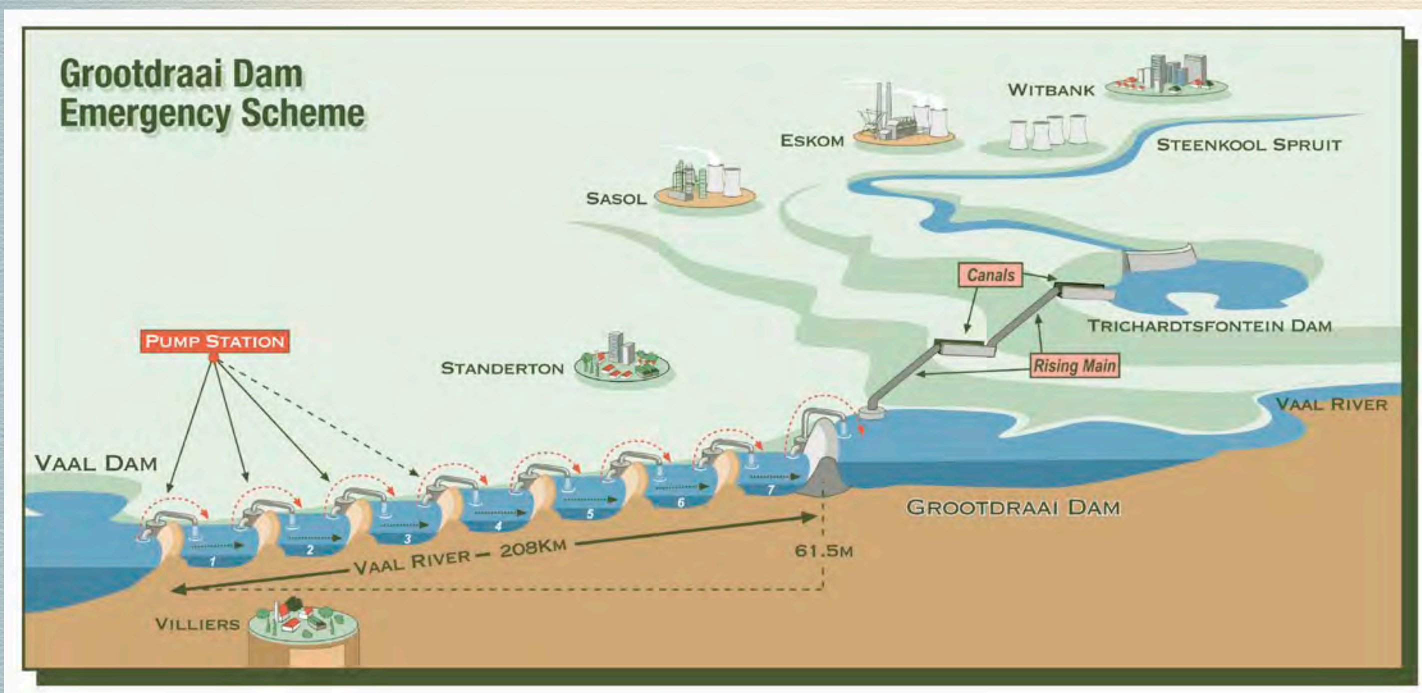
Grootdraai Dam Emergency Scheme

The Komati and Usutu-Vaal schemes were designed in such a way that most of the power stations could receive water from alternative sources during emergency situations. For example, the Matla and Kriel power stations can receive water from either the Usutu pipeline or the Usutu-Vaal water lead. The system's inherent flexibility proved its worth in the early 1980s.

In the autumn of 1983 South Africa was faced with an economic catastrophe – the projected demand of most of the country's power stations and of Sasol II and III showed that by September, before the normal onset of the rainy season in that area, the five dams of the Komati and the Usutu, as well as the Grootdraai Dam on the Vaal, would run dry. This would be an unthinkable situation, as 80% of the country's total electricity output is dependent on the availability of water in the Usutu-Vaal-Komati system.

Theo van Robbroeck explains the situation that stared DWA in the face at that time: "Although the Vaal Dam itself was also virtually empty (it was only 38% full), we had the water that was pumped from the Thukela River into Sterkfontein Dam [via the Thukela Vaal Transfer Scheme] in reserve. This could be let out by gravity to the Vaal Dam, but how to get it from the vicinity of Villiers from where it could be distributed via the Usutu-Vaal link project?"

The department had but 20 weeks in which to implement a project to transport some 1 million m^3/day over a distance of 90 km (at its shortest). A conventional pipeline of some 2 m in diameter and pumping station would not be feasible in such a short time. The only solution was the one that was subsequently adopted, namely constructing a chain of seven temporary earthen weirs in the Vaal River, each with a pumping station at its downstream toe. Said to be the brainchild of geologist David George, who was a consultant for DWA at that time, this effectively



Ralf Broemer

The Grootdraai Emergency Scheme. This scheme effectively reversed the flow of the Vaal River.

amounted to putting the Vaal Dam in reverse. The Vaal River's water was, in turn, supplemented by water from the Thukela-Vaal scheme. In this way, the Komati, Usutu, Vaal and Thukela rivers were connected to keep the 'energy heart' of the country beating.

The Grootdraai Emergency Scheme was approved by Parliament on 18 April, 1983. Work started on the scheme the very next day. This scheme is quite remarkable that, apart from a few aerial photographs and 1:50 000 maps, there were no detailed survey data available, and there was no time for geological or detailed design investigations. Everything had to be done on site as the project progressed.

More than a 1 000 DWA workers laboured on the project day and night. In addition, more than 40 contractors were employed on various aspects of the scheme. The seven weirs that had to be built ranged in height from 8,7 m to around 13,5 m and were placed in such a way that the reservoir formed by each weir would stretch to the toe of the weir upstream of it. Two of the weirs were constructed in the Vaal Dam basin. The total distance along which the water had to be transported was 208 km at a static height difference of 61,5 m between the Vaal and Grootdraai dams. Although engineered by DWA, the scheme was constructed in close collaboration with Eskom and Sasol who, as the main users requiring this water, were responsible for the financing of this project. Eskom also supplied and installed all the necessary pumps.

By 26 July all seven weirs had been completed, and by 18 August, the pipelines were finished. The scheme became operational on 18 September, 12 days before the deadline. As it turns out the pumps were not required for a long time because shortly after the onset of the rainy season, heavy rains restored dam levels to normal – ironically, some of the weirs were damaged by the resulting floods. The scheme received an award for the Most Outstanding Civil Engineering Achievement of 1983 from the SAICE.

The scheme was one of the most adrenaline producing schemes ever constructed by water engineers in South Africa. Former Minister of Water Affairs Sarel Hayward related in a department newsletter how a group of dignitaries visited the site via helicopter to check on its progress. Upon landing they were greeted by Resident Engineer Adam Botha who, after showing them around briefly for 15 minutes, coolly informed them that he had no more time to spend with them as he had work to do! When the scheme was inaugurated the same Botha and his team decided to present the minister with a gift. The speeches were made, the obligatory buttons were pushed, but when Botha had to hand over his gift he was so overwhelmed he could not get out a word. Hayward stepped forward to shake Botha's hand. He had just thanked the engineer when his eyes too started welling up with tears! "So there we stood both with tears in our eyes and all we could do was look at each other. I hope the audience understood," said Hayward of what he called "his most tearful speech".

DR JP KRIEL

As former Secretary of Water Affairs, Dr Jacques Kriel played an enormous role in the development of many of South Africa's most significant dams and water schemes.

The son of a reverend, Jacques Pierre Kriel was born on 18 April, 1915 in Alice, in the Eastern Cape. He was the fifth of six children. His father, Dr Abraham Kriel, founded the orphanage with the same name in Langlaagte, in Johannesburg, while his grandfather founded the Jan Kriel school for children with epilepsy at Kuilsrivier.

Dr Jacques Kriel completed his schooling at Paul Roos Gimnasium, in Stellenbosch, whereafter he studied Engineering at the University of Cape Town. During his student years he participated in many cultural and sporting activities (he played rugby for all the teams except the first team), and travelled overseas numerous times. Among others he received practical training in the engine room of the Clan Line cargo ship travelling from Cape Town to Liverpool, visiting the construction sites of numerous dams while in Europe.

In 1937, Dr Kriel joined the Irrigation Department as an Assistant Engineer in Cape Town. He would end up spending more than 40 years in service of the department. In his early years he worked on site at several schemes, including Vaalharts, OFS Goldfields, and Waterdown Dam (Queenstown). In 1957, he joined the head office in Pretoria in the Planning department, and two years later he became the first hydrologist in the Hydrology department. In 1968, Dr Kriel was appointed Secretary of Water Affairs, a post he held until his retirement in April 1980.

Dr Kriel is described as having been a formidable and hard-working civil engineer, and became personally involved in many dam projects, even after he was appointed to the highest position in the department, including the Orange River Development Project, and the Thukela-Vaal Transfer Scheme. Some of these projects, such as the Lesotho Highlands Water Project, only came to fruition long after his retirement.

In 1976, he was named honorary professor at the University of Pretoria for his contribution to the civil engineering profession, and in 1989 he received a Gold Medal from the SAICE. Between 1969 and 1980 he also acted as Secretary for ICOLD, and served as Vice President of the organisation between 1972 and 1975 (being the first South African to hold this position). In 1989, he received the State President's Order for Outstanding Service, Class 1: Gold. He was especially devoted to the recruitment of young engineers, and during his time at DWA established a special bursary scheme for matriculants.

He played a key role in the establishment of the Water Research Commission, and served as Chairman of the organisation for three years. Asked about the key to his success in an interview in 1989, he said the following: "I am not an 'empire builder'. I found out early in my life that cooperation with others is much more fruitful and delivers much better results than trying to keep people away from your area of expertise. Cooperation between specialists on different areas is especially crucial to the water sector, which is by nature multi-disciplinary."

ORANGE RIVER DEVELOPMENT PROJECT

South Africa had wished for a dam on its largest river course (the natural flow of the Orange River constitutes more than 22% of the country's surface water resources) ever since it was 'discovered' by European settlers centuries ago, but it was not until Dr AD Lewis' formidable trek along the lower stretches of the river in 1913 that serious investigations began to pin-point potential dam sites. In 1922, Irrigation Department Inspector of Surveys, GD Adamson, wrote of such potential sites in a departmental magazine. They were identified as being "at the entrance to the poort about one mile below the Orange-Caledon confluence...a mile upstream of the railway bridge at Norvals Pont...and at Van der Kloof [gorge]." (Adamson, 1922). Even then it was realised that building a structure across the Orange River would be no cheap affair due to the general slope of the river.

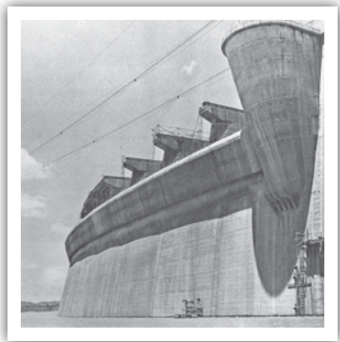
Lewis came up with the idea of transferring water from the Orange River to the Great Fish and Sundays Rivers through a

A locality map of the Orange River Development Project.

Ralf Broemer

tunnel, however, his plans were considered too ambitious for the time. Buchuberg Dam, constructed in the Lower Orange River in the Depression Years, would remain the only large water storage structure in the river for some time. Lewis' idea germinated until 1944 when field surveys and drillings were initiated, culminating in a technical report. This report was presented to Government in 1948 and proposed a project consisting of a diversion dam on the Orange River, and a diversion canal and tunnel to lead the water under the divide into the Great Fish River Valley, with a diversion into the Sundays River Valley. Again the scheme was shelved.

Various parties canvassed for the construction of a scheme on the Orange River in upcoming years. In 1959, when PK le Roux became Minister of Water Affairs, he instructed his staff to speed up investigations of the necessary survey work for the Orange River Project. Three dam sites were selected – at Ruigte Valley near Bethulie, Van der Kloof near Petrusville and Tourquay, which together formed the basis of this enormous undertaking. Political and economical considerations caused the Orange River Development Project (ORDP) to be announced suddenly in 1962. According to the government, the ORDP would 'transform the desert into a paradise' by increasing land under irrigation in the country by 40%. It would also provide much-needed water for domestic and industrial purposes, while supplying additional electricity through hydropower to Eskom. The original project was divided into six phases (including 12 dams and weirs) to be implemented over a period of 30 years. In June 1962, Parliament authorised the expenditure of R85-million for the first phase of the project. This phase would include the construction of Hendrik Verwoerd Dam (as it consequently became known and now known as Gariep), PK le Roux Dam (now Vanderkloof), the Orange-Fish Tunnel and associated weirs and canals.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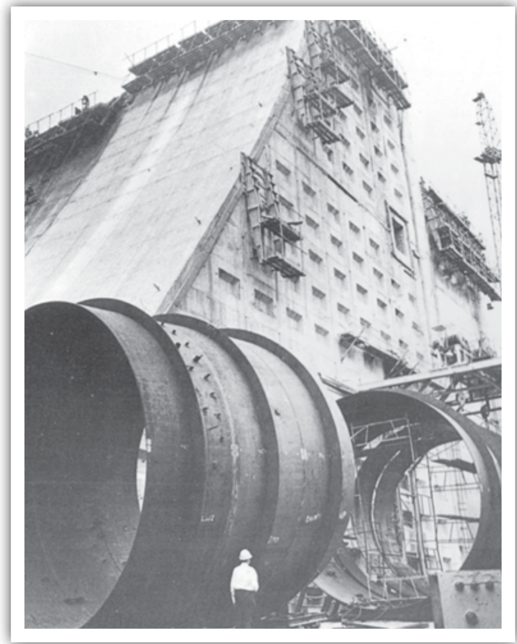
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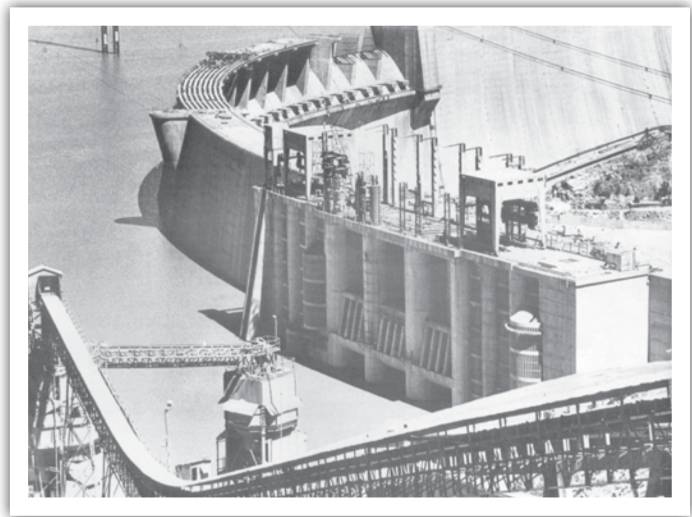
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Left: *Sections of steel liners of water penstocks prior to being welded together. Water is released downstream into the Vanderkloof Dam through four generators for the generation of hydro-electric power.*

Top right: *A general view of the Gariep Dam from the delivery conveyor. In the background the cableways can be seen. An average 36 399 m³ of concrete was placed a month.*

Bottom right: *The Gariep Dam main wall during construction. Since the hot-poured concrete would take a century to cool down on its own, engineers made use of an instant refrigeration system whereby chilled water was injected into a 240 km-long pipeline inserted throughout the structure.*

Outline of the original Orange River Development Project

Orange River section

- A main storage dam at Ruigte Valley
- A high diversion dam at Van der Kloof
- A left and right bank canal system from the Vanderkloof Dam
- A pumping scheme to supply supplementary water to the Riet River Government water scheme
- A further extension of the aforementioned pumping scheme to serve certain land located near Luckoff
- Water supplies to Bloemfontein, Kimberley and De Aar
- A high diversion dam at Tourquay, together with a canal system to serve land at the confluence-Prieska Project
- The development of additional land at Warmsand and Kakamas
- A diversion dam and canal system for the Marten and Krapohl Island Project
- The irrigation of additional land in the Richtersveld and Alexander Bay areas

Fish-Sundays River section

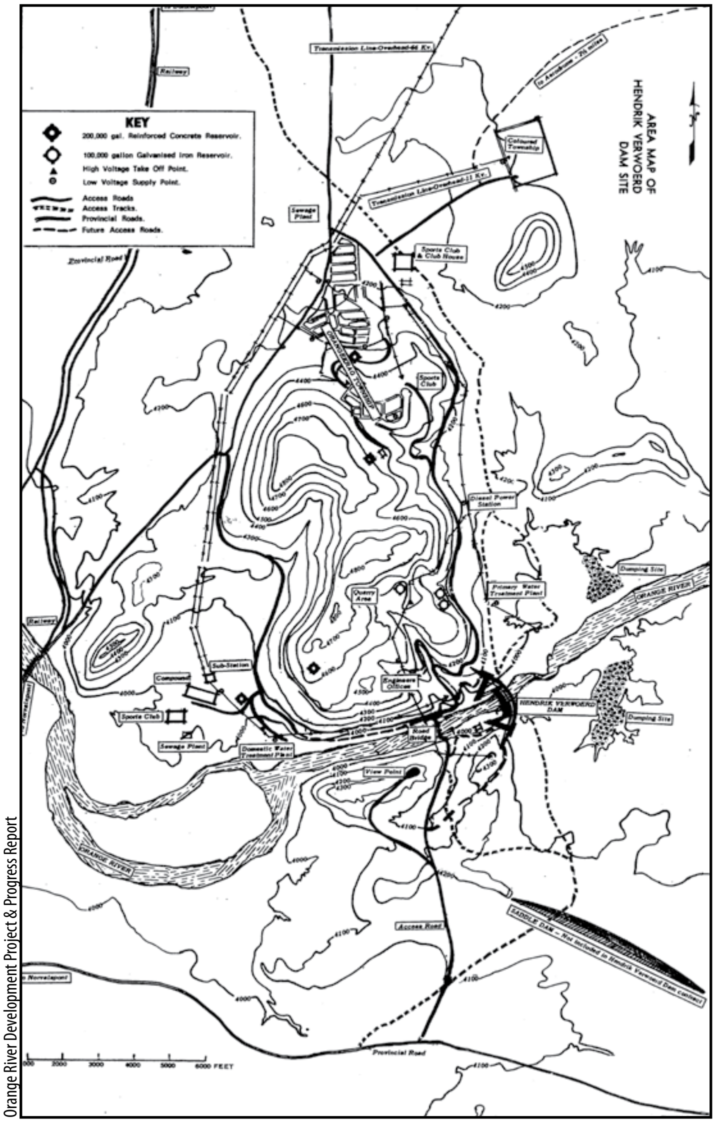
- The Orange-Fish River Tunnel
- The Klipfontein canal
- The Conway canal and Wapadsberg tunnel
- The Hofmeyer canal

While the South African press praised the government for its boldness to tackle such a project, the science community had its misgivings. In 1963, a special conference to discuss the matter was organised by the South African Association for the Advancement of Science. Among others, questions were raised about whether agricultural production should be the primary concern of the ORDP. Delegates agreed that "there was a need to re-examine more fully the economic implications of the scheme with special reference to the relative value of water utilisation for a variety of purposes under the headings of agricultural, pastoral, hydro-electric, industrial, and regional development." Several recommendations were proposed. Of special urgency were the recommendations for biological, palaeontological and archaeological surveys of the areas to be inundated and brought under irrigation. A grant of funds was promptly made to allow for these surveys and archaeologists subsequently retrieved thousands of stone artefacts from the dam basins, while palaeontologists uncovered fossils said to be 150 million years old. Many rare plants in areas to be flooded by the dams were also uprooted and moved. More than a thousand people had to make way for the dams (many of these were farmworkers who received no compensation).

Gariep Dam

The decision as to where to site the Gariep Dam was a complex one. West of the Vaal-Orange confluence the rainfall was too low and undependable to be worth collecting, but above that point the further east the dam was placed the less water it would receive. On the other hand, the furthest east and higher it was the more irrigable land would lie below it and the greater would be its potential for generating electricity. To serve one of its main purposes the dam had to be placed high enough above sea level for water to gravitate to the Great Fish River valley. Another consideration was to place the dam wall where it could impound the maximum quantity of water for the smallest cost in construction: that is making it as short and low as possible. With all of these factors in mind, the present site was selected in a gorge at the entrance to Ruigte Valley, five kilometres east of the Norvalspont.

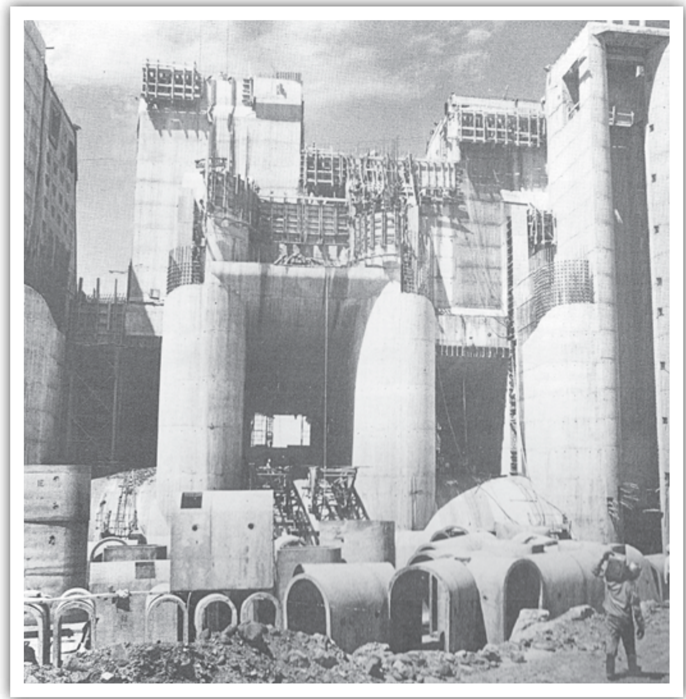
Initially, the government had appointed French consulting engineers to direct the project (allegedly as a quid pro quo for an agreement to supply arms),



Orange River Development Project & Progress Report

Left: *A map of the layout of the Gariep Dam site during early construction.*

Right: *An upstream view of the giant intake openings at Gariep Dam.*



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but after protest from Ninham Shand and others, South African consulting engineers were also included, forming a consortium with the Europeans. It was called the International Orange River Consultants Consortium or IORCC. Another consortium was also formed between British and South African consulting engineers and was called Gibb Hawkins and Partners (GHP). The latter was responsible for all the hydraulic structures, including the spillways and all the other outlets and control structures. IORCC led the site team at Gariep, while GHP led the site team at Vanderkloof. DWA would remain responsible for the design and construction of the canal systems and all other works. Apparently there was some dissatisfaction among departmental engineers over this arrangement, as previously all such work had been done in-house. This eventually led to

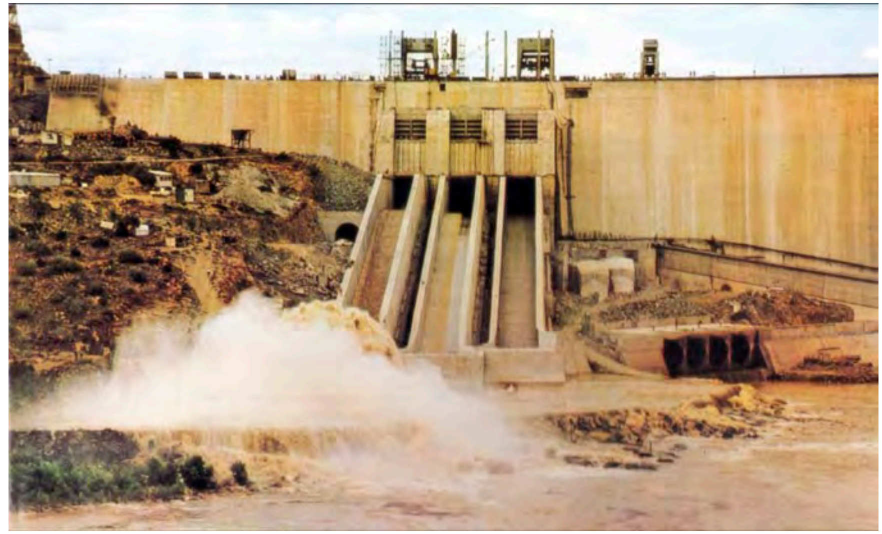

Eskom

much of the development work of capital projects being outsourced from then on.

Dr Henry Olivier, who at that time worked for British consulting engineering firm Sir Alexander Gibb writes of this cooperation: “Right from the first meeting there was disagreement about almost everything because of the wide differences in experiences and approach represented within the consortiums. One thing we had in common. We all disagreed with the White Paper designs for the dams.” (Olivier, 1995) These called for circular arch dams, which in the case of Gariep Dam could subsequently be raised. The French-South African consortium rather preferred a spiral arch or multiple arch or rockfill dam, while their British-South African counterparts proposed a curved gravity dam. Similarly, the White Paper prescribed that Vanderkloof Dam be built at one level and subsequently raised. Here again the consultants had qualms about the design. “The minutes [of those meetings] will make interesting reading for social archaeologists one day,” wrote Robert Blyth, who worked on the project as a young engineer (Blyth, 2002).

Left: *The Gariep Dam was the first internationally designed and constructed dam in South Africa.*

However, DWA's engineers insisted that the dams were to be arched and, while this design suited the Vanderkloof site, in the case of Gariep the consultants had to design a double curvature arch in a valley that was much too wide for that type of structure. It also added to the cost, with calculations showing a gravity design to be 30% cheaper. For the double curvature design to work Gariep Dam was developed with large gravity abutments and a double curvature arch thicker than normal standards. In addition, a special heel structure was incorporated into the design. The consultants urged the raising right from the start of both dams to increase their storage potential. Extensive hydraulic tests were undertaken in England and France with assistance from Prof Des Midgley of the Civil Engineering Department at the University of the Witwatersrand. Subsequently, in 1964 the Minister of Water Affairs announced that the Gariep Dam would be constructed 18 m higher than originally anticipated (the consultants wanted to build the dam 6 m higher still but this was turned down) and Vanderkloof Dam 12 m higher. The gross storage capacity of the former would thus be more than trebled and the latter doubled. In addition, Eskom was persuaded to enlarge the hydropower station from the original 62 MW to 360 MW.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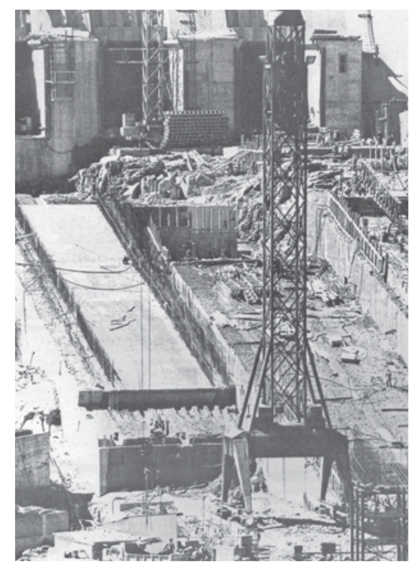
Competitive tenders were called from contractors all over the world. Meanwhile, between 1965 and 1967, several self-contained towns were built to accommodate the families of the men who would be engaged on the project. Other site preparation work, such as the construction of roads, bridges and power lines, also had to be undertaken. In April 1966, the main contract for the civil engineering works of the Gariep Dam was awarded to

Above: *Water cascading down one of the three spillways on the right bank of the Orange River during the first tests of the spillway gates of the Gariep Dam.*

Right: *The Gariep Dam outlet during construction.*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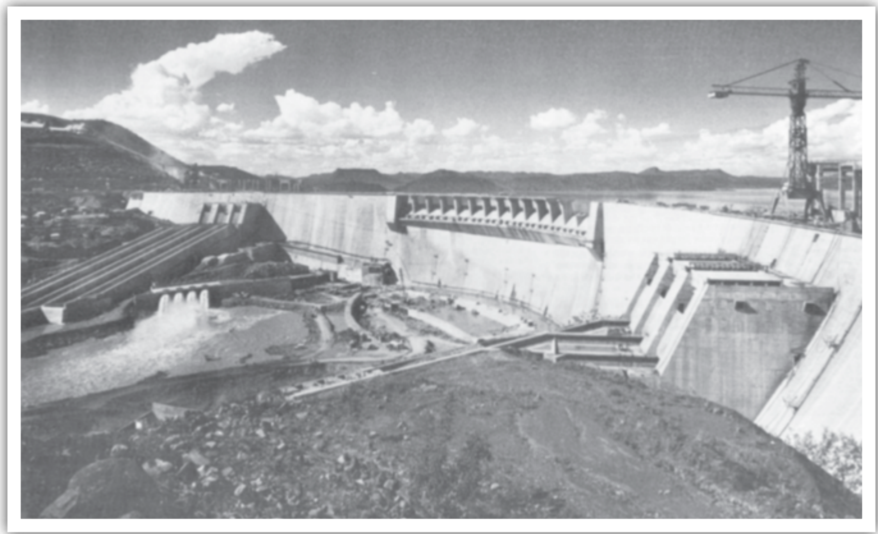

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The Gariep Dam nearing completion. The dam was completed in 1971.

the French-South African consortium of Union Corporation-Dumez-Borie Dams, and veteran European dam builder André Borie himself paid a special visit to the dam site. On 18 November, Prime Minister John Vorster pressed a button and blasted a ton of rock into the air signalling the start of construction of the dam wall. G Belin of Enterprises André Borie was in charge of the project, while the Union Corporation team was led by Mr McNamara, formerly mine manager at Bracken gold mine. The Resident Engineer for DWA was Dale Hobbs.

While the South African side of the consortium was responsible for the labour and management, general engineering services, drawing office facilities, purchasing, secretarial and medical-related activities, specialist engineers were drawn from France and other European countries (at high cost). As such the construction township of Oranjekrag, near Norvalspont, developed a distinctly cosmopolitan atmosphere where French was spoken as often as Afrikaans and English. In turn, it is said that Italian virtually became an official language in the towns of Venterstad and Steynsburg. The construction towns included several amenities, including shops, hospitals, schools, and recreation facilities. Houses were mainly prefabricated structures, and consisted of three to four bedrooms.

Curiously, the South African government took a decision early on in the project that only Xhosa labourers were to be used for unskilled work (at a rate of 7 cents an hour) on the Gariep Dam site. The workers were recruited from Transkei, and contractors were not allowed to make use of Sotho or coloured labourers, rather they had to draw workers from a labour desk established by the Department of Bantu Administration and Development at the Gariep Dam site (later on the project, however, labour shortages prompted the employment of coloured workers as well).

The Gariep Dam is the key work of the ORDP. Operation of the project is dependent on the water impounded by the dam; water is either passed through hydropower generators and down the Orange River to the Vanderkloof Dam, or diverted into the Great Fish and Sundays River valleys via the Orange-Fish Tunnel. The first concrete was placed in the main dam in July 1967. By 1969, the whole appearance of the works changed 'from what appeared to the layman to be a jumble of massive excavations, yawning penstock tunnel entrances and huge blocks of unrelated concrete into a cohesive whole' (RSA, 1969).

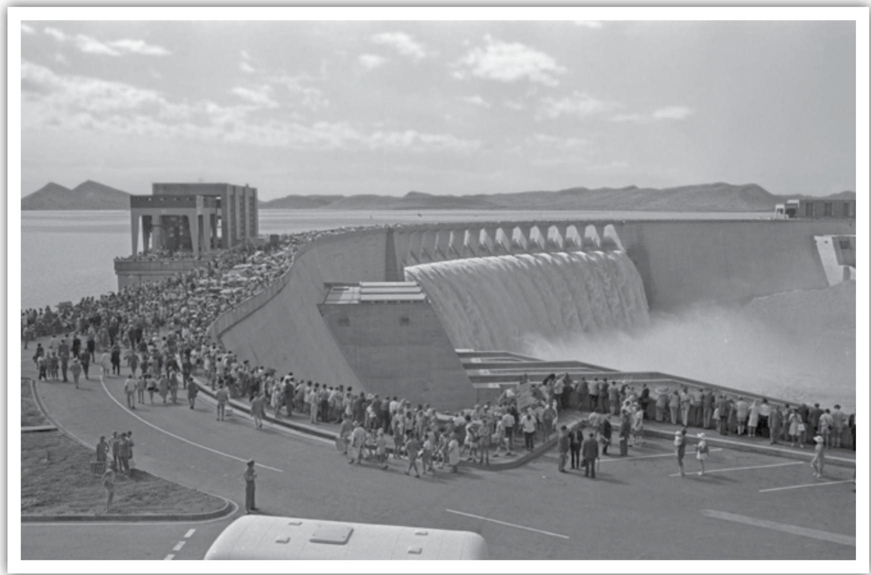
At the height of construction more than 2 000 people worked on the dam wall. Cement and slag was transported to Donkerpoort station in bulk. There the materials were transferred into road tankers and delivered to site. A 40 t/hour blending installation mixed the batches of blend. The blended material was then transferred to either of two batching and mixing plants. Crushed stone was sourced from a quarry established in the vicinity of the dam. Rock was loaded onto 18 m^3 capacity dumpers and transported to the primary crushing plant where it was dumped onto the apron feeder of a gyratory crusher where rocks were crushed to suitable sizes and then stockpiled prior to further handling. From the primary stockpile the stones were conveyed to the secondary crushing plant, where a series of cone crushers and screenings houses produced the required aggregate sizes.

From the stockpiles, aggregate and sand travelled by means of a one-metre delivery conveyor, 213 m long, to the primary and secondary batching plants. The primary batching plant had a rated output of 230 m^3/hour, and could produce 12 different mixes of concrete. The dam was divided into 63 numbered blocks, generally 15 m wide, with even numbers increasing from the centre along the right bank and with odd numbers along the left bank. Concrete was transported from the loading platform to the various blocks and to receiving hoppers conveniently erected near the dam, by means of four, 15-t capacity cableways. These cableways also covered the upper part of the right bank spillway and a large part of the apron.

The left bank intake, upper part of the left bank spillway and lower part of the right bank spillway were covered by two luffing cableways, having their fixed cabins on the right bank. These two cableways also fed indirectly most of the tower cranes on the left bank, with concrete being discharged from the cableways into receiving hoppers, from where hopper trucks transported it within the reach of these cranes.

A combined gravity-and-arch dam, the Gariep wall was constructed entirely of concrete. Since the gorge at the site where the dam was built was too wide to allow for a complete arch shape, only the central section of the dam is arched. Two concrete gravity section flank walls form artificial gravity abutments for this arch. The dam is a double curvature structure, i.e. shaped like an egg shell. Since the hot-poured concrete would take a century to cool down on its own, engineers made use of an instant refrigeration system whereby chilled water was injected into a 240 km-long pipeline inserted throughout the structure (a similar system was used for the construction of the Boulder Dam in the US decades earlier). The refrigeration unit, situated on site, produced 585 t of ice an hour, and was used to keep the water at a constant 7°C. Following construction of the dam the long lines of pipeline were pumped full of concrete to become part of the wall.

Two huge water sections – one on each flank of the main arch – control the release of water. In the wall on the right (Free State) bank of the river there are river outlet pipes; while in the wall on the left (Northern Cape) bank of the river there are four electric power penstocks. Six flood spillway openings are situated in the water intake sections, three on each bank, symmetrically positioned, and there are six large concrete channels or chutes – three on each side and a concrete apron beneath the overspill to prevent the falling water from eroding the rock at the base of the dam. Under normal maximum flood conditions 8 000 m^3/s of water can be discharged. This is in addition to the 8 100 m^3/s of water which can be discharged through the chute spillways.



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The official opening of Gariep Dam on 4 March, 1972 was attended by thousands of people.

Enormous radial gates, three on each side, are situated in the gravity sections of the wall on either side of the main arch. These discharge floodwaters into the six chutes. The radial gates are 8 m high, and the moving parts along in each gate weigh 95 t. The gates were rubber-sealed and faced with stainless steel. These gates are said to have a life expectancy of three centuries – way beyond the life of the dam itself. Gariep Dam's design also features Roberts' splitters or energy dissipaters to break up the sheet of water discharging over the spillway.

In the case of the intakes for the river flow outlets, the screens take the form of vertical concrete ribs with openings that are 0,305 m

Behind the Gariep Dam wall lies the biggest artificial water body in South Africa. The dam has a gross storage capacity of 5 950 million m^3.

Chris Marais/Karoospace

wide (known as trash-racks). For the intakes of the power generating penstocks, the screens consist of fine steel ribs with openings no more than a few centimetres wide. Because the lake is formed by the dam is used for pleasure boating, a heavy-mesh barrier, or boom, is anchored a short upstream of the main wall to prevent swimmers and small craft from coming too close to the intake orifices.

Former Prime Minister HF Verwoerd undertook an informal visit to the dam site in 1966 where foundation excavations were being undertaken. He is said to have been very impressed by the project. However, he would never see the completion of the dam that carried his name for many decades. A few months later Verwoerd was stabbed to death in Parliament by Dmitriou Tsafendas. In February 1967 the Orange River in one last act of defiance sent down a flood of 8 500 m^3/s through the works, flooding the right bank cofferdam where the foundations of the dam were still being excavated.

Gariep Dam started storing water in September 1970, and by June 1971 already contained 65% of its full capacity. It overflowed for the first time in 1972. It is South Africa's largest dam with 40 000 ha of land disappearing underneath the water. At its official opening on 4 March, 1972 Prime Minister BJ Vorster emphasised the importance of water to South Africa: "Water is too scarce in our country ever to be cheap and water tariffs must be high enough to make everybody realise this and to encourage users of water to do so sparingly...in this way the scarcity value of water in our country will be brought home to all consumers."

The dam has a gross storage capacity of 5 950 million m^3 and, when full, the shoreline of the reservoir is 528 km long. The average width of the reservoir is 3,5 km and at one place it is 19 km wide.

Engineering features of the Gariep Dam

Dam type: Double curvature arch

Max height above foundation: 90,5 m

Crest length of dam wall: 909,5 m

Gross storage capacity: 5 950 million m^3

Surface area of reservoir: 370 km^2

Volume of excavation: 1,91 million m^3

Volume of concrete placed: 1,92 million m^3

Orange-Fish Tunnel

The Orange-Fish Tunnel is the main link in the chain of delivery of water from the Orange River to the Fish-Sundays rivers. The 82,45 km-long tunnel (at one time the longest of its kind in the world) passes underneath the Suurberg Plateau to convey water between the Gariep Dam and the Teebus River, near Steynsburg in the Eastern Cape. From here water is fed to the Grassridge Dam, which acts as the regulator of the waters of the Orange River diverted along the Orange-Fish Tunnel to the Great Fish River valley. Water is gradually discharged into the Great Fish River. At Elandsdrift, near Somerset East, water from the Orange River is diverted from the Great Fish River and carried to Darlington Dam in the Sundays River.

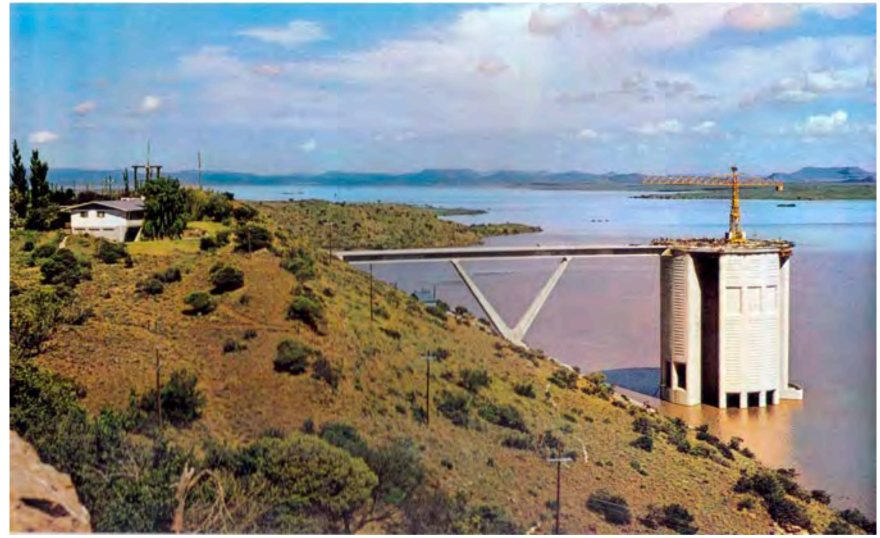
Intensive geological investigations and engineering tests, hitherto unknown in South Africa for a water project, were conducted prior to the start of construction. In his 2005 article on the tunnel, Prof Will Alexander (DWA Resident Engineer at the tunnel site from 1963 to 1969) explains that owing to the considerable length of the tunnel, the earth's curvature, as well as the effect of gravity, anomalies had to be taken into account during the design and construction of the tunnel. "All survey observations had to be carried out with a very high order of accuracy in order to ensure satisfactory horizontal and vertical alignment of the tunnel over the long distances between the construction shafts." (Alexander, 2005)

For contracting purposes the tunnel was divided into three sections of more or less equal lengths, namely an inlet section, the plateau, and the outlet section. Twelve consortiums (eight of which included South African companies) were pre-selected to bid on the project. Orange-Fish Tunnel Consultants, a consortium of British company Sir William Halcrow and Partners and South African firm Keeve Steyn and Partners, were the main consulting engineers on the project. The inlet contract, which included the water intake tower on the Oviston bank of the river, the access bridge to the tower and two access shafts to the tunnel was won by a joint venture known as Batignolles-Cogefar-African Batignolles (a consortium of French, Italian, and South African firms). In turn, Orco Consortium, comprising South African, American and French firms, was responsible for the Plateau or middle section of the tunnel, which comprised three shafts and the connected tunnel works. The outlet section, which covered two shafts, all underground control works and the outfall canal, was constructed by Dipenta-JCI, an Italian-South African consortium.

Construction of the tunnel started at the inlet section in 1967. Seven shafts roughly 11 km apart were put down to attack the tunnel at 16 different faces working towards each other. About 2,4 million m^3 of material was

The lady of the tunnel

A special figure watches over the inlet of the Orange-Fish Tunnel at Oviston. The consortium working on this section employed many Italian employees. Being devout Catholics they brought with them a statue of the Mother Mary, which was duly placed at the entrance of the tunnel in a specially-created crevice at the tunnel entrance.



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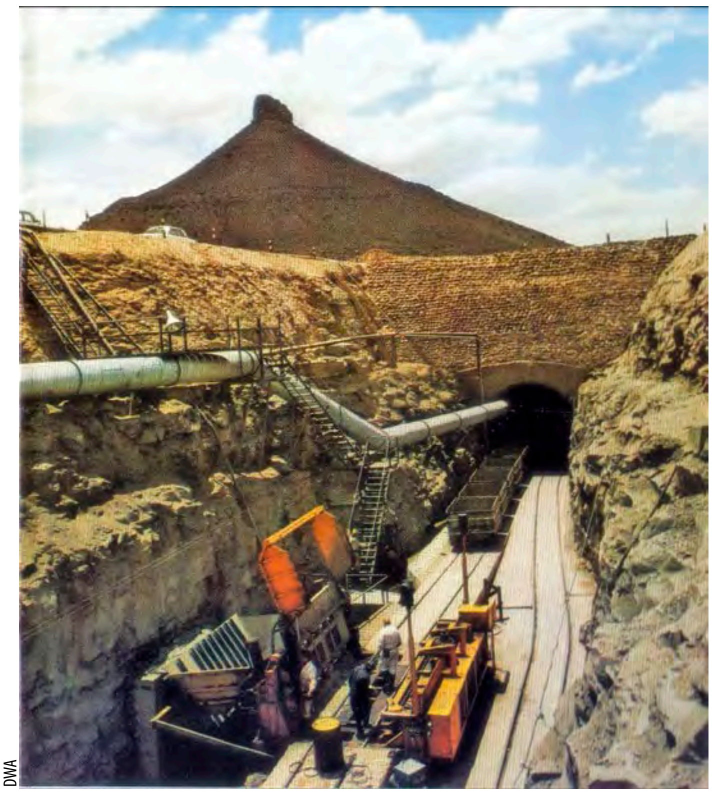
The inlet tower of the Orange-Fish Tunnel, located in the Gariep Dam. The lowest inlet is situated 30 m below the surface level of the dam and 9 m above the original bed of the Orange River.

DWA

Left: Inside one of the shafts of the Orange-Fish Tunnel during boring operations. With an internal diameter of 5,3 m, the Orange-Fish Tunnel can convey a maximum 56 m³/s of water.

Below: The outlet of the Orange-Fish Tunnel at the foot of Teebus Hill, near Steynsburg.



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excavated from the tunnel – enough to fill about 100 000 average-sized trucks. In some places the tunnel is 405 m below the surface. Around 684 000 m^3 of concrete were used to line the entire length of the tunnel, the minimum thickness being 230 mm. The structure is almost entirely indiscernible to the public eye, with only the inlet tower structure in the Gariep Dam, the shaft heads and the inconspicuous outlet structure being visible.

Driving of the tunnel proved a tremendous challenge to the engineers, complicated by the Karoo sedimentary rocks and dolerite intrusions and underground water. The rock through which the tunnel was constructed consisted of 10% dolerite, 15% sandstone, 15% green shale and 60% purple mudstone. The contractors approached the tunnelling problems in different ways, but with the same basic equipment. The traditional tunnelling method was used throughout, i.e. holes were drilled and filled with explosives, and then detonated, after which the rock was removed. The tunnel construction was very dangerous work – it is estimated that at least one life was lost for every kilometre of the tunnel. In 1969, an inrush of water, calculated to be some 2 000 m^3/hour, occurred in Shaft 2. Nearly two kilometres of tunnel was flooded to a depth of 87 m. From then on watertight bulkheads were installed in each heading prior to blasting. Other dangers encountered were pockets of methane gas and severe rockfalls.

The intake tower structure has a height of 77,7 m above its foundations and an external diameter of 38 m. Seen from above it is shaped like a four-leafed clover. The ‘leaves’ of the clover contain the gates controlling the level at which water is withdrawn from the dam. The tower has six intake levels to ensure that relatively sediment-free water can be drawn off the dam.

To protect the tunnel against any unforeseen rise of water in the river before the water intake tower gates were ready, a

The construction towns

A total of eight new construction towns and villages were constructed during the ORDP to house workers and their families. With no, or few, amenities in the immediate vicinity of most of the working sites, it was realised early on that the construction towns would have to provide all the accommodation and recreational facilities.

These 'instant towns' sprung up between 1965 and 1967, many with permanent structures designed to accommodate operational and maintenance staff after the completion of the project. Due to the laws of the time, white, black and coloured workers had to be housed in separate places and could not share amenities. Infrastructure included tarred roads, waterborne sewage and electricity as standard, while tennis courts, banks, cinemas, swimming pools, recreation halls, beauty parlours and football fields were also added.

The biggest town was Oranjekrag (meaning 'Orange power'), situated about 8 km from Norvalspont on the Free State side of the Orange River. The town of Oviston (derived from the Afrikaans *Oranje Vistonnel*) was the second-largest town. Located in the Northern Cape the town was sited on a bluff overlooking a curve of the Orange River at the inlet of the 82,3 km-long tunnel. About 40 km due south of Oviston, on the Suurberg Plateau midway along the tunnel, the construction town of Midshaft was created. At the end of the tunnel, there was Teebus, the headquarters of the outlet section.

The township of Vanderkloof served the dam of the same name. It was situated on the summit of a hill overlooking the deep gorge in which the dam was constructed, 5 km from the town of Petrusville, while Orania near Hopetown was the headquarters of the Vanderkloof canal schemes. (Interestingly, Orania was purchased from DWA in 1990 by Carel Boshoff who went on to develop it as an independent settlement exclusively for Afrikaans-speaking whites)

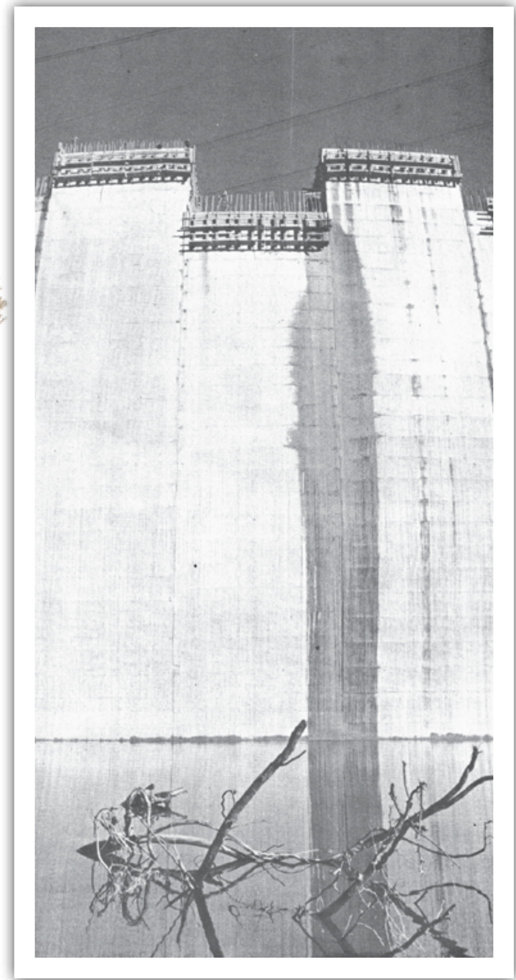
Near the town of Wepener, in the Eastern Cape, the construction town Welbedacht was established on the banks of the Caledon River. The town Uitkeer was also established midway between Somerset East and Cookhouse. Some of these towns, such as Oranjekrag and Vanderkloof, have since become holiday resorts.

concrete plug was installed at the mouth of the tunnel portion of the inlet section, together with a manhole through which any trapped person might escape. On 30 July, 1973 Prime Minister John Vorster marked the holing through of the tunnel at Teebus with a simple plaque-unveiling ceremony. The tunnel was eventually completed in 1975. It cost R160-million to complete making it the most expensive element of the ORDP.

Vanderkloof Dam

Vanderkloof Dam is the main control dam to release water into the river for use further downstream (and for the generation of electricity) and to divert water into the canal system for irrigation purposes. To meet these requirements it was necessary to build a high dam wall with discharge and control structures also sited at a high level. Similar to Gariep Dam, Vanderkloof was designed as a composite gravity arch dam, and was constructed with a central arch which transitions into a gravity flank on the left bank. Other than Gariep, the Vanderkloof site was much more suited

A view of the Vanderkloof Dam wall during construction. More than 1,1 million tons of concrete went into the dam wall.



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***Left**: At 107 m high, the Vanderkloof Dam is one of the highest dams in South Africa.*

***Above**: An artist's impression made of the Vanderkloof Dam prior to its construction.*

to this design, being narrower.

The dam features a centrally positioned spillway section. On the left flank there are four spillway chutes for the controlled release of water from the dam. The four 15 m x 9,5 m openings are controlled by radial gates which, in conjunction with the central spillway crest, discharge floodwater when the dam's storage capacity is exceeded. The normal river outlets as well as the right bank main canal outlet structures are on the right and the inlet to Eskom's underground power station is one the left flank. Provision has also been made for canal outlet structures on this flank. On each side of the spillway crest a silt outlet has been incorporated to discharge heavily silt-laden water, thereby minimising the siltation of the dam.

Originally scheduled to commence at the same time as Gariep Dam, construction of Vanderkloof Dam was postponed in 1967, while preliminary construction was already being undertaken. Economic reasons are given as the official cause for postponing construction of Vanderkloof, but not everybody believes this to be the real motive for the delay.

According to retired Professor of Soil Science, Giel Laker, it was rather the disillusionment of authorities on the fact that they would not be able to 'make the desert bloom' through the ORDP as originally envisaged. "To make a desert bloom by means of irrigation one needs both water and irrigable soils. In the planning of the Orange River scheme attention was given only to the provision of water. No soil surveys were done before or during the planning stage of the scheme to determine how much irrigable land there was in the envisaged irrigated areas and where these irrigable soils were. Soil surveys were conducted only when the Gariep Dam was already being constructed. When soil surveys eventually started in the northern Karoo, close to where the Vanderkloof Dam was to be built, it soon became clear that there were very little irrigable soils in the area."

The realisation led to nasty letters between the DWA and the Department of Soil Science at the University of the Free State, who had made the discovery, and eventually to a heated meeting between the two parties. At the meeting it was pointed out that

OOM VANDERKLOOF

One of the most prolific campaigners of the ORDP was Mr AV van der Merwe of Douglas, or Oom Vanderkloof as he became known. He travelled around the country with his suitcase full of maps (drawn on linen rather than paper), explaining his ideas to all and sundry.

the extent of the irrigable soil south of the river was extremely limited, but that there were large blocks of irrigable soils north of the river, especially in the Plooysburg area. Tough discussions were followed by a redesign of the Vanderkloof Dam (particularly the outlets). A week after the meeting the Minister of Water Affairs announced that the building of the dam had been postponed.

A re-examination of the proposed site resulted in a decision to move the main wall 200 m further downstream, to the west of the original position.

It was originally envisaged that the right bank canal would extend to the Brak River Valley in the Prieska-Britstown area as well as the Carnarvon-Leegte, the Beervlei area, the Sak River Valley and the Koa River Valley. It was decided not to proceed with the extensions of the right bank canal, which now stops near Hopetown. Similarly, it was originally intended to construct a left bank canal from the dam to Hopetown in order to supply irrigation on the left bank of the Orange River. This canal was not constructed and all irrigation along the left bank between Vanderkloof Dam and Hopetown is supplied directly from the river using pumps.

After a number of postponements the dam finally came up for tender in June 1970. The tenders were rejected for being too expensive, and DWA decided to construct the dam using departmental labour. Construction eventually started in 1971. Meanwhile, a re-examination of the proposed site resulted in a decision to move the main wall 200 m further downstream, to the west of the original position. July 1971 saw the first construction teams arriving on site and two years later the first concrete was placed. The river was diverted in August 1973 through a temporary opening in the right flank of the wall and it was then possible to start with the foundation excavations of the river section. The delay in the construction of Vanderkloof meant that the flow of the Orange River could now be controlled by Gariep Dam upstream. Although this did reduce the risk, flooding of the works did occur in February 1974, with 100 000 m^3 of silt and sand being deposited in the coffer dam. No appreciable damage was caused, however.

At 107 m high, it was the highest in South Africa at the time of its construction. The wall is 765 m long. Vanderkloof also features a road across the wall which links the Northern Cape and Free State provinces. The dam has a capacity of 3 255 million m^3 – almost half that of Gariep Dam. Vanderkloof Dam was eventually completed in 1977.

Engineering features of Vanderkloof Dam

Dam type: Double curvature arch
Full supply level: 1 170,5 million m^3
Max height above foundation: 107 m
Crest length of dam wall: 770 m
Gross storage capacity: 3 255 million m^3
Surface area of reservoir: 13 866 ha
Volume of excavation: 2 429 million m^3
Volume of concrete placed: 1,1 million m^3

The Fish-Sundays River canal system

The Elandsdrift Weir is large enough so that, apart from the water discharged by the Grassridge Dam into the Great Fish River, it can also store a considerable quantity of floodwater and divert it into the canal. The canal crosses the Great Fish River by means of siphon pipes and carries water to the 13,7 km-long Cookhouse Tunnel which conveys water underneath the Bosberg, halfway between Somerset East and Cookhouse, from where a 12 km-long canal carries the water further to discharge it into the Little Fish River. About 41 km downstream, at Wellington Grove, the water is diverted from the river and pumped into a canal 38 m higher up. This canal serves the Skoenmakers River, which flows into Darlington Dam.

The costs of constructing the ORDP were grossly underestimated. In the end it cost R490-million to construct the first phase compared to the originally estimated R85-million for the whole project. To date, no further phases have been developed.

THUKELA VAAL TRANSFER SCHEME

The 1960s were a decade of unprecedented economic growth in South Africa. Between 1962 and 1967 the average growth rate in the production of services and goods was 6,3%. Most of this growth was in the economic heartland of the country (then known as the Pretoria-Witwatersrand-Vereeniging complex). As economic growth took place the demand for water grew. The area received most of its water from the Vaal River system, which was by then already a hard working river.

Other large users of the Vaal River's resources included Sasol, Iscor (known today as Arcelor Mittal South Africa), Eskom, Orange Free State Goldfields, Western Transvaal Regional Water Company (known today as the Midvaal Water Company), the Vaal-Gamagara Government Water Scheme, the Vaalharts Irrigation Scheme and various towns.

Drought conditions experienced between 1960 and 1966 caused the Minister of Water Affairs to impose water restrictions in the PWV area for the first time in decades. While

The location of the Thukela-Vaal Transfer Scheme.

satisfactory rains allowed these restrictions to be lifted in February 1967, they were re-imposed from February to November 1969. Between October 1970 and November 1971 and in 1973 the area also faced restrictions, contributing to the stagnation of industrial investment in the region. At that stage the storage capacity of the storage schemes on the main stem of the Vaal River was 4 100-million m^3, capable of supplying 1 545 million m^3/year on a dependable basis. However, the demand for water from the Vaal was to reach 1 600 million m^3/year by 1976, and the realisation dawned on authorities that something needed to be done urgently.

The Vaal Dam had basically reached its limits as far as raising the dam wall was concerned. The dam's high evaporation rates would make such a project uneconomical. Indirect re-use of water was already taking place to the fullest extent possible and the only other feasible source for augmentation was transfer of water from a neighbouring catchment. By the 1960s negotiations with Lesotho to construct the Lesotho Highlands Water Project had already started, but was proving difficult and lengthy. In the meantime, demand kept growing. Attention subsequently became focused on the upper reaches of the Thukela River, several 100 metres below the headwaters of the Vaal and flowing in the opposite direction (towards the Indian Ocean). Other suitable neighbouring rivers considered were the Usutu and Komati rivers, but these were already being developed for water supply to Eskom's new power stations on the eastern Highveld. The remaining neighbouring rivers were tributaries of the Limpopo, the water resources of which were already being exploited. Thus, in June 1970, the first phase of the Thukela-Vaal Transfer Scheme was approved by the then Minister of Water Affairs, Fanie Botha.

The first gauging station for the observation of Thukela River

Ralf Broemer

By the 1960s negotiations with Lesotho to construct the Lesotho Highlands Water Project had already started, but was proving difficult and lengthy.

flow had actually been established at Colenso in 1928, and by the 1960s there were five well distributed gauging stations in the area. By the 1930s DWA started undertaking topographical surveys in the vicinity of Bergville. These surveys were in due course supplemented and expanded, leading to site investigations of two potential dam sites at Spioenkop and Schietdrift. Further analyses narrowed it down to the Spioenkop site on the farms *Rhenosterfontein* and *Emmadale* in the Bergville district.

The original layout of the Thukela-Vaal Transfer Scheme comprised Spioenkop Dam, two pumping stations and a pipeline conveying water along an aqueduct (comprising 37 km of rising main, 28 km of canal, 5,5 km of inverted siphons and 12 km of tunnels) which would discharge to the basin of the proposed Java Dam, near Harrismith. Construction of the conventional gravity-type Spioenkop Dam subsequently kicked off in 1968. However, when it was discovered that the proposed Java Dam would flood a large part of the then planned Qwa-Qwa homeland, the scheme had to be completely replanned. This proved a blessing in disguise as a new site for the reserve storage dam was found at the farm *Sterkfontein* on the Nuwejaarspruit – a tributary of the Liebenbergsvlei River, itself a tributary of the Wilge River, which in turn flows into the Vaal Dam.

This site was so close to the watershed near Oliviershoek, and on such a minor tributary, that initially DWA engineers did not believe it possible that it could command the required 2 000 to 3 000 million m³ capacity. In addition, the site was substantially closer to the then proposed aqueduct. In order to get the water to Java Dam, the Nuwejaarspruit valley had to be crossed by a long siphon, followed by a tunnel between the mentioned valley and that of the Klerkspruit, on which the Java Dam was to be built. These structures could be done away altogether.

Lani van Vuuren

Drinie van Rensburg

***Left:** The Department of Water Affairs established its first gauging station to measure flow from the Thukela River in 1928.*

***Below:** The Drakensberg Mountains, the source of the water-rich Thukela River system.*

Instead of starting all the way from Spioenkop, a new regulating dam was proposed at Woodstock below the confluence of the Thukela and Mnweni rivers, much higher up the river and thus also closer to the escarpment. In order to also catch the Mjambonja tributary, a barrage was proposed at Driel, below its confluence with the Thukela. A canal was proposed into which the water pumped from Driel and regulated by Woodstock was to be discharged. The canal flows in an upstream direction towards the foot of the escarpment at Jagersrust where the main pumps lifting the water 500 m towards the Free State were to be located. Subsidiary canals took water diverted from the upper Thukela and its tributaries directly under gravity to Jagersrust.

Theo van Robbroeck reports that this new layout saved lots of pumping energy. "The aqueduct was also substantially shorter and consisted mainly of canals, which are much cheaper than pipelines and can easily be enlarged for further phases, which in the end was done. Pipelines from Spioenkop, on the other hand, would have to be doubled physically. Once over the watershed, the water was taken by canal and a short tunnel to the Sterkfontein reservoir." It was decided to construct the Driel Barrage as a first phase of the project. The second phase would then entail the construction of the Woodstock Dam. The Spioenkop Dam would now serve to re-regulate the flow of the Thukela River for downstream users, since all the low flow was now to be abstracted at Driel.

As Assistant Chief Engineer (Design), Van Robbroeck with his staff was responsible for the design of the Sterkfontein Dam, the Woodstock Dam, the Driel Barrage and the diversion weirs of the Upper Thukela, the canals and the tunnel. Rand Water aided with the design of the pumpstation at Driel and the main high-lift pumping station at Jagersrust, including the pumping mains.

The Sterkfontein basin was found to have a remarkable shape in that it had a wide bottom through which the river meandered at a flat gradient and was surrounded by steep slopes.

Construction of the dam started in 1971 and at the time it was the largest earthfill embankment dam to be built in South Africa. The embankment is a typical earthfill design 2 290 m long with an impervious core sloping upstream. The dam had an original height of 68 m and a gross storage capacity of 1,2 million m³.

The main challenge on the site was to make use of the fill

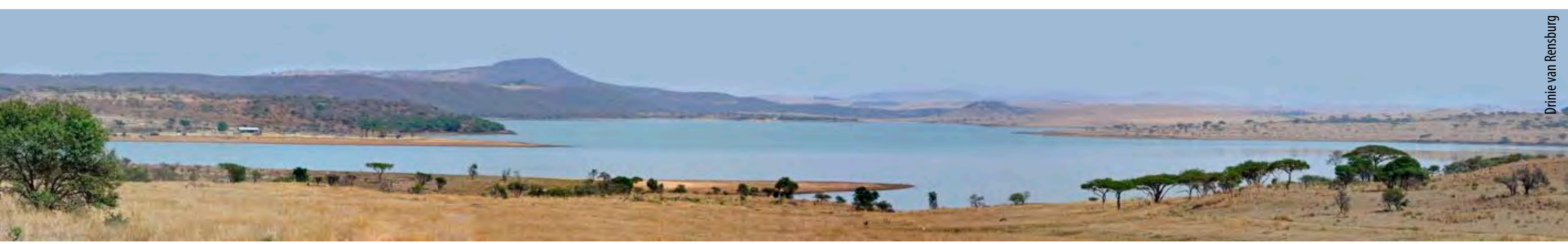
DWA

Opposite page: *The 51 m-high Woodstock Dam has a gross storage capacity of 381 million m³.*

Left: *Spioenkop Dam was the first large structure to be built in the Upper Thukela River. The dam has a full supply capacity of 270,6 million m³.*

Below: *Spioenkop Dam regulates the flow of the Thukela River for downstream users.*

Lani van Vuuren



Drinie van Rensburg

One of the largest dams in the world with no spillway, Sterkfontein Dam was the first South African dam to be included in the ICOLD World Register of Dams.

materials which were quite variable (mainly weathered mudstone, shale and dolerite). This gave rise to the rather flat upstream slope. Due to its small catchment area with negligible natural inflow the dam required no spillway, which made it pretty unique. Evaporation losses from Sterkfontein Dam are about 35 million m^3/year, which represent about 10% of the losses that would be experienced from Vaal Dam for a similar volume. When the dam was completed in 1977 it was the only dam in South Africa to qualify for inclusion in the ICOLD Register of the World's Largest Dams.

Following the completion of the first phase in 1974, up to 330 000 m^3/day of water was lifted 506 m by means of four vertical-spindle, centrifugal pumps, each with a capacity of 110 000 m^3/day. The 3 915 m-long rising main, which varied in diameter from 1 500 mm to 1 700 mm, took the shortest route directly up the mountain to end in an aqueduct consisting of 9 350 m of canals and 1 711 m of tunnels, the main one through the watershed between the Thukela and Vaal on the aptly-named farm *Tzamenkomst*. This aqueduct emptied into the Sterkfontein basin.

Even while the redesigned first phase of the project was under construction, the second phase of the scheme was being planned. Initially, the second phase was planned to increase the transfer rate to 11 m^3/s, corresponding to 950 000 m^3/day. The canals and tunnels had already been constructed to full capacity so that only the pump stations at Driel and Jagersrust would have to be duplicated as well as the associated rising mains and the Mpandweni siphon.

The Woodstock Dam would also now be constructed. Its purpose was to, in combination with Driel, help regulate the Thukela River to permit a constant 504 million m^3/year to be drawn, more than needed for the second phase. Once completed the 51 m-high Woodstock Dam would have a gross storage capacity of 381 million m^3. For the design flood the total spillway capacity required 1 000 m^3/s, of which 500 m^3/s could be discharged through the tunnel. An additional spillway with a capacity of 500 m^3/s had therefore to be built. Construction of this embankment dam was relatively short, starting in March 1979, with river diversion in April 1980 and impounding starting in March 1982.

Before the original Thukela-Vaal Transfer Scheme phase two was adopted, investigations were carried out for a pumped storage hydroelectric scheme which would augment the water supply by allowing only a part of the pumped water to be returned for electricity generation. As a result,

Engineering statistics of Sterkfontein Dam

Type: Earthfill
Height above lowest foundation: 93 m
Gross capacity: 2 656 million m^3
Crest length: 3 060 m
Volume content of dam: 19 million m^3
Type of spillway: None
Capacity of oulet works: 220 m^3/s
Volume concrete of dam wall: 17 million m^3
Surface area when full: 6 937 ha

this phase was amended, and the Drakensberg Pumped Storage Scheme (PSS) constructed instead as a joint venture between the DWA and Eskom. The PSS would replace both the existing Jagersrust station and its proposed extension.

During early investigations of the PSS by Eskom and DWA, Minister Botha found out about the proposed project. He immediately arranged for a press conference on site and announced the project publicly on 28 June 1974. "I advised strongly against this, because it had not been proved that a 16 m-wide cavern to house the pump turbines could be constructed in the relatively weak Karoo sediments of the site," notes Van Robbroeck. Unfortunately, being a politician, the Water Minister would not forego such an excellent opportunity for publicity.

The increased annual quantity of water created by the PSS was to be stored in Sterkfontein Dam, and in 1980 it was decided to raise the dam to its present height of 93 m with a crest length of 3 060 m and a full supply capacity of 2 656 million m^3. The dam wall contains 17 million m^3 of fill and at that time it was the biggest earthmoving job the DWA had ever undertaken. At full level the dam is 19 km long, 6 km wide, with an average depth of 58 m. The raising was completed in 1986.

For the lower reservoir, or tail pool, of the PSS, a suitable site was found on the Mnjaneni River on the farm Kilburn situated at the foothills of the escarpment. The required gross storage capacity of 36 million m^3 was created by a dam 51 m high. Since the water level would fluctuate over a depth of 21 m as the scheme operated, the upstream face of the dam has a flattish slope to improve its stability and is protected by rip-rap. The downstream face is grassed to combat erosion and blend in with the surrounding countryside. The dam has been operational since 1980. An extra pump station at Jagersrust, named the Kilburn pump station, was also erected. The four 250 600 m^3/day pumps lift the water through a 2 x 1 800 mm-diameter rising main, 1 645 m long.

South Africa experienced a serious drought between 1979 and 1986. The accumulative natural flow in the Vaal River during this time was only about 30% of the long-term average flow. By using water from the Thukela River system, serious water shortage could be averted.


DWA

Constructed during the first phase of the Thukela-Vaal Transfer Scheme, the Driel Barrage has a capacity of 18,3 million m^3.

The upper reservoir is created by the 47 m-high Driekloof Dam constructed across one of the arms of the large reservoir formed by Sterkfontein Dam. This arrangement is rather unusual compared with other schemes in the world as the full supply level of the Sterkfontein reservoir at 1 072 m above sea level is 2 m higher than the full supply level of the Driekloof reservoir. Consequently, for about 12% of the time, the crest of the Driekloof Dam spillway is submerged and the upper 2 m of the Sterkfontein Dam used as the upper reservoir of the PSS. In addition, the dam design was expected to handle spill either way across the wall and rapid drawdown on the upstream side. This dictated the need for a spillway across the crest. The chosen design was a rockfill dam with a central clay core and, the first of its kind in South Africa, a concrete spillway slab with multiple baffles on the

Eskom

Inside the Drakensberg PSS. Most of the electricity generating infrastructure of the pumped storage scheme was constructed underground to preserve the aesthetic beauty of the surrounding area.

downstream slope. The dam was completed in 1979.

The scheme now operates as follows: water is pumped from Driel Barrage into canals which flow via gravity into Kilburn Dam. Water from Kilburn Dam is then pumped underground, over the Drakensberg, and into Driekloof Dam. At peak periods when additional electricity is needed, water is dropped from Driekloof Dam, through the power station situated underground, and into Kilburn Dam. In quiet periods, water is pumped back from Kilburn Dam and into Driekloof Dam. When the latter is full, water flows into Sterkfontein Dam, where it is stored until needed. When water is required in the Vaal River system, water is released from Sterkfontein Dam into the Nuwejaarspruit, which then flows into Wilge River and then into the Vaal Dam.

No sooner was the Thukela-Vaal Transfer Scheme completed than it was required to perform its water lifeline function. South Africa experienced a serious drought between 1979 and 1986. The accumulative natural flow in the Vaal River during this time was only about 30% of the long-term average flow. By using water from the Thukela River system, serious water shortage could be averted. From 1983 to 1987 more than 1 600 million m^3 Thukela water was released which supplied about 43% of the demand during this period.

From the start of the second phase of the scheme concern was expressed over the potential environmental impact of the project on the pristine area in which it was to be located. Immediately after Minister Botha announced the project a committee was appointed to investigate the environmental implications of the project and to make recommendations to minimise adverse effects. The committee held its first meeting on 2 October, 1974. Despite environmental concerns there was never any doubt that the project would go ahead. It was just considered too strategically important.

However, this is probably one of the first large infrastructure projects in South Africa where concern for the environment dictated how the scheme was planned, designed and executed. For example, one of the decisions was to construct most of the electricity generating infrastructure underground to preserve the aesthetic beauty of the surrounding area.

Engineering statistics of Woodstock Dam

Type of dam: Earthfill
Height above lowest foundation: 51 m
Crest length: 760 m
Volume content of dam wall: 2 million m^3
Gross capacity of reservoir: 381 million m^3
Maximum discharge of spillway: 2 x 500 m^3/s
Type of spillway: 1 controlled spillway, 1 uncontrolled chute

Engineering statistics of Driekloof Dam

Type of dam: Rockfill
Height above lowest foundation: 46,6 m
Crest length: 500 m
Volume content of dam wall: 843 000 m^3
Gross capacity of reservoir: 35,6 million m^3
Type of spillway: Baffled apron on embankment
Capacity of spillway into Sterkfontein reservoir: 220 m^3/s

Engineering statistics of Kilburn Dam

Type of dam: Earthfill
Height above lowest foundation: 51 m
Crest length: 825 m
Volume content of dam wall: 2,9 million m^3
Gross capacity of reservoir: 36 million m^3
Type of spillway: Side channel with chute
Capacity of spillway: 320 m^3/s

The design and construction of the large underground cavern complex in poor sedimentary rock required the services of top specialists and numerous geotechnical tests. The underground machine hall, for instance, is about 195 m long, 16 m wide and 29 m high, thus its construction was no mean feat.

Another example is Kilburn Dam, where environmental considerations dictated that the haul roads and borrow areas for the earthfill embankment and the designated tip areas for the underground power station works be situated entirely within the basin. This resulted in a congested borrow-haul-tip configuration and spoon-picking was necessary in the available areas to get sufficient material. There was no environmental legislation with regards to infrastructure development in South Africa at the time and all the actions were entirely voluntary.

From June 1988, once the first water was received from Lesotho, the Thukela-Vaal canal was shut down for two years for rehabilitation and upgrade. The so-called Thukela-Vaal Betterments project arose when the sides of the existing canal were being undermined by hydrostatic forces, caused by build-up of groundwater seeping through the surrounding soil.

The problem began when the flow in the canal was increased during the second phase of the transfer scheme. To allow for this the height of the canal was increased through the construction of an 850-mm high, vertical wall right along the top of the existing canal wall. However, this caused surface runoff water from the surrounding area to collect behind the new vertical wall. The resulting pressures and hydrostatic dynamics of the runoff water behind the wall caused it to crack and eventually subside. During the betterments project this vertical wall was removed and the extension of the original canal sides upwards done by about 1,8 m for its entire length.

RIVIERSONDEREND-BERG RIVER WATER TRANSFER SCHEME

The Theewaterskloof Dam is not a significant achievement in itself – being as it is only the seventh largest dam in South Africa (12 times smaller than Gariep Dam.) However, it forms part of the one of the most imaginative water transfer schemes in South Africa which links the Berg and Sonderend rivers in the Western Cape.

The storage potential of the Riviersonderend was realised as far ago as the 1800s, but it was the Irrigation Department who started the first serious investigations into the possibility of a scheme here in 1929. This mountainous region has one of the highest rainfalls in South Africa (as much as 5 000 mm/year). A provisional dam design had actually been completed by 1952, and by 1964 the focus has zoomed in on the Theewaterskloof as the best storage site available. When the Greater Cape Town again started experiencing water shortages following the construction of the Wemmershoek Dam, it was decided to go ahead with

The intake tower of Theewaterskloof Dam. The dam was moved upstream from its original location to reduce damage to the surrounding environment.

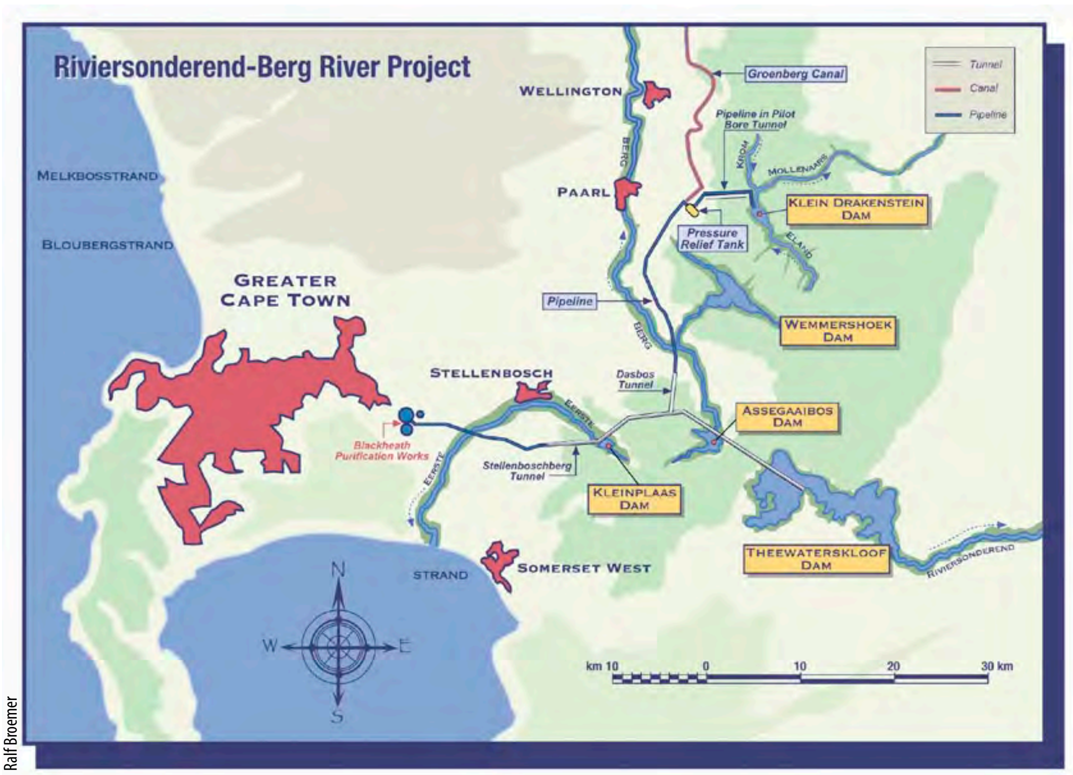
Frans Druyts

the Riviersonderend-Berg River scheme. The scheme would not only supplement water supply to Cape Town, but would also be used to provide irrigation water during the dry months to farmers in the Boland. The project was described as 'one of the most impressive civil engineering projects of the 1980s'.

The scheme essentially involved linking the two water-rich catchments of the Riviersonderend and the Berg River to discharge surplus winter runoff into one central storage dam. When the need for water arises, it is delivered by gravity through a series of tunnels to where it is needed. The interesting feature of the scheme lies in the fact that the flow can be reversed so that water from the Berg River can in the first place be stored in the Riviersonderend Valley and then be conveyed back in the dry summer to provide irrigation water in the supply of the valley from where it originated.

The project was constructed in two phases. The first phase comprised the construction of the Theewaterskloof Dam (the central storage unit for the scheme), the Franschhoek Tunnel and associated works, while the second comprised the Jonkershoek Tunnel system, including several shafts and balancing dams on the Eerste River at Kleinplaas and the Berg River at Assegaaibos. The White Paper for the provision of the first phase was laid before Parliament in 1968 and construction started in 1970. The project was planned, designed and constructed by DWA.

Theewaterskloof is a conventional earthfill dam. The structure, which was completed in 1979, is 37,5 m high above the lowest foundation, and has a crest length of 646 million m^3. The dam has a gross storage capacity of 482-million m^3. When full the dam water covers an area of 5 100 ha. A conduit through the embankment is divided into two chambers housing the low-level and normal outlets respectively. The low level outlet, which has a maximum capacity of 180 m^3/s is controlled by a slab gate at the upstream end of the culvert and the discharge energy is dissipated by means of a flip bucket. In turn, the normal outlet pipes in the upper chamber are controlled from an inlet tower with draw-offs at different levels in the reservoir. The spillway, which is capable of handling a probable maximum flood of 394 m^3/s, is



Ralf Broemer

***Opposite page**: Theewaterskloof Dam is the main storage unit of the Riviersonderend-Berg River water transfer scheme. The dam wall is 37,5 m high with a crest length of 646 m.*

***Left**: A locality map of the Riviersonderend-Berg River scheme.*

Trisa Hugo

Left: *The Charmaine wall structure under construction in December 1976. The wall, which houses the Charmaine intake and outlet is situated inside the basin of the Theewaterskloof Dam.*

Right: *The Wolwekloof Weir, which along with the Banhoek Weir aims to divert the headwaters of the Berg River.*

of the side-channel type and the chute ends in a stilling basin.

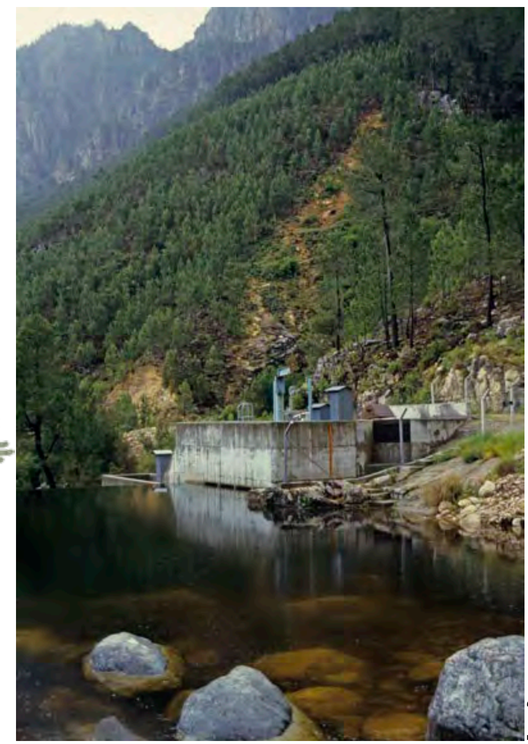
A subsidiary embankment inside the Theewaterskloof basin contains the Charmaine inlet and outlet. The embankment is a composite structure – a concrete spillway flanked by a 6 m-high earthfill of crest length 136 m – designed to create a sediment retention basin which allows the intakes to draw off clear water into the Franschhoek Tunnel.

The Franschhoek Tunnel is a reinforced concrete tunnel running from the Charmaine outlet through the Theewaterskloof basin. The 4,3 m-diameter tunnel penetrates the Franschhoek Mountains for a distance of 7,9 km and breaks through at Assegaaibos in the Berg River Valley.

Engineering features of the Theewaterskloof Dam

Type: Earthfill
Height above lowest foundation: 37,5 m
Gross storage capacity: 482 million m^3
Crest length: 646 m
Type of spillway: Side-channel
Spillway capacity: 390 m^3/s
Area at full supply level: 5 100 ha

Of the total length, 4,1 km was constructed as a reinforced concrete tunnel in an open cut, which was then later covered and the topsoil – which had previously been carefully removed and stored – replaced. This open cut required some 1,4 million m^3 of excavation. The tunnel has a maximum delivery capacity of 33,5 m^3/s. The remainder of the tunnel went through solid rock, 193 000 m^3 of which had to be removed.



At the end of the Franschhoek Tunnel, the Berg River is negotiated by means of a 33,5 m-diameter reinforced concrete siphon with supplementary intakes from the Assegaaibos Dam and outlets into the Berg River. Another tunnel, the Dasbos Tunnel, branches away from the main tunnel close to the 67 m-deep Wolwekloof shaft. This tunnel has a carrying capacity of 10,4 m³/s.

The first phase of the project was completed in 1980.

Constructed in the second phase which took off in 1974, the Jonkershoek Tunnel system includes a total of 23 km of tunnels, and two diversion weirs connected with the main tunnels by shafts. In total, some 481 00 m³ of excavation was required, while 236 000 m³ of concrete was used.

The main Jonkershoek tunnel cuts through the Groot Drakenstein and Jonkershoek mountains for 13 km to surface at the Kleinplaas Dam on the headwaters of the Eerste River in the Jonkershoek Valley. The Jonkershoek section contains two shafts connecting the tunnel to concrete diversion weirs, one the 67 m-deep and 4 m-diameter Wolwekloof shaft, which links the tunnel with a weir in the Wolwekloof River, and the other a 162 m-deep and 1,8 m-diameter shaft which links up the Banhoek diversion weir. Close to the Wolwekloof shaft, the Dasbos tunnel branches off from the main tunnel.

Between the Berg River and Wolwekloof the Jonkershoek Tunnel has an internal diameter of 4,3 m and a capacity of 33,5 m³/s, but after Wolwekloof it narrows to a diameter of 3,5 m and a capacity of 15 m³/s. The Kleinplaas balancing and diversion dam is fed by the Jonkershoek River as well as by the tunnel system, and diverts water into the Stellenboschberg Tunnel as well as supplementing the flow in the Eerste River. A 200 m-long inverted siphon of 3,5 m diameter connects the Jonkershoek Tunnel system to the Franschhoek Tunnel.

The Jonkershoek tunnel was the largest tunnel project ever undertaken by the DWA up to that time without the help of outside contractors and the second largest in South Africa. The tunnelling side of the project presented immense challenges to the department's engineers and it demanded great ingenuity, patience and resolve to solve the problems encountered.

Ground conditions were found to be exceptionally bad in some places, with geological formations varying tremendously from hard to soft, sandy conditions. Any route through the mountains was going to be challenging and so the designers opted for the shortest. They ran into several serious fault planes, which severely hampered progress. Tunnelling was made even more difficult in some places by the fact that, in order to allow

Frans Druyts

Frans Druyts

Left: *The Banhoek shaft under construction in 1979. The shaft is 162 m deep and 1,8 m in diameter.*

Bottom left: *The Berg River siphon under construction in 1981.*

Frans Druyts

water from the various catchment areas to flow by gravity, it was necessary to tunnel below the water table.

The soft formations encountered were very often outside the experience of even South African mining experts, and so experiments were conducted as work continued. Many a time tunnelling parties were forced back as sand and mud flooded into the working areas through faults. At one point during work on the Franschhoek Tunnel, operations broke through from granite into a plane of granite/sandstone. The roof collapsed and tons of mud and water poured into the tunnel. It took 22 months to pass through this 50 m-wide fault, as it was necessary to undertake extensive diamond core drilling to determine the extent of the bad ground.

Above: *Kleinplaas balancing dam on the Eerste River during construction. The wall is 25 m high and 345 m long.*

Right: *Water spills over the Kleinplaas Dam concrete gravity spillway in 1982. The dam has a storage capacity of 377 000 m³.*

Frans Druyts

When compared with the 45 m per week which the Berg River Tunnel team achieved, a concept of the extent of the problem can be formed.

In the process department engineers also had to develop new techniques to allow these faults to be crossed. Grouting failed hopelessly. After several months of high pressure grouting, using some 25 000 pockets of cement, the tunnel face, which had been closed by a 9 m concrete plug, was opened up to reveal that the grouting had been ineffective. Chemical grouting was also tried unsuccessfully.

Environmental conservation played an important part in the planning and execution of the project. Landscape architects were appointed for the whole project and disturbed areas were restored as naturally as possible. The open section of the Stellenbosch Tunnel from the Kleinplaas Dam is given as a fine example of the care with which environmental restoration was applied. Here the surface soil was carefully removed and kept aside so that, after the concrete works were covered, it could be placed on top again. Attention was also paid to the combating of potential driftsand problems in the Theewaterskloof Dam basin area. Where possible stone quarries were sited in dam basins or in less conspicuous places.

In 1981, this project received an achievement award from the SAICE. The project was officially concluded in 1982.

AWAKENING OF ENVIRONMENTAL CONSCIOUSNESS

In the 1970s dam construction started slowing in South Africa, in part because of inflation and the rising costs of building dams in increasingly difficult sites, and in part because of the growing realisation of what dams were doing to the river environment. Like elsewhere in the world, South Africa's dam teams started becoming increasingly multi-disciplinary, apart from engineers, now also including ecologists, archaeologists and landscape architects. In 1980, DWA for the first time made environmental impact assessments an official part of its policy, although as we have seen even projects undertaken before then were increasingly adapted to minimise environmental damage. However, the construction of dams did not cease entirely. The biggest – the Lesotho Highlands Water Project – was yet to come.

9

The final frontier: 1980-2012

The Mogol River outside Lephalale, in Limpopo. The Mokolo Dam – then known as Hans Strijdom Dam, was completed on this river to serve coal-mining and irrigation needs in 1980.

Lani van Vuuren

The 1980s onwards saw a progressive decline in the development of dams in South Africa. Nevertheless the few remaining projects sufficiently challenged dam engineers, not only technically, but increasingly socially and environmentally as these aspects became ever more important.

The early 1980s were a traumatic period in the history of DWA – South Africa's main dam building body. In 1980, the department was incorporated into the pre-existing Department of Environmental Affairs as part of a rationalisation exercise by government. JF Otto became the Director-General of the new department, known as the Department of Water Affairs, Forestry and Environmental Conservation, with JG du Plessis as the Deputy Director-General in charge of water affairs and AE Sonntag the Deputy Director-General in charge of forestry and environmental conservation. Many DWA engineers, who had hitherto been treated with some prestige within government, felt that they had been relegated to relative obscurity. This resulted in a mass exodus from the department. Between 1980 and 1982 around 190 engineers resigned. In addition, a curtailment of fund allocations from 1972 resulted in a backlog in the construction of additional water supply infrastructure, placing much pressure on remaining staff members.

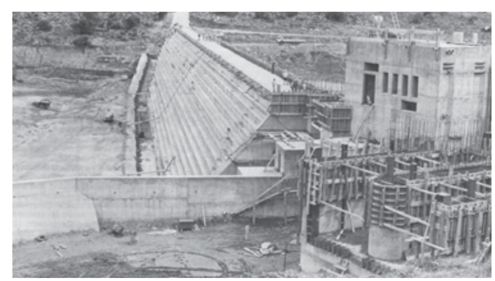
This marriage did not last long and DWA was reinstated as an independent department in 1984. By 1987 the department's construction division had shrunk to about 30% of its 1980 size, while capital expenditure had fallen to about 40% of 1970 levels. Still, of the more than 3 300 posts in the department, close to a thousand were occupied by engineers or technicians – quite unique among government departments at the time. Of the funds allocated to the department, an increasing percentage had to be spent on operating and maintaining the large number of schemes, as well as on the control of pollution and abstraction of water, while other activities such as research were expanding. In some cases the department had either to completely stop or slow down certain proposed waterworks to remain within budget.

The 1980s were also a challenging time for South African water engineers for other reasons. Some of the country's biggest water transfer schemes were being completed at this time, including the second phase of the Thukela-Vaal Transfer Scheme, as well as further phases of the Usutu River Government Water Scheme and Usutu-Vaal River Government Water Scheme. As had been alluded to in the previous chapter, a significant drought had started to take hold of the country, necessitating various emergency schemes, most notably the Grootdraai Dam emergency scheme. Believed to be the worst drought the country had experienced in at least 200 years, it caused water in main rivers such as the Vaal to reduce to a trickle. As a result severe water restrictions were introduced in various parts of the country, with abstraction being prohibited in certain rivers. However, South Africa has always been known as a land of contrast. In January 1984, while the rest of the country was struggling to come to grips with dwindling water resources, cyclone Domoina caused havoc in the Transvaal Lowveld, Northern Natal, Swaziland and southern Mozambique. A disaster area was declared and a flood relief fund set up.

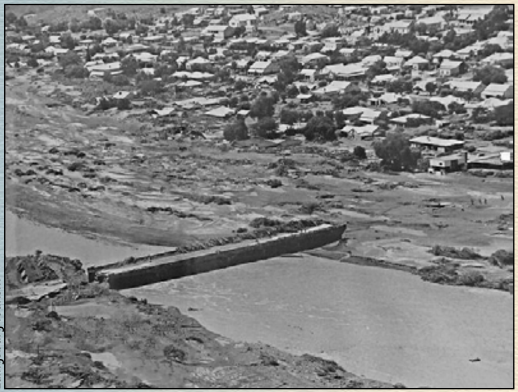
THE RISE AND RISE OF ROLLCRETE

The 1980s is perhaps best known for the introduction of roller compacted concrete (RCC or rollcrete) in South African dam building. Economic pressures – as well as a number of catastrophes in Europe involving arch dams – forced engineers to investigate new technologies to build dams faster with less material (SANCOLD, 1994). Rollcrete is basically a stiff concrete designed to be transported by high capacity equipment, such as dump trucks, conveyor belts etc and is usually spread by a bulldozer and compacted by a vibratory roller.

The successful application of rollcrete on dam projects in countries such as Pakistan and the USA spurred DWA to investigate the potential application of the technology in South Africa. The initiative was spearheaded by Frank Hollingworth and Frans Druyts, both engineers with the department. In 1978/79 a test section was rollcreted on the Kwena Dam (formerly Braam Raubenheimer Dam) near Lydenburg in Limpopo. Initial testing focused on establishing a workable rollcrete mix design and on selecting suitable plant for placing and compaction. Once confidence was gained with both the material


DWA

De Mistkraal Weir during construction. It was the first rollcrete dam to be built in South Africa.


Laingsburg Tourism


Laingsburg Tourism


Laingsburg Tourism

***Top left**: The swollen Buffalo River following the devastating flood at Laingsburg on 25 January, 1981, that claimed the lives of 104 people.*

***Middle left**: Many bodies of those killed in the Laingsburg disaster were never found.*

***Bottom left**: Debris from the Laingsburg flood swallowed 300 of the town's 367 houses and businesses.*

***Below**: The Floriskraal Dam today. Despite not being designed to deal with the size flood that hit Laingsburg in 1981, the dam managed to stand its ground with only little damage done to its structure.*

1981 – Laingsburg flood

On 24 and 25 January, 1981, the Moordenaars Karoo was pelted with excessive rain. More than 425 mm of rain fell in those two days over an area that usually receives an average of 175 mm for the whole year. The downpour transformed the normally dry Buffalo River into a raging monster. On the morning of 25 January the river burst its banks and a 6 m-high water enveloped the normally tranquil town of Laingsburg. Before this flood the greatest flood in the Buffalo River was recorded in 1925 – it was seven times less intense than the 1981 disaster. As a result, many of the town's houses had been constructed below the flood line. Residents unable to escape the deluge sought refuge on rooftops until they too were swept away by the flood. Seven hours after the floodwaters raged through the town 300 of the town's 367 houses and businesses were under water and around 104 lives were lost. One of the only buildings left standing was the Dutch Reformed Church. The bodies of 72 people were never found. The single largest loss was that of the Diko family where nine children drowned. Bodies and survivors were washed all the way into the Floriskraal Dam, situated 20 km outside town. The Buffalo River eventually becomes the Gouritz River, and fridges, car wrecks and other debris eventually spilt out into the Gouritz River mouth. More than 30 years later, the Laingsburg flood still remains one of South Africa's largest natural disasters.


Laingsburg Tourism

Completed in 1956, the Floriskraal Dam was not originally designed to accommodate such a large flood. From being only 40% full at the time the dam spilt only a few hours after the rains came. Its floodgates were, in fact, only intended to pass half the design flood. These flood gates were not even opened when the 5 700 m^3/s flood hit the dam wall – the electricity had been cut off and the operator was lending a hand in the rescue of flood victims. Water overtopped the entire structure, and water flowed 25 cm above the non-overspill section. Miraculously there was very little damage to the dam, apart from some damage to the parapets. The dam stands as a true testament to South Africa's excellent dam safety record.

and plant, rollcrete was placed in the right bank tongue wall of the composite dam comprising a concrete spillway with embankment flanks.

According to Hollingworth, the development of this new technique was very much a question of teamwork. "Any successes the department [may have had] in the field of rollcrete must be attributed to the efforts of all the design and construction engineers involved, right down to the technicians, foremen, craftsmen and operators to the labourers in the working area; and the cooperation achieved by all these people," he was quoted as saying in a departmental newsletter. In 1983, Hollingworth received a commendation for excellence in the use of concrete from the Concrete Society of South Africa. RCC proved to be cheaper than conventional mass concrete – this made it possible to build rollcrete dams on sites that would otherwise not be suitable for conventional concrete dams, In addition, when properly constructed, rollcrete is said to be superior to conventional mass concrete – the compactive effort is greater, and should produce a denser, more impermeable and more durable mass. Since less shrinkage takes place in RCC, it can be placed in continuous lengths rather than in single units, as is the case with mass concrete.

The good results obtained at Kwena Dam, led to South Africa's first rollcrete dams. De Mistkraal diversion dam in the Little Fish River near Somerset East was the first rollcrete dam in South Africa. The weir forms part of the Fish-Sundays scheme. Containing some 65 000 m³ of concrete De Mistkraal has a maximum height of 30 m and a crest length of 300 m. The bottom part of the dam was constructed with conventional concrete to above the drainage gallery on the upstream side, and to roughly the floor level of the gallery on the downstream side. The rest of De Mistkraal was then built using rollcrete. The first 30 000 m³ of concrete was placed in only 26 rollcreting days – this was great news for DWA's construction division – it meant dam construction time could now be considerably reduced, resulting in massive savings. From the weir, water flows into a canal and then into the Schoenmakers River on to Darlington Dam in the Sundays River. Wynand Maartens was the Resident Engineer on the project.

FLAG BOSHIELO DAM

In the same year the Arabie Dam (now called Flag Boshielo Dam) was completed for the Lebowa government using rollcrete methods. The dam, originally 36 m high and 455 m long was constructed in the Olifants River on a site straddling the Mpumalanga/Limpopo boundary, about 30 km from Marble Hall. It originally went out to tender as an embankment dam but an alternate tender for an RCC embankment composite dam was submitted by LTA consulting engineers and they eventually received the contract. The consultant to the former Lebowa government for this dam was Theron, Prinsloo and Van Tonder. The dam was designed with a centrally-located ogee spillway and an auxiliary fuse plug spillway on the right flank. The left flank featured an earth embankment, while a concrete gravity wall was situated on the right flank.

By the late 1990s, demand for water had increased so much that it necessitated the augmentation of water supplies in the region. The demand stemmed from an increase in platinum mining activities in the Lebalelo area. Following investigations it was initially decided to raise the dam

Flag Boshielo Dam (formerly known as Arabie Dam) prior to the raising of the wall.

Nico Swanepoel

wall through the installation of radial gates on the crest of the original spillway. However, a subsequent dam safety inspection revealed serious deficiencies at the dam: flood handling capacity was inadequate and the original toe drain system of the earth embankment was not functioning properly. In turn, this could jeopardise the stability of the original embankment's downstream slope. Moreover, it was found that the outlet system (river outlets and water for irrigation and domestic purposes) supplied water from a single outlet system.

It was then decided to address these concerns simultaneously to raising the dam. Another consideration was the need for minimal operational requirements and a reliable flood release system. DWA wanted the structure to be able to deal with floods safely and predictably without operator intervention. This ruled out any gated option. It was finally decided to raise the dam by 5 m thereby increasing its storage capacity from 100 million m^3 to 180 million m^3.

The final design was a fixed raising of the 180 m-long spillway rather than various gated alternatives. A rockfill raising of the embankment was selected to reduce potential construction delays. The left earthfill flank

Johan Beukes

Right: *The central spillway of the Flag Boshielo Dam was raised by 1 m steps. Here the variable height conveyor used to transport concrete from the batching plant can clearly be seen.*

Left: *The spillway rising close to the halfway mark. White PVA paint was used to cover the downstream face of the spillway and so reduce the temperature of the original concrete.*

Johan Beukes

of the dam was extended from 770 m to 1 150 m and the right rollcrete flank from 215 m to 270 m. The smooth spillway was raised by placing a 5 m-wide stepped layer of rollcrete against the downstream face. Rollcrete was also used to modify the non-overspill crest and the auxiliary spillway. The project was financed by the Lebalelo Water User Association in exchange for rights to the additional yield. DWA handled the

Top right: *Flag Flag Boshielo Dam spilling in 2010. Following its raising the dam has a gross capacity of 180 million m³.*

Bottom right: *Boshielo Dam in 2008. The new, stepped spillway can clearly be seen.*


Johan Beukes


Johan Beukes

raised by means of rollcrete.

Work started on site in June 2004, and by September the following year the first concrete was poured. An existing quarry, located 300 m upstream of the dam wall, was re-opened and a subcontractor provided all of the crushed granite aggregate. In terms of concrete placement access was challenging (only a marginal lowering of the reservoir level was allowed during construction) and, in the case of the spillway section, providing concrete against an existing incline proved tricky. As a result the spillway was built up in 1 m steps. Also, from a hydraulic aspect, the steps give a beneficial dissipation of the energy of the flowing water. To place the concrete DWA used a variable height conveyor all the way from the on-site batching plant, which fed onto a horizontal conveyor and attached to the inclined face of the spillway for final placement. For the last 5 m the team switched from the horizontal conveyor to a slower method using small skidsteer loaders, placing the concrete into shuttle dumpers. Most of the rollcrete was placed during the night with shuttering being undertaken during the day. DWA employed around 270 construction workers on site.

Several experiments were undertaken to find the best way of cooling down the original concrete so that the heat of hydration of the new concrete would not cause unwanted stress in the wall. The best technique proved to be painting the original downstream face of the concrete with white PVA paint. This resulted in temperature drops of as much as 4°C. In addition to reflecting the sun's heat the painted area also did not absorb water from the new layer of rollcrete or mass concrete. In addition to the paint, cooling water pipes were laid throughout the length of each metre lift to further accelerate the cooling of concrete. Interestingly, the vertical sections of the non-overspill crest were painted

Engineering statistics of Flag Boshielo Dam

Height of dam wall above lowest foundation: 40 m
Length of main spillway: 7 m
Length of left flank (earthfill): 1 150 m
Length of right flank (rollcrete): 270 m
Length of auxiliary spillway: 360 m
Gross capacity at full supply level: 180 million m^3

Who was Flag Boshielo?

Arabie Dam was renamed Flag Boshielo Dam by former President Thabo Mbeki in 2001, but who was he? Flag Marutle Boshielo was born in 1920 in Sekhukhuneland, Limpopo. He joined the ANC and the Communist Party in the 1940s and served in the ANC Transvaal Executive Committee. He was one of the participants in the 1952 Defiance Campaign and played a leading role in the 1958 Sekhukhuneland Revolt.

He later moved to Johannesburg and was elected to the leadership of the South African Congress of Trade Unions (SADTU). He became a prime target of the apartheid government and, as a result, was sent to Moscow by the ANC to receive military training. From there he went to Tanzania to join the Umkhonto we Sizwe camp there.

In 1972, he was captured near Caprivi by the then Rhodesian security while trying to infiltrate South Africa with two other freedom fighters on a mission. His fellow combatants were killed in the shootout; Boshielo was captured and never heard from again.

In 2005, he was awarded the Order of Luthuli in Gold for his contribution to the liberation struggle and workers' rights.

black. This resulted in a hotter downstream face which, in turn, bent the upper section of the original wall a few millimetres upstream. This was done to reduce tensile stress on the heel of the dam by creating a positive contact between the original and new concrete.

The original main earthfill embankment on the left flank was raised by 6 m with an impermeable silty clay-core and rockfill shoulders. An improved filter system (including a toe drain) for better drainage stability as well as an 11 m-wide berm was also added on the downstream side of the embankment to improve stability. The crest was paved for easy access and to restrict drying out of the clay core. The outlet works were also significantly improved and now features three pipes instead of one.

Along with the 100 people (mostly farmers) that were relocated and compensated, the project team also had to deal with a python and a crocodile. The python was nesting in the dam wall while the crocodile had selected the spot designated for the batch plant as its nesting place. Despite several challenges, the team managed to meet the original completion date of March 2006.

ZAAIHOEK DAM

Zaaihoek Dam on the Slang River (a tributary of the Buffalo River) was added to the rollcrete fold in 1987. The dam, built on a site outside Wakkerstroom, Mpumalanga by DWA, forms part of the Slang River Government Water Scheme developed specifically to provide water to Eskom's Majuba Power Station as well as the towns of Volksrust and Newcastle. It also augments the water supply of the Vaal River. From the dam water is transported over a distance of 22 km by means of a rising main to the Uitkyk reservoir. A gravity pipeline from the reservoir provides water to a balancing dam at the Majuba Power Station. A discharge point was provided where this pipeline crosses the Perdewaterspruit. From the discharge point, water can be released down the Schulpspruit, over the spillway of the Amersfoort Dam to the Vaal River upstream of the Grootdraai Dam.

It was the first medium-sized dam in South Africa on which the rollcrete construction method was implemented on full scale. The site, where an open valley makes way for a gorge, was quite unusual from a South African dam-building point of view as it represented relatively few difficulties – allowing as it did to easy access to both flanks and having a relatively shallow dolerite plate for the foundation. Since the construction crew could immediately be housed in Volksrust, situated about 20 km away, construction started soon after the White Paper was approved in Parliament in 1985.

Building of the wall started with conventional mass concrete, followed by a transition to rollcrete as soon as space permitted. By mid-September, 1986, some 70 000 m^3 of rollcrete had already been placed. Initially, concrete was moved from the 120 m^3/hour batch plant using rock tippers. Subsequently, a conveyor system

Workers rollcreting the Zaaihoek Dam wall. Some 97 000 m^3 of rollcrete and 130 000 m^3 of conventional concrete went into constructing the dam wall.

DWA/eWISA


DWA/eWISA

The completed mass gravity Zaaihoek Dam. Its stepped spillway – the first of its kind in South Africa, can clearly be seen.

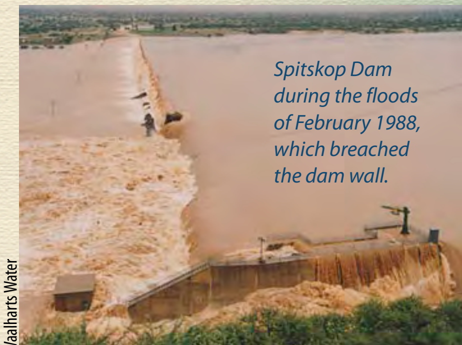
was installed, which proved highly successful. The rollcrete was placed on the wall and spread by rubber-tyred or tracked dozer in layers of 250 mm. Lifts of one metre at a time were placed with the maximum amount of concrete per lift in the order of 2 000 m^3. The rollcrete was then compacted using a double gum vibrating roller. After each lift was partially cured, the surface was 'green-washed' in preparation for the next lift. The rollcrete was placed without contraction joints across the length and width of the dam except on the flanks, where crack inducers with water stops were introduced at 10 m intervals.

The mass gravity dam contains a RCC volume of some 97 000 m^3 and 130 000 m^3 of conventional concrete. Zaaihoek has a crest length of 527 m and a maximum height of 46 m. The uncontrolled spillway is 160 m long with a capacity of 2 500 m^3/s. The original full capacity of the dam was 193 million m^3 and the reservoir covers an area of 1 245 ha at full supply level. The stepped downstream face of the spillway was the first of its kind in South Africa. The steps serve to dissipate the energy of the water discharged over the spillway, thereby reducing the size of the apron slab with resultant savings in cost. In addition, Zaaihoek Dam was, at the time of its construction, the steepest gravity dam in South Africa. In 1988, the dam won the SAICE Natal Regional Award for Excellence in Civil Engineering.

Spitskop Dam

Considered state-of-the-art at the time, Spitskop Dam was completed by DWA in the Harts River near Warrenton in 1974 to augment the Vaalharts Irrigation Scheme. The 13 m-high dam had a reservoir capacity of 61 million m^3. The original wall was a zoned earthfill embankment with a crest length of 770 m. This embankment comprised a central clay core supported by outer zones semi-pervious material. The upstream and downstream slopes were protected by rip-rap. Overflow from the dam basin was provided for by a side-channel spillway located on the left flank.

In February 1988, heavy rains caused the dam to fill rapidly from a mere 16% to 239% full within two days. The spillway proved totally inadequate to deal with this volume of water. The water level reached the top of the impervious core (460 mm below the non-overspill embankment crest) and the dam wall was overtopped soon afterwards. The flood peaked at about 2 400 mm^3/s. As a result of the flood of water a breach of about two metres deep and 25 cm long formed in the earth embankment next to the concrete side-channel spillway and outlet structure. Six hours later, the breach had widened to a length of about 120 m, and in this section the embankment had eroded virtually


Vaalharts Water

Spitskop Dam during the floods of February 1988, which breached the dam wall.

to riverbed level. Consequent investigations revealed that the breach had initially occurred at the junction between the concrete of the side channel spillway structure and the earth embankment. Once breaching started here it widened gradually. Within ten hours the dam wall failed completely, and a large quantity of eroded material was deposited immediately downstream of the dam wall.

DWA rebuilt the dam soon after, and it was decided to enlarge the spillway capacity and replace the section of embankment that washed away with rollcrete. The latter section was to serve as an additional spillway. The earth embankment was also raised. When reparations were complete a year later a total of 35 690 m^3 of rollcrete, 182 090 m^3 of earth and 34 880 m^3 of embankment protection material had been placed in the new dam wall.

KNELLPOORT DAM

According to SANCOLD, the confidence gained with rollcrete as a durable construction material led DWA engineers to believe that the technique could be extended to arch dams to even further advance the economic benefits to be gained from this construction method (SANCOLD, 1994). This resulted in the construction of Knellpoort Dam, on the Rietspruit (a tributary of the Caledon River) on a site near Wepener in the Free State. Completed in 1988, it was the first RCC arch/gravity dam in the world. The dam has a maximum height of 50 m, a crest length of 200 m, and contains an RCC volume of 45 000 m³ (out of a total concrete volume of 59 000 m³). The crest of the non-overspill section was built 5 m wide to accommodate rollcrete placing. Like Zaaihoek, Knellpoort also features a stepped spillway to aid energy dissipation. The dam had an original capacity of 136 million m³.

Knellpoort Dam forms part of the Caledon-Modder River Government Water Scheme, which supplies water to Bloemfontein and surrounds. The dam was developed mainly to counteract the silting up of the Welbedacht Dam on the Caledon River, which lost 70% of its capacity in a mere 17 years due to silt. In order to prevent similar siltation problems to those experienced at the Welbedacht Dam, the Knellpoort Dam functions as an off-channel storage dam with a relatively small catchment area of only 798 km². Water from the Caledon River is pumped to Knellpoort Dam from the Tienfontein Pumping Station via a 2 km-long canal which is equipped with a silt trap to reduce siltation in the main reservoir.

While only a medium-sized structure, the dam raised international interest. Locally, the project won the SAICE Bloemfontein regional award for Excellence in Civil Engineering.

The Knellpoort Dam is currently used to supplement the water in the Welbedacht Dam for abstraction to Bloemfontein via the Caledon Bloemfontein pipeline

At Knellpoort, the rollcrete technique had to be designed to suit the requirements of an arch dam while still retaining its beneficial qualities. For example, the concrete in arch dams is more highly stressed than in gravity dams, which means that resistance to shear and tensile stress becomes more critical when using rollcrete, which contains less cementitious material than conventional concrete. An arch dam also requires structural continuity and therefore cracking has to be minimised and provision made for grouting cracks. A richer rollcrete mix than used for gravity dams was therefore required, and special techniques used to control cracking. Rollcrete placement took place within a mere five months. While only a medium-sized structure, the dam raised international interest. Locally, the project won the SAICE Bloemfontein regional award for Excellence in Civil Engineering.

Interestingly significant San paintings were discovered in the dam basin during the archaeological studies which preceded construction. Large stone blocks containing the paintings were subsequently removed and displayed at a museum in Bloemfontein.

DWA/eWISA

Knellpoort Dam in the Free State during construction. Completed in 1988, it was the first rollcrete arch/gravity dam in the world.

The forgotten dam

In 1993, Taung Dam on the Harts River became the first roller compacted concrete dam to be completed in the Northern Cape region of South Africa. At the time it was the tallest of the country's rollcrete dams, standing at 50 m high with a crest length of 320 m. The narrow, steep-sided valley was better suited to a concrete gravity structure than an earthfill or rockfill embankment. The spillway had to be sized to pass extreme floods.

This gravity dam was originally constructed for the Bophuthatswana government for use by the people of the Taung district. The dam was to aid in the establishment of irrigation crop farming thereby bringing economic prosperity to the region. Two communities, the Kolong and Dikgageng, were displaced in the construction of the dam, and in 2007 a special memorial was unveiled on site to honour the ancestors of these communities, whose remains disappeared when the dam was filled. Unfortunately, the infrastructure to relay the water from the dam was never completed, and so the dam stands idle – even today.

Initial plans to develop the area around the dam as a recreation resort has also stalled as there is currently a dispute among two neighbouring communities about who the dam 'belongs' to. In 2006, DWA commissioned a study to assess options for the potential utilisation of the Taung Dam; however, to date no development has taken place.

***Right**: The waters of the Taung Dam are lying idle two decades after its construction. The dam has a maximum capacity of 60 million m³.*

Lani van Vuuren

***Below**: The Taung Dam wall. The stepped downstream face acts as an efficient energy dissipater.*

Lani van Vuuren

WOLWEDANS DAM

Simultaneously with Knellpoort Dam, DWA also designed and constructed the larger 24 million m³ capacity Wolwedans Dam, the world's second RCC arch/gravity dam. This 70 m-high dam was mainly constructed to supply water to the Mossgas oil-from-gas plant situated off the coast of Mossel Bay, in the southern Cape.

By 1980, Mossel Bay region had a permanent urban population of about 23 700, however, during the holiday season this number doubled as holidaymakers flocked to the popular resort town. The growth of the town was also stimulated by increased harbour activities. This increasingly put strain on available water resources. Prior to the completion of the Moordkuil River Government Water Scheme in 1983, the town was subject to periodic water shortages. When it was announced that the Mossgas processing plant, which would require around 4,8 million m³/year of water, would be constructed near Mossel Bay, the need to develop additional bulk water infrastructure became acute. The White Paper to construct the Wolwedans Dam in the Great Brak River was put before Parliament in 1988, and construction of the dam started soon thereafter. The dam was designed and constructed by DWA. The dam contains close to 200 000 m³ of rollcrete, placed over 14 months between 1988 and 1989.

With a downstream slope of 0,5 (horizontal) to 1 (vertical) the dam has to rely on arch-action for stability. Shrinkage of the rollcrete and the associated cracks would therefore pose serious problems especially if they are not grouted. A groutable system of induced crack joints was developed by DWA engineers to overcome this problem.

Interestingly, environmental considerations played a major role in the planning, design,

Dancing wolves

It is said that the name 'Wolwedans' refers to an occasion in history when a farmer went to slaughter an ox near the site of the present dam. A pack of hyenas smelt the blood and followed the farmer's cart, dragging the meat from it. Hyenas were commonly referred to as 'wolwe' or wolves. In the darkness it looked like the animals were dancing, hence the name of the area.

construction and operation of Wolwedans Dam. The dam site was chosen after thorough investigations by DWA, which included a comprehensive environmental impact report. There was some concern over the potential impact of the dam on the Great Brak estuary and, after an intensive study led by the CSIR; it was decided to reserve 1 million m^3 of water/year for the estuary from the dam's yield. The capacity of the Wolwedans Dam's outlets was also designed in such a way as to allow for the river mouth to be washed out by a release from the dam whenever necessary (and when water is available).

Two other rollcrete gravity dams were constructed in the late 1980s in the Eastern Cape, namely the 34 m-high and 740 m-long Wriggleswade Dam on the Kubusi River near Stutterheim (completed in 1989); as well as the 32 m-high and 390 m-long Glen Melville Dam on the Ecca River near Grahamstown (completed in 1990).

Forming part of the Amatole Water Supply Scheme, Wriggleswade Dam was constructed by contractors Savage & Lovemore to augment the water supply to East London and surrounds. At the time it was by far the largest dam in terms of surface area on the Border region. The surface area of the dam at full supply level is about 1 000 ha – considerably larger than that of the Bridledrift

DWA/eWISA

DWA/eWISA

DWA/eWISA

***Left**: Wolwedans Dam during construction. The dam has a crest length of 270 m, and an arch radius of 135 m.*

***Above**: Wolwedans Dam as seen from the air. It was the second rollcrete arch/gravity dam to be constructed in the world.*

***Right**: Wolwedans Dam spilling in 2006. The dam has an uncontrolled ogee spillway with a capacity of 1 920 m^3/s.*

Dam. The dam was the first in South Africa where rollcreting was not executed in continuous consecutive horizontal placements or in segments contained by formed conventional transverse contraction joints. Instead, the rollcrete was placed in about 150 m-long terraces to suit site conditions. Another unique design aspect was that it was the first rollcrete dam in the country where mortar was used as a bedding layer between two successive rollcrete layers or on horizontal construction joints. In addition, minimum use was made of skin concrete on the downstream steps on the non-overspill sections of the dam. Around 135 000 m^3 of rollcrete was used to construct the dam. Wriggleswade had an original storage capacity of 93 million m^3.

QEDUSIZI DAM

Situated on the base of a triangle formed by the Drakensberg and Biggarsberg mountain ranges, Ladysmith had its beginnings shortly before the Battle of Blood River (1838). That year Voortrekkers began to sparsely populate the area around the Klip River. Ten years later the first magistrate of Klip River was appointed (John Bird), and on 5 October of that year the magisterial district of Klip River was proclaimed. The town of Ladysmith (named after the wife of Cape Governor Sir Harry Smith) was proclaimed on 20 June, 1850.

Ladysmith was initially a trading post – a last haven prior to the long trek over the mountain. Once the railway arrived in 1885, the town flourished. Ladysmith gained international fame when it was besieged by Boer forces during the South African War between 2 November, 1899 and 28 February, 1900. The town was severely damaged during this bombardment before it was relieved by British reinforcements under General Buller. The first series of water furrows (with numerous side branches) were laid in 1849.

The central part of the business and residential area of Ladysmith is located on the floodplain of the Klip River. As a result, flooding has always been part of the town's history. The first hundred years of the town's records show no less than 27 flood events, many resulting in the loss of lives and damage to property. The historical Indian residential area was most specifically at risk (in any given year there was at least a 20% chance

History of water supply to Mossel Bay

Lani van Vuuren

The area known later as Mossel Bay was long frequented by local Khoisan people. The town's colonial history began when Portuguese explorer Bartholomew Dias came ashore in February 1488, followed by Vasco da Gama in 1497. The bay later became a regular stopover for European ships travelling to and from the East. During the era of Dutch occupation vryburger cattle farmers settled in the Brak River area, and in 1734 the area was officially declared part of the Dutch colony. The new territory was placed under the jurisdiction of the landdrost in Swellendam. The first official structure of the new town was a granary, built in 1787. The following year saw the first shipment of grain to be exported – to Batavia. Mossel Bay initially developed as a ward of nearby George, but in 1848 was declared a municipal magistry on its own. The town achieved municipal status in 1852.

The first municipal water supply was the construction of a diversion structure in Beneke River, a tributary of Moordkuil River, on the farm *Kleinbosch*. This structure was completed in 1890 and supplied water to the town through a gravity pipeline with a maximum carrying capacity of about 900 m^3/day. In 1944, a diversion weir was built in the upper reaches of the Great Brak River incorporating a new gravity pipeline which was linked to the Kleinbosch pipeline. This was followed in 1957 by the completion of the Robertson Dam also on the Great Brak River close to the original weir site. The assured yield of this dam is about 1,8 million m^3/year. The last scheme water scheme to come into operation before the construction of the Wolwedans Dam was the Moordkuil River Government Water Scheme. The scheme, which came into operation in 1983, comprised the Klipheuwel Dam, an off-channel storage dam in a tributary of the Moordkuil River. The dam had an original storage capacity of about 4 million m^3. In 2011, the municipality with Petro SA launched a 15 Mℓ/day desalination plant to augment conventional water supply.

of flooding of this area). During 1987/88 Ladysmith was flooded on three separate occasions and extensive damage was caused to residences and businesses. As a result a special committee was appointed to investigate the problem and come up with solutions. Various ideas were consequently put forward, including the relocation of residents (this was met with severe resistance), improved flood warning systems, channel improvements (including shortening river meanders and installing concrete linings), additional levees, and the construction of a flood attenuation dam. The latter recommendation received most interest, and in 1989, then Minister of Environmental & Water Affairs, GJ Kotzé, announced the construction of such a dam for Ladysmith. The dam was to be constructed on a site at Mount Pleasant, just downstream of the confluence of the Sand and Klip River – about 5 km upstream of Ladysmith. It was initially known as Mount Pleasant Dam, but was later renamed 'Qedusizi' meaning 'end of suffering'.

An economic downturn stalled the construction of the dam, but in 1994, after two further disastrous floods, building finally commenced. An undertaking was given that the project would be operational by October 1997. DWA engineers were faced with the daunting challenge of achieving this goal despite a very tight deadline. The dam was functional by that year, and was completed in 1998.

The resultant 32 m-high dam was designed to attenuate flood peaks by retarding the flow of floodwater from the upper region of the Klip River's catchment area. The flow is reduced to safe carrying capacity of the Klip River through Ladysmith, after accounting for runoff from the catchment area below the dam. While larger floods can still inundate low-lying parts of the town, the dam limits any large-scale damage and provides an adequate evacuation-warning period. Between flood events, the dam is emptied.

Designed and built by DWA, the dam is a composite structure comprising a central rollcrete spillway with an earthfill on each bank. The stepped spillway is 315 m long and has a maximum height of 28 m measured from spillway crest to lowest foundation level. To accommodate the runoff below the dam, the release from the dam is restricted to about 400 m^3/s by two uncontrolled openings at riverbed level, each 3,2 m high and 5 m wide. These outlets have the added advantage that it prevents sediment load from smaller floods from settling in the dam basin. The non-overspill sections and adjacent cut-off walls extending into the embankments were provided with smooth faces to ensure good compaction to the embankment material against the cut-off walls. At the beginning of the embankments the cut-off walls have the same cross-sections as that of the non-overspill sections. From these points onwards the cross-sections reduce uniformly until the minimum cross-sections are attained at the ends of the cut-off walls inside the embankments. Some 156 000 m^3 of concrete was placed in the dam (78 000 m^3 being rollcrete).

Sections of the Ladysmith-Van Reenen railway line and of Main Road 31 (an alternate route to the N3 highway), which lay within the dam basin, had to be realigned as part of this project. This required the building of two new incrementally launched bridges across the Klip River. About 1,5 km of the Petronet oil pipeline also had to be lowered where it traversed the dam basin while various telephone and electricity services were realigned and/or protected.

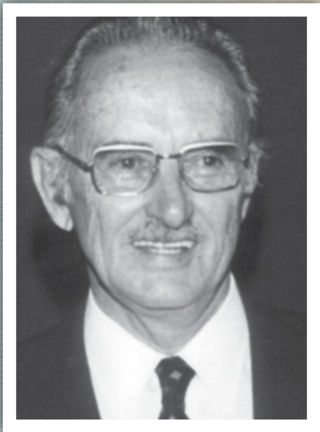
In addition to the dam, several disaster management measures had to be undertaken by the local municipality. This included the implementation of a flood warning system; the removal of sediment deposits at one of the railway bridges; the construction and upgrading of levees in the river to accommodate a flow of 700 m^3/s and betterments to the outlets of the stormwater system. Funds for this work were made available by DWA for this purpose.

In 2000, the dam was put to its first real test following heavy rains in the catchment. That year, the flood-warning sirens of Ladysmith thankfully remained silent. Lately there has been talk of converting Qedusizi into a dual-purpose dam, i.e. also using it for water storage. However, DWA has expressed its concerns that such a decision would cause the dam too silt up too quickly, thus reducing its lifespan. This would also greatly reduce its ability to store floodwater and so keep the town dry.


DWA/eWISA

The completed Qedusizi Dam. The dam has been designed to protect the town of Ladysmith against 1:100-year flood events.

SA's 'father of hydrological modelling'



The name 'Des Midgley' will forever by synonymous with hydrological modelling and water resources planning in South Africa.

One of seven children, Desmond Clifford Midgley was born in Durban in 1914. He matriculated from Hilton College at the age of 16 (it is said that he underperformed at school for fear of outshining his older brother who shared the same class). He went on to study civil engineering at Natal University, graduating in 1934.

The Depression was in full swing at that time and, after a long search for work Midgley was finally offered a post as field assistant in the Irrigation Department's surveying section. The prospect of an outdoor life appealed to him and he accepted. One of his first tasks was participating in surveys for the first national water planning maps of the country, drawn up under director of Irrigation Director, Dr AD Lewis. Midgley was put in charge of the magnetic survey (isogonic) mapping of South Africa, and in this capacity travelled widely throughout the country.

While he enjoyed his work he thought he was not getting enough engineering experience, and so requested a transfer to the department's construction division. He was promptly sent off to join the team building the Vaal Dam. When work on this dam was complete he was transferred to the Loskop project.

During the Second World War he joined the Works Battalion of the SA Engineering Corps and spent two years in Kenya, advancing with the troops to Addis Ababa. In 1942, he was drafted back to South Africa and assigned to the Directorate of Fortifications and Coastal Works where he took charge of coastal works from Port Elizabeth to Walvis Bay, particularly water supply and harbour works for Saldanha Bay.

In 1945, new Irrigation Director LA Mackenzie recalled Midgley from the army to participate in the Conroy Expedition to the Kalahari to investigate the controversial Schwarz scheme. (Schwarz, a German-born geologist at Rhodes University, had the idea that South Africa's climate for rain could be improved by diverting the Zambezi and Kunene rivers into vast evaporation lakes in the Kalahari) "I had to drive the food truck and had a wonderful time," Midgley later said of the experience.

The Schwarz scheme might have come to nought but it did peak Midgley's interest in engineering hydrology and, as he had been placed in the research division of the department, he was able to exercise his initiative in the study of what appeared to him to be the most important matter of all – the water resources of the country. Working on his own he collected all the available data and built up consolidated national and regional files which, until then, had been scattered among various authorities in the country.

At a critical stage of his work he was sent off to build the Albasini Dam. He took all his papers with him, and worked late into the night to complete the first comprehensive survey of the surface water resources of South Africa. The effort earned him his PhD and established him as the leader in water resource hydrology in the country.

In 1956, he was appointed to the Chair of Hydraulic Engineering at the University of Witwatersrand. His work with the Hydrological Research Unit, which he started in 1959, is well known in many parts of the world. The unit design flood report, published in 1969, updated in 1972 and again in 1979, has been widely used in southern Africa. Another major publication of the unit was the six-volume report of 1981 on *Surface Water Resources of South Africa*, for which a Guide and Addendum were published by the WRC in 1983. He also led the team which updated the report in the 1990s. In 1986 he was awarded an Honorary DSc (Eng) by the University of the Witwatersrand.

In his decade-long career, Midgley published more than 50 major papers, presented to learned societies all over the world. He managed many teams in developing mathematical models to study the behaviour and salinity fluctuations in various hydrological systems (including the now famous Pitman catchment model). He also consulted on various South African and international water engineering schemes.

Following his retirement from the University of the Witwatersrand, Midgley joined the firm of Watermeyer, Legge, Piesold and Uhlmann as a consultant and carried on with much of the work he had always been busy with. During his career he received numerous awards from local and international professional organisations. In 1993 then State President FW de Klerk bestowed on him the Order of Meritorious Service (Gold). A year later, a special symposium titled 'Fifty Years of Water Engineering' was organised in his honour.

Midgley passed away on 13 April, 1997 following a short illness.

CROSS-BORDER COOPERATION

South Africa shares four major river systems with neighbouring countries, namely the Orange-Senqu system (shared with Lesotho and Namibia); Limpopo River (Botswana, Zimbabwe and Mozambique); Incomati River system (Swaziland) and the Usutu/Pongola-Maputo system, which is shared with Mozambique and Swaziland. Yet despite its historical political differences with its neighbours, disputes over transboundary water have been few and far between. In fact, the country has a long and rich history of entering into agreements with other states starting from colonial times.

Interestingly, the earliest agreement between South Africa and a neighbouring state, which included water, was signed in 1926 with Mozambique titled 'Agreement between the Union of South Africa and Portugal on the Settlement of the Boundary between the Union of South Africa and Province of Mozambique'. During the 1960s, when South Africa became a republic and several of the other states in the region gained independence from their former colonial powers, there was an increase in the formation of treaties. During the final years of the Cold War, in the decade up until 1990, a surprisingly large number of agreements were entered into (Ashton et al, 2006).

A study into these freshwater agreements undertaken a few years ago by the CSIR and the African Water Research Unit for the WRC also discovered that older agreements that were entered into while South Africa was still under British control, or with other colonial powers prior to those territories gaining independence, are still valid and their provisions – both rights and responsibilities – are still in place, unless they have been specifically provoked by the country concerned after independence. The study also revealed the intricacy of international agreements – both in terms of the domestic ratification process that must be followed, and on an international level with other states (Ashton et al, 2006).

Lani van Vuuren

The Orange-Senqu River system is shared with Lesotho and Namibia

In the last decade, South Africa has ratified the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (which promotes the principles of equitable and reasonable use of transboundary water), and promulgated the National Water Act (Act 36 of 1998) or NWA, which gives international requirements high priority in national water resources planning, development and management. This means that no infrastructure may be developed in any transboundary waters without considering the needs (or without the involvement) of the other countries involved. At least 20 agreements were signed in the 1990s between South Africa and its neighbouring states, of which 12 were bilateral agreements focusing on a range of issues, such as the establishment of commissions of cooperation and the utilisation of water, as well as several agreements with the Kingdom of Lesotho on the Lesotho Highlands Water Project as we shall see in the next few pages.

Ralf Broemer

LESOTHO HIGHLANDS WATER PROJECT

Small, land-locked and covering about 30 300 km², Lesotho is one of the poorest countries in the world. Its natural resources are generally scarce – except for water. In the Highlands of Lesotho, where the mighty Orange River springs from mountain streams, an average of 1 200 mm of rain falls a year, nearly three times the average of South Africa. This rainfall contributes about half the flow of the Senqu River (as it is known in Lesotho), helping to make it the largest river system in South Africa.

Unfortunately, Lesotho has been unable to make use of this most precious of natural resources. Mountainous by nature (80% of the country lies above 1 800 metres above sea level), little of Lesotho's land area is suitable for permanent agriculture. By the 1980s, only about 10% of its water was consumed domestically.

***Left:** Location of Phase 1 dams of the Lesotho Highlands Water Project.*

***Right:** The Katse Dam reservoir with the Malibamatso Bridge with its impressively tall piers in the background.*

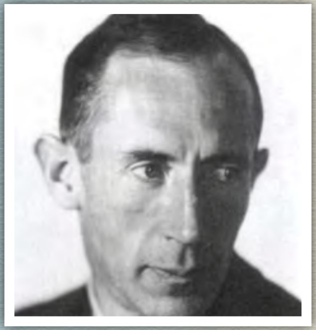
However, Lesotho's 'white gold' would eventually lead to arguably one of the most imaginative water transfer schemes of its time.

The earliest published records of rainfall measurements in Basutoland date back to 1896. However, it was only in 1932 that the Irrigation Department of South Africa established a permanent gauge on the Orange River at Whitehill for low flow measurements and flood warning purposes. Shortly after the discovery of gold in the Free State in the 1950s Sir Evelyn Baring, High Commissioner of what was then known as Basotuland, initiated a survey of the water potential of the British protectorate. Baring had hoped that water could be exported from Lesotho to feed the newly established gold-mines in the Free State.

Basutoland Director of Public Works, Peter Ballenden, later employed South Africa's Ninham Shand to establish the possibility of such a scheme. The surveys were done on foot and on Basotho ponies (Shand had to re-learn some horsemanship for these expeditions), the only mode of transport possible up the narrow, mountain paths. Many of the expeditions took place in winter when some of the rivers were frozen over. It was during these studies that Shand came up with the now infamous Oxbow Scheme. This scheme envisaged the westward division of the Malibamatso River (a tributary of the Senqu) from a dam site on an oxbow into the Caledon River and from there to the Free State goldfields, generating hydroelectricity from the elevation difference.


TCTA

NINHAM SHAND



DWA

The name Ninham Shand is synonymous with water engineering in South Africa. It is also synonymous with the biggest interbasin-transfer scheme on the sub-continent – the Lesotho Highlands Water Project.

Named after his maternal grandmother, Henry Ninham Shand was born on 26 January, 1899, in Middelburg, Cape. The son of magistrate, John Shand, he is said to have been born with engineering talent, spending his childhood building miniature towns, complete with roads, bridges and waterways. Due to his father's occupation the family moved around a lot, and Shand attended many schools, however, he still managed to matriculate top of his class at the age of 16.

The young Ninham went on to study engineering at the University of Cape Town, where again he took all the honours as top student. He graduated in 1920, earning the coveted gold medal in his final year. He started his career with the Irrigation Department, working on the Kamanassie Dam near Oudtshoorn under Resident Engineer FT Patterson. Later he helped build grain elevators in the Free State.

In 1924, he became Assistant Engineer on the Steenbras Dam. Two years later, he went on a number of study tours in the USA, gaining valuable experience with the Bureau of Reclamation, the body responsible for dams and irrigation in that country. He returned in 1927 to carry on with the Steenbras project, but left Cape Town the next year working as Deputy City Engineer and Waterworks Engineer of Port Elizabeth.

In 1932, while the world was in the grips of the Great Depression, the 33-year-old Shand took the brave decision to start his own consulting engineering practice. While the Irrigation Department was building larger schemes than ever before, it was doing all of its own design work. Shand turned his attention to the municipalities. Among his first projects was an investigation of difficulties at the Groendal Dam at Uitenhage as well as water schemes for Prieska, Alice and Upington. He was also approached by farmers, irrigation boards and agricultural cooperatives requiring private water schemes for their farming areas.

Soon Shand was travelling an average 4 800 km a month on bad roads in his quest for potential clients (he once held the speed record between Cape Town and Port Elizabeth). Described as 'friendly and courteous' people took to the tall, lean Shand, praising his quiet confidence. To make the job easier, he later replaced his car with an aeroplane, flown by lauded pilot Pat Murdoch.

Shand was extremely dedicated to the profession. He was invited in his personal capacity to the Congress of ICOLD and later formed the South African branch of the Commission (known as SANCOLD). He was universally admired and respected for his integrity and dedication to his work. Throughout his working life of nearly 50 years he kept abreast of world developments in his specialty by wide reading, maintaining professional contacts and visiting engineering works on a world scale. He was President of SAICE and served on the Council of the University of Cape Town.

But Shand was not all work and no play. As a young man he played rugby and tennis, and was a keen fisherman and hiker, a passion he shared with his wife Lesley, whom he married in 1939 (although their honeymoon abroad turned into a programme for the investigation of current engineering practices). Their only son, Mike, was born in 1941.

During the war years Shand was made a Major and assumed responsibility for the engineering side of local fortifications. He planned coastal defences and designed new aerodromes, while still keeping the essential work of the practice on the go. He also surveyed routes for the National Roads Board.

Shand's practice (now part of Aurecon) would later have offices countrywide, and his name was linked with almost all the major water schemes in South Africa, including the Orange River Development Project. However, he would become most famous for his far-sighted vision which would eventually become the Lesotho Highlands Water Project.

It was in 1953, while carrying out investigations commissioned by the British government into the rivers of Lesotho that Shand first conceived the idea of diverting the headwaters of the Orange (known as the Senqu in Lesotho) river to augment the water supplies for the Witwatersrand and the Free State.

Unfortunately, Shand would never see his vision become reality. In 1969, he became ill during an inspection in Lesotho (he was diagnosed with double pneumonia), and died in July of that year.

The now famous Katse Dam forms the cornerstone of the Lesotho Highlands Water Project.

TCTA

Since South African authorities had already decided to supply the Free State goldfields from the Vaal River at this time, attention was turned towards the water needs of the fast-growing Johannesburg region. Shand showed that tunnelling from the Oxbow in a north-easterly direction would allow discharge into the catchment of the Eland River, a tributary of the Vaal. The diverted water would be available to the users from the Vaal River system, either via the rivers, or, if the quality were to be conserved, via a pipeline to the Johannesburg region.

Several more proposals followed along similar lines, and in 1967 a consolidated scheme was presented to the Lesotho government. Differing perceptions of the advantages of the project led to the abandonment of proposals. Meanwhile DWA proceeded with the Thukela-Vaal Transfer Scheme. The department's engineers also started studying the prospect of diverting water to Johannesburg and surrounds from the Upper Orange River. The so-called Orange-Vaal project envisaged pumping Orange River water via the Vaal River upstream to the Vaal Barrage via a series of 35 weirs. (Economic analyses later showed the Lesotho Highlands Water Project to be much more cost-effective)

In 1974, South Africa again opened the door to the possibility of importing water from Lesotho, and several studies followed. The two countries also resumed negotiations, however, politics threatened to derail the process several times. Theo van Robbroeck, who was involved in the project for over 20 years, describes what happened during one such a top-level meeting in 1976: "I accompanied the then Minister of Water Affairs, Braam Raubenheimer, and a few top officials from Water Affairs and Foreign Affairs to Maseru for Ministerial level discussions. We were met at the border by the Lesotho Deputy Prime Minister and accompanied to our hotel. That evening there was a reception, attended by everybody of importance in Lesotho bar the King and the Prime Minister. Early the next morning, the Deputy Prime Minister arrived back at the hotel, requesting Minister Raubenheimer and his party to quietly leave the country so as to avoid embarrassment as the Lesotho government was planning to issue a strongly worded anti-South African statement. The date was 18 June, 1976, two days after the Soweto uprisings."

(Police had opened fire and killed children who were protesting against the so-called Bantu education system). In 1984, the project was again almost called off when the South African Defence Force invaded Lesotho to attack members of Umkhonto we Sizwe, the African National Congress' military arm.

Despite the two countries' different political policies negotiations were re-opened in 1977, and in 1978, the two countries established a Joint Technical Committee to oversee a preliminary feasibility study, financed by South Africa. Progress was regularly monitored by the Joint Technical Committee. The Lesotho government insisted on two conditions: a hydroelectric component for supply to Lesotho had to be incorporated, and that no dam would be built on the Caledon River as part of a proposed layout. Van Robbroeck explains why: "The reason for this was that Lesotho lays claim to parts of the eastern Free State, which

Katse Dam during construction. Concreting of the arch was completed in just over three years, with production peaking at 115 000 m³ a month.

DWA/eWISA

Pardon me, Sir, but you are not allowed in here

One of more interesting, and perhaps shameful, obstacles that the South African engineers had to conquer was where to dine their Lesotho counterparts when the latter came to the country for meetings. In those years black people were only allowed in so-called 'international restaurants' situated mostly in the major cities. This meant that when dinner arrangements had to be made, the restaurant had to be very carefully selected so as to avoid embarrassment.

they consider as territory conquered from the Basotho by the then Republic of the Orange Free State." All reasonable alternatives were to be identified for consideration by the Joint Technical Committee and the ultimate delivery of these should be at least 30 m^3/s of water for South Africa.

The pre-feasibility report, submitted in May 1979, proposed a phased project consisting of five dams, ultimately delivering 35 m^3/s, with hydropower forming an integral part. It was then decided to continue with a final feasibility study, with each country paying half the cost. Lesotho had to turn to the European Development Fund for its share of the cost of the feasibility study. The organisation provided funding on condition that investigations are divided into two physical parts, with each country's consultants investigating its half, while reviewing the work of the other. It therefore became necessary to devise a complicated arrangement for coordinating and supervising the study. Each country's study supervisor could only control the work of his own consultants and coordination had to take place by way of regular meetings. Provision was also made for meetings of the two technical departments involved as well as ad hoc meetings at Heads of Department level if required.

South Africa appointed a consortium comprising mainly the company Ninham Shand and Henry Olivier & Associates. Lesotho appointed a German/British consortium, Lahmeyer MacDonald. The study addressed various engineering and financial appraisals, project cost estimates, legal issues and management and manpower studies. More than 2 000 variants of several alternatives were evaluated before the final proposals were made. However, it was not without argument. Initially it was shown that the most economic layout would be one situated partly in Lesotho and partly in South Africa. This layout was rejected by Lesotho in favour of a layout situated squarely in that country. This made the South Africans very nervous as it would enable Lesotho to cut off the water during a drought when it was most needed. The ensuing argument almost led to an abandonment of the project. Thankfully, in the end a diplomatic solution was found. The final report, which appeared in 1986, consisted of 19 volumes of text and eight albums of drawings – altogether 62 cm thick and weighing 33 kg.

By now water demand in Gauteng had outstripped the mean annual runoff of the Vaal River. The region's problems were compounded by a terrible drought, leading to severe water restrictions. With the region responsible for almost 60% of national gross domestic product and 42% of the urban population water needed to be imported urgently to meet the growing supply-demand gap. Moreover, DWA in 1989 estimated that the total water demand in the Vaal River supply area was increasing by about 3% a year, making the need for water even more acute.

On 24 October, 1986 the two governments were finally ready to

Tenders a matter of international interest

A project of the size and scale of the Lesotho Highlands Water Project certainly does not go unnoticed, and when the time came for tenders to be called there were many consortia from all over the world hoping to attain a piece of the project. One of the conditions of the Treaty was that South African firms would be responsible for at least half of the engineering and construction work; however, this left a large slice of the pie for possible international involvement. Theo van Robbroeck recalls how, far from being a mere technical matter, the tender process also attracted political attention: "One day, after the tenders for the main works had been received and were being evaluated, then Foreign Minister Pik Botha called me to his office and told me that an American firm of contractors in consortium with a Japanese firm wanted an opportunity to re-tender after they had lost because of their exorbitant price. Apparently they had already convinced our counterparts in Lesotho to reopen the process. I told Mr Botha that we would do no such thing as we would lose all credibility in the eyes of the world, and that I would not be prepared to continue leading the project if that request were to be met. I never heard of it again."

Phase 1A engineering components

- The double curvature concrete arch Katse Dam and associated works.
- The 44,6 km-long transfer tunnel, excavated mainly in basalt to 4,95 m-diameter.
- The 72 MW underground power station and 'Muela dam (tailpond).
- The 37 km delivery tunnel which runs from 'Muela, under the Lesotho-South Africa border to an outfall in the Ash River.

sign the Treaty committing them to phase 1 (A and B) of the Lesotho Highlands Water Project. The project had been divided into four phases, with the ultimate aim of transferring 70 m³/s from Lesotho to South Africa. Under the treaty South Africa accepted responsibility for the costs and financial risks associated with those parts of the project related to the transfer and delivery of water to South Africa, while Lesotho accepted responsibility for the costs and financial risks associated with the generation of hydropower.

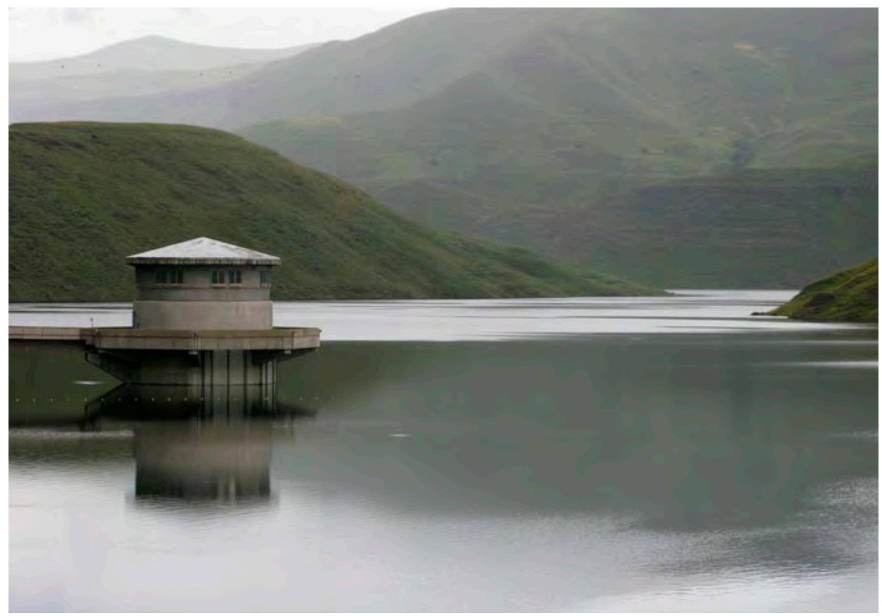
Phase 1A

Shortly after the Treaty was signed in 1986, the wheels were put into motion for Phase 1A. This part of the project mainly comprised the construction of the Katse Dam; the 'Muela hydropower station and more than 80 km of tunnels to convey water from the mountain streams of Lesotho to the Vaal River system in South Africa. The participating countries each established their own parastatal body to oversee the project: the Lesotho Highlands Development Authority (LHDA) was to supervise all construction work on the Lesotho side of the border (about 80% of the project), while the Trans Caledon Tunnel Authority (TCTA) was to supervise work in South Africa.

The TCTA and LHDA engaged three consortia of consulting engineers to undertake project optimisation studies, tender design and preparation of tender documents for the main works. A World Bank-funded technical assistance contract was also awarded to Acres International of Canada to assist the Lesotho organisation in the management of these consultancy contracts, to undertake reviews of the various designs and to transfer technology to Basotho staff they employed.

Lesotho's existing infrastructure was not prepared for such a massive project and, as a result, extensive preliminary infrastructure was required before the main construction work could begin. Many of these structures were engineering feats in themselves, such as the 109 km-long northern access road, which cuts through some of the most rugged mountainous terrain southern Africa has to offer. This road includes three mountain passes, the highest of which rises to over 3 000 m, and the incrementally launched Malibamatso Bridge, 86 m high and 465 m long. The latter structure received the Fulton Award for Outstanding Civil Engineering in 1991. Despite these excellent roads it still took about seven hours for a fully loaded cement

Water from the Katse reservoir dwarf the 98 m-high intake tower. Comprising some 33 000 m³ of concrete, the tower provides for one vertical internal shaft as well as a range of horizontal, tapered intakes to allow water to be drawn off the dam at different levels.



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truck to make a trip from the cement silos in Ficksburg to the Katse Dam site, and logistics had to be planned very carefully.

To cope with the increased traffic from the construction activities, the border crossing facilities at the two main project points of entry to Lesotho were upgraded and two new bridges over the Caledon River were constructed. In addition, four residential camps were built along with grid power and telecommunications. All of these projects were completed in time for the main work to start in 1991.

For contractual purposes, Phase 1A was divided into four main components, namely the Katse Dam, the 45 km-long transfer tunnel and 15 km delivery tunnel south, the 'Muela hydropower station and the 22 km-long delivery tunnel north. For each of the components, prospective contractors had to show their suitability, technically and financially, to handle these major undertakings. Around 40 international consortia registered, eight of whom had

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South African partners – altogether 64 contractors from 21 countries. The closing date was 20 April, 1990. The tender evaluation was completed four months later. It is estimated that it cost the tenderers some R5-million each to complete their documents.

The major feature of Phase 1A was the Katse Dam, situated in the Malibamatso River, about 2 km downstream of the confluence with the Bokong River. Here engineers came across a gorge about 230 m deep forming a wide, trapezoidal-shaped valley cut into the massive basalt rock. During the feasibility studies, several different dam designs were considered, including earth-core rockfill and rollcrete options. However, in the end it was decided to design the dam as a double-curvature concrete arch, 185 m in height and 710 m long. At the time of its construction, Katse Dam was the highest dam in Africa and one of the highest of its type in the world. The dam features an overflow crest spillway comprising ten bays, each 16 m wide to accommodate the maximum

Phase 1A consulting consortia

- **Katse Dam and transfer tunnel**: Lesotho Highlands Consortium, comprising Sogreah (France), Coyne et Bellier (France), Sir Alexander Gibb & Partners (UK), Ninham Shand, Knight Píesold, Keeve Steyn, MJ Mountain, SRK and VKE, all from South Africa.
- **'Muela Dam and power station**: Gibb Sogreah Joint Venture, comprising Sir Alexander Gibb & Partners and Sogreah. (The consortium of Lahmeyer MacDonald of the UK was later appointed for the detailed design and construction supervision).
- **Delivery Tunnel:** Highlands Delivery Tunnel Partnership, comprising Lahmeyer (Germany) and Mott MacDonald (UK), with Ninham Shand, Keeve Steyn, VKE and SRK from South Africa.

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About 2,3 million m³ of concrete was used to construct the 185 m-high Katse Dam wall.

flood overflow of 6 250 m³/s. This water flows into a plunge pool, created by a 32 m high tailpond dam with a shaped ogee weir, which is situated 100 m from the base of the dam wall. The crest is 9 m wide, incorporating a roadway.

After decades of planning and negotiations, construction of the dam finally got underway in 1991 with the start of excavations. In the beginning it was slow going, with the clashing of cultures and languages providing for much frustration. After a few months the Europeans had picked up some English and the Basotho workers some Italian and Spanish (many of the contracting staff had been recruited from a project in Colombia) for everyone to get along most of the time. At peak construction more than 2 000 people worked on site representing more than 30 different nationalities. A clinic was established on site to treat minor injuries; however, serious cases had to be transported by ambulance or helicopter to hospitals in South Africa. Eleven people died during the construction of Katse Dam.

Together with clearing of the site, one of the first operations was to excavate the diversion tunnels and construct the coffer dam to create a dry working area. The latter was a feat in itself, having been 35 m high and containing about 90 000 m³ of rollcrete. The cofferdam was completed in a mere four months. Another coffer dam, 15 m high, was constructed on the downstream side. Together, these structures were capable of handling a ten-year flood. Ironically, all this work coincided with a prolonged drought, with the lowest river flows recorded in over 60 years. The diversion works were completed in January 1993.

Meanwhile work started on the foundations for the dam. More than 950 000 m³ of rock and 280 000 m³ of soft material were removed during this time. During excavation the contractor discovered geological conditions that made it necessary to dig deeper into the riverbed than originally planned to establish a sound foundation for the dam wall (later the downstream foundations were further strengthened with massive concrete plugs cast in tunnels below the arch). As a result, some 30 000 m³ of additional rock had to be excavated for the dam wall.

By mid-1993 the pouring of concrete for the main wall had begun. The double curvature wall was constructed by cast *in situ* concrete blocks, 15 m wide along the centre line, constructed in

Phase 1A main construction consortia

- **Katse Dam:** Highlands Water Venture comprising Impregilo (Italy), Bouygues (France), Hochtief (Germany), Stirling (UK), Kier (UK) with South African firms Concor and Group Five.
- **Transfer Tunnel and Delivery Tunnel South:** Lesotho Highlands Project Contractors comprising Spie Batignolles (France), Balfour Beatty (UK), Ed Zublin (Germany), Campenon Bernard (France) and South African firm LTA.
- **Delivery Tunnel North:** HMC Tunnelling Venture comprising Hochtief (Germany), Marti-Inter (Switzerland) and Concor (South Africa).

Main engineering characteristics of Katse Dam

Dam type: Double-curvature concrete arch
Crest length: 710 m
Height above foundation: 185 m
Thickness of dam wall: 60 m at base and 9 m at crest
Rock excavation: 900 000 m^3
Concrete volume: 2,32 million m^3
Spillway maximum capacity: 6 252 m^3/s
Spillway length: 150 m
Total storage capacity: 1 950-million m^3
Surface area at full supply level: 36 km^2

2,5 m lifts. To transport the concrete, the contractor erected an overhead cableway comprising two mobile masts, which supported two individual cables, spanning nearly a kilometre across the valley to a 90 m blondin tower on the west bank. The crane, which had a capacity of more than 33 t, lowered 9 m^3 buckets of cement for pouring onto the wall. Work continued 24 hours a day and, at peak capacity, up to 115 000 m^3 (the average was 75 000 m^3/month) of concrete was poured every month. By July 1994, 600 000 m^3 of concrete had been poured into the dam wall and, once completed; it contained 2,3 million m^3 of concrete. The harsh Lesotho climate proved quite challenging for the project team.

In winter temperatures dipped so low that the top of the concrete on the wall would freeze every night. It would have to be thawed every morning before the new concrete pour could start. In summer the concrete had to be cooled down to prevent cracking. To enable this, a network of refrigeration coils was built into the concrete blocks in

***Top right**: The Lesotho winters proved a trying team for man and machine working on the Lesotho Highlands Water Project.*

***Bottom right**: The Ash River outfall. 'Ash' is not actually the name of the river in which the water of Lesotho flows on its way to South Africa's economic heartland. The Afrikaans name 'As' (meaning both 'ash' and 'axle') has been incorrectly translated.*

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More than 80 km of tunnels were constructed to convey water from the Lesotho mountains to the Vaal River system in South Africa. The main tunnels have an internal diameter of more than 4 m.

the dam. In addition, a 22 t/day refrigeration plant was established on site.

Towards the end of 1995 construction had reached such an advanced stage that impoundment could start. By this time, the partially completed dam was able to impound the reservoir up to 50 m above riverbed level. After 77 months of construction, Katse Dam was finally completed in 1997. Exceptional rains filled it quickly, and it reached its full supply level by early 1998.

Work on the tender design for the transfer and delivery tunnels began in parallel with completing optimisation and conceptual design studies in 1988. A 45 km-long transfer tunnel takes water from Katse Dam, through the Maluti mountains, to the 'Muela hydropower station. A delivery tunnel then takes the water from the tailrace of the power station north into South Africa. The 4,5 m-diameter delivery tunnel is 38 km long in total, the southern section in Lesotho being 16 km and the northern section in South Africa being 22 km. The consortium, Lesotho Highlands Project Contractors, eventually won the contract to construct the transfer tunnel and Delivery Tunnel South in Lesotho, while the HMC Tunnelling Venture became responsible for building the tunnel in South Africa (known as Delivery Tunnel North).

Three tunnel boring machines were obtained to carry out the excavations for the transfer tunnel and Delivery Tunnel South. Access to the tunnels was through drill and blast accesses (adits) that were excavated prior to the arrival of the machines on site. In addition, five ventilation shafts were created along the length of the tunnel to assist natural ventilation during inspections. The Delivery Tunnel South was completed 20 months ahead of schedule, saving millions of Rand in the process. The original plans for the transfer tunnel required a minimum of 6 km of the structure's length to be lined with concrete for structural support. Instability in the exposed basalt rock convinced the engineers that lining the full 45 km of the tunnel with 300 mm-thick concrete would be a safer, if more expensive option. Nevertheless, the tunnel was completed in time to receive water by late 1996. The transfer tunnel intake is located a kilometre upstream of the Malibamatso Bridge, some 80 km north of the Katse Dam wall.

The 22 km-long Delivery Tunnel North was also completed ahead of time. This tunnel, the first pressurised water tunnel in the world lined with precast concrete segments, stretches from the South African-Lesotho border to the Ash River outfall. Here only one tunnel boring machine was used – it was christened 'Margot' after the wife of former Minister of Water Affairs & Forestry General Magnus Malan. Interestingly, the Delivery Tunnel North included the crossing of the Caledon River, leading to the necessity of declaring a small area within Lesotho to be fenced off and put under the care of the contractor. This area became known as Trans Caledonia for the duration of the project.

Phase 1A was officially inaugurated by dignitaries from Lesotho and South Africa on 22 January, 1998. In his speech then President Nelson Mandela said of the project: "The resounding success of the Lesotho Highlands Water Project testifies to the powerful spirit of cooperation that is growing as Africa lifts itself through its own efforts, with the strong support of the international community. The flow of fresh water is a concrete result of the welding together of our efforts at nation building and regional development."

Fighting bribery at a large scale

Unfortunately the ingenuity of the Lesotho Highlands Water Project has been largely overshadowed by the huge corruption scandal uncovered by Lesotho authorities.

In 1993, following the election of a civil government in Lesotho, a comprehensive audit of the LHDA revealed massive financial mismanagement by the organisation's CEO, Masupha Ephraim Sole. An engineer by training, Sole entered Lesotho public service in 1972 and became the first CEO of LHDA following its establishment in 1986. The ensuing disciplinary enquiry exposed how Sole had charged private expenses to the project, and abused the housing scheme. He was also guilty of nepotism. He was dismissed in 1995, and the following year the LHDA brought civil proceedings against Sole to recover some of the mismanagement funds (the court eventually ordered him to pay back M8,9-million).

Investigations produced evidence of a number of bank accounts in Switzerland and South Africa. For two years the Lesotho government fought for disclosure of the Swiss accounts, which it finally gained in 1999. This proved the key in uncovering the web of bribery that had been spun with the former CEO at the centre. The bank accounts indicated that throughout the lifetime of the project Sole, using 'middlemen', had indirectly received vast sums of money from certain international companies and consortia who had been awarded contracts in the project.

Sole was finally found guilty of bribery and fraud and sentenced to 18 years' imprisonment, reduced to 15 years on appeal. In addition, three of the companies have been found guilty of bribery and sentenced to the payment of various fines, including Acres International (Canadian firm), fined M12-million; Lahmeyer Consulting Engineers (German), fined M12-million; and Spie Batignolles (French), fined R10-million. Cases against the other companies are still pending. Furthermore, the South African government has instituted legal proceedings against the convicted companies to recover the amounts they paid to Sole as bribes, the argument being that those costs were added to the total project costs and would have to be covered by the water consumers of the project.

Lesotho, that small country in southern Africa, has been hailed internationally for its tenacity in pursuing the matter, despite having no outside financial support. Many of the legal aspects of corruption have now been thoroughly tested in the country's courts. Learning from this project, TCTA have since added a specific section to their pre-qualification and final contracts dealing with bribery. Among others, firms have to declare if they have been accused of bribery anywhere in the previous ten years and declare that they have not and will not engage in bribery.

Phase 1B

Following South Africa's first democratic elections in 1994, the Treaty was ratified by the new government, allowing the second part of the first phase of the Lesotho Highlands Water Project to continue. Construction of Phase 1B of the scheme kicked off in 1998. This phase was basically designed to supplement the inflow into the Katse reservoir and to increase the average flow of water to South Africa. Phase 1B was divided into three main aspects, namely construction of Mohale Dam, the diversion of water from the Matsoku River through a tunnel and from the Senqunyane River through the Mohale tunnel into the Katse reservoir. The contracts for these three projects were awarded to Matsoku Civil Contractors, Mohale Tunnel Contractors and Mohale Dam Contractors, all joint venture companies consisting of Hochtief, Impregilo and Concor. Just like the phase before it, Phase 1B also required preliminary infrastructure, including

The construction village where 80 houses were constructed to house staff of Mohale Dam.

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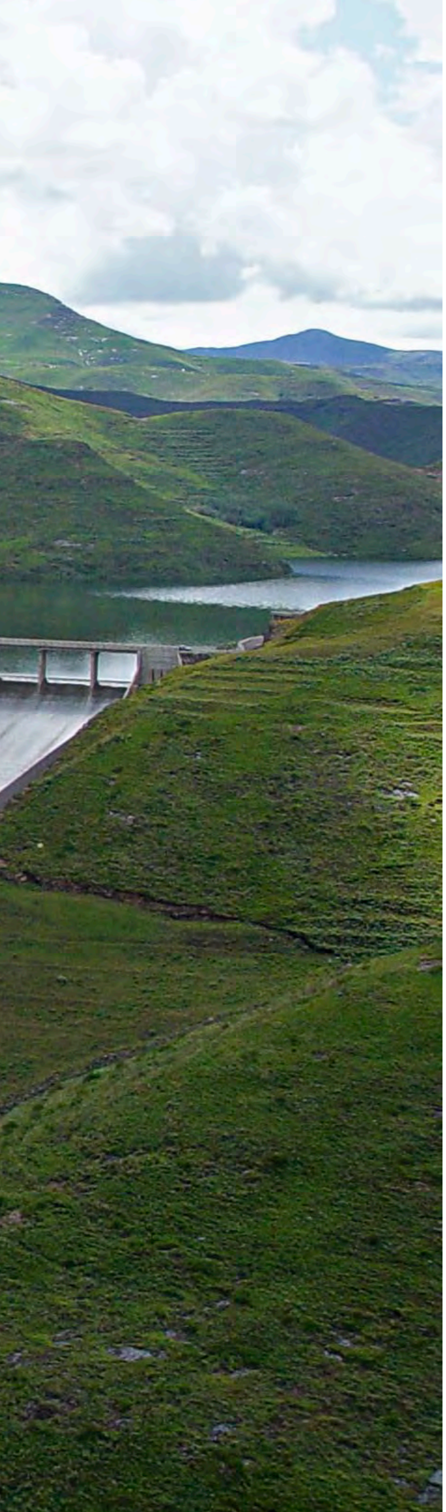

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Left: Mohale Dam is a concrete-faced rockfill embankment, 145 m high. Here the ungated spillway, built on the left abutment of the dam, can clearly be seen.

Right: The tunnel boring machine used on the 32 km-long Mohale tunnel linking the Mohale and Katse dams.

three mountain passes, 72 km of tarred roads, a bridge, a clinic, construction village, digital microwave and radio telecoms, along with 80 km of power lines.

Constructed between 1998 and 2002, the Mohale Dam forms the main storage element of this phase of the Lesotho Highlands Water Project. Situated in the Senqunyane River, the 145 m high Mohale is a rockfill concrete-faced dam with a total embankment volume of 7,5 million m^3. The dam has a crest length of 700 m and crest width of 12 m. It is the highest dam of its kind in Africa. One of the considerations leading to the selection of the dam type is the fact that concrete-faced rockfill dams are very stable when earthquakes or seismic activity are experienced as can be the case in Lesotho. The rockfill construction also made good use of the basalt materials which were readily available in the surrounding Lesotho mountains.

Since two fault zones cross the dam's foundation on the right bank, the first essential step was to grout and cover these zones and also construct a gallery from the downstream side to the two zones to ensure that grouting works could also be carried out after the completion of the dam. In order to reduce construction time, the fill material for the upstream part of the dam body was placed up to about 75% of the final height. The rockfill material for the downstream part of the dam was placed simultaneously with the construction of the concrete surface. Once sealing was finished, rockfill for the rest of the dam body was placed to enable the face slab to be executed up to the crest.

The main elements of the surface sealing system are a plinth and a concrete face slab, with the plinth connecting the face slab to the rock below and serving as a working deck for grouting. The concrete slab, which varies in thickness from 710 mm at the bottom to 300 mm at the top, covers an area of 81 000 m^2 and has a volume of 34 000 m^3. Since work on the slab was divided into two phases, a horizontal construction

Engineering characteristics of Mohale Dam

Type of dam: Concrete-faced rockfill

Height above foundation: 145 m

Crest length: 700 m

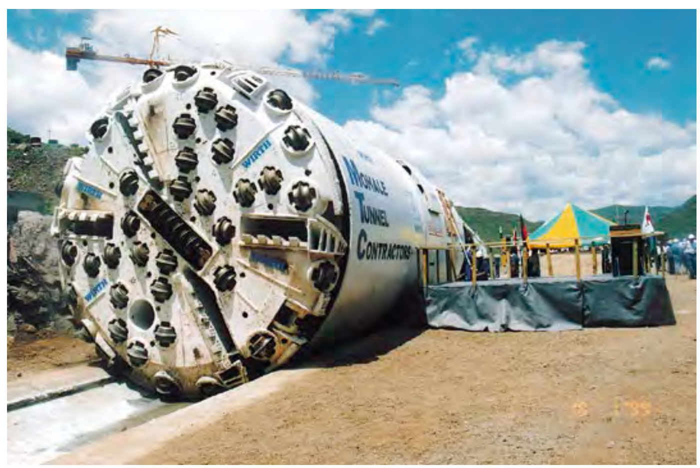
Crest width: 12 m

Volume of rockfill in wall: 7,5 million m^3

Maximum capacity of spillway: 2 600 m^3/s

Total storage capacity: 938 million m^3

Surface area at full supply level: 22 km^2



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The Mohale reservoir can store over 950 million m^3 of water.

joint was required at a level of 100 m above the deepest foundation.

The concreting works were carried out with a slipform pulled up the dam slope by two 10 t winches. On average, a placement rate of 10 m^3/h was achieved. Concreting the longest slabs, with a length of 170 m, took up to four days. Twenty-four hours or so after one concreting slab was completed the slipform was lowered down the hardened concrete on wheels. Once at the bottom, it was pulled sideways on to the starter slab of the next strip to start a maximum of four shifts later.

The spillway comprises a laterally positioned three-element weir with a fixed crest and a total length of 50 m. The attached structure channels the water to a 25 m chute with double ventilation. The discharged water is directed via a flip bucket into the natural river bed. The spillway is designed for a maximum flood of 2 600 m^3/s. Other associated structures are two diversion tunnels, 650 m and 560 m long respectively, as well as upstream and downstream cofferdams with a total volume of about 150 000 m^3.

Concerning the other main elements of Phase 1B, the Matsoku Weir and tunnel is another means of increasing the Katse reservoir supply level. The weir is situated on a bend in the Matsoku River upstream of the village of Ha Tsela, some 12 km north of the Katse Dam. Water is directed by an in-stream ledge towards a forebay on the left side of the weir. Here, the baseflow passes through, while the excess water enters the tunnel. The weir was commissioned in October 2001. The Matsoku tunnel was constructed using drill-and-blast techniques to maximise employment and lined with 75 mm-thick steel-fibre reinforced shotcrete.

In turn, the 32 km-long Mohale tunnel links the Mohale and Katse dams to augment the supply of water and allow free flow of water in either direction to balance the volumes in each reservoir. The 4,5 m-diameter tunnel was constructed in basalt rock using two shielded tunnel-boring machines working from each portal at opposite ends towards a mid-tunnel meeting. Some 91 500 precast concrete segments were used in its construction. The intake structure to the Mohale tunnel lies about 5 km upstream of Mohale dam.

The start of impoundment at Mohale Dam in November 2002 effectively marked the end


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Left: *Around 100 000 m^3 of concrete and 7,2 million m^3 of rockfill went into the Mohale Dam wall.*

Below: *Snow covers the landscape surrounding the reservoir at Mohale.*

Lesotho – The social and environmental cost

One of the largest water resource developments ever to be undertaken in Africa the Lesotho Highlands Water Project has affected the lives of thousands of people. There is no doubt that the once remote mountain communities of the Lesotho Highlands have been dramatically changed by the project. While there have been tremendous benefits in terms of much needed roads, water, sanitation, and other infrastructure, the project has also had some negative impacts.

During construction, for example, the project brought an influx of thousands of job seekers, who brought with them HIV/AIDS and other before unheard of sexually transmitted diseases. The villagers also suddenly found themselves having to deal with issues such as alcoholism and prostitution. Furthermore, at least 500 families were relocated during Phase 1 of the project. Whereas all phase 1A resettlees relocated to villages in the Highlands (within the same administrative jurisdiction) phase 1B offered the choice of rural Lowlands as well as urban areas. People were allowed to choose the design of replacement houses equal in surface area to their original home. Households were compensated for the loss of arable land at 1 000 kg/ha yield per annum and pulses (almost double the average yield of 560 kg/year in the Highlands). After revising the policy for Phase 1B, where cash compensation became an additional option, it was retrofitted for Phase 1A as well. Despite authorities' best efforts there have been reports of households not receiving their compensation, of replacement housing being of inferior quality, and supplies of replacement foods and fodders being insufficient.

It must be appreciated, however, that when the project was planned and designed in the 1970s and 1980s, awareness of environmental and social issues, in general, was much lower than it is today and neither Lesotho nor South Africa had any legislation compelling authorities to undertake environmental and social impact assessment studies. Nevertheless, environmental and social welfare issue were embedded in the founding treaty as legally binding articles according to the international trends of the time.

One of the most integral aspects to consider was the instream flow requirements (IFR) of the affected rivers. This refers to the volume, quality and timing of water released through or over dams and associated downstream of dams. It was only as Katse Dam neared completion in 1997 that an assessment of the project's impacts to downstream ecosystems and communities was undertaken.

Unfortunately, IFR requirements have indicated that design limitations on Katse Dam do not allow much flexibility of release regime since this was not considered such an important requirement when the dam was designed and built (the dam can only release 0,5 m^3/s downstream). Mohale Dam, on the other hand, holds the greater potential for manipulating releases to meet river health targets in the Senqunyane River (the design of its outlet valves were changed following environmental impact studies). An IFR Policy released in 2003 specifies operating rules for the dams and a programme to monitor compliance with agreed releases. The operating rules provide for changes to releases depending on climatic conditions, so that some natural variation is maintained.

In 2008 it was reported the rivers downstream of the structures were found to be either in their target ecological condition, or better than their target condition. "Although some changes are expected to take upward of 20 years, the monitoring results indicate that some aspects have not responded as predicted" (Brown, 2008).

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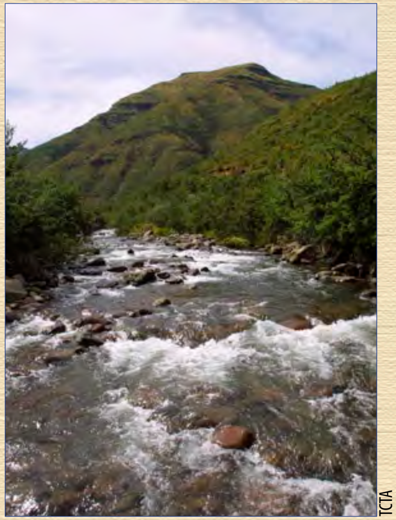
Left: A new homestead next to the Mohale Dam.

Right: The Tshehle River in Lesotho.



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Bottom right: *Commissioned in October 2001 the Matsoku Weir and tunnel increases the supply of the Katse reservoir by transferred up to 55 m³/s into the dam during high flow conditions. The weir's downstream face features a series of large steps, designed to dissipate the energy of water overflowing the weir.*

Bottom left: *Matsoku weir during construction. The 15 m-high weir is situated on a bend in the Matsoku River about 12 km north of Katse Dam.*

of construction of Phase 1 of the Lesotho Highlands Water Project. Together, phases 1A and 1B yield about 27 m^3/s of water to South Africa. By the end of January 2003, the dam had already filled halfway in depth. At the official opening of Phase 1B on 16 March, 2004, then President of South Africa, Thabo Mbeki, said: "This project sparkles like a jewel in the crown of the Southern African Development Community and the African Union, proving that we can, as Africans, accomplish sustainable development, to the mutual benefit of neighbouring countries and as an example of projects that are needed all over our continent to achieve our renaissance."

Phase 2

In 2004, the governments of South Africa and Lesotho agreed to proceed with feasibility studies of the further phases of the Lesotho Highlands Water Project. A Memorandum of Understanding was signed a year later to commence feasibility studies for Phase 2, which were completed in 2007. A year later, Cabinet approved the project, projected to cost around R7,3-billion.

In August 2011, the project was officially launched by Water & Environmental Affairs Minister Edna Molewa and her Lesotho counterpart, Natural Resources Minister Monyane Moleleki in Maseru. Phase 2 will include the construction of the Polihali Dam downstream of the confluence of the Senqu and Khubela Rivers. At this stage a concrete-faced rockfill dam (similar to Mohale) is envisaged. The dam is planned to have a maximum height of 163,5 m, a crest width of 10 m and a crest length of 915 m, with a full supply level of 2 075 m above sea level. A 49,5 m-high saddle dam will also be constructed as well as a side-channel spillway. The reservoir capacity is expected to be 1 892-million m^3. This dam will increase the yield from the Lesotho Highlands Water Project from 780 million m^3/year to 1 281 million m^3/year.

In addition to the dam, a 38 km-long, 5 m-diameter tunnel will be constructed from Polihali to Katse Dam. The tunnel is sized to convey a peak power generation flow of 35 m^3/s. Water will be extracted from the Polihali reservoir through two separate concrete bell-mouth intakes on the western side of the reservoir. Water will be transferred through the lower and upper intake tunnels to the intake gate shaft. Both of these tunnels will be constructed by drill-and-blast methods and will be fully concrete

Main envisaged engineering characteristics of Polihali Dam

Dam type: Concrete-faced rockfill dam
Height above foundation: 163,5 m
Crest width: 10 m
Crest length: 915 m
Embankment volume: 12,3 million m^3
Excavation volume: 40 000 m^3
Length of plinth: 1 150 m
Area of facing slab: 12 343 m^3
Storage capacity: 2 322 million m^3
Surface area when full: 5 ha
Spillway type: Reinforced side-channel with concrete rectangular chute and flip bucket discharging into pre-excavated stilling basin in rock.
Spillway length: 100 m

lined. Hydraulic control will be affected by the valves in the intake structure. The Polihali intake gate shaft will only be used for maintenance and water quality control functions.

As with the previous phase significant advance infrastructure will be required, including roads, telecommunications, power lines and employment housing. The project also has various social and environmental challenges and studies are being undertaken to determine and mitigate any impact. As many as 2 500 people in 17 villages will have to be resettled, with another 72 villages that will have to be compensated in terms lost fields and grazing lands. Construction is due to start as soon as February 2014, with the target date for impoundment being August 2018. The scheme is expected to deliver water by July 2020.

Interestingly, the Lesotho government wanted to appoint Masupha Sole, the disgraced former CEO of the LHDA, as a technical adviser on Phase two. Sole was found guilty of corruption and taking bribes during the first phase of the project. However, after objections raised from the South African government, his appointment was 'reconsidered'.

KOMATI RIVER BASIN PROJECT

Before South Africa could construct its first dams in the Komati River basin to feed the hungry coal-fired power stations on the Mpumalanga Highveld in the 1950s and 1960s it first had to enter into agreements with the small Kingdom of Swaziland over its use of this international river. In 1967, the two countries entered a treaty for 'the best joint utilisation of rivers of common interest'. The late 1970s saw an increase in water demand, particularly for irrigation, in the Komati River basin. Subsequently, following negotiations the two countries established a Joint Permanent Technical Committee in 1978, and it was agreed that South Africa would fund the necessary studies to identify potential dam sites. Between 1981 and 1982 a number of studies were undertaken to prepare proposals for agreement on, among others, water use, water resource development and cost sharing. These were followed by technical investigations which concluded with identification of two sites – one in South Africa and the other in Swaziland. In total, 18 different sites were investigated.

In 1986, DWA put its first White Paper before Parliament proposing the construction of the South African dam as part of the development of the Komati River basin. According to the department, the development was intended to "stabilise river flows and to improve the assurance of water supplies to the existing irrigation and urban development in the Komati River basin so as to provide for the expected increases in primary water use and also allow for a moderate increase in irrigation development." It also noted that no other proposals for the further transfer of water from the Komati River system for thermal power generation on the Highveld could be considered prior to ensuring there was enough water for irrigation development in the catchment. The beneficiaries of the dams were situated along the Lomati River downstream of the northern border of Swaziland and along the Komati River downstream of the western border of Swaziland. At that time it was estimated that once both Driekoppies and Maguga dams were completed, the combined system would permit a net total draft of 678 million m^3/year for 80% of the time on average.

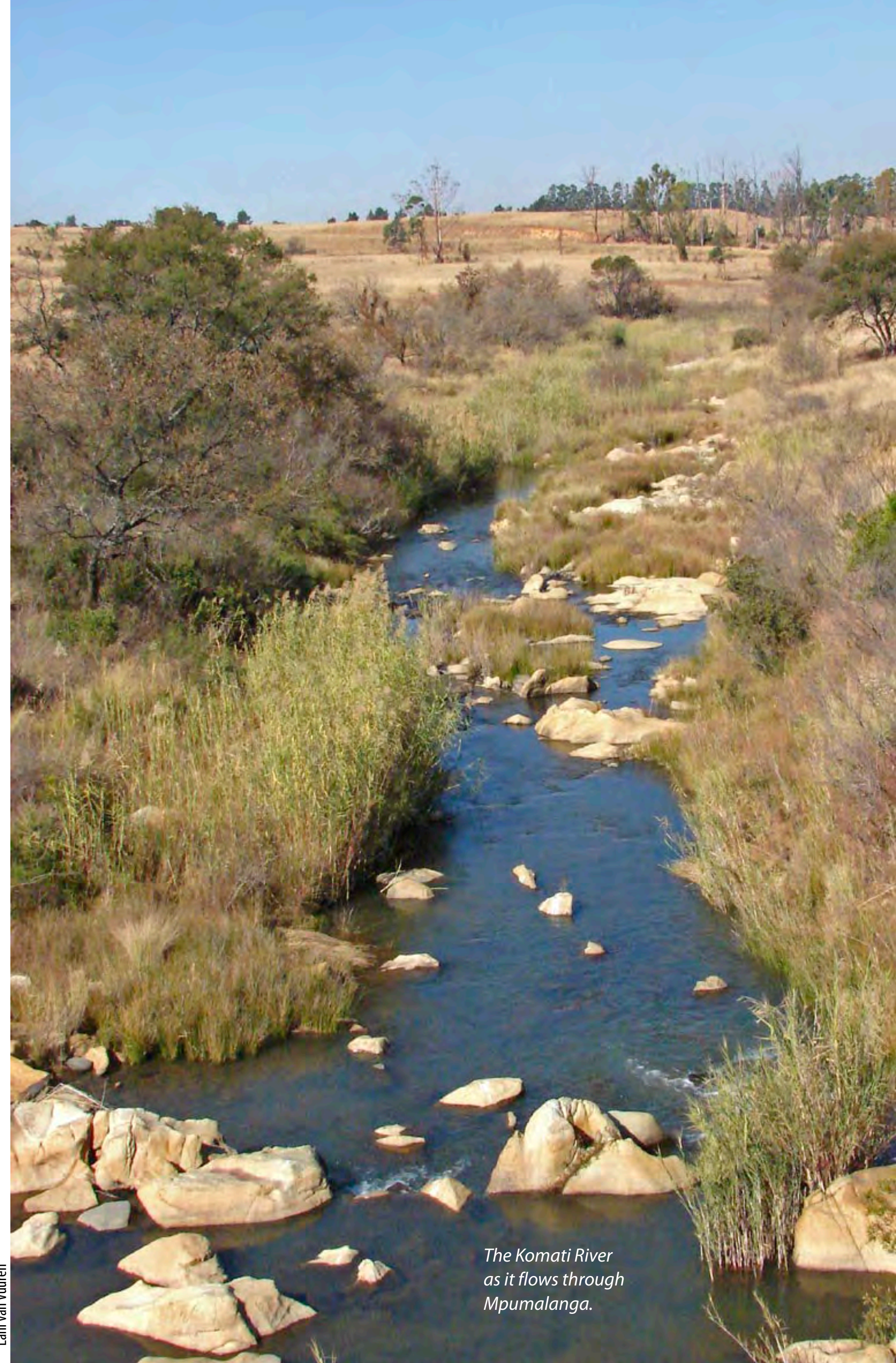
It must be noted that at that time the area surrounding the proposed Driekoppies Dam site had been declared a 'homeland' known as KaNgwane. In terms of the South African government's policy regarding decentralisation at that time, it considered the development of KaNgwane of crucial importance. Expanding irrigation was considered an important component of this development.

While the South African Parliament accepted the proposal it would take six more years of negotiations with the country's neighbours before the project commenced in 1992. The delay seems to have been caused mainly by objections from Mozambique situated downstream of the proposed development, who was concerned over the effect the project would have on its water supply. Consensus was eventually reached with this country in 1991. Swaziland and South Africa went on to establish the Komati Basin Water Authority (KOBWA) to implement and operate the infrastructure. South Africa would be responsible for 100% of the cost of the Driekoppies Dam, while costs would be split 60% (South Africa), 40% (Swaziland) on Maguga Dam. In addition to water for irrigators, water would also be released for downstream Mozambique.

Driekoppies Dam

Construction of Driekoppies Dam started in 1993 after a slight delay caused by challenges in the relocation of affected people. The dam was built on the Lomati River between the villages of Schoemansdal and Middelplaas, about 25 km south of Malelane, in Mpumalanga. The dam was constructed by the Construction Directorate of DWA, with Chunnett Fourie & Partners being the main consultant on the project. Finance was provided mainly by the Development Bank of Southern Africa (DBSA). At the time it was the largest dam under construction in South Africa (with the exception of the Lesotho Highlands Water Project underway in the mountain kingdom).

The dam consists of earth embankments flanking a 150 m-long, uncontrolled concrete gravity spillway. The overall length of the wall is 2 400 m, with a maximum height of 50 m. The width of the embankment, measured at the base at its widest point, is over 300 m. The design of the dam was very much dictated by the complex geology of the area. The dam is underlain by granite on the right bank and more easily



Lani van Vuuren

The Komati River as it flows through Mpumalanga.

Engineering features of Driekoppies Dam

Dam wall type: Earth embankments flanking an uncontrolled concrete gravity spillway section
Reservoir capacity at full supply level: 251 million m^3
Reservoir surface area at full supply level: 1 870 ha
Maximum wall height: 50 m
Overall length of dam wall: 2 400 m
Spillway design flood: 3 900 m^3/s
Rated outlet release capacity: 33 m^3/s
Volume of materials in embankments: 4,9 million m^3
Volume of concrete: 223 000 m^3
Volume of excavations for the dam wall, river diversion channel and spillway return channels: 1,6 million m^3

weathered and lower strength granite gneiss on the left bank. A geological thrust fault crosses the Lomati River at the site and forms the transition between these rock types with shear and fracture zones containing highly fractured and deeply weathered rock occurring to the right of the fault. As a result extensive foundation treatment and dental concrete were required to prepare the spillway foundation for concreting on the right bank near the thrust fault.

Extensive preparatory work was also done to prepare the alluvial plain on the lower left bank for embankment construction. Drilling of a line of 38 pressure relief wells at 20 m centres along the downstream toe of the embankment was followed by densification of 72 500 m^2 of low-density cohesionless material by means of dynamic compaction. An 800 m-long portion of the cut-off below the relevant part of the embankment, where it passes through the alluvial deposits, was constructed as a grout curtain by means of the tube-a-manchette grouting process.

The spillway was profiled for an overflow of 3 900 m^3/s. Energy dissipation of the spillway overflow is by means of a row of individual splitters above a continuous step. Erosion protection is provided immediately downstream of the spillway section by means of concrete aprons with baffle blocks. The outlet works provide for multi-level intakes into a dual 2 m-diameter pipe system with downstream sleeve valve control. The outlet system was sized to release the estimated short-term peak downstream demand of 33 m^3/s.

The construction of Driekoppies Dam was a plant-intensive operation, with over 200 units of plant being used on site. This included a fleet of 100 t-capacity bottom dump trucks and a range of articulated dump trucks of 50 t, 35 t and 25 t capacities. At the height of construction more than 850 people worked on site, 70% of whom were recruited from surrounding towns and villages.

The Driekoppies Dam project is interesting as the reservoir actually straddles the border between South Africa and Swaziland. More than 300 families situated on either side of the border had to be resettled as a result of the dam project. Relocation policies were put in place through wide consultation with stakeholders and the affected people. The underlying principle of the relocation policies was that people affected by the project must be left better off than they were prior to project implementation. Housing was provided in a resettlement area about 5 km from Schoemansdal. Fencing of the reservoir would isolate some of the local population, livestock and game from customary sources of water and alternative supplies had to be provided. Other activities aimed at compensating the loss of communal assets, such as grazing and medicinal plants included replacement land and the development of a nursery, while fuel wood was compensated with a capital investment for each community. In addition, 260 graves had to be removed, with reburial organised with consent of relatives of the deceased.

In its White Paper on the project, DWA stated that Driekoppies Dam would generally have no significant effect on the natural environment, with the effect on fauna, especially fish, being sited as 'slightly harmful'. The Driekoppies Environmental Task Group was established to guide the process of employing integrated environmental management procedures to integrate environmental considerations into the planning, design, construction, operation and maintenance of the dam. For example, all stripped topsoil was placed in carefully controlled spoil banks for reuse at the end of the construction period when it was spread over the landscaped site and prepared for seeding with indigenous grass species. Particular attention was also given to downstream instream flow requirements in the Lomati River.

The first milestone was reached on 30 September, 1994, when the first phase of the river diversion was successfully completed, and by mid-1995, 220 000 m^3 of concrete had been placed. Phase two of the river diversion was completed on 31 October, 1995. The dam was eventually finished in 1997, and spilled for the first time in 2000.

Maguga Dam

Construction of Maguga Dam was due to start a year after commencement of construction of Driekoppies Dam to enable the simultaneous completion of the two dams comprising the first phase development of the Komati Basin. However, Swaziland only re-committed itself to building the dam in 1994 and the resettlement of people to be affected by the reservoir lagged behind design and planning of the dam. As a result, construction only started on Maguga Dam in 1998.

The dam is located on the Komati River, about 12 km south of Piggs Peak in Swaziland. It was designed by the consortium Maguga Dam Joint Venture, comprising Ninham Shand, VKE Engineers, SRK Consulting, Goba (then Keeve Steyn), Swazi Group and Lahmeyer International. Appointed in 1996 they reviewed the existing information with specialist advice from a European consultant, and proceeded to carry out additional geotechnical studies, undertook a dam selection study, and prepared tender designs. The joint venture was later also responsible for construction supervision. Among others, the extra studies identified a source of clay within the reservoir basin, less than 2 km from the selected dam site. This led to reviews of the economics and resultant exclusion of the previously selected dam types, namely concrete arch or roller compacted gravity dam. In the end, a rockfill embankment dam with a clay core was decided upon, leading to savings of some R100-million over the earlier feasibility options. Construction of the dam was undertaken by Komati Dam Joint Venture, a consortium comprising Group 5, Grinaker-LTA, WBHO, SCA and Swazi Six.

The design programme was extremely tight and required close cooperation and communication between the design team, staff and the contractor. Compared with earlier programme time projections of up to 45 months for construction to first impoundment the project team managed to bring the project to fruition only 39 months after the contract was awarded – no mean feat for a dam this large. The tight programme schedule also required intense effort and maximum production from the start right up until completion. The typical work regime for the site was 24 hours a day, six days a week, with a long pay weekend at the end of each month. Extra shifts on Sundays and over pay weekends were worked on an ad hoc basis in order to maintain the required production levels. This was particularly the case on the main embankment, which was plagued by extremely wet weather during early 2000. Additional resources were also brought onto site at times of critical activity.

With a dam wall rising up to 115 m, Maguga Dam is the fifth highest dam in southern Africa, and the highest dam of its kind in the region. It was the biggest government construction project Swaziland had ever undertaken up to that date. The main wall comprises a rockfill embankment with a clay core, flanked both upstream and downstream by graded filters of crushed rock. The upstream face is protected against wave action by a layer of selected riprap. Some 760 000 m^3 of clay, 2,7 million m^3 of rock and 420 000 m^3 of crushed rock filter material was placed and compacted to

A partially completed Maguga Dam wall.

Group 5

The Maguga Dam spilling in 2006.

Group 5

form the embankment.

All concrete aggregates and plant material used in the embankment were quarried from within the reservoir basin or obtained from essential excavations. A crushing plant was established near the quarry and used to produce graded material and aggregate ranging in size from 75 mm to fine sand. Extensive testing procedures were conducted in an on-site laboratory to ensure that the requirements of the specifications were met. Rockfill, filters and clay were transported along specially constructed haul roads to the embankment using a variety of vehicles.

In order to divert the flow of the Komati River during construction a 385 m-long diversion tunnel, 9 m high and 8 m wide, was excavated in the right bank at the start of construction. This tunnel operated until the main embankment was completed in the middle of 2001, where after it was completed plugged. A second tunnel, 7 m high and 8 m wide, and 460 m long, was driven parallel to the diversion tunnel and provided additional capacity to divert the summer floods of 1999/2000. Thereafter, the tunnel was closed and twin 2 m-diameter steel pipelines installed to convey water from the intake shaft to the outlet works. A bifurcation upstream of the outlet works connects these outlet pipes to the penstocks to serve the hydroelectric power station, which was completed by Swaziland in 2006.

The intake tower is another interesting structure. A dry well, it rises 105 m from its base at the invert of the outlet tunnel to the level of the crest of the main embankment. At this level a control house and gantries were erected. The tower was constructed as a shaft for the first 40 m and freestanding for the remaining 65 m. A bridge provides vehicular access from the top of the tower to the embankment crest. Interestingly, the intake tower was also designed to withstand maximum credible earthquake loads.

An additional notable feature of the dam is the spillway, which is of a 'labyrinth' design. This effectively compresses the length from 460 m to only 181 m to accommodate a flood of 15 000 m^3/s. The labyrinth walls are 12 m high and are capable of carrying an overflow depth of 8,4 m at maximum discharge. The concrete-lined chute, finished to extremely high tolerances, discharges via a flip bucket into a 75 m by 100 m by 40 m deep energy-dissipating plunge pool at river level downstream of the dam. Instead of a cable crane to place concrete in the spillway chute, the contractor made use of six rail-mounted tower cranes located strategically down the chute. The discharge per unit length over this labyrinth and the performance of the flip-bucket and plunge pool were determined by extensive hydraulic modelling at Stellenbosch University. At the time of construction the spillway had the largest capacity in Africa and the second-highest capacity in the world for a labyrinth spillway (this being necessary as the area is often influenced by cyclones).

The contract for the construction of Maguga Dam was carefully structured to maximise the benefits to affected communities and, to this end, specially drafted contractual requirements regarding the employment of local labour were included. Special committees were set up to ensure that the employment of local labour was equitably shared among surrounding villages. Construction peaked at over 1 100 workers on site (around 800 being Swazi).

Water releases from the Komati River are controlled from the outlet works situated immediately downstream of the outlet tunnel portal. All water discharged from the reservoir pass either through the twin, 1,2 m-diameter fixed cone sleeve valves at the outlet works or through the turbines of the power station. Also situated in the outlet works are three multi-stage high-lift pumps providing bulk water for Piggs Peak's municipal water supply.

With the relocation and compensation strategies employed with the Maguga Dam project some of the lessons learnt from Driekoppies Dam assisted in improving the relocation process. This mainly revolved around involving the people of Maguga better in decisions to so accrue more benefits to them. Among others, people were relocated to

Engineering features of Maguga Dam

Dam wall type: A rockfill embankment dam with a clay core

Reservoir capacity at full supply level: 332 million m^3

Reservoir surface area at full supply level: 1 042 ha

Maximum wall height: 115 m

Overall length of dam wall: 870 m

Spillway design flood: 15 000 m^3/s

Volume of materials: 760 000 m^3 of clay, 2,7 million m^3 of rock and 420 000 m^3 of crushed rock filter material an area where they would benefit from irrigation water provided by the dam, and they became actively involved in their own relocation. Most people preferred to relocate to Nhlambeni, and during the relocation process households were assisted with transport, temporary housing where required, advice regarding building materials and suitable construction methods, as well as a choice of contractor. As with Driekoppies, this project also necessitated the move of ancestral graves.

A full environmental impact assessment was undertaken and the project took steps to mitigate environmental impacts. For example, a deep gorge was excavated to minimise the reservoir's surface area in relation to its volume of water. With a relatively small surface area, the lake would lose less of its stored volume to evaporation and, as an added bonus; a shorter stretch of the Komati River had to be inundated. Rare pink and yellow *Crassula* wildflowers were also transplanted out of the zone of inundation.

The Maguga Dam was completed in 2002, and spilled for the first time in 2006 after poor rainfall caused it to stand practically empty. The project won engineering excellence awards from SAICE, SAACE and the Cement and Concrete Society. The completion of Maguga Dam marked the end of Phase 1 of the Komati River Basin Development project. The Treaty between Swaziland and South Africa makes provision for the further establishment of five more dams to benefit the two countries.


Group 5

Maguga Dam's labyrinth spillway has one of the highest capacities of its type in the world.

VOLUNTEERS FOR CHANGE

The growing awareness around the environmental and social impacts of dams in the global arena in the 1980s and 1990s certainly had an impact on South Africa, despite its political isolation at the time. The country's engineers were definitely in close contact with the international scene through organisations such as ICOLD, in which they not only participated but often played leading roles. As we saw in the previous chapter, as projects grew in size, so did the concern over their potential impact, with the first real multi-disciplinary committee to oversee and manage environmental impact being established in the 1970s with the construction of the Thukela-Vaal Transfer Scheme.

From 1980, DWA included environmental impact assessments as part of all their project investigations. This was a voluntary action – there was as of yet no legislation compelling the department to do so. As a result of these studies the designs of several dams were modified, for example the outlets of the Wolwedans and Impofu dams were both modified to allow the release of sufficient water to support the estuaries downstream. These investigations also influenced the siting of projects. For example, environmental impact assessment studies undertaken in the Mfolozi River catchment, in KwaZulu-Natal, in the late 1970s to investigate environmental concerns over proposed dam sites identified by DWA's water resources planning directorate, eventually influenced the decision to construct the Klipfontein Dam outside Vryheid, a site with the least effects on the environment.

Independent studies conducted in the 1980s indicated that South Africa's dams were not all necessarily detrimental to the aquatic environment. The Laing Dam, for example, was found to actually improve water quality in the Buffalo River as it effectively trapped pollution from settlements upstream. By 1986, the department had two approaches towards environmental impact assessments, the first being an internal assessment of any planned water resource development projects using data gathered from outside experts in the field; and secondly, interdisciplinary environmental committees

The World Commission on Dams

The World Commission on Dams (WCD) began its work in May, 1998. It was born out of a small IUCN-World Bank sponsored workshop held in Switzerland, in 1997. The Commission was chaired by former South African Minister of Water Affairs & Forestry, Kader Asmal.

Its mandate was to review the development effectiveness of dams, and to develop standards and guidelines for future dams.

During its two-year lifetime, the Commission carried out the most comprehensive evaluation of large dams ever undertaken to date. It commissioned 130 technical papers, studied seven dams and three dam-building countries in great depth, reviewed another 125 dams in less detail, carried out consultation in different parts of the world with 1 400 participants, and accepted 950 submissions from experts and the interested public. Altogether, the WCD reviewed experiences from around 1 000 dams in 79 countries.

The final report of the WCD was published in November 2000, and still stands as one of the most important documents in the history of the water sector. It concluded that while "dams have made an important and significant contribution to human development" in "too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment."

Some criticised the report for not emphasising enough the role of dams in thirsty countries, such as South Africa. At the launch of the report former South African President Nelson Mandela said: "[The Commission] recognises that while there must be greater accountability, it is too easy and not too productive to simply blame the industries that build, the governments that authorise, the agencies that fund, the engineers who design the large dam. The problem..is not the dams. It is the hunger. It is the thirst. It is the darkness of a township. It is townships and rural huts without running water, lights or sanitation. It is the time wasted gathering water by hand. There is a real pressing need for power in every sense of the word. Rather than single out dams for excessive blame, or credit, we must learn the answer: "It is all of us!" All of us must wrestle with the difficult questions we face."

The ten key WCD recommendations are:

- Development needs and objectives should be clearly formulated through an open and participatory process, before various project options are identified.
- A balanced and comprehensive assessment of all options should be conducted, giving social and environmental aspects the same significance as technical, economic and financial factors.
- Before a decision is taken to build a new dam, outstanding social and environmental issues from existing dams should be addressed, and the benefits from existing projects should be maximised.
- All stakeholders should have the opportunity for informed participation in decision-making processes related to large dams through stakeholder fora. Public acceptance of all key decisions should be demonstrated. Decisions affecting indigenous peoples should be taken with their free, prior and informed consent.
- The project should provide entitlements to affected people to improve their livelihoods and ensure that they receive the priority share of project benefits (beyond compensation for their losses). Affected people include communities living downstream of dams and those affected by dam-related infrastructure such as transmission lines and irrigation canals.
- Affected people should be able to negotiate mutually agreed and legally enforceable agreements to ensure the implementation of mitigation, resettlement and development entitlements.
- The project should be selected based on a basin-wide assessment of the river ecosystem and an attempt to avoid significant impacts on threatened and endangered species.
- The project should provide for the release of environmental flows to help maintain downstream ecosystems.
- Mechanisms to ensure compliance with regulations and negotiated agreements should be developed and budgeted for, compliance mechanisms should be established, and compliance should be subject to independent review.
- A dam should not be constructed on a shared river if other riparian States raise an objection that is upheld by an independent panel.

Following the launch of the report, South Africa took up the challenge of the WCD. After initial discussions in 2001 a multi-stakeholder steering committee, chaired by Brian Hollingworth, was established to take the local WCD contextualisation process forward. The composition of the steering committee included representatives of government, the private sector, non-governmental organisations, affected parties, research, finance and utilities.

The initiative's final report was released in 2004. It provides, for each strategic priority, an assessment against the WCD principles and guidelines of South African policy and practice; highlights gaps in the policy and institutional frameworks and in operating procedures, and makes recommendations for improvements to policy, decision making and practice.

Trisa Hugo

INANDA DAM

The Inanda Dam site on the uMgeni River in the Valley of a Thousand Hills had been identified decades earlier as a good potential site for a dam. But it was only when Durban's water situation was again becoming precarious that investigations into constructing a dam there started anew. It was to be the fourth major dam to be built in the uMgeni River, after Nagle, Midmar and Prince Albert dams. A White Paper in this regard was first tabled in Parliament in 1981. It was initially proposed that the dam be constructed in two stages, with the first stage to have an initial capacity of 44 million m^3. Preparatory infrastructure, such as the construction of access roads and bridges, actually started in 1983.

Unfortunately, a large rural community were living in the dam basin. In 1981, it was estimated that around 25 000 people would have to be resettled to make way for the dam's water. The White Paper said people were to be compensated for loss of land and dwellings by "provision of alternate land and dwellings and by payment of compensation so that no person will be financially worse off." Matters were made complicated from a socio-political point of view by the fact that many of the people in the dam basin were considered 'illegal settlers'. As such there were uncertainties as to whether these households would be entitled to any form of compensation.

As a result of these challenges, construction of the dam did not get underway until 1984. It was then decided to build the dam to its eventual height as initially envisioned in phase two of the planned water resource development. This meant that the dam's capacity would be increased from an initial 70 million m^3 to 251 million m^3. Engineers settled on constructing the dam as a composite earth and concrete structure with a central mass gravity concrete section, which contains the spillway. The dam wall was built 54 m high with a total crest length of 608 m.

Regrettably, the engineering feats of the dam are overshadowed by the controversy surrounding the resettlement of communities whose land and houses were submerged by the dam's water. It is reported that, as a result of corruption and mismanagement, many impacted families did not receive the compensation due to them and, instead of proper reburial; the ancestral graves which had to be moved were all reburied in one mass grave – going against the culture of the local inhabitants. In September 1987, when severe flooding overtopped the works, many people, who had not yet been resettled, were forced to abandon their homes and flee for their lives, losing belongings and livestock. Many of these were moved to 'temporary' housing, which some are still living in decades later.

Bottom left: *Inanda Dam during construction. The dam wall is a composite earth and concrete structure, and is 54 m high.*

Bottom middle: *The Inanda reservoir. The dam has a surface area of 1 440 ha when full.*

Bottom right: *Inanda was the fourth dam to be constructed in the uMgeni River.*

DWA/eWISA

Teddy Gounden

DWA/eWISA

representative of members of the department, interested and affected parties, and various research fields to oversee the planning and construction of projects. Many recall the close collaboration between engineers and ecologists working together on these committees.

The committees were not open for public participation at this stage due to the confidential nature of many of the projects at the time. In order to prevent land speculation, DWA would often keep the planning of projects under wraps for as long as possible, only revealing its intentions to dam a river with the presentation of the relevant White Papers to Parliament. The White Papers, however, did publicly disclose the results of the environmental impact studies and any recommendations stemming from them.

South Africa's democratisation would bring many changes, including the introduction of mandatory environmental impact assessments for major infrastructure projects, including the construction of dams and weirs. Other alternatives, such as water demand management and wastewater reuse would now take precedence, with dams now considered a last resort.

PALMIET PUMPED STORAGE SCHEME

Soon after the second raising of Steenbras Dam in 1954 and the completion of Wemmershoek Dam in 1957, Cape Town again found itself running out of water. All eyes turned to the Palmiet, a short river (only about 74 km) which rises in the Hottentots-Holland mountains and winds south-west to its estuary near Kleinmond. The river had actually been identified as a possible water source as far back as the 1900s. A Mr St V Erskine, learning that the Town Council of Cape Town was investigating potential water supplies, looked to purchase land around one such a possible river and acquiring the water rights. (His plan was to sell the land and water rights back to the municipality for a profit). He passed by the Steenbras River 'a mere dribble he could jump over' and settled on the Palmiet River, which he had to cross by using a punt and wire rope. With financial backing of a London firm and some local investors Erskine started acquiring land in the catchment. However, the distance of the Palmiet River to Cape Town at that stage completely put off the municipality (it would have to be pumped 130 km – quite a task at that time). Erskine then offered to build the infrastructure himself, selling the water to the municipality at 7½ d per 1 000 gallons (4 546 ℓ), but even that did not persuade them. Instead Cape Town chose to develop the Steenbras scheme.

We do not know what happened to Erskine, but 70 years later DWA conducted investigations to survey possible dam sites in the Palmiet River to further augment Cape Town's water supply. Initially it was assumed that a long tunnel would be needed to convey the water from such a dam north-westwards under the Kogelberg and Hottentots Mountain ranges towards the city (both economically and environmentally unsound), however, the construction of the Steenbras Pumped Storage Scheme in 1978 opened up a new avenue. By incorporating this scheme to convey Palmiet water towards Cape Town the length of the conduit could be shortened.

The Palmiet River is a short, though ecologically important river, which has its source in the Hottentots-Holland mountains.


Helen Dallas

If the new scheme could be developed as another pumped storage scheme this would even make it more economical as pumping cost will be reduced by using the cheaper off-peak power. So the idea of the Palmiet Pumped Storage Scheme was born.

Eskom undertook the initial feasibility study into the viability of such a scheme, which was completed in 1979. Between 1978 and 1979 initial geological investigations were also conducted. Among others, this involved mapping of the geology from aerial photographs, ground surveys and the examination of boreholes. A complex geology was uncovered, and it was realised that much more geological data would be required in critical areas before a final feasibility study and cost estimate could be undertaken. Thus, a second geological study was undertaken between 1979 and 1980. Together these two studies produced 47 boreholes recovering 2 452 m of core material upon which the final feasibility study and cost estimate were based. As the scheme developed, it was found that Eskom's need for peak power generating capacity

Location of the Palmiet Pumped Storage Scheme in the Western Cape.

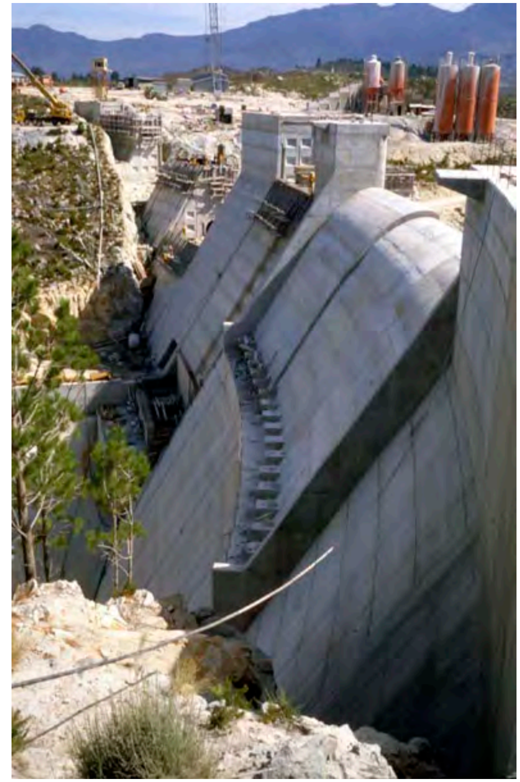
was more urgent than Cape Town's need for additional water and that the required generating capacity far outweighed the pumping capacity required for the transfer of the available water. As a result, the project took the form of a major hydroelectric pumped storage facility, with provision for the water transfer facility to be brought into use when required.

The final proposed scheme comprised two new dams with an active storage capacity of 15 million m³ each and a level difference of 285 m to be linked by a 2 km tunnel and 400 MW hydropower station. During the night and over weekends water would be pumped from the lower reservoir (Kogelberg) on the Palmiet River, to the upper reservoir (Rockview) situated on the watershed between the Palmiet and Steenbras rivers. During hours of peak electricity demand, electricity would be generated by releasing water from Rockview through the same waterway system to the power station and returning it to Kogelberg. Additional water over and above that required for generation would be pumped to the upper reservoir and released into the Upper Steenbras Dam. In this way, Cape Town's water would be augmented by about 25 million m³ a year.

DWA/eWISA

DWA/eWISA

A close working relationship was forged between members of Eskom and DWA involved in the scheme. Eskom became responsible for the design and construction of the power station and the waterways. In turn, the two dams together with the connecting canal and pipeline between the Rockview and Upper Steenbras dams became the responsibility of DWA. The scheme was approved in

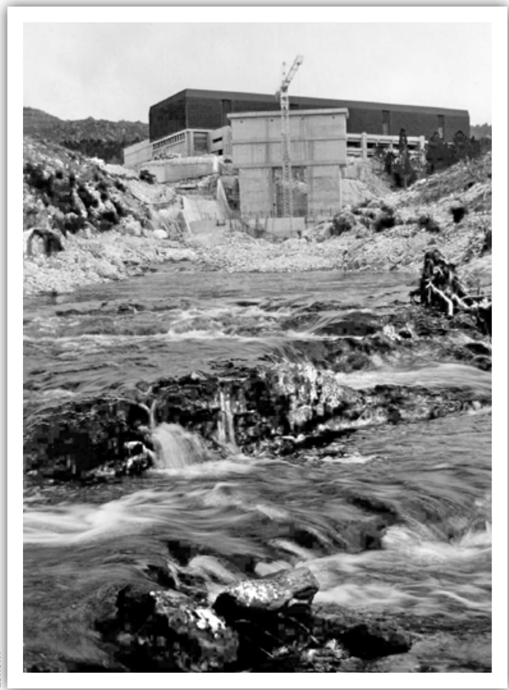


DWA/eWISA

***Above**: Kogelberg Dam nearing completion as part of the Palmiet Pumped Storage Scheme. The dam features a two-level spillway that is a 45 m-long uncontrolled crest in the river section.*

***Top left**: Work is undertaken on the bottom of the Kogelberg Dam, the lower storage unit of the Palmiet Pumped Storage Scheme.*

***Bottom left**: The inlet/outlet works in Rockview Dam comprise a reinforced/pre-stressed concrete tower, 68 m high. To ensure the tower's stability in the event of an earthquake it was necessary to provide 32 anchors, each of 3 000 kN capacity, anchored 20 m into the rock.*



1982 and construction started soon after. The consulting engineers on the project were Ninham Shand and VKE along with Elektroconsult Engineering Services of Switzerland. The main civil works contractors were Clifford Harris-Marti Tunnelling and Philipp Holtzmann of Germany, although the dams were constructed internally by DWA, with Peter Hume and Niel van Wyk of the department acting as resident engineers. Most of the workforce on the dams were transferred from the Jonkershoek Tunnel project and, at the height of construction close to 800 people worked on the dam sites. No housing could be established on site, and so everyone had to be accommodated in nearby Grabouw.

The environment was always going to be an important consideration of the project. The Palmiet runs through the Kogelberg Nature Reserve – a particularly sensitive area endowed with a wealth of fynbos species, and the pumped storage scheme was to be situated close by. DWA carried out environmental studies during the planning stages of the project, and it was during this time that a special environmental ministerial committee was found under the chairmanship of Dr Paul Roberts to investigate the potential environmental impacts of the scheme. The committee included wide representation from key institutions and individuals using water in the catchment.

Various alternatives were investigated while the committee identified pertinent issues requiring attention. A 'construction plan' was eventually drawn up with 54 recommendations on reducing the anticipated negative environmental effects of the project. This included demarcating work areas prior to the start of any construction activities; delineating specific eating areas in order to contain the spread of exotic Argentinean ants; inspecting construction materials to eliminate the possible introduction of non-indigenous plants; providing adequate toilet facilities for workers (largely unheard of on construction sites at the time); and devising a refuse control system. In addition, all polluted and sediment-carrying water had to be controlled and directed to special ponds before being released, while all disturbed areas had to be rehabilitated by replacing the topsoil that had been removed and stored (restoration was done concurrently with construction).

Even access roads were routed to avoid scenic outcrops of rock of sensitive plant growth areas and followed natural contours thus blending in with the landscape. The Palmiet Power Station – as well as the waterway linking the Rockview

Above: The Palmiet hydropower plant during construction. The plant has a total power generating capacity of 400 MW and can be brought on stream in less than 3 minutes, compared to coal-fired stations which require around eight hours to start generating power from cold start-up.

Right: Rockview Dam during construction. At the time, Rockview was the largest rockfill dam in the country by volume.

and Kogelberg dams – was placed underground. The recommendations were accepted and a resident environmental control officer was appointed to see that they were carried out. The main approach of the environmental programme was to prevent pollution. Interestingly, this preventative approach ended up saving as much as 1,5% of the anticipated project cost.

Rockview Dam

Situated 285 m above Kogelberg Dam, Rockview Dam being situated on a watershed virtually has no catchment area and is solely dependent on pumping to fill it. The dam basin consists of two natural depressions, with the larger one located on the southern side. These depressions are linked by an excavated channel. The main embankment, which is about 1 300 m long and has a maximum height of 48 m, was constructed mainly along the southern perimeter of the basin. This main wall was constructed of rockfill with a central clay core, and has a material content of 3,1 million m^3.

The secondary (or northern) embankment is about 670 m in length, and has a maximum height of 33 m. The natural topography borders the remainder of the basin. The northern embankment also has a clay core and rockfill outer zones but, in order to make use of the sandy overburden material within the dam basin, relatively large sandy transition zones were also incorporated. This embankment also houses the outlet system which comprises two pipes each able to discharge the required flow of 6 m^3/s at the lowest drawdown level. Each outlet pipe is of 1 500 mm internal diameter, and is provided with a hydraulically controlled slide gate for isolating purposes at its inlet and is terminated by a 1 400 mm sleeve valve. The outlet pipes are encased in concrete over the full length and the concrete encasement is founded on rock.

The quarry needed to provide the rockfill was the biggest ever established by DWA at that time and, when completed, Rockview dam was the largest rockfill dam (by volume) in the country. By constructing a rockfill dam DWA was ensured of a larger capacity structure created by the removal of material for the embankment from the dam basin. An estimated 2,5 million m^3 additional capacity was created by excavation of rockfill from the basin. At full supply capacity the water area within the dam basin is about 77 ha and the live storage capacity is 15 million m^3. Construction of Rockfill Dam kicked off in 1983 and was completed in November 1986.

Engineering features of Rockview Dam

Type: Rockfill with clay core (main embankment), and earthfill and rockfill with clay core (northern embankment)
Height above lowest foundation: 48 m (main embankment), 33 m (northern embankment)
Gross storage capacity: 16,8 million m^3
Crest length: 1 300 (main embankment), 670 m (northern embankment)
Material content of dam wall: 3,1 million m^3 (main embankment), 450 000 m^3 (northern embankment)
Type of spillway: None
Surface area at full supply level: 77 ha

Kogelberg Dam

The lower storage unit, Kogelberg Dam, is situated on the Palmiet River some 2 km downstream of the power station. It consists of a concrete arch/gravity wall in the river section with a separate earth embankment on a saddle on the eastern flank. The concrete wall has a total length of 182,5 m with a maximum height of 54 m above its lowest foundation level and contains 72 000 m^3 of concrete. The earth embankment is 850 m long, with a maximum height of 17 m, containing about 202 000 m^3 of earth. A 45 m-long ogee crest spillway permits passage of a 1 360 m^3/s flood, the energy generated being dissipated by a splitter-and-step system that aerates the nappe. A concrete apron protects the riverbed from erosion. River outlets were provided to permit the passage of compensation water to downstream riparian owners. All material for the construction was obtained from the Rockview reservoir basin. Initially, access to the dam site was difficult, and a 5 km permanent road had to be constructed before construction could start. Eventually building started in May 1983. A 6 t luffing cableway was used to construct the main concrete wall. The cableway towers were 263 m apart and 60 m high. Concrete was transported from the mixer to the cableway in two 2,25 m^3 buckets on an electrically-driven trolley. The cableway was able to reach 18 m to each side of its centreline, and was able to cover most of the dam

Engineering features of the Kogelberg Dam

Type: Mass arch gravity concrete with separate earth embankment
Height above lowest foundation: 54 m
Gross storage capacity: 17,3 million m^3
Crest length: 182,5 m
Material content of wall: 72 000 m^3 (concrete)
Earth embankment: 202 000 m^3
Type of spillway: Ogee (uncontrolled)
Surface area of reservoir at full supply level: 142,6 ha

wall. Concrete for the apron was placed by mobile crane.

Work in the riverbed was executed during the summer months when the flows were low and easily diverted. To stop the dam from impounding and thereby flooding the power station works in the basin, a temporary opening of 6 m by 6 m was left in the dam at a low level. This opening was successfully closed in April 1987 by constructing a 2,4 m-thick reinforced concrete wall at the upstream end. The dam was completed in July 1987, and spilled for the first time on 10 July that year. The entire project was officially inaugurated on 14 October 1988 and in that year won a SAICE Award for 'Most Outstanding Civil Engineering Achievement'.

A NEW ERA DAWNS

From the mid-1980s negotiations were held with exiled organisations such as the ANC. This, in addition to the fall of the Berlin Wall in 1989, led to eventual lifting on the ban of all freedom organisations on 2 February 1990. A few days later Nelson Mandela finally walked out of prison where he had spent most of his adult life. (During this time DWA was going through changes of its own having expanded to include forestry) Following extensive multi-party negotiations South Africa finally held its first democratic elections in April 1994. Of the 22,7 million eligible voters, 19,7-million voted in the elections, and pictures of the long trains of people queuing patiently outside voter stations were viewed the world over. Nelson Mandela was inaugurated as the President of South Africa on 10 May 1994.

Mandela's new Cabinet had a gigantic task before them, not least the portfolio of Water Affairs & Forestry (DWAF), to which Kader Asmal was appointed from 1994 to 1999. In 1994, an estimated 14 million people lacked access to basic water supply services (21 million did not have access to basic sanitation). These backlogs were especially severe in the poorer, rural areas


Guy Stubbs


Lani van Vuuren

***Top right**: In 1994, 59% of the country's people did not have access to even basic water supply.*

***Bottom right**: A woman fills her bucket at a public standpipe in Khayelitsha, Cape Town. Sustainable service delivery remains one of the greatest challenges in South Africa.*

of the country. South Africa now had around 460 large dams, but most of these were constructed to serve agricultural and industrial interests. Through its reconstruction and development (RDP) programme, government committed itself to taking corrective action to redress the country's legacy of discrimination and deprivation. The post-1994 era thus heralded a new chapter in the history of water resources development, namely constructing dams for people.

The critical roll-out of services was not the department's only challenge. It also inherited the infrastructure and employees of the former homelands' water departments. As a result, the number of employees now working for the DWAF swelled overnight from 6 000 to 27 000. The work put into addressing these challenges can be seen in the growth of the department's budget immediately following democratisation. DWAF's annual budget grew from a mere R490-million in 1994 to R2 352-million in 1996/1997.

In the first ten years following democracy, government rolled out basic water services to at least 13 million people. Of all South Africans with access to at least a basic water supply, 76% were now also receiving free basic water – in which every household is entitled to 6 000 ℓ/month of water free of charge. In a 2004 review of DWAF's progress Asmal said: "I look back on the extraordinary efforts of so many people, and am left with real optimism for the future of our country. People-centred government must succeed, and DWAF and its partners have played their part with commitment, insight and flair. It was an honour to be part of this process. Much still needs to be done, and there can be no disputing the government's resolve to do what needs to be done." (DWAF, 2004).

In 1997, the Water Services Act was promulgated, which addressed domestic water needs. Basic water supply was defined as a standpipe supplying 25 ℓ per person per day within 200 m of the household and with a minimum flow of 10 ℓ/s. This would be considered the lowest rung of the so-called water ladder to which government would strive. Another significant milestone was the promulgation of the NWA in 1998 after an extensive consultation process. Among others the new water legislation demanded a shift away from centralised control of water resources towards decentralised government and an overhaul of the responsibilities and systems of management. With the adoption of the Act irrigation boards were required to transform into water user associations, consisting of a broad spectrum of stakeholders, with the main aim of fostering dialogue and agreement on water resource management, allocation and development. Water could no longer be privately owned. Instead the NWA gives the State trusteeship of all water in South Africa regardless of where in the hydrological cycle the water is found.

Importantly, the NWA also, for the first time in the world, enshrines the basic right of people and the environment into law (the so-called Reserve). The environment can no longer be

The failed dam

In 1993, the 38 m-high Zoeknog Dam, constructed in the Mutlumuvi River, a tributary of the Sand River, failed on first filling. The dam was constructed for the Lebowa government mainly for irrigation purposes. Investigations revealed that the dam, which had received an award from SAICE the previous year, had failed because of poor construction.

Reconstructing the dam was later deemed uneconomical, and the remainder of the dam wall was demolished in 2000.

Kader Asmal


WRC archives

Prof Kader Asmal was born in Stanger, KwaZulu-Natal, on 8 October, 1934, as he put it "in the midst of the sugarcane belt". He was inspired by former ANC president Chief Albert Luthuli, whom he met while still at school and wanted to become a lawyer; however, his parents couldn't afford to send him to university so he became a teacher instead, qualifying in 1959. While he was teaching he earned his first BA degree through UNISA.

Shortly after, he went into exile, spending nearly 30 years in Britain and Ireland. Here, he became a banister, studying at the London School of Economics. He also taught at Trinity College in Dublin. He specialised in human rights law, winning the UNESCO Prize in 1983 for teaching in the field. It was also here that he met his wife, Louise Parkinson, with whom he had two sons, Rafiq and Adam.

He had always been a fierce believer in social justice and equal rights, and while abroad Prof Asmal became best known as an activist against the South African apartheid regime. He founded both the British and Irish Anti-Apartheid Movements, and was honoured by various awards and citations acclaiming his persistent campaigning. This included an honorary doctorate for services in human rights by Queen's University in Belfast in 1966.

Upon his return to South Africa he became a professor in human rights at the University of the Western Cape between 1990 and 1994. He became a key member of the ANC executive committee, and played an important role in constitutional negotiations prior to his appointment in 1994 as Minister of Water Affairs & Forestry in Nelson Mandela's Cabinet (a post he held until 1999).

In 2004, in a special publication celebrating the department's first decade of service delivery, Prof Asmal explained the challenge faced by his personnel at the start of the new democracy: "For so many South Africans, under apartheid, it was not that the well had run dry. Rather the wells had been commandeered. Through a doctrine based on the crudity of colour of skin, these South Africans had an outrageous assault on their health, their development, their dignity, by a government for whom they were invisible, for whom they were of no consequence... Democracy unleashed the extraordinary scope and energy in redressing the injustices of the past. It was a time of both exhilaration and of almost overwhelming challenges. We had a choice to be awed by the magnitude of the tasks at hand, or to roll up our sleeves and use innovation and dedication to make the differences demanded of us by the people of our country."

The department chose to tackle the challenges head on. Among Prof Asmal's initiatives were the Working for Water Programme, the Community Water Supply and Sanitation Programme, and the National Water Conservation Campaign. By 2000, ten million more people had been served with clean water.

Prof Asmal gave impetus to a conservation-based approach to water management in South Africa, including the notion that there must be a 'water reserve'. In 1998, the National Water Act was promulgated. It is described as 'the world's most comprehensive and visionary piece of water legislation'.

Prof Asmal was awarded the Stockholm Water Prize by King Carl XVI Gustaf of Sweden in 2000 in recognition of his efforts in the field of water management in South Africa. He also served as chair of the World Commission on Dams, which had the goal of developing international ethical standards and guidelines for all parties interested in large dams.

Between 1999 and 2004 he was Minister of Education. While at the helm of education, he pushed for mergers of a number of tertiary institutions, with the first successful merger being that of ML Sultan and Natal Technikon to form the Durban University of Technology. He left Parliament in 2007, and joined the University of Cape Town in the faculty of law in 2008. He authored and co-authored numerous papers, chapters in publications and books, including *Reconciliation through Trust: A Reckoning of Apartheid's Criminal Governance,* published in 1996.

Prof Asmal died on 22 June, 2011 at the age of 76 after suffering a heart attack while in hospital for a stomach ailment. In 2008, he wrote: "Water has been called the oil of the twenty-first century, with all the political and economic pressures accompanying that. Failure to ensure its judicious use will put paid to aspirations for the kind of economic growth required to provide our citizens with the basic rights they are entitled to under our Constitution. No fresh water, no economic growth, no social justice."

seen as a competing user of water, but is now entitled to the water it requires to sustain its important ecological functions. With the National Environmental Management Act, also promulgated in 1998, environmental impact assessments became a legal requirement for all major infrastructure considerations, including dams.

INYAKA DAM

One of the first dams constructed after 1994 was Inyaka Dam in the catchment of the Sabie River to supply water to the Bushbuckridge area, Mpumalanga. The dam was proposed after six years of investigation indicated the need for additional water resources to assure basic supply to around a million people. A drought situation in 1992 had left several hundreds of thousands of people with adequate water. It was also suggested that the water be used to stabilise irrigation activities in the area.

Interestingly, another motivation for the dam was to improve environmental flows to the Sabie River, one of the main rivers of the Kruger National Park. In its 1994 report the DWAF stated: "Unless steps are taken to ensure perenniality by augmenting low flows in the Sabie and the Sand Rivers, the natural riverine environments of the Sand River in both the Sabie Sand Game Reserve and the Kruger National Park and the Sabie River in the Kruger National Park will be irreparably damaged."

The Sabie River government water scheme, with the Inyaka Dam as central element, was approved by government in 1994. The dam was constructed on the Marite River, a tributary of the Sabie. Inyaka was to be situated on the farm of the same name in the Mapulaneng district near Bushbuckridge. Also forming part of this phase of development was a pump station at the dam and a rising main.

The dam was constructed to a maximum height of 53 m with an overall length of 550 m. The dam consists of earth-filled flank walls on either side of a central trough spillway and an outlet tower of reinforced concrete. Its trough spillway comprises a 58 m-long horseshoe-shaped overspill section at the upstream end followed by a 141,1 m-long sloping spillway chute that ends in a 64 m long stilling basin at the downstream end. The spillway itself is 263 m long in total, and was constructed mainly with rollcrete. A total of 1,4 million m³ of earth was used to construct the flanks, while

Engineering features of Inyaka Dam

Maximum height: 53 m
Length of dam wall: 550 m
Spillway discharge at high flood level (1:200 year): 1 300 m^3/s
Maximum capacity of outlet works: 30,5 m^3/s
Maximum spillway capacity: 3 000 m^3/s
Gross storage capacity: 123 million m^3
Surface area at full supply level: 795 ha

Tony Moore

The view from the Inyaka Dam wall. The dam comprises a 53 m-high earthfill embankment with a central trough spillway of mass and reinforced concrete.


Tony Moore


Tony Moore

Above left: *Inyaka Dam seen from the air.*

Above right: *Local employment was maximised at the Nandoni Dam construction site. At the height of construction around 350 people were employed.*

330 000 m^3 of concrete was used to construct the spillway and intake tower. The dam has a gross storage capacity of 123 million m^3. The dam was officially opened by Minister of Water Affairs & Forestry, Ronnie Kasrils, in 2002.

The project also involved the construction of a new bridge over the dam to replace one that was to be submerged by Inyaka's waters. Unfortunately, the new bridge, a 300-m seven-span pre-stressed concrete structure, collapsed during its launch in 1998, killing 14 workers. The bridge was later rebuilt.

NANDONI DAM

In the early 1990s severe drought resulted in the failing of boreholes in the Venda and Gazankulu region, in Limpopo, leaving millions of people with no other option but to fetch water from irregular water tankers. This prompted DWAF to start investigations into more sustainable bulk water supply to people in the area. This feasibility study, which was completed in 1996, investigated the water requirements of the area from Makhado in the west to Punda Maria on the border of the Kruger National Park in the east. The total population to be provided for was estimated at 950 000. It was also found that many of the rural water supply schemes in the region, constructed as part of the department's RDP would only be sustainable if a secure source of supply was established.

After investigating several possible engineering options it was decided to construct the Luvuvhu Government Water Scheme, with the Nandoni Dam near Thohoyandou as the main infrastructural element. Incidentally, Thohoyandou was also the centre of the highest demand from the dam. The dam would have a net storage capacity of 150 million m^3 – enough to supply the water requirements in the area. Parliament approved the project in 1997, and construction started soon after. At the time, it was one of the biggest projects undertaken by the post-1994 government. The dam was to be constructed on the Luvuvhu River, a tributary of the Limpopo River. In addition to the dam, other elements of the scheme included a 120 000 m^3/day water treatment works to be built immediately downstream

Tony Moore

Top left: *Nandoni Dam during construction. The composite dam is 2 215 m long and 47 m high, with a central uncontrolled mass gravity section of 200 m.*

Bottom left: *Nandoni Dam has secured water supply to nearly a million people in Limpopo.*

of the dam, as well as a pumping station to pump potable water upstream for use at Makhado and rural environs. A third element was the Xikundu Weir and water treatment works, with its associated bulk pipelines and service reservoirs.

Nandoni Dam was designed as a composite dam, 2 215 m long, with a central uncontrolled mass gravity section of 200 m. The dam is designed to accommodate a 200-year-flood of 1 980 m^3/s. The maximum height of the non-overspill crest above the lowest foundation is 47 m. The reservoir surface area at full supply level is 15,7 million m^2. The dam was designed and constructed by DWAF. Construction was done in such a way as to maximise the employment of people from the various local communities surrounding the dam site. Around 350 people worked on the dam at the height of construction. About 20% of the labour force were women.

Engineering achievements in spite, the dam is best known for the excellent manner in which the relocation of affected families was achieved. The villages of Budeli, Mulenzhe, Tshiulongoma and Dididi were directly affected by construction of the dam, and about 400 families had to be resettled as a result. According to the department's relocation policy, every relocated person had to be left in the same, or a better, financial position after relocation. Due to the impact the resettlement could have on these families, a relocation action plan was developed by the local communities with the assistance of DWAF and several consulting firms. A Community Action Committee liaised with the local community on how their

The place of the iron smelting furnace

Nandoni Dam was originally called Mutoti Dam, after the local village near which it is situated. Prior to the construction of the dam comprehensive archaeological studies were carried out in the dam basin as part of the environmental impact assessment studies. During these investigations, several sites of recent iron smelting dating from the 18th century were uncovered. Remains of furnaces were found on both banks of the Luvuvhu River. As a result, the dam was renamed 'Nandoni', a Tshivenda word meaning 'where the iron smelting furnace is found'.

Nandoni Dam has a full supply level of 15,75 million m³.

replacement houses should look, the removal of graves, arable land/agriculture crop production, and access to land for grazing, as well as the replacement of the Misanda (Chief's village), clinics, churches, community buildings and businesses. Smaller building contracts were awarded to previously disadvantaged building contractors. The three new villages were successfully constructed, including 465 new houses and community buildings. Basic water and sanitation services were also included. In addition, 1 000 graves were relocated, with over 30 km of roads built.

The final river diversion was closed on 2 March, 2004, and impoundment started. On 20 March, heavy rains were experienced in the catchment. Within three days the water level rose several metres. All four sleeve valves of the outlet works were opened to discharge nearly 20 m^3/s. Water also overflowed the spillway section and stopped all construction activities for about a month. The dam was finally completed in 2005. Construction of the distribution networks to bring water to all the recipients is still ongoing. However, it is hoped that the vision of bringing Nandoni Dam's water to thousands of needy people will be met sooner rather than later.

BERG RIVER DAM

The first dam to be constructed following the promulgation of the NWA in 1998, the Berg River Dam, was actually more than 100 years in the making. It was Thomas Bain who first suggested damming the Berg River as far back as 1886. Then, shortly after the South African War, the Cape Town municipality investigated several options to further augment its water supply. One of these investigated was the so-called Franschhoek scheme, and it was actually decided to secure options on the farms in the valley in 1902 to enable the Town Council to go ahead with such a project.

It is uncertain whether these properties were actually purchased, but in a December 1902 report submitted by the Cape Town water engineer it was recommended that a dam be constructed 30 m high to impound about 45 million m^3 of water. In July 1903, representatives from the Town Council lay the scheme before government in order to secure funds for its construction. The scheme was tentatively adopted only to be later replaced by the first Steenbras Dam.

Following the construction

TCTA

A map showing the elements of the Berg Water Project comprising the Berg River Dam and Supplement Scheme.

of the Palmiet River Pumped Storage Scheme, water demand in Cape Town was again starting to outstrip supply, leading to an in-depth study starting in 1985 into the future water needs of the area. There are over three million people served by the integrated Western Cape water supply system, which includes the Palmiet, Riviersonderend and other schemes. A total of 24 possible supply options and alternatives were identified and investigated during the study, including desalination and groundwater options. Following the compilation of a short list based on technical, financial, environmental and social factors, the decision fell on the Berg Water Project. At the centre of this scheme would be what was then known as the Skuifraam Dam (later renamed the Berg River Dam), to be constructed in the Berg River outside Franschhoek. This project would increase the yield of the Western Cape water supply system by 81 million m³ or 18%.

Environmental impact assessment (EIA) studies were initiated by DWA, with an EIA report produced for decision-making in 1996. Then Minister of Water Affairs & Forestry Kader Asmal approved the scheme on

Sue Matthews

Sue Matthews

Top left: *In November 2005 the Berg River was closed off and diverted temporarily through the outlet conduit shown here.*

Bottom left: *A scale model shows how the Berg River Dam is prevented from overflowing. Excess water spills over a 40 m spillway and flows down a deep concrete chute to a 'ski jump'. After being thrown 30 m up into the air, the water lands in a plunge pool 80 m away.*

TCTA

The south section of the Berg River Dam intake tower is an open vertical shaft (wet well) with multi-level gates for drawing water from the dam for high flows/floods (up to 200 m³/s) as required by the Ecological Reserve.

condition that the City of Cape Town simultaneously implement a water conservation and water demand management programme. The Berg Water Project therefore became the first bulk water supply scheme in the country to be linked to water demand management. On 8 August, 2000, then Minister of Environmental Affairs & Tourism, Valli Moosa, officially rejected all appeals lodged regarding environmental aspects of the proposed scheme and approved its implementation in terms of environmental legislation. The project then received the final nod from DWAF. Cabinet finally gave its approval to the project in 2002. In the meantime Cape Town residents were subject to stringent curbs in water use as a 100-year drought hit the city.

TCTA was appointed to act as the implementing agent on behalf of DWAF, with the design of the dam being undertaken by the Berg River Consortium, which included Knight Piésold, Goba and Ninham Shand. Funding was provided through long-term loans from the DBSA, the European Investment Bank and ABSA. The contract for the construction of the dam was awarded to the Berg River Project Joint Venture (a consortium comprising Grinaker-LTA, Group 5, WBHO and Western Cape Empowerment Contractors) in June, 2004. This marked the official start of construction on the dam, with construction of the access roads having started a few months before. The building schedule was particularly tight as the dam had to be completed in time to start impounding water by the winter of 2007 to prevent critical shortages in the Cape Town supply area.

The dam site is located on the upper reaches of the Berg River in the former La Motte forestry plantation in the Drakenstein Mountains, 8 km outside Franschhoek. Much of the 560 ha of land required was already State-owned, and thankfully there were no resettlement concerns. Various service components for the project were provided, including the construction village of 80 houses with sports fields at nearby La Motte (At the conclusion of the project, the village was transferred to the Stellenbosch Municipality. Proceeds from the sale of the houses were used to fund further housing development in the area)

The embankment footprint was the first area to undergo bush-clearing to enable the contractor commence foundation preparations. As part of the latter, the entire dam footprint

***Right**: An aerial view of the concrete-faced rockfill Berg River Dam during construction. The dam wall is 65 m high, 990 m long and 220 m wide.*

***Below**: The Berg River Dam during construction in 2007. The dam has a gross storage capacity of 130 million m³.*

TCTA

TCTA

TCTA

TCTA

Above: *The Berg River Dam is the first large in-stream dam in South Africa required to make both low and high flow Ecological Releases.*

Left: *The Franschhoek First policy ensured that maximum employment was provided to people living near the Berg River Dam.*

Below: *A panoramic view of the Berg River Dam construction site in 2007.*

was stripped of topsoil to expose the underlying conditions. The ground conditions encountered on the right bank proved especially challenging, requiring special dynamic compaction.

Dam optimisation studies identified a concrete-face rockfill dam as the most appropriate type considering the site, founding conditions and time constraints. The dam was constructed 65 m high, 990 m long and 220 m wide with a gross storage capacity of 130 million m^3. More than 3,1-million m^3 of earth was excavated during construction, most of which now forms part of the earthfill embankment. The spillway is a side-channel ogee with a crest length of 40 m. It discharges water via a reinforced concrete chute into a flip bucket ahead of a plunge pool, before returning floods to the river. A supplement scheme makes up the other part of the Berg Water Project, comprising an abstraction works on the Berg River, located downstream below the confluence with the Dwars, Franschhoek and Wemmershoek rivers. This includes a diversion weir across the Berg River, a bypass channel, a balancing dam, a pump station, a power line and 9,5 km of pipeline.

In accordance with post-1994 legislation, the Berg River Dam design had to accommodate strict environmental requirements, particularly the Environmental Reserve. This resulted in the development of the dam's unique, unusually large 63 m-high (wet and dry well) intake tower connected to the outlet works. The intake tower is designed to cater for two distinct flow releases namely small releases (0,3 m^3/s to 12 m^3/s) and large releases (up to 200 m^3/s). These releases occur continually and are adjusted in magnitude as required by the Ecological Reserve, depending on the inflow into the Berg River Dam.

The intake tower is divided into two sections: wet and dry well sections. The north section is a dry shaft equipped with multi-level inlets with pipes and valves, which

TCTA


TCTA

The Berg River Dam intake tower is divided into two sections. The north section is a dry shaft (well) equipped with multi-level inlets, pipes and valves which provide the facility for drawing water into the Cape Town supply system and provide low flow environmental releases.

provides the facility for drawing water into the Cape Town supply system and provides for low flow environmental releases. The south section is an open vertical shaft (wet well) with multi-level gates for drawing water from the dam for high flows. These large flow releases mimic natural flood events. Another interesting feature is the fact that indigenous flora was planted on the downstream face of the dam wall which is visible from the main road into Franschhoek. This ensures that the dam and associated structures blend in more with the surrounding landscape.

Through its Franschhoek First policy, the project aimed to maximise the employment and development opportunities to the valley and surrounds. In line with this an employment information desk was established through which the local community could access job opportunities and training. The dam was successfully completed in late 2007, meeting its impoundment targets. A year later it was full thanks to good rainfall. The Berg River Dam was officially inaugurated by former President Kgalema Motlanthe in 2009.

INGULA PUMPED STORAGE SCHEME

The cement had hardly been dry on the Palmiet Pumped Storage Scheme when Eskom started investigations into its next pumped storage venture. Initially more than 90 potential sites were investigated, culminating in the short-listing of three sites. Eskom eventually settled on a site straddling the Klein Drakensberg escarpment and spanning the farms *Braamhoek* and *Zaaifontein*, some 40 km northwest of Ladysmith, KwaZulu-Natal and *Bedford* farm, located some 23 km east-north-east of Van Reenen, in the Free State. The pumped storage scheme itself would be located in KwaZulu-Natal. With a capacity of 1 332 MW, Eskom's latest pumped storage scheme, Ingula, will be the largest of its kind in South Africa. The scheme was designed to complement the mainstream coal-fired power stations by feeding electricity into the national grid during peak demand periods.

Development of the scheme started in earnest following environmental authorisation in 2002. The main consultants, Braamhoek Consultants Joint Venture, comprising Knight Piésold, SSI and Arcus Gibb, started basic design in

Eskom's new Ingula Pumped Storage Scheme is being constructed in the breathtaking Little Drakensberg on the border between the Free State and KwaZulu-Natal.


Lani van Vuuren

From Braamhoek to Ingula

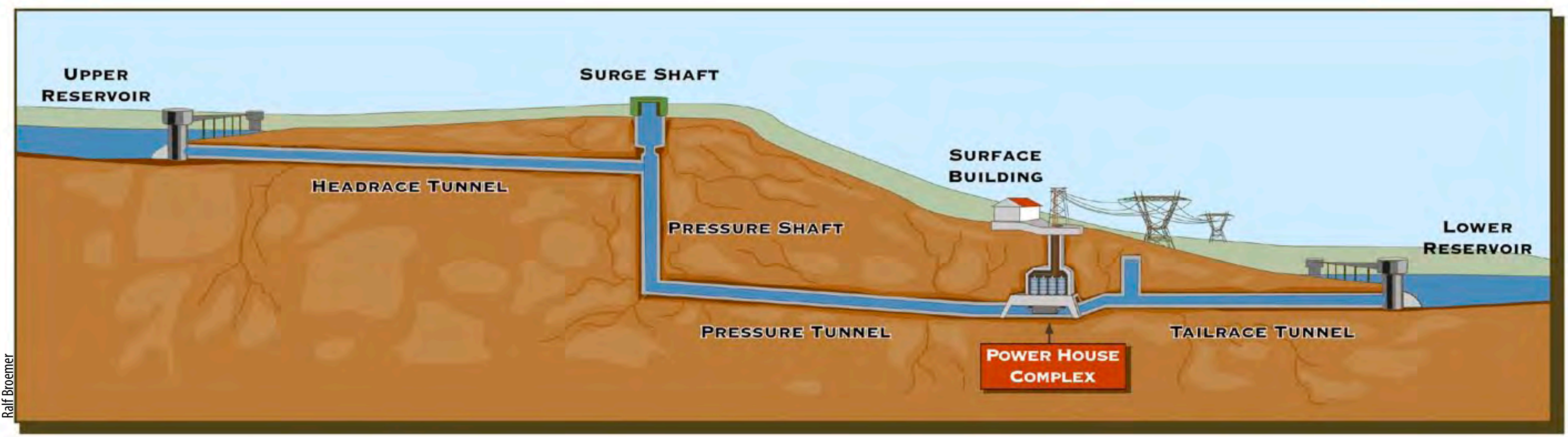
The Braamhoek Pumped Storage Scheme was renamed Ingula in March, 2007. The Zulu word refers to the creamy contents of the top of a milk calabash. The name, according to Eskom, is inspired by the mountains and the river waters, which represent the rich cultural symbols and traditions of the local people on both sides of the border.

2004. The scheme basically comprises two reservoirs situated about 6 km apart, with an elevation difference of 470 m between them. Unlike the Drakensberg Pumped Storage Scheme, Ingula is designed exclusively for the purpose of generating peak-time electricity, and will not be used for the inter-basin transfer of water. Therefore the dams are relatively small and water will only be drawn to top up the reservoirs. The reservoirs are connected by underground waterway tunnels, an underground powerhouse complex and access tunnels. Access roads and a new substation were also constructed as part of the project.

The first construction contract was awarded to the Concor-Ukhozi Joint Venture in 2005 for the construction of the 873-m long exploration tunnel. The 5 m by 5 m horseshoe-shaped tunnel had a gradient of 1:8 and led to the underground powerhouse complex. As the name implies, the exploration tunnel was initially planned for investigating support materials, exploratory drilling and for the installation and monitoring of instrumentation to provide geotechnical data for design purposes. Since construction of the machine hall started prior to the completion of the main access tunnel initially formed the only access for the excavation of the underground works. This tunnel was completed in 2007.

The geology of the area has proven quite challenging. The area is underlain by sedimentary rocks (mostly sandstone and mudrock) of the Ecca and Beaufort Groups of the Karoo Supergroup intruded by dolerite dykes and sills, with some faulting occurring. About 137 boreholes were drilled around the site to explore the underlying rock formations in the dam foundations, along the various tunnel alignments, potential quarry sites and cuttings for the access roads. By studying this core material, the project team gained important insight into what lay where. Nevertheless, foundations conditions of the two dams still proved tricky.

The Ingula Pumped Storage Scheme.



Ralf Broemer

Lani van Vuuren

Bramhoek Spruit prior to the construction of the Bramhoek Dam. Compensation flows are expected to ensure uninterrupted flow to downstream users.

Lani van Vuuren

Construction of the 873 m-long, 5 m by 5 m exploration tunnel took place between 2005 and 2007.

Upper reservoir (Bedford Dam)

In 2008, the contract to construct the upper and lower reservoirs of the Ingula Pumped Storage Scheme were awarded to the Bramhoek Dams Joint Venture, comprising Concor Roads and Earthworks (now part of Murray & Roberts), WBHO, Edwin Construction and Silver Rock. The team moved onto site in April of that year, and construction of the dams started soon thereafter.

Situated in the top catchment, the upper reservoir, Bedford Dam, is located in the headwater tributary of the Wilge River, which flows into the Vaal River system.

***Below left**: The Bedford Dam site early during construction. All the rockfill material for the dam was sourced on site, with the main quarry being located in the reservoir basin.*

***Below right**: Bedford Dam in June 2010. Rockfill was completed in April of that year with construction of the face slab starting a month later.*

The concrete-faced rockfill dam has a length of 577 m and a height of 49 m, with an 80 m-long emergency spillway. The concrete face was designed to accommodate movement caused by the expected rockfill settlement after construction when the dam filled.

Since the Bedford Dam area serves as the upper catchment of the Wilge River, which eventually flows into the Vaal River, maintaining the water quality during construction was of paramount importance. Excavation also had to take place through an existing peatland. Delays of almost two months were experienced in getting down to bedrock when the contractor encountered peat in the riverbed. During excavation and construction, water analyses were carried out every month at a SANAS accredited laboratory which added much value in keeping up the quality of the works in progress. Water had to be deviated through the site in such a manner as to not impact on the wetland situated downstream. A diversion channel was consequently constructed between the outlet conduit situated on the left bank of the river and the riverbed comprising a 5 m saturated peat layer. Once this channel was completed a pre-cofferdam was placed across the river to deviate the water through the channel. As rockfill was used for this cofferdam the contamination of the water with sediment was limited. At the

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downstream side of this pre-cofferdam the main cofferdam was then constructed to commence with the peat excavation.

The latter proved to be a major challenge due to the high water table. It was eventually decided to drill four dewatering holes to draw down the water table. All of this unpolluted water was returned to the downstream wetland. The excavation of the intake structure, conduit and outlet works was done concurrently with the peat excavation as the conduit had to be completed to enable the placing of rockfill to continue. The conduit was a challenging aspect in terms of formwork as it starts off as a rectangular section at the inlet tower, changing to a circular shape diverting into two horseshoe conduits and ending as a rectangular section at the radial gates. Specialist sub-contractors were used to design and manufacture the formwork. Once the conduit was completed it was covered with rockfill.

Requiring close to a million m^3 of rockfill and 27 000 m^3 of conventional concrete, the dam's capacity at full supply level is 22,43 million m^3, covering 225 ha. The dam also boasts a 52 m-high intake tower with a 1 m-diameter reinforced concrete outlet conduit along with a 15 m by 45 m energy dissipating basin. The outlet works are capable of a range of discharges at all impounded water levels to meet the strict release requirements to accommodate the conditions set out in the environmental authorisation. The intake tower, on the other hand, consists of a circular structure with two square sections to house the two intake pipes and the inlet to the conduit. Purpose-made gang formwork was used as climbing formwork for the 2 m lifts.

Careful management of the quarry site was required to ensure constant supply of the different grades of rockfill for the dam wall placing. The geology of the quarry was intricate as mudrock and sandstone occurred in layers. Mudrock could not be used and the threat of contamination

__Below left__: Bedford Dam during construction in 2009. The outlet tower can clearly be seen. The outlet works are capable of a range of discharges at all impounded water levels to meet the strict release requirements as set out in the environmental authorisation.

__Below right__: The completed Bedford Dam. About a million m^3 of rockfill went into the dam wall.

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Discovering the past

Excavation of the foundations for the Bedford Dam yielded more than just interesting geological conditions. One area (which was consequently dubbed 'Jurassic Park' by the construction team) yielded in excess of 150 fossil finds. Some 19 t of rock was blasted from the area to allow for investigations by palaeontologists. The process of removing the surrounding rock from the fragile fossils was started in January 2011. Following excavations the animal fossils were sent to the Bloemfontein National Museum for investigation while some fossilised tree material was sent to the Bernard Price Institute for Paleontological Research at the University of the Witwatersrand.

According to Dr Jennifer Botha-Brink, Head of the Karoo Palaeontology Department at the Bloemfontein National Museum, it is thought that the fossils mostly stem from the late Permian period, which makes them in the order of 255 million years old. The fossil material appears to comprise a massive bone bed, consisting mostly of herbivorous vertebrates known as dicynodont therapsids. At the time of writing not all the material had been identified but at least two genera were present, namely Dicynodon and Dinanomodon. The latter genus is particularly interesting because it is very rare – only a handful of skulls have been discovered to date. At least two skulls of Dinanomodon are present in this bone bed. In addition, some skeletal remains that may also be of Dinanomodon have been recovered. If the skeletal material turns out to indeed belong to Dinanomodon it will be the first skeleton found for this genus, and will be a very exciting find indeed.

Other vertebrates that are present include Gornopsian therapsids – dominant predators of the time, which would have fed on the Dicynodont herbivores. The hindquarters of some kind of reptile had also been recovered, which still needed to be identified.

An artist impression of a typical gornopsian.

required special attention. A major milestone was reached in April 2010, when the rockfill on the left flank reached its top level. Construction of the main concrete face slab started a month later. By the time it was completed the massive slab, which is only 300 mm thick, covered an area of around 3 ha. It consists of 32 panels, each 15 m wide. The longest panel is 81 m long. Around 9 000 m^3 of concrete was used for the slab.

At the height of construction around 680 people worked on the dam. In winter the project team had to battle wind speeds of up to 140 km per hour and temperatures as low as -10°C. The extreme freeze-thaw conditions were taken into consideration when the face slab concrete mix was designed. To prevent cracking a special chemical (air retainer) was mixed into the concrete which created tiny air bubbles throughout the concrete paste. The air bubbles acted as capillary breaks and provided spaces into which the pressure exerted by freezing water could be dissipated.

While the dam has been completed it will only be filled when the project machinery for the underground power complex is commissioned in December 2013. This dam was awarded a CESA Excellence Award in 2011.

Lower reservoir (Bramhoek Dam)

The 37 m-high single-curvature Bramhoek Dam is located in a very distinct poort in the headwater of the Klip River (the Braamhoek Spruit), which flows southeast into the Thukela River. The spillway is a stepped chute located on the downstream face of the dam, with a 40 m-long crest length ogee, stepped spillway. The dam has a length of 337 m and a crest width of 5 m. Bramhoek Dam has a full supply level of 26,3 million m^3 and a surface area of 240 ha.

The first major challenge encountered at the Bramhoek Dam site related to the ground conditions – the site is in a relatively narrow valley where the Bramhoek Spruit has cut through a massive horizontal dolerite sill into the underlying mudrock. Initial earthworks encountered innumerable huge dolerite boulders embedded in clay which required blasting and the use of 70-t excavators to reach suitable foundations for the dam wall. As a result of these conditions, an additional 6 m of excavations had to be undertaken.

Following excavation construction started with the intake outlet works' 162 064 m^3 bulk excavation. This was because the construction of the intake tower works was on the critical path of the project, with this structure leading to the balance of the dam wall where the rollcrete works were to be constructed. The intake tower with outlet works consists of 12 000 m^3 of conventional structural and mass concrete and two flood release outlets at the bottom, each with a diameter of 2,8 m as well as a 1 m outlet for environmental releases. Since the tower incorporates hydromechanical components and internal structures, it required a high structural integrity, which was provided by 350 t of reinforced steel and conventional concrete.

Large volumes of concrete were poured for each lift, at one time reaching a record lift of 1 000 m^3. This was achieved using

__Right:__ A 400 mm group-enriched rollcrete was used to construct Bramhoek Dam. Following placement the rollcrete was compacted to a smooth finish using vibratory rollers to retain a slightly spongy finish.

__Below:__ The completed Bramhoek Dam.

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Top left: *Another view of Bramhoek Dam, taking in 2010. At the height of construction about 350 workers were employed on this dam.*

Bottom left: *An aerial view of Bramhoek Dam during construction in early 2010. The lower section of the right bank had pour ground conditions which meant that the concrete founding level had to be about 12 m deeper than originally anticipated.*

two 36 m boom placing pumps. Another challenge was keeping the concrete placing temperature below the specified 23°C. This was achieved by pouring at night and by cooling the aggregate using two chiller plants where water was cooled down to 4°C and then sprayed into the aggregates. This water was also used in the batching process. The first tower pour was completed in March 2009, with the final pour being completed in October that year. At completion the structure was 32 m high with a footprint of 20 m by 34 m. A 10 t capacity portal crane was installed at the top of the intake tower to operate the maintenance gate and fine screens while a 16 t gantry crane was placed at the outlet house for maintenance purposes.

A 400 mm group-enriched rollcrete was used to construct the main dam wall. Although this mix has been used in countries such as China, Jordan and Syria, it had never before been used in South Africa so, initially there were some misgivings about its implementation. However, once the site team had mastered the process, the speed and simplicity of the operation quickly overcame the reservations. The first major challenge with regards to the construction of Bramhoek Dam concerned optimisation of the mix design for the material. The rollcrete aggregates and other processed stone materials were mined in a quarry on site from the dolerite sill on which the dam itself is founded. This mix had to be modified five times before a suitable product could be found.

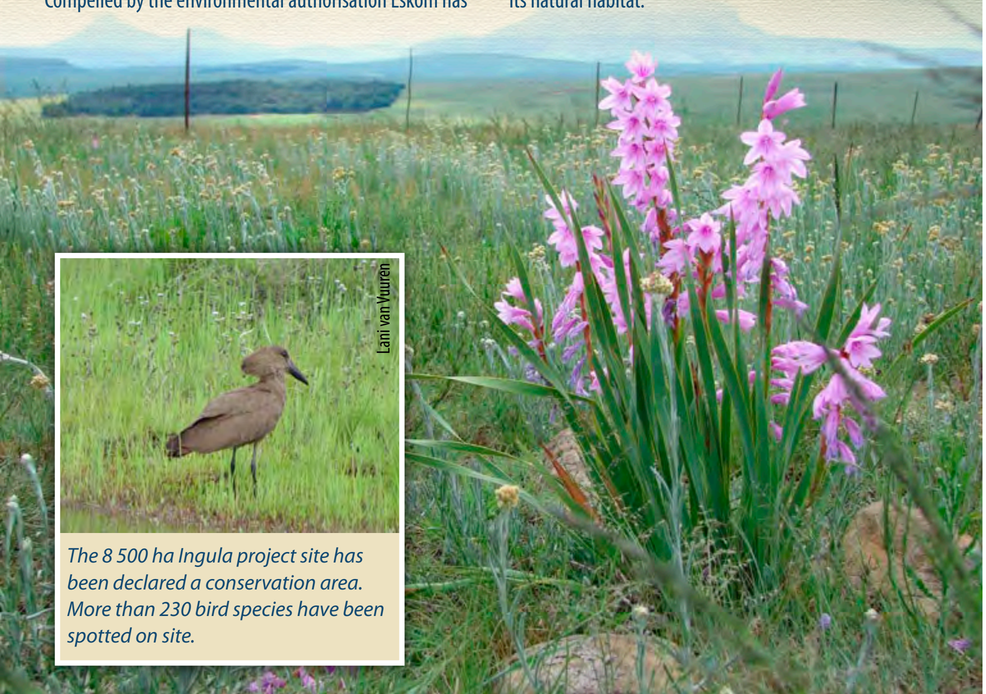
Placing and compaction of the rollcrete were controlled very tightly to limit the time from batching to final compaction to not more than 40 minutes. This resulted in a rollcrete which did not segregate and retained its moisture, thus remaining workable for longer. The rollcrete was transported to site in articulated dump trucks carrying about 10 m^3 of rollcrete at a time. Once the surface to be covered had been cleaned with a high-pressure air or water hose, the excess water was blown away and rollcrete could be placed at the most distant point from the access. Dozers then levelled the rollcrete to an uncompacted thickness of about 300 mm. Following placement the rollcrete was compacted to a smooth finish using 16 t vibratory rollers to within a metre of the upstream and downstream formwork to retain a slightly spongy finish. Grout with a water

Conserving the future

Conservation organisations initially opposed the construction of the Ingula Pumped Storage Scheme. Sparsely populated, the 8 500 ha sites features mainly grasslands with wooded gulleys along the mountain streams. The biggest bone of contention was a 240 ha peatland situated in the Bedford Dam catchment area. This wetland is home to a number of bird species, many of which are either critically endangered, near endangered or at risk, including the extremely rare white-whinged flufftail, a migratory bird of which there is estimated to be less than 750 left in the world. About 5% of the total wetland area will be covered by the Bedford reservoir.

Following negotiations, various non-governmental organisations are now working together with Eskom to improve conservation in the area. A team of full-time professional environmentalists monitor all activities on site. Compelled by the environmental authorisation Eskom has turned the entire site into a conservation area and, at the time of writing, it was seeking authorisation to have the site declared a nature reserve. Several farms in the area were purchased for this objective. This has increased the present extent of conserved grasslands by more than 80%. In addition, the power generator is rehabilitating eroded areas, halting alien plant encroachment and rehabilitating all areas affected by construction. Several indigenous and medicinal species of plants were also removed by representatives from the Pietermaritzburg Botanical Gardens for replanting in the gardens.

Care has been taken to ensure that structures blend in with the surrounding landscape. There will be no elaborate landscaping around the buildings. Materials from the area will be used to further soften any visual impact. All construction of temporary work areas will be restored to its natural habitat.



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The 8 500 ha Ingula project site has been declared a conservation area. More than 230 bird species have been spotted on site.

to cement ratio of 0,9 was then poured over the uncompacted rollcrete with a 400 mm-wide strip from the facing formwork and allowed to seep in for roughly five minutes. This strip was then vibrated with immersion poker vibrators pushed into the underlying rollcrete layer.

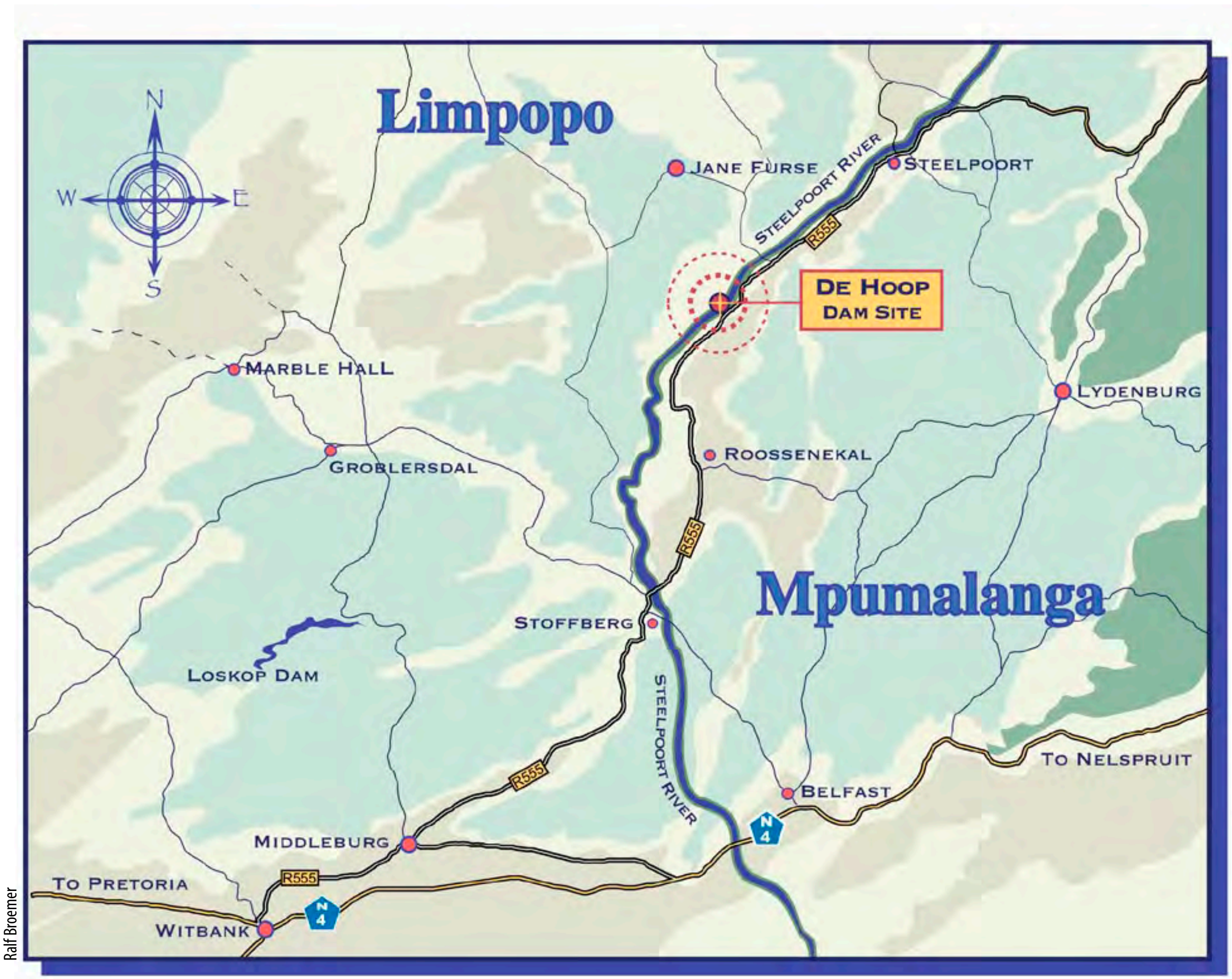
The dam wall height has been selected to provide a 0,5 m freeboard to accommodate flood inflows, such that a 1:200-year flood will not cause the dam to spill. Nonetheless, flood inflows will normally be released downstream through the outlet works to minic the natural flow of the stream. The dam therefore attenuates the effects of natural floods. Bramhoek dam was successfully completed in April 2011, and two months later was already full.

Similar to the Drakensberg PSS power generation will be conducted entirely underground. This underground powerhouse complex consists of a machine hall, a transformer hall and associated tunnels, shafts and caverns. The machine hall, which is 26 m wide and 184 m long, will house four 333 MW single-stage, reversible Francis pump turbine units. This cavern is reportedly the largest of its kind in the world. By the end of February 2011, about 5 million tons of rock had already been removed from the underground works, and construction was progressing according to schedule. The first items for the complex were due to be installed during 2011. The main access tunnel contract was awarded to CMC Mavundla, a joint venture of South African and Italian companies. The project is expected to come on line in 2014.

DE HOOP DAM

The biggest dam to be constructed in South Africa in the last 20 years, the De Hoop Dam is set for completion in 2013. The dam is located on the Steelpoort River, about 40 km east of the town of Roossenekal, in one of the poorest regions of the country. De Hoop forms part of the Olifants River Water Resources Development Project, and was first announced in the State of the Nation Address by former President Thabo Mbeki in 2003.

After extensive investigations in which DWA considered several alternative water supply selections it was decided that the dam would be the most viable option to meet the medium- to long-term domestic water requirements of the



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The location of the De Hoop Dam site in Limpopo.

hundreds of thousands of poor people in the Sekhukhune area as well as expected increased mining activity. Originally the dam was also to supply Eskom's proposed Tubatse Pumped Storage Scheme, however, this scheme has since been shelved.

The dam project was approved by Cabinet in 2004, and construction started in 2007 following a revised Record of Decision by the then Minister of Environmental Affair & Tourism in 2005. Among other environmental considerations the dam had to be designed to enable it to release the required volumes of water needed to meet the Environmental Reserve. This is extremely important, as De Hoop is located upstream of the Kruger National Park. The dam is a true State affair, being financed by Treasury and designed and constructed by the DWA.

Before the construction of the dam wall could start the project team first had to tackle the realignment of the R555, which would be inundated by the dam's waters. The road was relocated over a length of 20 km to higher ground on the western side of the dam basin. To allow DWA to continue work on the right flank of the dam, where the original road was situated, a temporary road was constructed and surfaced across the coffer dams to accommodate the traffic while the road realignment was being completed. This meant that, for the first time in South Africa, the general public was able to drive through the centre of a dam construction site! The new road section was completed in 2009.

Construction has not been without its challenges. Among others, geological conditions were found to be more varied than anticipated and the foundations encountered were generally poorer than expected. As a result, excavations were undertaken up to 12 m below design foundations, with close to 500 000 m^3 of material excavated for foundations. This delayed the project by almost a year, giving rise to the need for an accelerated programme. The workforce is working three shifts, 24 hours, seven days a week, with a one-and-a-half hour overlap between shifts. Once completed the dam wall will be 88 m high above the lowest foundation. In addition, the site is located in the middle of a valley with steep slopes of loose soil running either side, which makes access extremely limited. The river diversion also runs through the site. Another challenge has been continuous labour unrest, which has delayed work for months at a time. The problem generally

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The multi-level outlet structure of De Hoop Dam. The outlet works will have a maximum capacity of 20 m^3/s – 15 m^3/s of which is to meet Environmental Reserve requirements.

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DWA

Top left: *The crusher plant in operation in October 2010.*

Bottom left: *The last of the crusher plant waiting to be removed almost a year later. The area will eventually be inundated by water once impoundment starts.*

seems to be the employment of local labour, the majority of which have never been exposed to a formal working environment. More than 1 000 people are employed on the dam site, of which 80% are from the local community and 27% are female.

De Hoop is being constructed as a rollcrete gravity dam with a vertical upstream face. It is the highest rollcrete dam yet to be

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constructed in South Africa. The dam wall will be 1 020 m long and is slightly curved to make the best of the existing topography. The dam lends itself to the mass production of rollcrete and entails delivering the concrete to site in trucks or on conveyors where it is spread by a bulldozer and then compacted with a vibratory roller. Due to the large volumes of concrete required a 500 m^3 capacity batching plant was established on site, while a quarry was set up inside the dam basin. The first concrete was placed in May 2008. In November 2010 a new national record was achieved at the De Hoop site when 103 600 m^3 of concrete was placed in only 23 days – more than double the previous record of 40 600 m^3 placed in a month at Wolwedans Dam. The peak hourly production during this time was 329 m^3. Around a million cubic metres of concrete will eventually be placed at De Hoop.

A locally developed rollcrete mix is used. The mix design, known as immersion vibrated rollcrete, is a wet high-paste concrete containing 30% fly ash. Being more workable the mix is easier to compact and accelerates construction. The denser concrete is suitable for the upstream face of the dam wall. The addition of conventional concrete (so-called skin concrete) on the face of the dam to form a water barrier is no longer required.

Engineering characteristics of De Hoop Dam

Type of dam: Rollcrete gravity
Maximum height of dam above lowest foundation: 88 m
Maximum crest width: 7 m
Total length of dam wall: 1 020 m
Type of spillway: Uncontrolled central gravity
Length of spillway: 110 m
Spillway crest length: 110 m
Design flood discharge: 1 140 m^3/s
Total excavation volume: 500 000 m^3
Rollcrete volume: 500 000 m^3
Conventional concrete volume: 250 000 m^3
Gross capacity at full supply level: 347 million m^3
Surface area when full: 1 690 ha

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Above: *The enormous 2 m-diameter stainless steel outlet pipes. All the pipes are being manufactured at the DWA Central Construction workshops in Jan Kempdorp.*

Right: *The initial width of the wall allowed trucks to move around easily. This has become more difficult as the wall rose and became narrower.*

A multi-level outlet will ensure that water will be released from the upper levels of the dam to ensure that the water is sufficiently oxygenated and warm enough not to have negative impacts downstream. The twin stacks of multi-level offtakes have a combined capacity of 20 m^3/s. The outlet works is situated on the right bank between the spillway and the right bank overspill section and are being constructed

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Providing work opportunities for local people have been an important aim of the De Hoop project. Around 80% of the workforce has been recruited from the area.

DWA/Piet Duminy

A general view of the upper left bank at De Hoop Dam as it stood in June 2011. Note the specially-designed scaffolding.

DWA/Piet Duminy

General view of the De Hoop Dam wall in October 2011.

DWA/Piet Duminy

The De Hoop Dam spillway as it stood at August 2011. The special rollcrete mix negated the need for skin concrete.

DWA/Piet Duminy

Supports being placed to construct the valve control room roof.

DWA/Piet Duminy

The Gauging weir upstream of the De Hoop Dam during construction.

Where have all the wildflowers gone?

De Hoop Dam is situated in a relatively unspoilt, environmentally sensitive region. For this reason, extensive environmental investigations were required. The original Record of Decision, granted by the Department of Environmental Affairs & Tourism (now the Department of Environmental Affairs) in 2004, was followed by five appeals against the decision. As a result, a revised Record of Decision was issued in 2005 incorporating more stringent environmental requirements. An independent environmental control officer was appointed, and on-site compliance has been around 95%.

The mixed bushveld of the Steelpoort River valley where the De Hoop Dam is located, presents a wide plant diversity, including many rare species. As a result, an agreement has been reached with non-profit organisation, Operation Wildflower, to remove indigenous plants from designated areas prior to inundation. Since 2008, around 9 000 indigenous plants have been transplanted in private gardens from more than 70 species. The organisation reports that over 250 t of plant material have been removed from the De Hoop area. Of the species collected, 33 species yielded less than ten plants each while in five cases only one specimen of a particular species was recorded.

with the aid of ten cranes.

At full supply level the gross capacity of De Hoop Dam will be 347 million m³ and the dam will have an annual yield of 80 million m³. The reservoir will have a surface area of 1 690 ha (at full supply level). By October 2011 the dam had reached 76% completion, and partial impoundment was scheduled for November that year.

SPRING GROVE DAM

As we have seen in previous chapters, despite its relatively water-rich climate, the history of the urban centres of KwaZulu-Natal have been inundated with spells of water stress. Water demand again outstripped supply in the early 2000s that caused DWA to approve Phase 2 of the Mooi-uMgeni Transfer Scheme and, at one stage the assurance of supply from the existing water sources of the uMgeni system dropped to less than 95% despite the implementation of water conservation and water demand measures, highlighting the urgent need for the augmentation of the system. DWA completed various water resources planning studies for the uMgeni River system to address the increasing water demand, but opportunities for development were limited due to the water resources being largely developed and continued. As a result, it was decided to develop Phase 2 of the Mooi-uMgeni Transfer Scheme to increase the availability and assurance of water to downstream users.

In February, 2011, construction officially started of the main component of the scheme, namely Spring Grove Dam, near Rosetta in the KwaZulu-Natal Midlands (other components of the project include three gauging weirs and the realignment of private access roads to be inundated by the dam). Spring Grove is the fifth dam to be built in the Mooi-uMgeni system, which already comprises Midmar, Albert Falls, Nagle and Inanda dams. Together, these dams provide water to more than five million people and industries in Durban, Pietermaritzburg and surrounding towns and villages. The first phase of the Mooi-uMgeni Transfer Scheme was already completed in 2003, and comprised the construction of Mearns Weir on the Mooi River to increase the volume of water that can annually be transferred from the Mooi to the uMgeni River, as well as the raising of Midmar Dam, which was described in Chapter 8.

The new dam will augment the yield of the system by providing an additional 60 million m³/year. TCTA is the implementing agent


BKS

The site where Spring Grove Dam will stand in the near future. The site is located near Rosetta, in KwaZulu-Natal.

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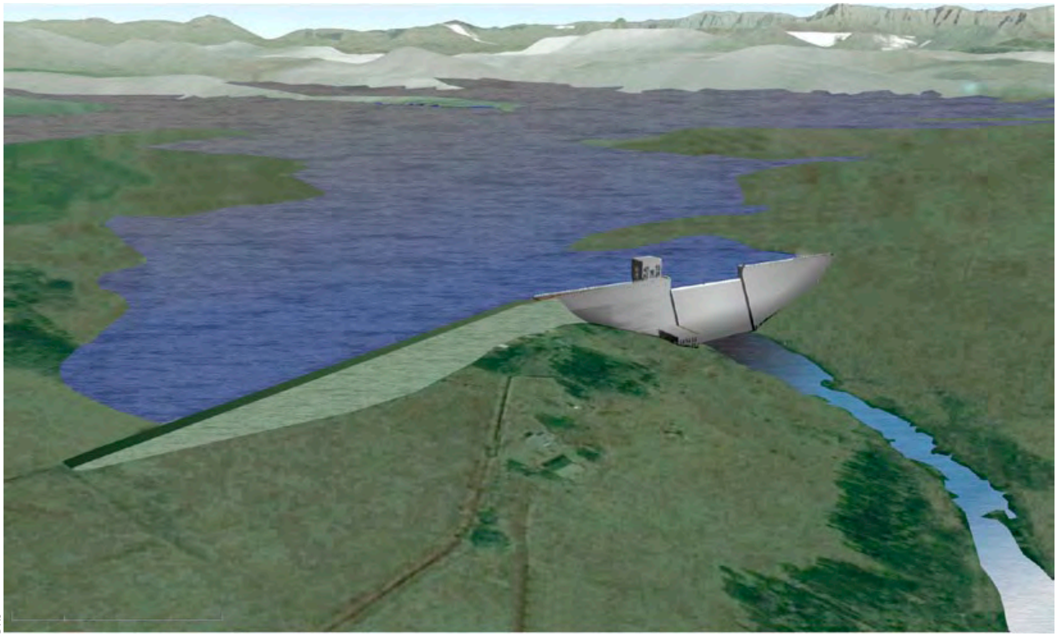
The proposed site of the Spring Grove Dam.

for the project on behalf of DWA. BKS is the main consultant on the project, while Group 5-Pandev Spring Grove Joint Venture is the main contractor. Once complete, the dam and associated pipelines will be handed over to Umgeni Water to operate and maintain on behalf of DWA. Spring Grove Dam has been designed as a rollcrete gravity dam with an earthfill embankment. It will have a maximum capacity of about 140 million m^3 and a dam wall height of 37 m.

Concerning the environment, the dam has been designed with outlet works capable of river releases that will meet the demands of downstream users as well as the Ecological Reserve. The outlet works will also be capable of abstracting water from the dam for transfer to the uMgeni River catchment. Some rare plant communities growing at the Inchbrakie Falls will be lost through inundation of the falls by the dam, however, it has been established that these plant communities can be retained for the ecology if transplanted at the Reekie Lynn Falls some 20 km upstream of the Inchbrakie Falls on the Mooi River. Three San rock paintings have been discovered just below the Inchbrakie Falls. These will be removed and curated in the Natal Museum. The site will also be excavated to save any archaeological artefacts. At the time of writing, 60 graves had been identified in the basin. These will have to be relocated in consultation with families, heritage and archaeological specialists, and traditional spiritual leaders. The project has taken the necessary measures to identify appropriate reburial sites and was consulting with the affected families and authorities on the processes to be adopted for the exhumations and reburials.

Impoundment is scheduled for November 2012, with commissioning expected within the



A 3D artist's view of the Spring Grove Dam.

BKS

Spring Grove Dam engineering features

Dam type: Composite roller compacted concrete and embankment dam
Gross storage volume at full supply level: 139,5 million m^3
Water surface are at full supply level: 1 022 ha
Total length of dam wall: 607 m
Maximum height above river: 32 m
Total length of concrete section: 280 m
Height of spillway: 32 m
Crest length of spillway (ogee crest): 70 m
Total freeboard: 5,2 m
Earthfill embankment crest length: 327 m
Earthfill embankment height: 11,5 m

first quarter of 2013. The project is being financed off-budget, and funding arrangements have been signed with several European developments banks as well as the DBSA. Unfortunately, the eThekwini-Pietermaritzburg region will continue to be under extreme stress even when Phase 2 of the Mooi-uMgeni Transfer Scheme comes into operation, and additional water resources will need to be developed in conjunction with the need for ongoing water demand management.

FUTURE OF DAM BUILDING IN SOUTH AFRICA

Today, there are 1 082 dams on SANCOLD's list of large dams with a total storage capacity of 31 619 million m^3 or 65% of the country's mean annual runoff. In the last couple of the years dam construction in South Africa has tapered off significantly to a mere trickle of what it was a decade or so ago. Studies have shown that the country only has a handful of suitable sites left, and even here dam construction is bound to be excessively expensive and only to be implemented as a last resort when all other options have been exhausted.

In 2009 DWAF again became DWA when the Forestry component was moved to the Department of Agriculture.

New dams feature very low on the list of options in DWA's latest water resource planning strategy reports, which review the current water supply demand situation and indicate how the country is to be supplied with water over the next 25 to 30 years. There is a definite shift away from the construction of large bulk water schemes towards the careful management and optimisation of existing use, increased use of groundwater resources, the reuse of water, as well as the desalination of brackish groundwater, mine-water and seawater. At the time of writing a few projects were still under investigation though. These include a dam on the uMkomaas River to supply Durban, the Nwamitwa Dam on the Great Letaba River, the Violsdrift Dam on the Orange River, and the iSithundu Dam on the Mvoti River. Every one of

The percentage of distribution of large dams

Dam type	% of total
Earthfill	74%
Rockfill	2%
Concrete gravity	12%
Concrete arch/ buttress	10%

SANCOLD

these projects will take at least a decade to implement, which means that we will have to work very carefully with the water we have.

We should also not forget about the existing infrastructure. As Paul Roberts points out: "South Africa has in fact a large investment in dam infrastructure and this infrastructure needs regular maintenance and periodic rehabilitation" (Roberts, 2011). With the majority of our bulk infrastructure older than 50 years, a lot of attention will have to be paid now and in the future to keep these structures safe and ensure they keep on providing their valuable service for years to come. Prof Will Alexander's words were prophetic when in 1994 he said: "The challenge of the future is then going to be not so much the building of more and more dams, but the more efficient operation of the systems to ensure that water is available during very severe droughts." (Symons, 1994)

South Africa's dams are an inextricable part of the country's national heritage. They are not mere concrete and earthen structures – behind each wall lies a tale of people and their passion for water. Each of these stories is a piece of thread that together weaves the tale of socio-economic development in this country. In this book we have relived some of the most amazing achievements of the country's dam builders and their legacies: from the first to the last, from the simple design of rock and earth to those of sophisticated concrete materials. In the end, there can be no denying the important role dams have played and will continue to play in the country's development. Now it is our duty to look after them, and to manage and use the water they hold carefully and with reverence. Looking at the future, in the words of former President Nelson Mandela, may there be work, bread and salt for all – but above everything else, may there be water. ◈

"The challenge of the future is then going to be not so much the building of more and more dams, but the more efficient operation of the systems to ensure that water is available during very severe droughts."

Water from icebergs?

With close to 70% of the world's water trapped in glaciers in ice caps, South African engineers have contemplated icebergs as a possible unconventional water resource for the country since at least the 1960s.

Icebergs found off the coast can be captured and towed by tug-like vessels to South Africa. However, since they are so big they cannot be brought close to shore, which means they will have to be broken up out to sea and then brought inland. Pumping the water to where it is needed can also be an expensive process. Other challenges include preventing the melting and therefore loss of previous water.

Still it was said in a DWA newsletter in 1992: "Eventually the success of iceberg utilisation will rest on its economic merits. It stands to reason that the world will have to take timeous steps in realising the iceberg dream, if it wants to utilise this water source before water shortages become an international crisis...There will be problems, yes, but what in comparison with those already overcome like the building of the Panama Canal etc? The world has the brain power and the potential technology at its disposal to make this a reality – what is stopping us?" (*Water*, May 1992)

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Glossary

Abutment – The part of the valley side (wall) against which a dam is constructed.

Active storage – The volume of the reservoir that is available for some use.

Arch dam – Curved masonry or concrete dam curved in the shape of an arch, with the top of the arch pointing back into the water.

Borrow pit – The area from which natural materials, such as gravel, rock or soil, used for construction purposes is excavated.

Buttress dam – A dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of buttresses (usually triangular-shaped walls). The buttresses resist the force of the reservoir water trying to push the dam over.

Canal – A constructed open channel for transported water.

Catchment (also called a drainage basin or a watershed) – The land area from which a river or reservoir is fed.

Coffer dam – A temporary structure enclosing all or part of a construction area so the construction can proceed in a dry area. A diversion cofferdam diverts a stream into a pipe, channel, tunnel or other watercourse.

Compaction – The mechanical action that increases the density by reducing the voids in a material.

Concrete lift – The vertical distance measured in metres (or feet) between successive placements of concrete delineated by horizontal construction joints.

Conduit – A closed channel to convey water through, around, or under a dam.

Core – A zone of low permeability material in an embankment dam. The core is sometimes referred to as central core, inclined core, puddle clay core, rolled clay core, or impervious zone.

Crest length – The length of the top of a dam from left abutment to right abutment.

Crest of dam – The elevation of the uppermost surface of a dam excluding any parapet wall, railings, etc.

Crest gate – A gate on the crest of a spillway to control overflow of reservoir water level.

Crest width – The width or thickness of a dam at the level of the crest of the dam.

Cross section – The elevation view of a dam formed by passing a plane through the dam perpendicular to the axis.

Dam – A barrier or structure across a stream, river or waterway to confine and then control the flow of water.

Dead storage – The storage that lies below the invert of the lowest outlet and that, therefore, cannot readily be withdrawn from the reservoir.

Design flood – The largest flood that a dam is designed to safely accommodate.

Diversion dam – A dam built to divert water from a waterway or stream into a different watercourse.

Earthfill dam – An embankment dam in which more than 50% of the total volume is formed of compacted fine-grained material obtained from a borrow area (also known as an excavation pit).

Ecological Reserve – Legal entitlement of all water resources to the quantity and quality of water needed to protect their aquatic ecosystems and to secure their ecologically sustainable development and use.

Embankment – Artificial hill or ridge constructed of fill material, usually earth or rock, placed with sloping sides and usually with a length greater than its height.

Embankment dam – A dam structure constructed of fill material, usually earth or rock, placed with sloping sides and usually with a length greater than its height. Embankment dams represent about 75% of all the dams in the world.

Environmental flows – The quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and human livelihoods.

Eutrophication – The process whereby high levels of nutrients result in the excessive growth of water plants and algae.

Fill dam – Any dam constructed of excavated natural materials or of industrial waste materials.

Flood gate – A gate to control flood releases from a dam.

Foundation of dam – The material on which the dam structure is placed.

Freeboard – Vertical distance between a specified reservoir surface elevation and the top of the dam.

Full supply level – The maximum normal operating level of a reservoir behind a dam. The water level can go above this, such as during floods when the spillway is operating, but if the water level rises above the crest of the dam then the dam will be overtopped, and it may fail.

Gallery – A passageway within the body of a dam or abutment.

Gate – A moveable water barrier for the control of water.

Gravity dam – A dam constructed of concrete and/or masonry that relies on its weight for stability.

Headgate – The gate that controls water flow into irrigation canals and ditches.

Headworks – A flow control structure on an irrigation canal.

Headwater – The water immediately upstream from a dam.

Heel of dam – The junction of the upstream face of a dam with the ground surface.

Hydrology – The branch of science that deals with the properties, distribution and circulation of water on earth.

Hydrometeorology – The study of the atmospheric and land-surface phases of the hydrologic cycle with emphasis on the interrelationships involved.

Impoundment – A body of water formed behind a dam.

Inflow – Water that flows into a reservoir.

Instrumentation – An arrangement of devices installed into or near dams that provide for measurements that can be used to evaluate the structural behaviour and performance parameters of the structure.

Intake – The entrance to a dam, diversion works or pumping station. The intake establishes the ultimate drawdown level of the reservoir by the position and size of its opening(s) to the outlet works.

Length of dam – The length along the top of the dam.

Low level outlet – An opening at a low level from a reservoir generally used for emptying or for scouring sediment and sometimes for irrigation releases.

Masonry dam – A dam constructed mainly of stone, brick or concrete blocks that may or may not be joined with mortar.

Multiple arch dam – A buttress dam comprised of a series of arches for the upstream face.

Outflow – The water that is released from a dam during a specified period.

Outlet – An opening through which water can be discharged from a reservoir to the river.

Outlet works – A facility of a dam that provides for the controlled release of water from a reservoir.

Parapet wall – A solid wall built along the top of a dam for ornament, for the safety of vehicles and pedestrians, or to prevent overtopping.

Penstock – Vertical, centrally located, withdrawal pipe column for decanting purposes, with horizontal conduit to outside of dam.

Radial gate – A gate with a curved upstream plate and radial arms hinged to piers or other supporting structure.

Reservoir – A body of water collected and stored in an artificial lake behind a dam.

Reservoir surface area – The area covered by a reservoir when filled to a specific level.

Rip rap – A layer of stones, broken rock or precast blocks placed in random fashion on the upstream slope of an embankment dam, on a reservoir shore or on the sides of a channel as protection against waves and flowing water. Very large rip rap is sometimes referred to as armouring.

Rockfill dam – An embankment dam in which more than 50% of the total volume is comprised of compacted or dumped pervious natural or crushed rock.

Roller fill dam – An embankment dam of earth or rock in which the material is placed in layers and compacted by using rollers or rolling equipment.

Runoff – Rainfall that runs over the surface of the ground rather than filtering into it.

Salinisation – Saltiness: the mass of dissolved organic solids in a kilogram of water.

Sediment – Fragmentary material (sand, silt, mud etc) weathered from rocks and (recently) deposited.

Sedimentation – The process whereby sediments are deposited.

Siphon – Draw-off device (over canal bank).

Slide gate – A gate that can be opened or closed by sliding in supporting guides.

Spill – Releasing water through the spillway.

Spillway – The channel or passageway around or over a dam through which excess water is released or 'spilled' past the dam. A spillway is a 'safety valve' for a dam and, as such, must be capable of discharging major floods without damaging the dam, while maintaining the reservoir level below some predetermined maximum level.

Spillway capacity – The maximum spillway outflow that a dam can safely pass with the reservoir at its maximum level.

Spillway crest – The lowest level at which water can flow over or through the spillway.

Stilling basin – A basin constructed to dissipate the energy of rapidly flowing water e.g. from a spillway or outlet, and to protect the riverbed from erosion.

Storage – The volume of water in a reservoir at a given time.

Tailwater – the water immediately downstream from a dam.

Toe of the dam – The junction of the downstream slope or face of a dam with the ground surface; also referred to as the downstream toe.

Transboundary – Rivers or other water sources that cross the boundaries of countries.

Tributary – A stream that flows into a larger stream or body of water.

Tunnel – A long underground excavation with two or more openings to the surface, usually having a uniform cross section used for access, conveying flows, etc.

Volume of dam – The total space occupied by the materials forming the dam structure computed between abutments and from top to bottom of a dam.

Watershed (catchment) - The geographic boundaries of a particular waterbody, its ecosystem and the land that drains to it.

Weir – A dam in a river to stop and raise the water, for the purpose of conducting it to a mill, forming a fishpond, or the like. When uncontrolled, the weir is termed a fixed-crest weir. Other types of weirs include broad-crested, sharp-crested, drowned or submerged.

ABBREVIATIONS

ANC – African National Congress

CSIR – Council of Scientific and Industrial Research

DBSA – The Development Bank of Southern Africa

DWA – The Department of Water Affairs

DWAF – The Department of Water Affairs & Forestry

EIA – Environmental impact assessment

ESKOM – The Electricity Supply Commission

GHP – Gibb Hawkins & Partners

ICOLD – International Committee on Large Dams

IFR – Instream flow requirement

IORCC – Orange River Consultants Consortium

IUCN – International Union for Conservation of Nature

KOBWA – Komati Basin Water Authority

LHDA – Lesotho Highlands Development Authority

LMS – London Missionary Society

NWA – National Water Act

ORDP – Orange River Development Project

PAC – Pan Africanist Congress

PSS – Pumped storage scheme

PWV – Pretoria-Witwatersrand-Vereeniging

RDP – Reconstruction & Development Programme

SAACE – South African Association of Consulting Engineering (now known as CESA)

SAICE – South African Institution of Civil Engineering

SANCOLD – South African National Committee on Large Dams

TCTA – Trans Caledon Tunnel Authority

VOC – Vereenigde Landsche Ge-Oktroyeerde Oost-indische Compagnie (Dutch East India Company)

WCD – World Commission on Dams

WRC – Water Research Commission

ZAR – Zuid-Afrikaansche Republiek

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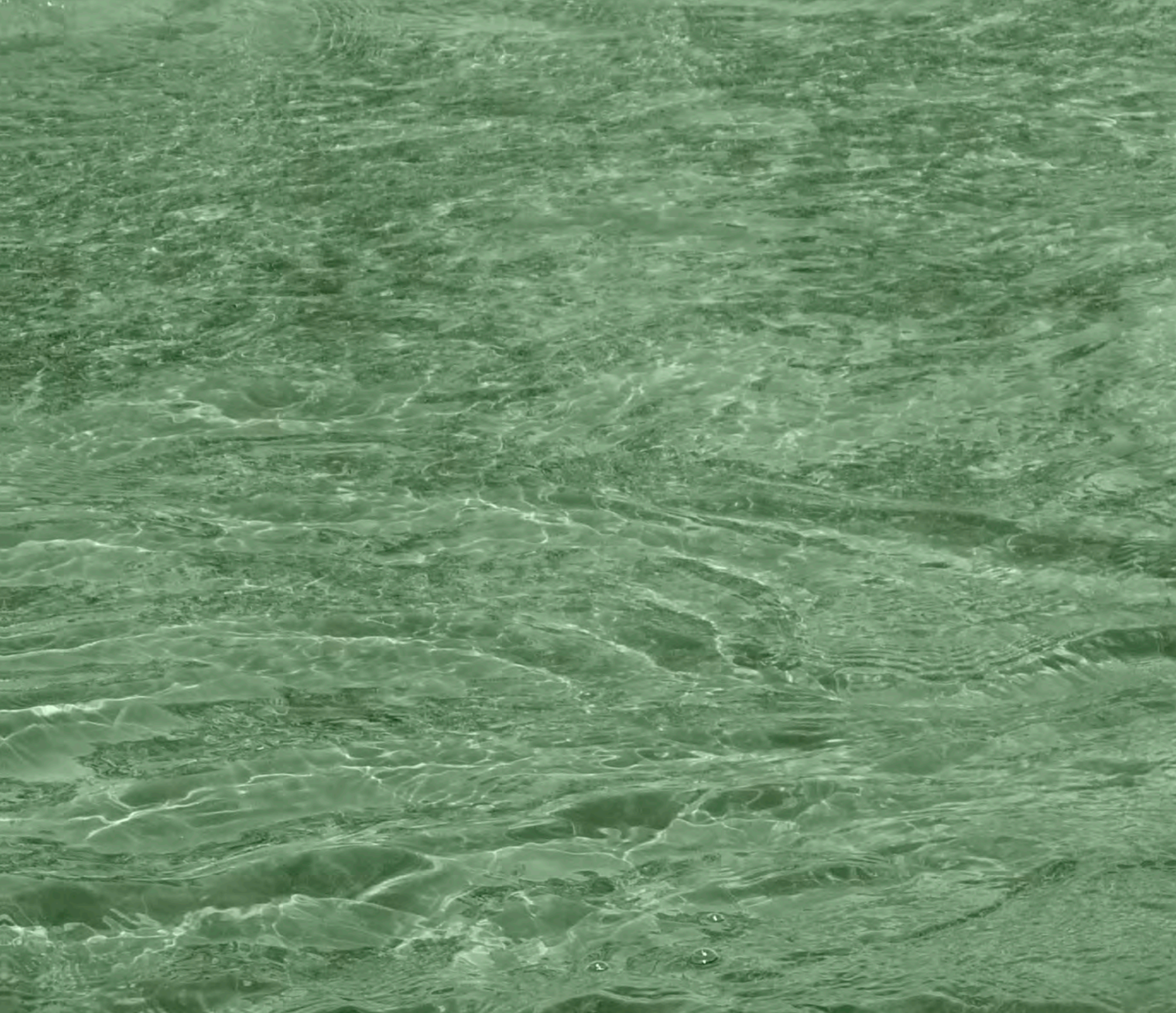

Throughout the ages the lives of people and water have been inextricably linked. On a planet that is mostly covered in water, but where less than 2,5% of it is fresh the ability of societies to regulate and manipulate the water that is available to them have not only been key to their progress and development, but to their very survival. While dams are no longer considered the sole answer to improving access to water resources, there is no denying the role that these impressive structures have played in the history and development of South Africa. The country's estimated 500 large dams hold back millions upon millions of litres of water, allowing us to pursue activities that would otherwise have been near impossible in a semi-arid climate. Dams bring us water for consumption in our large cities, irrigation to grow our crops, water to drive our main economic ventures and to generate power, all while holding back huge volumes of floodwaters that might have otherwise engulfed our settlements. Far from being mere earth and concrete structures, our dams serve as monuments of our past and beacons on our path to socio-economic prosperity. Behind each dam lies a tale of imaginative thinking, daring spirit, and resolve to make South Africa a better place to live in. South Africa's history of dams goes back at least five centuries. Many of our most important dams were built with nothing more than bare hands and sheer determination. This book is not only dedicated to the pioneering engineers who dared to dream big, but also to the thousands of labourers who toiled in sun and dust to turn dreams into reality as well as the families who supported them.

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