

Kruger National Park river research: A history of conservation and the 'reserve' legislation in South Africa (1988-2000)

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It all starts here TM

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Masters of Arts in the subject group History, School of Basic Sciences, Vaal Triangle Faculty, North-West University. It has not been submitted before for any degree or examination in any other university.

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ABSTRACT

Like arteries in a human body, rivers not only transport water and life-giving nutrients to the landscape they feed, they are also shaped and characterised by the catchments which they drain.¹ The river habitat and resultant biodiversity is a result of several physical (or abiotic) processes, of which flow is considered the most important. Flows of various quantities and quality are required to flush away sediments, transport nutrients, and kick-start life processes in the freshwater ecosystem. South Africa's river systems are characterised by particularly variable flow regimes – a result of the country's fluctuating climate regime, which varies considerably between wet and dry seasons. When these flows are disrupted or diminished through, for example, direct water abstraction or the construction of a weir or dam, it can have severe consequences on the ecological process which depend on these flows. A particular example of this is the Kruger National Park, South Africa's largest national conservation area. The availability of water resources has been a prime consideration for the management of the Kruger National Park since its establishment 90 years ago in 1926. While the park is fed by five, biologically-rich, perennial systems, its location at the downstream end of the river catchments, in addition to its semi-arid rainfall and non-perennial, localised water resources, has left the park vulnerable to upstream anthropogenic impacts, and has led much of its management actions through the decades.

The National Water Act [Act No. 36 of 1998] (NWA) was one of the first new pieces of legislation to be passed after South Africa became a democracy in 1994. This Act not only recognised the right to water of all citizens, but marked the first time in South African history when the right of the environment to water (the environmental reserve – or flows of adequate quantity and quality) became enshrined in the country's laws. The role of South Africa's aquatic science community has been acknowledged as playing an important role in the passing of the Act. Yet there has been little by way of historiography on how aquatic science and the aquatic science community have evolved in South Africa and how this influence played itself out in South Africa's water legislation. In particular, the influence of collaborative, multidisciplinary aquatic science programmes in driving policy changes during the 1980s and 1990s had not been subject to detailed historical

¹ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 1.

investigation. Therefore, this study aimed to, by way of a historical discourse, determine a part of the history of aquatic science that led to the passing of the environmental reserve in the South African water legislation. The study specifically focused on the Kruger National Park and the KNP rivers research programme. The KNP rivers research programme, was a multidisciplinary, collaborative, aquatic research programme, which ran from 1988 to 1999. The main aim of the programme was to determine the water quantity and quality needs of the perennial rivers and their ecosystems in the Kruger National Park, as well as to develop, test and refine suitable scientific methods by which the responses of aquatic ecosystems to change could be established.² The Kruger National Park, in essence, became a living laboratory for newly-developed aquatic science methodologies that were being developed in South Africa, and later laid the groundwork for the environmental reserve to be included in the NWA.

² C. Breen *et al.*, The Kruger National Park Rivers Research Programme. Final Report, p. 2.

OPSOMMING

Soos are wat deur die menslike liggaam loop, so vervoer riviere die water en nutriente deur die landskap wat hulle voed, en word hulle gevorm en gekarakteriseer deur die opvangsgebiede waaruit hulle dreineer.³ Die habitat en biodiversiteit van riviere is die produk van verskeie fisiese (of abiotiese) prosesse, waarvan watervloei die belangrikste is. Watervloei van verskeidenheid kwantiteit en kwaliteit word benodig om sediment en nutriente te vervoer, asook om lewensprosesse af te skop in die varswater ekosisteem. Suid-Afrika se rivierstelsels word in die besonder gekenmerk deur hulle veranderlike vloei – 'n direkte uitvloeisel van die land se wisselende klimaat wat gedurig verander tussen droë en nat toestande. Wanneer die natuurlike vloei van riviere onderbreek word deur, byvoorbeeld die konstruksie van 'n dam of keerwal, kan dit ernstige gevolge meebring vir die ekologiese prosesse wat van hierdie water vloei afhanklik is. Een voorbeeld hiervan is die Nasionale Kruger Wildtuin, Suid-Afrika se grootste bewaringsgebied. Die beskikbaarheid van waterbronne is 'n belangrike oorweging in die parkbestuur se besluitneming sedert die park 90 jaar terug (in 1926) gevestig is. Terwyl die park deur vyf, biologies-ryk, standhoudende riviere gevoed word, is dit ongunstig geleë aan die onderkant van die opvanggebiede van hierdie riviere. Die park se ongunstige reënval en semi-droë gelokaliseerde waterbronne maak dit kwesbaar teen menslike aktiwiteite hoër op in die opvanggebiede. Hierdie kwesbaarheid het deur dekades heen baie van die park se bestuuraksies gelei.

Die Nasionale Waterwet [Wet no. 36 van 1998] of NWA was een van die eerste nuwe wette wat goedgekeur is nadat Suid-Afrika in 1994 sy eerste demokratiese regering aangestel het. In hierdie wet word nie alleen die reg tot water vir sy burgers erken nie, maar is dieselfde regte ook aan die omgewing toegeken (dit staan bekend as die sogenaamde ekologiese reserwe). Dit is die eerste keer in die land se geskiedenis dat hierdie reg van die natuur in sy wette vervat is. Die rol wat Suid-Afrika se waterwetenskaplikes gespeel het in die verwesenliking van die waterwet word wyd erken, maar die historiografie ontbreek oor hoe die waterwetenskap en gemeenskap ontwikkel het in Suid-Afrika, asook hoe hierdie ontwikkeling die land se waterwette beïnvloed het. Veral die belangrike rol wat medewerkende, multidissiplinêre

³ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 1.

waternavorsingsprogramme gespeel het, het tot dusver geen merkbare aandag geniet vanuit 'n historiese navorsingsoogpunt nie. In hierdie studie is gepoog om deur middel van 'n historiese diskoers 'n deel van die Suid-Afrikaanse waterwetenskappe geskiedenis na vore te bring wat gelei het tot die goedkeuring van die ekologiese reserwe in die Suid-Afrikaanse waterwet. Die studie fokus spesifiek op die Nasionale Kruger Wildtuin en die wildtuin se riviernavorsingsprogram. Die Nasionale Kruger Wildtuin riviernavorsingsprogram is 'n multidissiplinêre, gemeenskaplike, navorsingsprogram wat van 1988 tot 1999 van stapel gestuur is. Die hoofdoel van die program was om vas te stel wat die watervloeibehoeftes ten opsigte van kwantiteit en kwaliteit van die park se standhoudende riviere en hulle ekostelsels is, sowel as om wetenskaplike metodes te ontwikkel en te toets om hierdie vloei te bewerkstellig.⁴ Dit het van die Nasionale Kruger Wildtuin 'n lewende laboratorium gemaak waar wetenskaplike metodes ontwikkel kon word, en het later die fondament gelê vir die ekologiese reserwe om in die NWA ingesluit te word.

⁴ C. Breen *et al.*, The Kruger National Park Rivers Research Programme. Final Report, p. 2.

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LIST OF ABBREVIATIONS

CSIR	Council for Scientific and Industrial Research
CWE	Centre for Water in the Environment
DSS	Decision support system
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
FRD	Foundation for Research and Development
IBP	International Biological Programme
ICOLD	International Commission for Large Dams
ICSU	International Council of Scientific Unions
Ifim	Instream flow incremental methodology
IFR	Instream flow requirement
IWE	Inland water ecosystems
KNP	Kruger National Park
NIWR	National Institute for Water Research
NPB	National Parks Board
NPES	National Programme for Environmental Sciences
NWA	National Water Act
Phabsim	Physical habitat simulation system
SANCOLD	South African National Committee for Large Dams
Sanparks	South African National Parks
SASAqS	Southern African Society of Aquatic Scientists
Scope	Scientific Committee on Problems of the Environment
UCT	University of Cape Town
Wits	University of the Witwatersrand
WRC	Water Research Commission

GLOSSARY OF TERMS

Aquatic ecosystem	The biotic and non-biotic communities of organisms that are dependent on and interact with each other within a water environment, including rivers, wetlands and estuaries.
Catchment	The total landscape that is drained by a river from the river's source to the sea.
Diadromous	Describes those fish species which migrate between salt and fresh water.
Ecology	The branch of science dealing with the inter-relationships of different organisms to one another and their physical surroundings.
Ecological flow	The quantity and quality of water required in a river to maintain its ecological functioning. In South Africa this is known as the environmental reserve.
Ecological flow science	The study of, development and application of methods to determine the quantity, quality and timing of flows required to sustain aquatic ecosystems.
Endemic	Describes fauna or flora that are confined to a specific region or area and found nowhere else.
Ephemeral	A river which only flows following a precipitation event.
Fluvial geomorphology	The study of how rivers are shaped, particularly with regards to the movement of sediment.
Intermittent	A collective description for rivers that do not flow throughout the year. The term includes seasonal and ephemeral rivers.
Perennial	A river which flows throughout the year.
Riparian zone	The plant habitats found directly along riverbanks.
Seasonal	A river which flows for a part of the year (usually during the rainy season).
Trophic dynamics	The science studying the transfer of energy in a system from one component to another.

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Chapter 1 Introduction

1.1 Orientation

South Africa is blessed with many natural riches, but not with water. As a result of its location between cold and warm sea currents, its semi-arid climate, high evaporation rates and its general topography, the country's river flow is extremely variable both in space and time, resulting in a mean annual runoff of only 49 210 million m³/a – less than the mean annual flow of the Zambezi River.¹

While indigenous cultures were able to live within the constraints of South Africa's hydrological limitations in pre-colonial times, the arrival of European settlers from the 17th century led to the development of an increasingly complex hydrologically engineered system to store and convey water to areas of socio-economic activity. The storing of water behind the walls of large dams² was an attempt to overcome the naturally erratic behaviour of South African water resources.³ The majority of South Africa's early water engineers were of European origin (mostly British),⁴ where they were accustomed to a culture of control over nature, since the industrial revolution.⁵ These ideas were later adopted by South African authorities, who up to the 1980s, focused largely on supplying water to the country's main socio-economic sectors, including urban water use, agriculture, mining, power generation and heavy industry.⁶ This traditional system of controlling and managing the country's freshwater neither took cognisance of the need to balance water demand between users in a catchment, nor did the engineers and water managers of former times consider the needs of the aquatic environment.⁷ It was only in 1986 that the Department of Water Affairs (DWA)⁸ accepted the environment as a

¹ B.J. Middleton & A.K. Bailey, Water Resources of South Africa, 2005 study (WR2005). Executive Summary Version 1, p. 15.

² A dam is considered large when its wall is 15 m or higher.

³ T.C. Robertson, *Water*, p. 173.

⁴ H. Mäki, Town engineers in South Africa before 1910, with reference to water supply, *The Journal for Transdisciplinary Research in Southern Africa*, 9(1), July 2013, p. 144.

⁵ T. Tvedt, Why England and not China and India? Water systems and the Industrial Revolution, *Journal of Global History*, 5(1), March 2010, p. 30.

⁶ J. King & H. Pienaar (eds.), Sustainable use of South Africa's inland water, p. 12.

⁷ A.A. Ferrar (ed), Ecological flow requirements for South African rivers, p. 2.

⁸ The Department of Water Affairs has undergone various name changes through the decades. For the sake of simplicity the name 'Department of Water Affairs' or DWA is used throughout.

legitimate user of water (although the environment was technically supposed to still compete with other water users).⁹

In 1998, four years after the country's first democratic elections, the South African government passed a new water law. Based on the Constitution of South Africa's principles of equity and sustainability,¹⁰ not only did the National Water Act [Act no. 36 of 1998] (NWA) legally enshrine the human right to water – a right that had hitherto been denied to the majority of the population – it also formally recognised the right of the aquatic environment to water of sufficient quantity and quality in order to sustain its ecosystems and the services these ecosystems provide to society.¹¹ The “environmental reserve”, as the concept is known in South African water legislation, has priority over all other water uses in the country. It is the only use for which an automatic right to water is awarded, with all other uses (including domestic, industrial, and agricultural) being subject to a licensing process. Prof Carolyn Palmer, who was part of the ministerial advisory committee that formulated the NWA, summarises the importance of the inclusion of the environmental right to water in South Africa's water legislation as follows:

*The concept of an environmental right recognises that water cannot be viewed simply as a commodity, because functionally it is part of the ecosystems in which it occurs. It was finally accepted that water supply and water quality depend on ecosystem health, and that aquatic ecosystems provide humans with a number of important, free services.*¹²

The environmental reserve was but one of many fundamental changes between the National Water Act and the previous Water Act [Act No. 54 of 1956] which had prevailed for over 40 years. The NWA recognises that South Africa is a water-scarce country, and that careful consideration of the protection, use and management of the resource is required for all parts of the water cycle, including groundwater, which was previously regarded as a private resource.¹³ The new water legislation abolished the riparian ownership of water, instead recognising that water cannot be owned by a minority of

⁹ DWA, Management of the water resources of the Republic of South Africa, p. 2.25.

¹⁰ Constitution of the Republic of South Africa No 108 of 1996.

¹¹ RSA, National Water Act 36 of 1998.

¹² C.G. Palmer, Application of ecological research to the development of a new South Africa water law, *Journal of the North American Benthological Society*, 18(1), March 1999, p. 133.

¹³ RSA, National Water Act 36 of 1998.

people, but should rather be a resource in the trusteeship of all South Africans.¹⁴ Through the NWA, the minister of water affairs became the custodian of the country's water with the responsibility of ensuring the resource's responsible use and protection.¹⁵ The NWA not only allows for, but insists on, stakeholder participation in all decisions made around water, with user-representative organisations such as water user associations and catchment management agencies now expected to decide, on a democratic basis, how the water in their catchment is used.¹⁶ At the time of its promulgation, the NWA was seen as a "leading" and "pioneering" type of legislation by the international water community, who praised the South African water sector for its "new approach" in managing the country's freshwater.¹⁷

1.2 Aquatic science and the Kruger National Park

It is recognised that the abolishment of apartheid, and South Africa's transition to multiracial democratic rule in 1994, created a "window of opportunity" – led by former minister of water affairs and forestry, Kader Asmal – to move away from the Water Act of 1956 towards more inclusive water legislation.¹⁸ However, it was the pioneering work by the South African aquatic science community, in collaboration with water managers, over many decades in the twentieth century that laid the groundwork for the change to take place. The scientists' research knowledge and their practical engagement with officials nurtured and informed the need to recognise the environment and its water requirements in the new South African water legislation.¹⁹ In line with international trends, South African aquatic research evolved from the naming and counting of aquatic species and a focus on reservoir limnology towards building knowledge around South African river

¹⁴ K. Asmal, Reflections on the birth of the National Water Act, 1998, *Water SA*, 34(6), IWRM Special Edition 2008, p. 662.

¹⁵ K. Asmal, Reflections on the birth of the National Water Act, 1998, *Water SA*, 34(6), IWRM Special Edition 2008, p. 662.

¹⁶ T. Palmer *et al.*, Some for all, forever. Water ecosystems and people, p. 14.

¹⁷ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 84; J.S. Wallace *et al.*, The sharing of water between society and ecosystems: from conflict to catchment-based co-management, *Philosophical Transactions: Biological Sciences*, 358 (1 440), December 2003, p. 2018; J. King and C. Brown, Integrated basin flow assessments: concepts and method development in Africa and south-east Asia, *Freshwater Biology*, 55(1), January 2010, p. 131.

¹⁸ C.G. Palmer, Application of ecological research to the development of a new South African water law, *Journal of the North American Benthological Society*, 18(1), March 1999 p. 132.

¹⁹ C.G. Palmer, Application of ecological research to the development of a new South African water law, *Journal of the North American Benthological Society*, 18(1), March 1999, p. 132.

ecosystems.²⁰ The multidisciplinary, cooperative research, gained impetus through state-funded programmes such as the National Programme for Environmental Sciences, which ran from 1972-1988.²¹ Government made available funding of R9.2-million for the first ten years of the programme, R2.7-million of which was spent on the Inland Water Ecosystems sub-programme.²² Although the initial focus of this sub-programme was on reservoirs, the focus later shifted towards understanding the peculiar needs of South African river systems, and included one of the first flow requirement studies in South Africa undertaken on the Pongolo (also spelt Pongola) floodplain.²³

Early studies on the flow needs for river ecosystems focused on adapting methods which had been developed in the northern hemisphere since the 1970s.²⁴ However, along with Australia, South Africa soon realised that these methods were more applicable to water-rich areas, and the two countries of the southern hemisphere simultaneously started developing their own methods of determining ecological flow.²⁵ The need for ecological flow knowledge increasingly led to collaboration and the exchange of information between aquatic scientists from the two countries.²⁶ The biggest collaborative state-funded environmental water research programme in South Africa in the final two decades of the twentieth century was the Kruger National Park (KNP) rivers research programme, which is the subject of this study. The programme, which ran from 1988 to 1999, is described by King and Louw as

²⁰ D.J. Roux *et al.*, Reflections on the history of aquatic science in South Africa with particular reference to the period after 1994, *Water SA*, 40(2), April 2014, pp. 256-257.

²¹ P.J. Ashton *et al.*, The freshwater landscape in South Africa 1900-2010. Overview of research topics, key individuals, institutional change and operating culture, pp. 27-29.

²² B.J. Huntley, Ten years of cooperative ecological research in South Africa, *South African Journal of Science*, 83(2), February 1987, pp. 72-73.

²³ J.H. O'Keeffe (ed.), Ecological research in South African rivers – A preliminary synthesis, pp. 88-107.

²⁴ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, pp. 45-47.

²⁵ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 51.

²⁶ See for example, M.C. Uys (ed.), Classification of rivers and environmental health indicators. A joint South Africa/Australian workshop; A.H. Arthington *et al.*, Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems (In Pigram, J.J. & Hooper, B.P. (eds.). *Water allocation for the environment. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991*, pp. 69-76.)

[t]he most comprehensive attempt ever organised [in South Africa] to promote an understanding of river functioning and to develop ways of managing rivers and their waters in a sustainable way.²⁷

During the 1980s South Africa was experiencing one of the worst droughts in its recorded history.²⁸ The Kruger National Park made several pleas to government to assist the park in securing its water supplies. As a result, the three-phased KNP rivers research programme was established as a multi-disciplinary, multi-organisational programme.²⁹ The main aim of the programme was to determine the water quantity and quality needs of the perennial rivers and their ecosystems in the Kruger National Park, as well as to develop, test and refine suitable scientific methods by which the responses of aquatic ecosystems to change could be established.³⁰ In essence, the Kruger National Park became a living laboratory for newly-developed aquatic science methodologies that were being developed in South Africa, and later laid the groundwork for the reserve to be included in the NWA.

The final report of the programme to the main funder, the Water Research Commission (WRC), states a number of positive outcomes of this research programme. It was said to have been:

- innovative in its design and operation;
- responsible for producing science of high quality;
- cost effective;
- instrumental in contributing meaningfully to policy and legislation review and to strategy development;
- important in contributing to the process of strategic adaptive management principles and practices;
- a useful mediating facility for promoting a culture of collaboration and generative learning;
- a key element in enabling individual and institutional growth in collaborative transdisciplinary research; and

²⁷ J. King & D. Louw, Instream flow assessments for regulated rivers using the Building Block Methodology, *Aquatic Ecosystem and Health Management*, 1(2), January 1998, p. 110.

²⁸ A.R. Turton, *et al.*, A hydropolitical history of South Africa's international river basins, p. 79.

²⁹ P.J. Ashton *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 46.

³⁰ C. Breen *et al.*, The Kruger National Park Rivers Research Programme. Final Report, p. 2.

- paved the way for the establishment of a national rivers research initiative.³¹

1.3 Problem statement

The democratisation of South Africa led to the re-evaluation of the Water Act of 1956, and the passing of ground-breaking new legislation in 1998.³² The new water legislation enshrined the right of the environment to water in law (the so-called environmental or ecological reserve). However, the development of the scientific knowledge that led to this historic occurrence, particularly the role of collaborative, multidisciplinary programmes such as the Kruger National Park rivers research programme, have not yet been sufficiently scrutinised. Furthermore, the role of the Kruger National Park as a living laboratory in which new water management ideas could be implemented remains to be investigated. It is theorised that the KNP rivers research programme had a deeper impact on South Africa's water history than its initial focus on determining the ecological requirements of the rivers of South Africa's largest conservation area.³³ However, there is no consensus in the literature over the depth of this impact. Apart from the discourse on the accomplishments of the research programme among the scientists involved in the programme, its consequences and implications for water governance in South Africa has not yet been subject to proper historical investigation.

Furthermore, the KNP rivers research programme needs to be contemplated against the backdrop of South African aquatic science research in the twentieth century and the increasingly important role it has played in the planning, operations and governance of the DWA. It is specifically in respect of the manner in which the water governance sector started making use of aquatic science outputs that needs to be contextualised in a historical discourse.

1.4 Research questions and main objectives

There are diverse views on the accomplishment of the KNP rivers research programme and its impact on South African water management legislation. This study aimed to, by means of a historical discourse, determine a part of the history of aquatic science that led

³¹ C. Breen *et al.*, The Kruger National Park Rivers Research Programme. Final Report, p. 3.

³² RSA, National Water Act 36 of 1998.

³³ C.M. Breen *et al.*, Designing a research programme to promote river basin management, *Water Science & Technology*, 32(5-6), 1995, pp. 104-106.

to the environmental reserve in the South African water legislation, with particular focus on the Kruger National Park, as well as the KNP river research programme and its impact on the evolution of water management in the country.

In the execution of the research project the following questions guided the investigation:

- What role does flow play in the characteristics and functioning of river ecosystems, and what sets the rivers that feed into the Kruger National Park apart as important river systems to be conserved?
- How has humankind influenced the flow of rivers through the ages, and how has water resource development impacted on river ecosystems, particularly in South Africa?
- How did aquatic science evolve internationally and in South Africa, and what role did collaborative research programmes play in growing this scientific discipline, and its influence over policies and legislation?
- How has water management evolved in the Kruger National Park, and what role did the Kruger National Park play in research related to determining the environmental reserve of South Africa's rivers?
- What was the KNP rivers research programme and how did scientific research on the rivers of the Kruger National Park contribute to a new approach to South African water management in the form of the environmental reserve?
- How did ecological flow science develop as a discipline in South Africa, and what role did flow science scientists play in introducing the role of the environmental reserve into law
- What can a critical investigation into the legacy of the KNP rivers research programme contribute towards our understanding of the way in which the park's rivers and their catchments are managed?
- From the general findings of the study, what lessons can be applied to the management of freshwater resources, in particular, rivers in South Africa?

The aims of the research project were to:

- Describe the general characteristics of river ecosystems and the importance of flow to the sustainability of these ecosystems, focusing specifically on South Africa and the Lowveld rivers that feed into the Kruger National Park.
- Provide a concise historiographical overview of water resource development and how anthropogenic activities have impacted on river ecosystems both globally and in South Africa, with particular focus on water use activities in the Lowveld river catchments.
- Investigate the development of aquatic science in South Africa, focusing on the role of collaborative science programmes in the context of the country's unique aquatic ecosystems.
- Outline the importance of the Kruger National Park and its rivers as a living laboratory for the development of water resource management in South Africa, specifically the development of the environmental reserve.
- Determine how scientific research on rivers of the Kruger National Park contributed to a new approach to South African water management with the introduction of the concept of the environmental reserve.
- Determine the origins of ecological flow science, how this discipline evolved in South Africa, and the role this discipline and its scientists played in the passing of the environmental reserve into law.
- Describe the KNP rivers research programme, its main scientific outputs and legacy in terms of the management of rivers in the Kruger National Park and South Africa.
- Report on the general findings of the study and provide recommendations for the current and future management of river ecosystems in South Africa.

1.5 Overall objectives of the study

Historical records suggest that the KNP rivers research programme was a seminal event in the evolution of South African aquatic science, and played a crucial role in the enhancement of the conceptual understanding of the functioning and ecological water needs of South Africa's rivers by both aquatic scientists and water managers. This study aimed to determine whether this was the case and whether, as a result of a better understanding of the natural manner in which river ecosystems function, there was a growing awareness among governance stakeholders in the water sector to promote the inclusion of the environmental reserve in South Africa's ground-breaking NWA. This study also considered the historical

development of aquatic science as a discipline in South Africa with the Kruger National Park and its rivers at the centre.

1.6 Methodology

The study followed the specific methodology for the discipline of History, namely the hermeneutic approach, which focuses on the understanding of the past through the interpretation of various sources. This methodology has been used successfully in, for example, the interpretation of historical flood data in Europe.³⁴ In this case the way in which individuals historically observed and recorded natural phenomena, such as floods, was considered during the interpretation of the sources. The researchers also considered the socio-economic background of the authors of the texts they were studying together with climate data models in order to determine the reliability of the historic information.³⁵ In much the same way, this study relied on a combination of personal interpretations of the past as well as recorded scientific data.

This study interpreted both primary and secondary sources and contextualised these sources in the framework of a historical narrative discourse. As with many histories focusing on the more recent past, both in South Africa and elsewhere, locating relevant sources proved challenging.³⁶ This is particularly so in this case as the KNP Rivers Research Programme website and electronic database (<http://www.ccwr.ac.za/KNPRRP/>) no longer exists. The demise of similar databases around this period, such as the WRC's Waterlit, seems to point to a period in the history of the South African water science sector when it was grappling with change and restructuring (brought on by political changes) as well as its freedom from isolation.³⁷ South African scientists were now free to both access research, as well as publish research, beyond internal knowledge systems. Once local researchers were able to access information from anywhere in the world through the Internet they seemingly lost

³⁴ R. Glaser *et al.*, The variability of European floods since AD 1500, *Climatic Change*, 101, March 2010, pp. 235-256.

³⁵ R. Glaser *et al.*, The variability of European floods since AD 1500, *Climatic Change*, 101, March 2010, pp. 235-256.

³⁶ R. Guha, The challenge of contemporary history, *Historia*, 54(1), May 2009, p. 120.

³⁷ J.W.N. Tempelhoff, A history of the Waterlit Collection (1974-1999): A hard copy research collection on water studies and its digital catalogue, *Journal for Contemporary History*, 40(1), (no month) 2015, p. 194.

interest in locally-managed knowledge databases. However, the historic data hosted in these systems – such as streamflow and water quality – remain important to the optimal management of South African water resources.³⁸ Research points to the diminution of hydrological monitoring in South Africa in recent years, which may render the historical information important once again, not only from a historical point of view but also from a water resource management point of view.³⁹ The fact that the Waterlit collection has been taken up by North-West University's South African Water History Archival Repository (SAWHAR) points to the usefulness of the information contained in these, previously defunct, knowledge databases for historical discourse.

The study relied strongly on scientific output in the form of scholarly articles. Chen points to the important role that the study of scientific journal articles in a specific discipline and/or by a specific set of authors can play in creating a picture of emerging trends with regards to the “intellectual [scientific] landscape”.⁴⁰ The author refers to the body of research that is actively cited in a field as the “research front” – this represents the state-of-the-art thinking in the discipline at a given time.⁴¹ By studying scholarly articles in the aquatic science discipline over time, particularly focusing on the research front, this study could determine the progression of aquatic science and, specifically, the emergence and evolution of ecological flow science both internationally and in South Africa. Similarly, scholarly articles emanating from the KNP river research programme along with several WRC research reports were identified and used collectively to provide an overview of the scientific history of the programme.

In term of primary sources the South African National Parks (Sanparks) Skukuza archives, in the Kruger National Park, as well as the archives located at Sanparks' head office, in Pretoria, were consulted. These archives provided insight into especially the history of water management in the Kruger National Park – particularly executive decisions related to water

³⁸ W.V Pitman, Overview of water resource assessment in South Africa: Current state and future challenges, *Water SA*, 37(5), Special Edition 2011, p. 662.

³⁹ W.V Pitman, Overview of water resource assessment in South Africa: Current state and future challenges, *Water SA*, 37(5), Special Edition 2011, p. 662.

⁴⁰ C. Chen, CiteSapce II: Detecting and visualising emerging trends and transient patterns in scientific literature, *Journal of the American Society for Information Science and Technology*, 57(3), 2006, p. 359, doi: 10.1002/asi.20315.

⁴¹ C. Chen, CiteSapce II: Detecting and visualising emerging trends and transient patterns in scientific literature, *Journal of the American Society for Information Science and Technology*, 57(3), 2006, p. 360, doi: 10.1002/asi.20315

and the rivers of the park although both sets of archives were found to be incomplete as far as the KNP rivers research programme is concerned. Archival information was further filled in with annual reports, research reports and minutes of meetings. The Central Archives Repository located in the National Archive Repository in Pretoria provided useful input from a national perspective in terms of the establishment of the Water Act and the problems of water resources management (such as pollution) which contributed to the development of aquatic science in South Africa. Finally, the Waterlit collection was consulted specifically for descriptions and progress reports pertaining to the KNP rivers research programme.

Apart from written textual and illustrative sources, the researcher conducted a number of interviews with relevant role-players. Guha identifies oral history as a useful way to overcome the challenge of the availability of written sources and describes this method of information collection, especially when used in conjunction with traditional sources, as being of “much value in reconstructing the somewhat recent past”.⁴² His views are shared by Oelofse and Du Bruyn, who draw attention to the need for memories recorded through oral history to be cross-checked against other sources.⁴³ Given the fact that there was extensive reporting on the research work, there was substantial grounds for cross-checking details provided by respondents at the time of oral interviews.

Respondents were asked to participate in the research via a letter of consent. The letter specified the main topic and objectives of the study and requested the participation of the interviewee in line with the North-West University’s ethics committee prescriptions. In cases where face-to-face interviews were not possible due to the remote location/schedule of the interviewee, questionnaires were sent via email. While the interviews were semi-structured, questions were gathered, as suggested by Oelofse and De Bruyn, “through relaxed conversations based on well-planned questions, in order to determine why, how and through what things came to pass.”⁴⁴ Interview questions were adapted according to the role of each individual respondent. A concerted effort was made to ensure that questions did not reflect any bias from the point of view of the interviewer.

⁴² R. Guha, The challenge of contemporary history, *Historia*, 54(1), May 2009, p. 123 and 124.

⁴³ M. Oelofse & D. du Bruyn, A critical evaluation of memory as a potential source of evidence for oral history, *Journal of Contemporary History*, 30(2), September 2005, p.123.

⁴⁴ M. Oelofse and D. du Bruyn, A critical evaluation of memory as a potential source of evidence for oral history, *Journal of Contemporary History*, 30(2), 2005, p.101.

1.7 Ethical considerations

The study is of an environmental and legislative nature in the field of water history. As such, the primary potential ethical risks of the research project are related to dealing with the collection of oral historical information from respondents. People remember events differently, meaning that respondents at times had different memories of the evolution of ecological science in South Africa and the KNP rivers research programme.⁴⁵ Where memories of an event differed between respondents, the researcher consulted alternative sources (either oral history or written sources) to resolve any potential disputes in variations in the memories of respondents. It was then especially important to take the ethics of oral history into consideration, as described by Denis, namely:

- informed consent and transparency;
- respect for the respondent; and
- benefit to the community.⁴⁶

Thus each respondent was duly informed of the purpose of the research and had to provide written consent. Participation remained completely voluntary and participants were given a choice as far as possible in terms of the type of interview (i.e. one-on-one or written questionnaire). Respondents had the right to withdraw from the research project at any stage. Diverse views were presented as fairly and equally as possible. Once the research project has been concluded, a copy of the research thesis and any other academic writings that may result from the research (e.g. conference papers, journal articles) will be sent to the respondents.

1.8 Chapter division

In the first chapter attention is focused on rivers as unique natural entities, with the ultimate objective of linking up South Africa's Kruger National Park rivers against the backdrop of a global environmental context. As they cut through mountains and valleys, rivers not only provide water, food and shelter, they also mirror the activities of the

⁴⁵ M. Oelofse and D. du Bruyn, A critical evaluation of memory as a potential source of evidence for oral history, *Journal of Contemporary History*, 30(2), 2005, p. 109.

⁴⁶ D. Philippe. Oral history: Research in the South African context, *Journal for Contemporary History*, 30(2), 2005, p.98.

catchments that feed them. Thus, rivers not only receive the sediments and micronutrients that drive their own ecosystems. Rivers are also recipients of the pollution that flow from man's activities in a catchment. Unlike terrestrial ecosystems, however, freshwater systems cannot be easily fenced to protect them from outside impacts. This makes the protection of river systems difficult. Of all the mechanics that influence a river system, its flow is arguably the most important. River flow also forms the centre of this study as the core of the ecological reserve legislation is to protect the quantity and quality of river flow. The next chapter provides the framework on which this study is based by giving an overview of the uniqueness of rivers as ecosystems, their importance as habitats and how these function, with a particular focus on the rivers of South Africa and the Kruger National Park as the setting of this study.

In order for us to understand the need for legislation to protect rivers we need to appreciate that communities have not only depended on, but have disrupted and impacted river systems for thousands of years. This increasing disruption of natural freshwater systems, particularly after the industrial revolution – and the unintended consequences for communities living next to the river – strongly influenced the evolution of water resource management through the ages. In the third chapter the relationship of man with the freshwater environment is discussed by providing a brief overview of water resources development, both at a global and South African scale. While South Africa had a late start in terms of the construction of large dams and weirs, it progressed to become one of the leading water engineering countries in the world in the 20th century. The river catchments of the Kruger National Park were not immune to the desire to stabilise river systems for socio-economic development. As human settlements grew the perennial rivers feeding the Kruger National Park were increasingly influenced by anthropogenic activities in their catchments. This greatly influenced the way in which the Kruger National Park managed its river systems.

As water resource development intensified so did the need to understand how river systems functioned. Ecological flow science is a relatively young discipline in South Africa, and remains a branch of science practiced by only a handful of individuals. However, these few scientists have played an important role in the way South African rivers are governed, particularly after 1994. The fourth chapter traces the origins of ecological flow science in South Africa, starting with the contribution of European

travelling scientists in the 18th century up to the first dedicated ecological flow methodology workshop in 1987. An important part of this chapter is the role of collaborative science programmes in propelling aquatic science forward and promoting the collaboration between aquatic scientists and government officials towards more integrated water resource management of South Africa's freshwater systems.

Chapter five provides a historical overview of water management in the Kruger National Park. Due to its location at the lower end of the perennial rivers on which its animals and visitors depend, as well as its semi-arid nature, water management has been an important aspect of the Kruger National Park throughout its history. The chapter describes the evolution of water management in the park from low intervention in its early years to quests for complete control over the freshwater systems, exemplified through the park's water-for-game programme.

The South African environmental reserve was made possible by the fact that, in a short space of time, ecological scientists had developed the necessary methods and tools to determine the water quantity and quality requirements of freshwater systems. This provided decision-makers with the confidence required to make the environmental reserve part of the country's post-1994 water legislation. Chapter six traces the development of ecological flow methodologies in South Africa, starting with attempts to adapt international ecological flow methodologies. The study then moves to the role of the rivers of the Kruger National Park in advancing ecological science to evolve as a discipline in South Africa, eventually resulting in the environmental reserve being written into law.

By the 1980s there was a realisation that the Kruger National Park's water management initiatives were not preventing the continuing deterioration of the park's perennial rivers. Prolonged discussions with the DWA and the aquatic science community resulted in the establishment of the KNP rivers research programme. Chapter seven provides a historical overview of the programme and its progression through its three main phases from its establishment in 1988 to its conclusion in 1999. Particular emphasis is placed on the legacy of the programme in terms of management aspects of the rivers of the Kruger National Park and knowledge garnered on the freshwater ecosystems that make up the perennial rivers of the park. This is followed by the last chapter, which provides overall summarising analysis of the study.

Chapter 2

Characterising the Lowveld river ecosystems

2.1 Introduction

Whether they are raging torrents of swirling water or tiny streams, rivers have unequivocally shaped the history of society. It is difficult to imagine the complexity by which these systems are shaped, and by which they shape the landscape around them.¹ In order to understand the historical narrative around the development of ecological science in South Africa, and particularly the influence the country's Lowveld rivers have had on determining the path of freshwater conservation, it is advisable to start with the characteristics of these aquatic ecosystems. This chapter explores the peculiarity of river ecosystems and how they are formed. It then goes on to unpack the importance of the natural function of rivers, with a specific focus on the significance of river flow to the sustainability of these systems. In particular, the chapter highlights the characteristics of South African river systems which influenced the development of aquatic science as a discipline in South Africa and ends with a description of the Lowveld rivers that feed the Kruger National Park as rivers of national conservation importance.

2.2 The peculiarity of river systems

Like history, rivers are never static – a myriad of variables give them form, determines life, and allows water to flow.² When these natural rhythms are disrupted – either by pollution or flow alteration – it can have severe consequences for both the human and natural biota dependent on these rivers.³ While each river has its own peculiar characteristics, most have the same basic stages of development. A river usually originates at a high elevation. It can have various sources, for example a spring, snowmelt, rain or a wetland.⁴ From the source small, clear, cool streams descend fast into the lower areas of the catchment. As these rivers descend, small rivulets and

¹ A.A. Ferrar (ed.), *Ecological flow requirements for South African rivers*, p. 13.

² P. McCully, *Silenced rivers. The ecology and politics of large dams*, p. 8.

³ S.L. Postel, Securing water for people, crops and ecosystems: New mindset and priorities, *Natural Resources Forum*, 27(2), May 2003, p. 89.

⁴ J.H. O'Keeffe (ed.), *Conservation of South African rivers*, p. 2.

tributaries may join together to form the larger, slower moving main stem of the river.⁵ The middle reaches of the river may be more turbulent due to the presence of silt and plant material, and the temperature is generally higher than that of the upper reaches, allowing for more varied forms of biological life.⁶ As the variety of invertebrates increase, so do the animals that feed on them, such as fish, frogs and birds. Once the river has reached its lower reaches it has matured. It may be rich with sediment, nutrients and organic matter, and as flow slows this material may be deposited. Then the river enters the estuary or river mouth. In the estuary the fresh waters of the river mix with the saline water from the ocean, creating the perfect nursery for a variety of sea and freshwater species. Rivers are indivisible from their catchments. Like arteries in a human body, rivers not only transport water and life-giving nutrients to the landscape they feed, they are also shaped and characterised by the catchments which they drain.⁷ The river habitat and resultant biodiversity is a result of several physical (or abiotic) processes, including the underlying geology, flow, water quality (physical and chemical characteristics of the water) and sediment transport. According to O'Keeffe and Le Quesne, the most important characteristic of a river is its flow, because

*[Flow] creates the aquatic habitats, brings the food down from upstream, it covers the floodplain with water during high flows, and it flushes the sediment and poor quality water through the system.*⁸

Each river system is unique in terms of its flow requirements, but all rivers have a need for flows of different velocities over time and space. This variation includes base flows to maintain river habitats, low (drought) flows to allow for the establishment of certain, more sedate, species of plants and animals, and torrents of flood flows to scour the river bed and wash away sediments and pollutants.⁹ This variable flow regime might also serve as the lifecycle cues to different vertebrate and invertebrate species. To keep rivers in a natural state, it is important that these diversified flows be maintained at a time and quantity when they are required. Freshwater biota have evolved and adapted to these

⁵ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 5.

⁶ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 6.

⁷ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 1.

⁸ J. O'Keeffe & T le Quesne, Keeping rivers alive. A primer on environmental flows, p. 8.

⁹ J. O'Keeffe & T le Quesne, Keeping rivers alive. A primer on environmental flows, pp. 13-14.

diversified flows, resulting in freshwater systems developing into the richest habitats on earth.¹⁰ Rivers contain more species per area than any other ecosystem.¹¹ While freshwater systems present only a small percentage of the earth's surface (0.8%) they are home to as much as a third of all vertebrate species on the planet, including at least 10 000 species of fish.¹² Large river systems such as China's Mekong are considered "biodiversity hotspots", containing as many as 1 700 different species of fish.¹³ Africa's rivers are particularly species-rich. There are an estimated 2 800 African freshwater fish species alone, despite of, or perhaps attributable to, the extreme variability of its river systems.¹⁴ The large Congo River is home to 700 different fish species, while more than 500 different species can be found in the African Rift lakes (Lakes Malawi, Victoria and Tanganyika).¹⁵

Human activities, such as the construction of dams, weirs and other infrastructure, may disrupt river flow – and concomitantly the natural rhythms guided by various river flows. Dams may hold back all but the greatest of floods, and release water to downstream users at a time of the year when the system is not expecting it.¹⁶ This can lead to downstream habitat changes while disrupting the natural cues that allow invertebrate species to breed.¹⁷ Silt collects behind dam walls rather than being passed down river to feed floodplains, while migratory species might be hindered from travelling upstream as part of their natural lifecycle.¹⁸ There are examples worldwide of the negative consequences of flow disruptions in rivers through man-made systems such as dams. In several countries dependent on fisheries, dams have caused severe declines in fish stocks. In the Columbia River basin, in the USA, for example, fish stocks have become

¹⁰ D. Dudgeon *et al.*, Freshwater biodiversity, importance, threats, status and conservation challenges, *Biological Review*, 81(2), May 2006, p. 165.

¹¹ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 26.

¹² D. Dudgeon *et al.*, Freshwater biodiversity, importance, threats, status and conservation challenges, *Biological Review*, 81(2), May 2006, p. 165.

¹³ D. Dudgeon *et al.*, Freshwater biodiversity, importance, threats, status and conservation challenges, *Biological Review*, 81(2), May 2006, p. 165.

¹⁴ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 31.

¹⁵ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 70.

¹⁶ K.F. Walker, A review of the ecological effects of river regulation in Australia, *Hydrobiologia*, 125(1), June 1985, p. 111.

¹⁷ K.F. Walker, A review of the ecological effects of river regulation in Australia, *Hydrobiologia*, 125(1), June 1985, p. 111.

¹⁸ B.R. Allanson *et al.*, *Inland waters of Southern Africa: An ecological perspective*, p. 120.

radically depleted as a result of the construction of a series of dams – the largest being the 168m-high Grand Coulee Dam – which prevent the fish from migrating upstream to spawn.¹⁹ Richter et al. present several case studies where the construction of dams have disrupted downstream ecological processes and, in the process, also local livelihoods.²⁰ In Brazil, construction of the Tucuruí Dam, in the Tocantins River, in 1984 led fish and freshwater shrimp catches to decline by nearly two thirds, while similar examples of declining fish numbers post-dam construction are cited for the Niger, Nile, Senegal and Kafue rivers in Africa.²¹ When rivers no longer run unhindered it not only prevents the flow of water but also of sediment. Nutrient-rich sediment which sustained communities in the Nile River catchments for thousands of years are now trapped in the High Aswan Dam, causing farmers to now rely on fertilisers to feed their crops.²² In South Africa, pollution from agriculture, mining and industrial activities in the Olifants River upstream of the Loskop Dam, end up becoming trapped in the sediment of the dam, with deadly consequences for wildlife (fish, terrapins, crocodiles) living in Lake Loskop.²³

2.3 South Africa's river systems

In comparison to the world average, South African rivers are considered generally as species poor. The country's rivers house less than 300 species of freshwater fish.²⁴ The majority (61%) of these species are endemic, however, with several species only occurring in single, small rivers.²⁵ Skelton notes two examples in particular where this is the case, namely the Namaqua barb (*Barbus hospes*), which is confined to the Augrabies Falls in the Orange River system, and the Maloti minnow (*Pseudobarbus quathlambae*) which is only found in small river systems in the mountains of Lesotho.²⁶ This makes South African fish fauna particularly vulnerable to human impact. Endemism is not

¹⁹ P. McCully, *Silenced rivers. The ecology and politics of large dams*, p. 41.

²⁰ B.D. Richter *et al.*, Lost in development's shadow: The downstream human consequences of dams, *Water Alternatives*, 3(2), June 2010, pp. 14-42.

²¹ B.D. Richter *et al.*, Lost in development's shadow: The downstream human consequences of dams, *Water Alternatives*, 3(2), June 2010, pp. 20-22.

²² P. McCully, *Silenced rivers. The ecology and politics of large dams*, p. 35.

²³ L. van Vuuren, Olifants – Time to stand up for a river under siege, *The Water Wheel*, 12(3), May/June 2013, p. 22.

²⁴ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 70.

²⁵ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 71.

²⁶ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 72.

confined to large vertebrate aquatic fauna, but may also include invertebrate species.²⁷ South Africa's lack of faunal species can be attributed to its shortage of perennial rivers, a result of the country's inherent water scarcity. South Africa's average annual precipitation is only about 450mm a year – well below the world average of 860mm a year.²⁸ The distribution of rain varies widely across the country, generally reducing from east to west, with 65% of the country receiving less than 500mm a year.²⁹ Precipitation is not only spread unevenly across space but also across time, with years of below-average rainfall usually followed by sudden above-average rainfall. The lack of rainfall is compounded by South Africa's generally high evaporation rates, which may exceed precipitation, as is the case in Gauteng.³⁰ On average, only 9% of precipitation reaches the country's rivers as mean annual runoff.³¹ A considerable percentage of this runoff (67%) is, however, captured behind large storage dams.³²

South Africa's few perennial rivers are located mainly in the south- and southwestern Cape and eastern Indian Ocean seaboard.³³ The perennial rivers, which make up only about a quarter of the country's total river systems, channel over 50% of South Africa's mean annual runoff.³⁴ Another quarter of the country's rivers are periodic, while the rest of South Africa's rivers are considered episodic, meaning that they only flow after heavy rainfall, and are therefore dry most of the time.³⁵ The country's largest river system, the Orange River, receives around 25% of total runoff.³⁶ South Africa is further described as

²⁷ D. Dudgeon *et al.*, Freshwater biodiversity, importance, threats, status and conservation challenges, *Biological Review*, 81(2), May 2006, p. 165.

²⁸ Department of Environmental Affairs & Tourism (DEAT), *South African Outlook. A report on the state of the environment*, p. 145.

²⁹ DWA, *Water 75*, p. 3.

³⁰ B. Davies & J. Day, *Vanishing waters*, p. 30.

³¹ L. van Vuuren, Together we can do more – environmental consciousness in the South African dam construction sector (1945-1980), *TD – The Journal for Transdisciplinary Research in Southern Africa*, 9(1), July 2013, p. 53.

³² P.J. Ashton, Riverine biodiversity conservation in South Africa: Current situation and future prospects, *Aquatic conservation: marine and freshwater ecosystems*, 17(5), July 2007, p. 441.

³³ South African National Committee on Large Dams (SANCOLD), *Large dams and water systems in South Africa*, p. 22.

³⁴ H.A. Strydom & N.D. King (eds.), *Fuggie and Rabie's environmental management in South Africa*, p. 844.

³⁵ SANCOLD, *Large dams and water systems in South Africa*, p. 23.

³⁶ H.A. Strydom & N.D. King (eds.), *Fuggie and Rabie's environmental management in South Africa*, p. 844.

having one of the most variable river flow regimes in the world.³⁷ During times of excessive rain water flow in our river systems may be seven times above normal, while in times of aridity our rivers may contain only a tenth of normal flows.³⁸ These characteristics result in South African rivers being unlike the more temperate rivers of the northern hemisphere. Local aquatic fauna and flora have evolved in accordance with South African rivers' flow regimes.³⁹ Aquatic animals (and water-loving terrestrial animals – such as hippopotami) seek out refuge pools when flow ceases, while invertebrates and fish may scuttle beneath the surface into moist layers of the riverbed.⁴⁰ Many South African aquatic invertebrates have also developed a part of their lifecycle that can withstand long periods without water.⁴¹ When the river starts flowing again these species reproduce quickly to repopulate the aquatic habitat.

2.4 Landscape and characteristics of the Lowveld rivers feeding the Kruger National Park

In the decades preceding the passing of the NWA and the recognition of the environmental reserve, South Africa's aquatic scientists – in cooperation with officers of the DWA – undertook important groundwork to develop the understanding, tools and methodologies to determine the country's river ecosystems' water needs.⁴² Much of this work was centred around the rivers feeding the Kruger National Park. While the Kruger National Park was not originally established around the protection of its freshwater resources, the management of the park's water has evolved as a central function. The following section describes the main natural characteristics of the Kruger National Park as well as those of its main rivers and their catchments as a way of establishing the importance of the park and its aquatic ecosystems from a conservation perspective.

³⁷ J. King and H. Pienaar (eds.), *Sustainable use of South Africa's inland water*, p. 1.

³⁸ F.A. Venter, *Water*, p. 101.

³⁹ B. Davies & J. Day, *Vanishing waters*, p. 43.

⁴⁰ B. Davies & J. Day, *Vanishing waters*, p. 43.

⁴¹ B. Davies & J. Day, *Vanishing waters*, p. 43.

⁴² P.J. Ashton *et al.*, *Africa The freshwater science landscape in South Africa, 1900-2010*, p. 87.

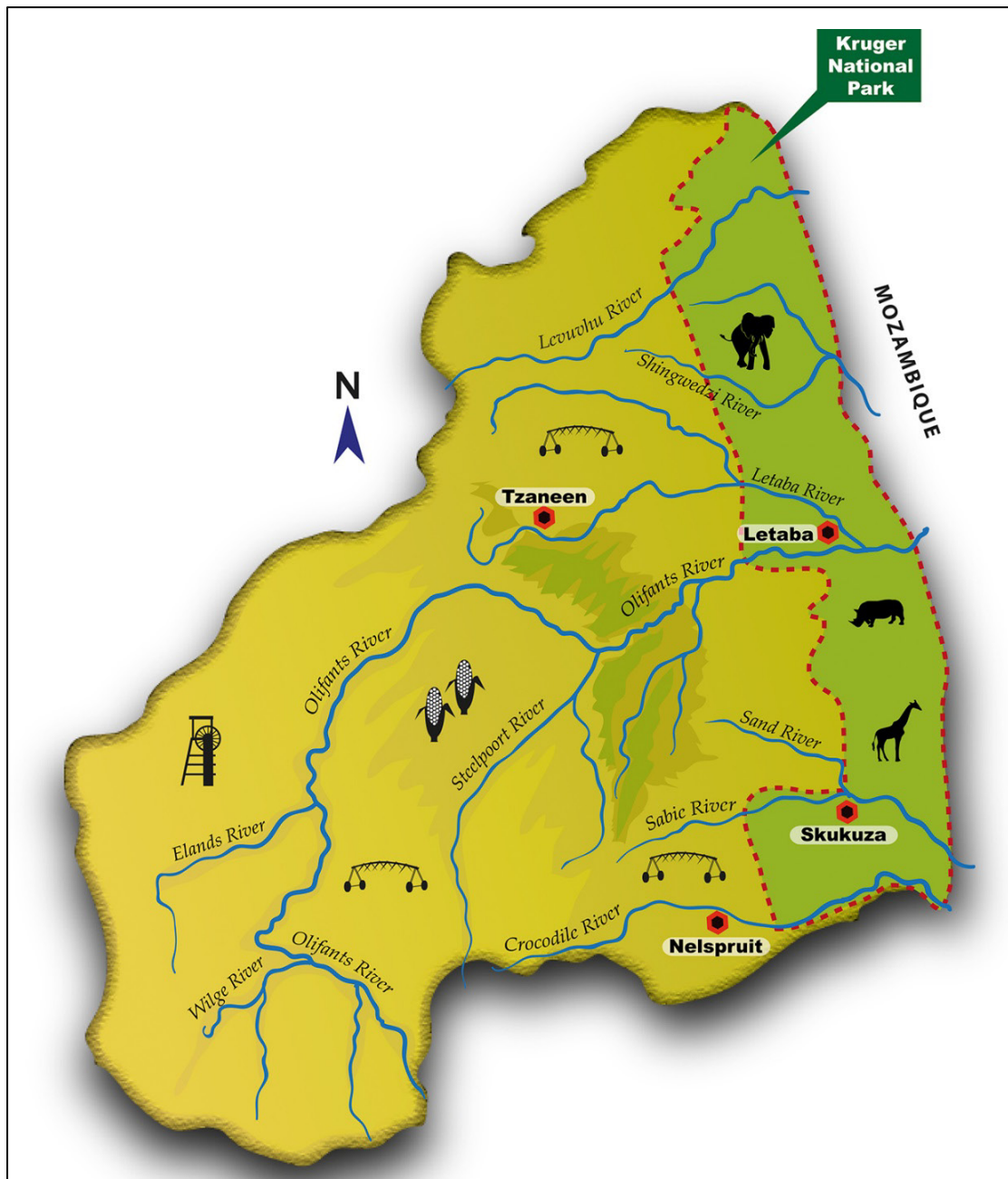


Figure 2-1: The location of the Kruger National Park in relation to its main rivers and their catchments⁴³

At close to 20 000km², the Kruger National Park is the largest national park in South Africa.⁴⁴ The park runs vertically across the provinces of Mpumalanga and Limpopo in the north-eastern corner of the country, with Mozambique bordering the park in the east

⁴³ H.C. Biggs, C.M. Breen and C.G. Palmer, Engaging a window of opportunity: Synchronicity between a regional river conservation initiative and broader water law reform in South Africa, *International Journal of Water Resources Development*, 24(3), September 2008, p. 334.

⁴⁴ S.C.J. Joubert, The Kruger National Park – An introduction, *Koedoe*, 29(1), November 1986, p. 1.

and Zimbabwe in the north. The park is oriented from north to south, with a length of 350km and a width varying between 35 and 70km.⁴⁵ Typical of its Lowveld surroundings, the Kruger National Park's summers can be hot and uncomfortable, with temperatures rising well over 40°C.⁴⁶ Winters are milder, and generally dry. The park mainly receives its annual rainfall in summer between the months of October and March.⁴⁷ The average annual rainfall for the Kruger National Park is 550mm (well below the world average of 800mm), although this figure ranges quite widely between the south (where the average annual rainfall is 750mm) and the north (where the average annual rainfall is 350mm).⁴⁸ This average rainfall figure can be deceptive, as the Kruger National Park's climate fluctuates between dry and wet cycles every ten or so years.⁴⁹ As a result of these cycles, periods of drought are often interspersed by periodic flooding.

In addition to a number of natural springs, the Kruger National Park is drained by two large river systems, namely the Limpopo system in the north and the Incomati system in the south. Feeding these two large river systems are a series of subsystems, which together form the main water resources of the park.⁵⁰ This study focuses on the five main rivers and their catchments, namely the Olifants, Letaba, Luvuvhu (also spelt Levuvhu or Levubu) – that form part of the Limpopo system – and the Sabie, and Crocodile rivers – that form part of the Incomati system. All five of these rivers are historically perennial. The remaining rivers in the Kruger National Park are all naturally seasonal, flowing only after sufficient rains, although some of them contain semi-permanent to permanent pools. The largest of these seasonal rivers are the Shingwedzi and Nwanetzi rivers. Apart from providing water to surrounding terrestrial fauna and flora, the rivers of the Kruger National Park house biologically rich aquatic ecosystems, in some cases, endemic to the region.⁵¹

⁴⁵ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 14.

⁴⁶ F.J. Venter & W.P.D. Gertenbach, A cursory review of the climate and vegetation of the Kruger National Park, *Koedoe*, 29(1), November 1986, p. 139.

⁴⁷ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 16.

⁴⁸ S.C.J. Joubert, The Kruger National Park – An introduction, *Koedoe*, 29 (1), November 1986, p. 4.

⁴⁹ J.V. Redfern *et al.*, Surface water availability and the management of herbivore distributions in an African savannah ecosystem, *Journal of Arid Environments*, 63(1), October 2005, p. 409.

⁵⁰ U. de V. Pienaar, The freshwater fishes of the Kruger National Park, *Koedoe*, 11(1), May 1968, p. 2.

⁵¹ C.A. Bruwer (ed.), Proceedings of a workshop on the flow requirements of the Kruger National Park rivers, p. 10.

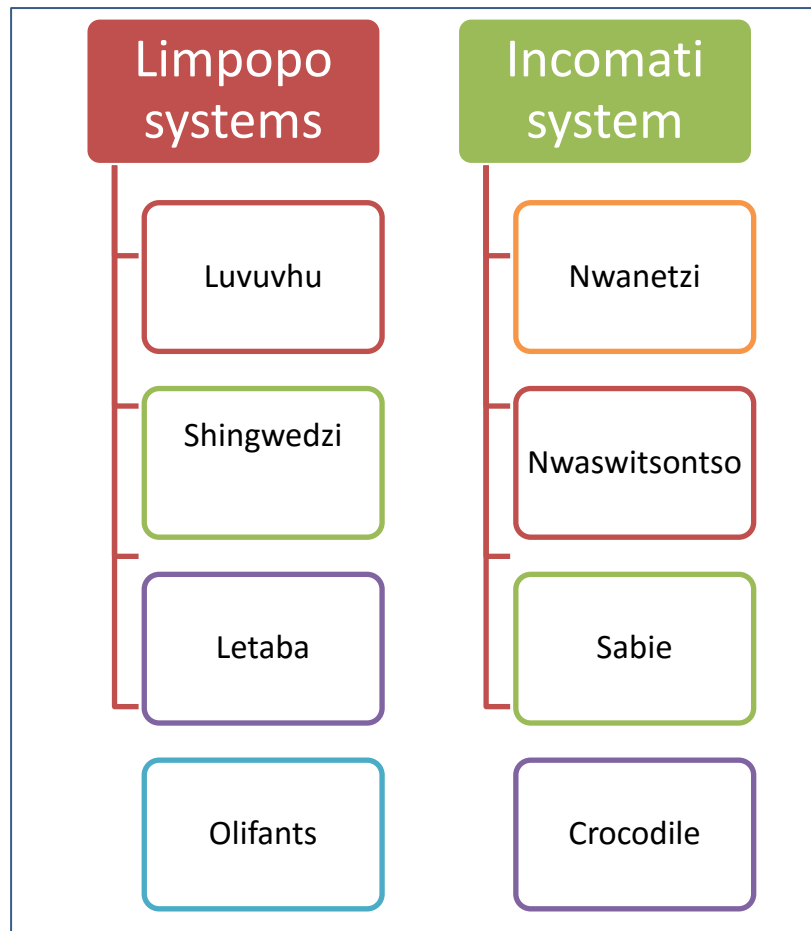


Figure 2-2: The two major river systems draining the Kruger National Park and their main subsystems⁵²

The terrain covered by the Kruger National Park is mostly flat, comprising savanna-type vegetation, including woodland and grassland. Close to 2 000 plant species have been identified in the park.⁵³ Inhabiting this floral habitat is an assortment of fauna, from the “big five” (elephant (*Loxodonta Africana*), buffalo (*Syncerus caffer*), lion (*Panthera leo*), rhinoceros (both *Ceratotherium simum* and *Diceros bicornis*), and leopard (*Panthera pardus*)) to the endangered wild dog (*Lycaon pictus*) and cheetah (*Acinonyx jubatus*). Close to 500 bird species and 255 faunal species have been indexed in the park.⁵⁴ At least 45 freshwater fish species out of the 102 freshwater fishes found in South Africa,

⁵² U. de V. Pienaar, The freshwater fishes of the Kruger National Park, *Koedoe*, 11(1), May 1968, pp. 2-3.

⁵³ F.J. Venter & W.P.D. Gertenbach, A cursory review of the climate and vegetation of the Kruger National Park, *Koedoe*, 29(1), November 1986, p. 143.

⁵⁴ S.C.J. Joubert, The Kruger National Park – An introduction, *Koedoe*, 29 (1), November 1986, p. 2.

have been identified in the park's rivers, in addition to a number of aquatic birds, mammals and amphibians, confirming the Kruger National Park's central place in biodiversity conservation in South Africa.⁵⁵



Figure 2-3: A view of the landscape from Nkumbe in the central section of the Kruger National Park, illustrating the general flat landscape of the park⁵⁶

There are periodic, episodic and perennial rivers flowing through the Kruger National Park, although this study focuses only on the latter. While each of the main rivers of the park are distinct in terms of their features, they do share some similarities in terms of their catchment characteristics and anthropogenic impacts. Together, the catchments of the Olifants, Crocodile, Letaba, Luvuvhu and Sabie rivers cover a large segment of the Limpopo and Mpumalanga provinces. With the exception of the Olifants River, which rises in the Highveld, the sources of all the Kruger National Park main rivers are in the Great Escarpment, in either the Soutpansberg or Drakensberg. From the mountains the rivers drop over the Escarpment into the Lowveld. Waterfalls are a notable feature for many of these rivers and their tributaries. Consider the MacMac falls in the Sabie River system,

⁵⁵ U. de V. Pienaar, Inaugural address, *Zoologica Africana*, 11(2), January 1976, p. 227.

⁵⁶ Photograph: Van Vuuren Private Archive (VVPA), Photographs File 1 (PF1), Nkumbe lookout, 2016-06-26.

or the Debengeni falls in the Letaba River system as examples. From west to east, geological conditions underlying the Kruger National Park rivers range from granite from the Basement Complex, Karoo sediments, to basalt and rhyolite.⁵⁷ Here the upper catchment of the Luvuvhu is the exception, as this river is mainly underlain by quartzite and sandstone of the Soutpansberg group, as well as sedimentary rocks of the Karoo sequence and basalt.⁵⁸

Average annual rainfall in the river catchments shows a distinct decrease from west to east, varying from around 2 000mm a year in the headwaters of the rivers to less than 500mm where the rivers enter the Kruger National Park. In contrast, evaporation rises markedly from west to east. As a result of these climate characteristics, the vast majority of water runoff in these river systems is generated in the upper catchments. In the Sabie River catchment the upper 20% of the catchment generates as much as 80% of the runoff.⁵⁹ In contrast, the Kruger National Park area, while making up around 48% of the Sabie River catchment, generates only 1% of the runoff.⁶⁰ Similar figures are cited for the Luvuvhu River, where 38% of the total water runoff is generated in the upper 9% of the catchment.⁶¹ The catchments are further characterised by a distinct rainy season – lasting mainly from October to March, with rain falling in short bursts as a result of thunderstorms. The climate characteristics give the rivers a distinct high flow and low flow season. Flooding of riverbanks is not uncommon during high flows.⁶² Each of the catchments will now be described in a little more detail.

⁵⁷ South African Water History Archival Repository (SAWHAR), Waterlit Collection, F.J. Venter, Physical characteristics of the reaches of perennial rivers in the Kruger National Park, p. 2.

⁵⁸ SAWHAR, Waterlit Collection, F.J. Venter, Physical characteristics of the reaches of perennial rivers in the Kruger National Park, p. 2.

⁵⁹ G.P.W. Jewitt *et al.*, Kruger National Park Rivers Research Programme (KNPRRP). Modelling abiotic-biotic links in the Sabie River, p. 28.

⁶⁰ SAWHAR, Waterlit Collection, F. van Zyl, Making it happen – The Sabie experience (In Pigram J.J. & Hooper, B.P., eds. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991. pp. 247-258.)

⁶¹ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park River Research Programme Phase 3, p. 4.

⁶² U. de V. Pienaar, *The freshwater fishes of the Kruger National Park*, p. 3.

2.4.1 Sabie River catchment



Figure 2-4: The Sabie River catchment⁶³

Of all the catchments the Sabie River and its main tributary, the Sand River, are the least influenced by anthropogenic impacts. The Sabie River forms part of the Incomati River catchment which straddles South Africa, Mozambique and Swaziland, and drains a catchment area of 7 096km².⁶⁴ The river runs through the Kruger National Park for 111km – longer than any other major river in the Park.⁶⁵ The Sabie River starts flowing on the eastern slopes of the Drakensberg near the town of Sabie. From here it flows eastwards for about 210m, dropping into the Lowveld before merging with the Nkomati River inside Mozambique at around 40m above sea level.⁶⁶ The Sabie River is a fast-flowing river, which results in river water having a fairly cool temperature (around 20°C) where the river enters the Kruger National Park.⁶⁷ A mean annual runoff of 762 million m³ has been

⁶³ River health programme (RHP), State of the rivers report. Crocodile, Sabie-Sand and Olifants river systems, p. 18.

⁶⁴ DWA, Water resources planning of the Sabie River catchment. Study of development potential and management of water resources: Executive summary, p. 2.

⁶⁵ W.J. Muller & M.H. Villet, Similarities and differences between rivers of the Kruger National Park, p. 11.

⁶⁶ Anon, State of the rivers reports. Crocodile, Sabie-Sand and Olifants River system, p. 18.

⁶⁷ U. de V. Pienaar, *The freshwater fishes of the Kruger National Park*, p.3.

recorded for the Sabie-Sand river system, although anthropogenic influences, most notably forestry, has reduced this to around 633 million m³/a.⁶⁸

The Sabie River is one of the most biologically diverse rivers in South Africa, and its water quality remains the most unspoilt of all the perennial rivers flowing into the Kruger National Park.⁶⁹ The river includes species found nowhere else in the country, including the Lowveld largemouth kurper (*Serranochromis meridianus*).⁷⁰ This biological richness was recognised from the establishment of the Kruger National Park's predecessor, the Sabi game reserve, although the need to conserve aquatic ecosystems was not generally expressed at the time.⁷¹



Figure 2-5: The Sabie River outside the Kruger Skukuza gate⁷²

⁶⁸ SAWHAR, Waterlit Collection, C.M. Breen *et al.*, A description of the Kruger National Park Rivers Research Programme Phase 3, p. 12.

⁶⁹ SAWHAR, Waterlit Collection, J.H. O' Keeffe & B.R. Davies, Management of water releases from proposed impoundments on the Sabie and Sand rivers: Ecological consequences for the rivers within the Kruger National Park, p. 1.

⁷⁰ Anon, Fish for Africa, *Custos*, March 1994, p. 18.

⁷¹ J. Stevenson-Hamilton, Game preservation in the Transvaal, *South African Journal of Science*, 1(1), (no month) 1905, p. 365.

⁷² Photograph: VVPA, PF1, Sabie River, 2006-10-10.

2.4.2 The Crocodile River catchment



Figure 2-6: The Crocodile River catchment⁷³

Next to the Sabie River, the Crocodile River is the most biologically diverse river flowing through the Kruger National Park.⁷⁴ The river not only provides a habitat for a number of invertebrate species but also for rare fish species such as the airbreathing shellfish (*Kneria auriculata*), Incomati suckermouth (*Chiloglanis bifurcus*) and Southern barred minnow (*Opsaridium peringueyi*).⁷⁵ The river has a catchment of 10 450km², and is the largest tributary of the Nkomati River.⁷⁶ The Crocodile River also has its own tributaries, the largest being the Elands River. The 320km-long Crocodile River has its source in the Escarpment, just north of the town of Dullstroom, and flows eastwards past the Mpumalanga capital, Nelspruit, before entering the Lowveld.⁷⁷ The river flows past the

⁷³ RHP, State of the Rivers Report. Crocodile, Sabie-Sand and Olifants river systems, p. 10.

⁷⁴ W.J. Muller *et al.*, Similarities and differences between rivers of the Kruger National Park, p. 9.

⁷⁵ SAWHAR, Waterlit Collection, C.M. Breen *et al.*, A description of the Kruger National Park Rivers Research Programme Phase 3, p. 16.

⁷⁶ RHP, State of the rivers report. Crocodile, Sabie-Sand and Olifants River system, p. 10.

⁷⁷ SAWHAR, Waterlit Collection, C.M. Breen *et al.*, A description of the Kruger National Park Phase 3, p. 14.

town of Kaapmuiden and forms the southern boundary of the Kruger National Park. After flowing through the park the Crocodile River merges with the Nkomati River in Mozambique.⁷⁸



Figure 2-7: The Crocodile River forms the southern boundary of the Kruger National Park. Note the private game lodges on the left bank of the river, while the Kruger National Park is located on the right⁷⁹

2.4.3 The Luvuvhu River catchment

The Luvuvhu River is the northern most river of the Kruger National Park. The river forms part of the Limpopo system and has a catchment area of 5 477km².⁸⁰ The Luvuvhu River has its source in the Soutpansberg, rising east of the town of Makhado (Louis Trichardt).⁸¹ From here the river flows for about 200km, first southwards and then in an easterly direction. It traverses the former homelands of Venda and Gazankulu before reaching the

⁷⁸ A. Deacon, Riviere gee wildtuin sy ekologiese karakter, *Custos*, 21(4), July 1992, p. 15.

⁷⁹ Photograph: VVPA, PF1, Crocodile River, 2011-07-20.

⁸⁰ Griscom, H., The drying of the Luvuvhu River, South Africa: Distinguishing the roles of dams and land cover change, MA University of Wyoming, 2007, p. 28.

⁸¹ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park Rivers Research Programme Phase 3, p. 4.

Kruger National Park.⁸² After meandering through the park, the Luvuvhu River merges with the Limpopo River on the border between South Africa and Mozambique.⁸³

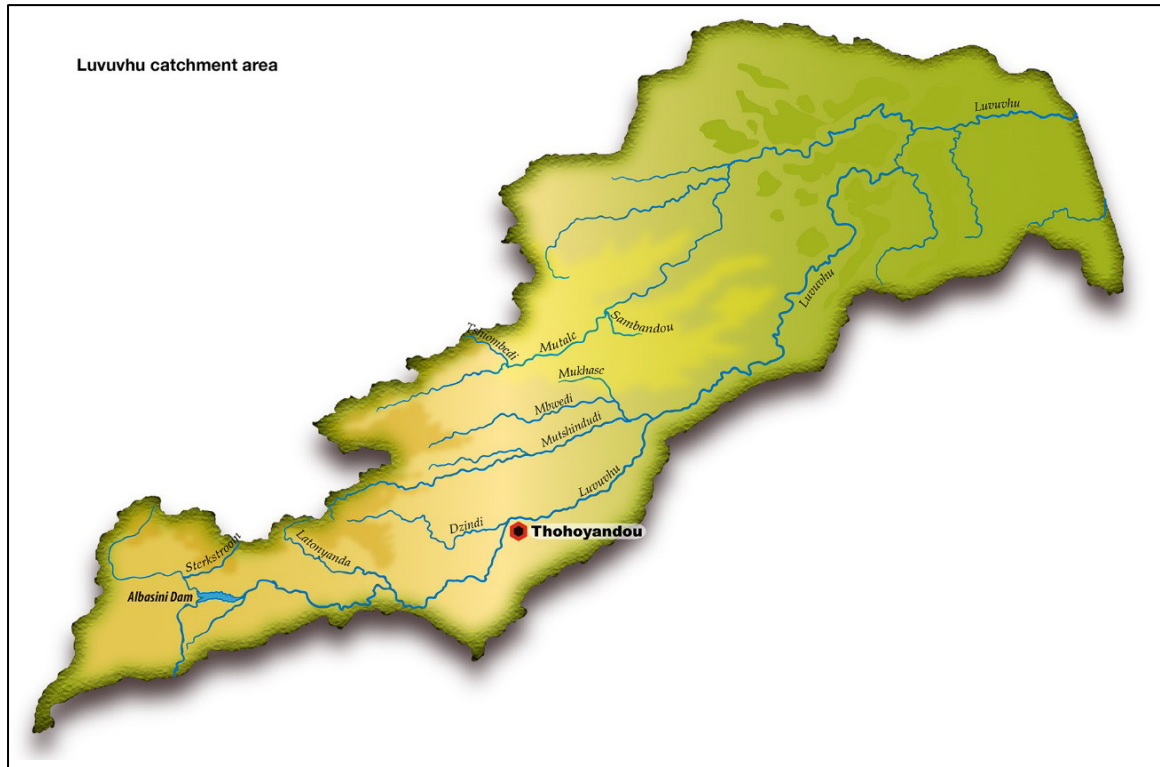


Figure 2-8: The Luvuvhu River catchment⁸⁴

Only 30% of the catchment lies in the Kruger National Park. Tributaries of the Luvuvhu River include the Latanyanda, Dzindi, Mutshindudi and Mutale rivers.⁸⁵ The latter tributary features Lake Fundudzi – a natural inland lake of substantial cultural importance to Venda communities in the Soutpansberg.⁸⁶ On the other, lower side of the catchment, the lower floodplain at Pafuri is known for its riparian forests. The only major urban settlement in the catchment is Thohoyandou, and urban development in the catchment has been

⁸² I.D. Neilson & M.L.J. Botha, Water resources of the Luvuvhu River basin (In Environmental Planning Professions Interdisciplinary Committee (EPPIC), Environmental conference: Water, 16-17 May, 1991, Mintek, Randburg. pp. 1-11.)

⁸³ Water Research Commission (WRC), State of Rivers Report. Letaba and Luvuvhu river systems, p. 6.

⁸⁴ W.F. Strydom *et al.* (eds.), Achievements of the River Health Programme 1994-2004. A national perspective on the ecological health of selected South African Rivers, p. 45.

⁸⁵ WRC, State of Rivers Report. Letaba and Luvuvhu river systems, p. 6.

⁸⁶ W.F. Strydom *et al.* (eds.), Achievements of the River Health Programme 1994-2004. A national perspective on the ecological health of selected South African Rivers, p. 44.

limited, with the majority of the population in the catchment living in rural villages.⁸⁷ Economic activities in the Luvuvhu River catchment are mostly centred on agriculture and forestry, with subsistence agriculture being practiced in the middle sections of the catchment area.⁸⁸ Agricultural produce includes vegetables, fruits such as banana, citrus, and mango as well as various vegetables.

2.4.4 The Letaba River catchment

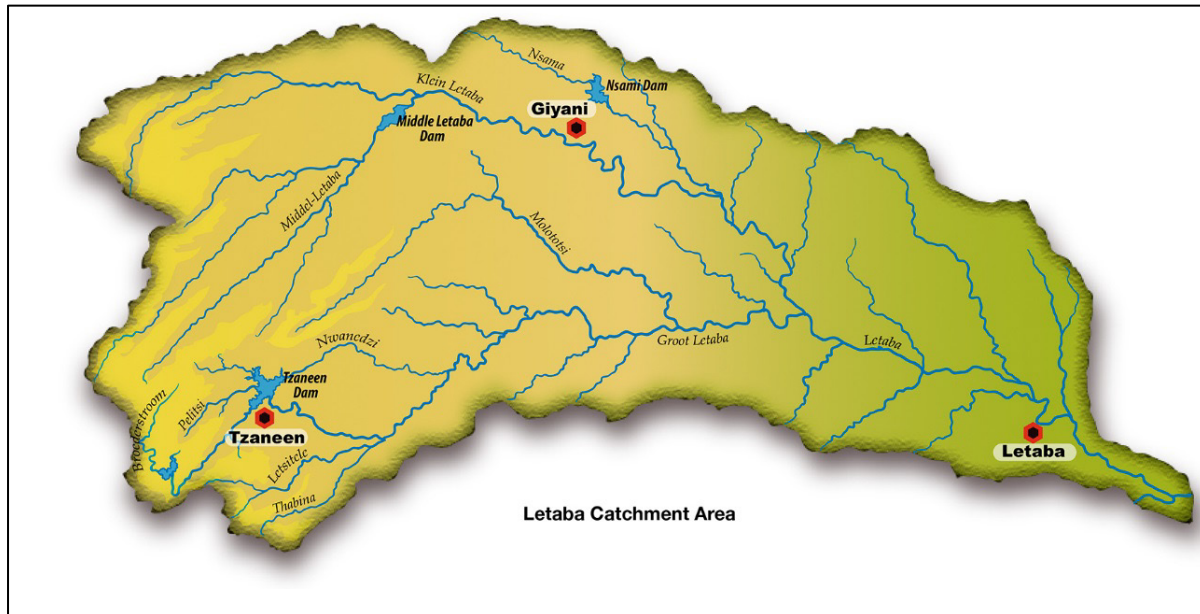


Figure 2-9: The Letaba River catchment⁸⁹

The Letaba River (also called the Groot Letaba River) forms part of the Limpopo River system, and has a total catchment area of 13 400km². From its source in the Drakensberg the river flows for about 500km in an easterly direction through the Kruger National Park before merging with the Olifants River just before the Mozambique border.⁹⁰ The main tributaries of the Letaba River are the Klein Letaba, Middel Letaba, Nsama and Molototsi

⁸⁷ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park River Research Programme Phase 3, p. 4.

⁸⁸ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park River Research Programme Phase 3, p. 4.

⁸⁹ W.F. Strydom *et al.* (eds.), Achievements of the River Health Programme 1994-2004. A national perspective on the ecological health of selected South African Rivers, p. 43.

⁹⁰ WRC, State of Rivers Report. Letaba and Luvuvhu river systems, p. 6.

rivers.⁹¹ The Shingwedzi River joins the Letaba River east of the Mozambique border.⁹² About 40% of the Letaba River catchment falls within the Kruger National Park. Agriculture and forestry activities have severely disrupted the natural flow of the Letaba River. Irrigated agriculture in the Letaba catchment uses about 220 million m³/a of water.⁹³



Figure 2-10: The Letaba River inside the Kruger National Park⁹⁴

Commercial agriculture, which is concentrated mostly in and around Tzaneen, is focused on the production of a variety of fruits and vegetables. River flow is further affected by forestry in the upper catchment, which in 2001 covered nearly 4% of the catchment.⁹⁵ Exotic plantations of eucalyptus and pines have reduced river runoff by around 25% or

⁹¹ WRC, State of Rivers Report. Letaba and Luvuvhu river systems, p. 6.

⁹² G.L. Heritage *et al.*, The geomorphological response to changing flow regimes of the Sabie and Letaba river systems, p. 133.

⁹³ SAWHAR, Waterlit Collection, C. Breen, *et al.*, A description of the Kruger National Park River Research Programme Phase 3, p. 7.

⁹⁴ Photograph, VVPA, PF1, Letaba River, 2011-07-04.

⁹⁵ Anon, State of the Rivers Report for the Letaba and Luvuvhu River systems, p. 13.

64 million m³.⁹⁶ By the mid-1980s water use in the catchment had reached such proportions that water shortages started occurring in the catchment regularly, causing the river to stop flowing during dry parts of the year.⁹⁷ This has had a devastating impact on the biodiversity of especially freshwater fish found in the river, with species such as tiger fish (*Hydrocynus vittatus*) disappearing from the river and other species such as the Southern barred minnow (*Opsaridium peringueyi*), red-spotted labeo (*Labeo congoro*) and small-scale yellowfish (*Labeobarbus polylepis*) no longer found in the middle and lower reaches of the river.⁹⁸

2.4.5 The Olifants River catchment

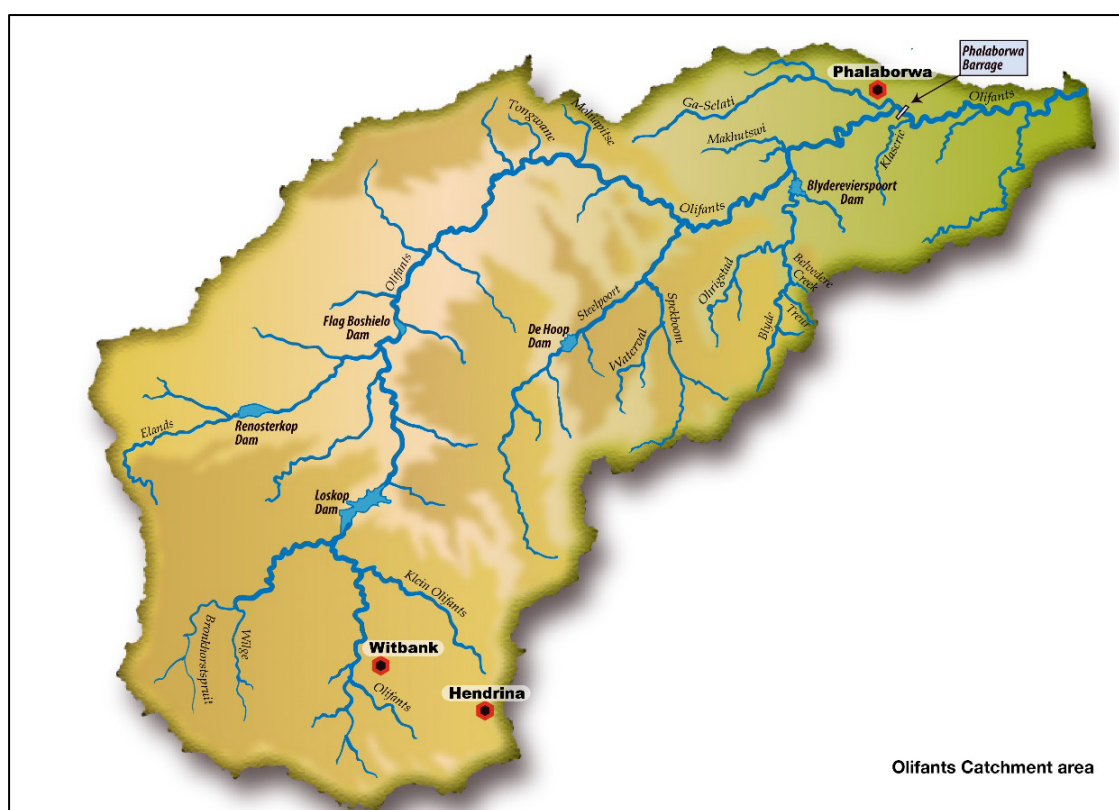


Figure 2-11: The Olifants River catchment⁹⁹

⁹⁶ DWA, Water resources planning of the Letaba River basin. Study of development potential and management of the water resources, p. 9.

⁹⁷ DWA, Water resources planning of the Letaba River basin. Study of development potential and management of the water resources, p. 9.

⁹⁸ W. Vlok & J.S. Engelbrecht, Some aspects of the Groot Letaba River in the Northern Province, South Africa, *African Journal of Aquatic Science*, 25(1), October 2000, p. 80.

⁹⁹ W.F. Strydom et al. (eds.), Achievements of the River Health Programme 1994-2004. A national perspective on the ecological health of selected South African Rivers, p. 41.

Unlike the other main rivers of the Kruger National Park the Olifants River does not have its source in the Great Escarpment. Instead this river cuts through the Escarpment, and rises in the wetlands of the Mpumalanga Highveld.¹⁰⁰ The river flows east through Mpumalanga and Limpopo, with the middle section of the river crossing the Springbok Flats. After the river passes the industrial complex of Phalaborwa it enters the Kruger National Park. The river traverses the park before entering Mozambique where it merges with the Limpopo River and then flows into the Indian Ocean. The Olifants River has the largest catchment area of all the Kruger National Park rivers, namely 54 500km², providing the river with a mean annual runoff of 1 861 million m³.¹⁰¹ Major tributaries include the Wilge, Klein Olifants, Steelpoort, Blyde, Selati and Timbavati rivers.



Figure 2-12: The upper Olifants River immediately downstream from Loskop Dam, Mpumalanga¹⁰²

¹⁰⁰ RHP, State of the rivers report. Crocodile, Sabie-Sand and Olifants River system, p. 26.

¹⁰¹ D.F. Grobler, P.L Kempster & L. van der Merwe, A note on the occurrence of metals in the Olifants River, Eastern Transvaal, South Africa, *Water SA*, 20(3), July 1994, p. 195.

¹⁰² Photograph: VVPA, Photograph File 2 (PF2), Olifants River, 2008-03-28.

The Olifants River catchment is intensively utilised by human activities. The Highveld area (upper catchment) has been subject to extensive mining activities for more than a century, most notably for coal.¹⁰³ In the Steelpoort area (middle catchment) the main mining products are iron, chromium, manganese and magnesium, while phosphate and copper are mined in the lower catchment around Phalaborwa.¹⁰⁴ More than 390 mines have been registered in the Olifants River catchment.¹⁰⁵ Runoff from especially closed and abandoned mines have led to acidification of the Olifants River and pollution with various metals, particularly in the upper section of the river above Loskop Dam.¹⁰⁶ The abundance of coal in the upper catchment led to the establishment of eight power stations in the Highveld area by the mid-1980s. To supplement the water from the Olifants River in the upper catchment, a series of water-transfer schemes were developed to import water from neighbouring catchments, the Komati, Vaal and Usuthu, to meet the constant water needs of power generation.¹⁰⁷ The catchment further hosts a number of irrigation schemes, and irrigated agriculture is the largest water user in the catchment. In 1991 the annual water use by agriculture in the Olifants River catchment reached 510 million m³ used by 17 irrigation boards.¹⁰⁸ The largest irrigation scheme in the catchment is the Loskop irrigation scheme, located in the upper catchment of the Olifants River, near Groblersdal. Supporting more than 16 000ha, this is the second-largest irrigation scheme in South Africa.¹⁰⁹ Non-point source pollution from agricultural activities along with point pollution from dilapidated wastewater treatment have led to nutrient enrichment of the river. In turn, this has led to increased algal growth in the river and outbreaks of cyanobacteria in the Loskop Dam.¹¹⁰ Like the other Kruger National Park river catchments

¹⁰³ F.G. Bell, S.E.T. Bullock, T.F.J. Hällich, P. Lindsay, Environmental impacts associated with an abandoned mine in the Witbank Coalfield, South Africa, *International Journal of Coal Geology*, 45(2-3), January 2001, p. 195.

¹⁰⁴ DWA. Water resources planning of the Olifants river basin. Study of development potential and management of the water resources, p 6.

¹⁰⁵ R. Petersen, Presentation at the dialogue to celebrate world fisheries day and workshop on South African swimway programme, 21 November 2016.

¹⁰⁶ P.J. Kotze, Aspects of water quality, metal contamination of sediment and fish in the Olifants River, Mpumalanga, MSc, RAU, 1997, p. 10.

¹⁰⁷ DWA. Water resources planning of the Olifants river basin. Study of development potential and management of the water resources, p 11.

¹⁰⁸ DWA. Water resources planning of the Olifants river basin. Study of development potential and management of the water resources, p 10.

¹⁰⁹ J. Dabrowski *et al.*, Chemical characteristics and limnology of Loskop Dam on the Olifants River (South Africa), in light of recent fish and crocodile mortalities, *Water SA*, 39(5), October 2013, p. 675.

¹¹⁰ L. van Vuuren, Olifants – Time to stand up for a river under siege, *The Water Wheel*, 12(3), May/June 2013, p. 19.

forestry also occurs in the Olifants River basin where it flows through the Drakensberg. It has been estimated that afforested areas have reduced the mean annual runoff of the river by as much as 56 million m³/a.¹¹¹



Figure 2-13: Kriel Power Station, one of eight power stations that have been developed in the Upper Olifants River catchment¹¹²

2.5 Conclusion

This section provided an overview of the unique characteristics of freshwater systems that serves to provide context to the historical narrative that will follow. Rivers are exceptional not only in terms of the services they provide humankind, but also in terms of their complexity and the richness of species that they harbour. These ecosystem services have been exploited for thousands of years, as the next chapter will demonstrate. Flow is an essential part of river function, and when this function is disrupted, for example, through the construction of dams, it has severe consequences for the downstream aquatic ecosystem. While South Africa's rivers are generally poor in terms of species

¹¹¹ DWA. Water resources planning of the Olifants river basin. Study of development potential and management of the water resources, p. 11.

¹¹² Photograph: VVPA, PF2, Kriel Power Station, 2007-06-11.

composition (compared to international systems) due to the country's natural aridity, South African river systems have a high level of endemism, with species having adapted to a high natural variability of flow. This makes South Africa's aquatic ecosystems both unique and difficult to conserve. South Africa's largest national park, the Kruger National Park, is situated at the lower end of the catchments of five perennial rivers, and is dependent on the water in these perennial rivers where rain generates most of the flow in the upper catchments before the rivers enter the park. Compared to other rivers in the country the rivers feeding the Kruger National Park are biologically diverse, with the Sabie River containing not only the highest number of freshwater species of all the rivers in the park, but also in the country. The main rivers of the Kruger National Park are utilised to various degrees, with the agriculture, industrial and mining sectors being the main water users in these catchments. The next chapter elaborates on the impact of these anthropological impacts on the river systems of the Kruger National Park.

Chapter 3 Man's ties to the river – An overview of the history of water resource development

3.1 Introduction

Freshwater systems are an unequivocal part of human life. Rivers, in particular, run like a golden thread through the ages, being the source of life to small communities and the secret to success of large, ancient settlements alike. Rivers are a rich source not only of freshwater, but also of food, fodder, sediment, nutrients and plant material.¹ From the time the first farmers planted their crops, humans have been altering river ecosystems to suit their needs by way of terraces and canals, dams, weirs and aqueducts.² While the impact of human development on aquatic ecosystems has been noted even from ancient waterworks, it was the advent of the 18th century industrial revolution that ushered in a new era of water resource development on a large scale, with concomitant unprecedented disruptions to natural aquatic processes, as this chapter will demonstrate.³

The chapter then goes on to describe, in short, the development of South Africa's water resources. It is demonstrated that, while South Africa's water resource development had a late start compared to other countries, the construction of dams and concomitant disruption of river flow drastically accelerated following the arrival of European settlers at the Cape in the 17th century, and followed a similar world pattern of acceleration of dam infrastructure.⁴ While the catchments of the Lowveld rivers, which are the focus of this study, have been occupied literally for thousands of years by Stone Age and, since about 300CE, by Iron Age people, water resource development took on a particular urgency in

¹ P. McCully, *Silenced rivers. The ecology and politics of large dams*, p. 8.

² F.A. Hassan, Water management and early civilisations: From cooperation to conflict, http://webworld.unesco.org/water/wwap/pccp/cd/pdf/history_future_shared_water_resources/water_management_early.pdf, p. 2.

³ P. Beaumont, Man's impact on river systems: A worldwide view, *Area*, 10(1), (no month) 1978, pp. 40-41; G. Haidvogel *et al.*, Historical ecology of riverine fish in Europe, *Aquatic Science*, 77(3), July 2015, p. 317.

⁴ L. van Vuuren, Together we can do more – environmental consciousness in the South African dam construction sector (1945-1980), *TD – The journal for transdisciplinary research in South Africa*, 9(1), July 2013, p. 58.

the second half of the 20th century.⁵ The increasing number of dams and weirs in the rivers feeding the Kruger National Park greatly influenced the way in which the park managed the water resources inside its borders in order to overcome increasing water shortages.⁶

3.2 Man's influences on freshwater systems and (un)intended consequences

Rivers have rightly been described as a “fundamental life support”.⁷ Apart from providing humans with food and material for shelter rivers also wash down valuable sediment, sweep away pollution, power industries, and play an important role in cultural beliefs and practices.⁸ The global economic value of freshwater ecosystem services has been estimated at US\$6.5 trillion/a (2010 figures)⁹ or about R90 trillion/a as at 4 April 2017 exchange rates.¹⁰ Humankind has been altering river systems for thousands of years, be it for water-supply, flood protection, transport or electricity generating purposes. Water resources development around large river systems in ancient civilisations is well documented, in particular the dams and canal systems along the Nile, Euphrates and Tigris, Indus as well as the Yangtze rivers.¹¹ Constructed between 7000 and 5000 years ago, these early structures were mostly associated with agriculture and the rise of centralised state systems. While we are mostly left with only remnants of ancient infrastructure there is little doubt about the sophistication of some of these early water

⁵ R. Packard, Malaria blocks development revisited: The role of disease in the history of agricultural development in the Eastern and Northern Transvaal Lowveld, *Journal of Southern African Studies*, 27(3), September 2001, p. 608.

⁶ Archive of South African National Parks (Sanparks), NK/18/1 [K39/1], U. de V. Pienaar, Interne memorandum gegewe die waterbronne van die Krugerwildtuin – 'n Opsomming van die huidige toestand, asook die waterverskaffingsprogram – wat reeds vermag is en die pad verder, 1969-05-30.

⁷ S.L. Postel, Securing water for people, crops and ecosystems: New mindset and new priorities, *Natural Resources Forum*, 27(2), May 2003, p. 89.

⁸ P. McCully, *Silenced rivers. The ecology and politics of large dams*, p. 9.

⁹ D.L. Strayer & D. Dudgeon, Freshwater biodiversity conservation: Recent progress and future challenges, *Journal of the North American Benthological Society*, 29(1), March 2010, p. 345.

¹⁰ At an exchange rate of R13.87 to US\$1 as at 10 April 2017.

¹¹ See for example, P. Viollet, *Water engineering in ancient civilisations. 5 000 years of history*. (CRC Press: USA, 2007); V.L. Scarborough, Water management adaptations in non-industrial complex societies: An archaeological perspective, *Archaeological Method and Theory*, 3(1), (no month) 1991, pp. 191-154; and F.A. Hassan et al. (eds.), *History and future of shared water resources*. (PCCP Series No. 6, UNESCO: Paris, 2003).

structures, such as the 15m-high masonry dam constructed by Pharaoh Menes outside the Egyptian city of Memphis.¹²

In Sri Lanka, surviving records detail the history of dams dating back to the sixth century BCE.¹³ The Minneriya Dam, which was built between 276 and 303CE, is one of 50 ancient dams that have been restored and are still in use in Sri Lanka today.¹⁴ Further east, Japan boasts the largest number of surviving dam structures (i.e. 14), most of them built between 400 and 1000CE.¹⁵ The remains of water resources infrastructure can also be found in parts of South America. Here, ancient civilisations, such as the Maya, exploited lowland wetland systems through canals for agricultural purposes.¹⁶ The Aztec capital Tenochtitlán's 200 000 inhabitants were supplied with water by a network of canals, while food was grown through a flood irrigation system made possible by the construction of terraces and captured mountain runoff and spring water.¹⁷ Groundwater contributes to the base flow of rivers, and therefore also plays an important role in the sustainability of surface freshwater systems.¹⁸ While groundwater is not the focus of this study, it must be recognised that aquifers have been exploited in equal measure to freshwater systems through the ages. The *qanat*, a water engineering system, comprising tunnels and wells, has been used in Middle Eastern and North African countries to exploit aquifers for thousands of years.¹⁹ Countries such as Iran, said to be one of the first regions in the world where the technology evolved, have around 22 000 *qanats*, illustrating the intensity with which these underground sources have been tapped for human use.²⁰

While the reasons for the demise of ancient civilisations remain open to debate and, in particular, the degree to which elements such as climate change and natural events

¹² S. Solomon, *Water. The epic struggle for wealth, power and civilisation*, p. 31.

¹³ International Committee on Large Dams (ICOLD), *Dams and the world's water*, p. 18.

¹⁴ ICOLD, *Dams and the world's water*, p. 18.

¹⁵ ICOLD, General synthesis of the register of dams, http://www.icold-cigb.net/GB/World_register/general_synthesis.asp?IDA=206.

¹⁶ K.O. Pope & B.H. Dahlin, Ancient Maya wetland agriculture: New insights from ecological and remote sensing research, *Journal of Field Archaeology*, 16(1), Spring 1989, p. 87.

¹⁷ B. Fagan, *Elixir – A human history of water*, pp. 247-248.

¹⁸ D.C. le Maitre & C.A. Colvin, Assessment of the contribution of groundwater discharges to rivers using monthly flow statistics and flow seasonality, *Water SA*, 34(5), October 2008, p. 551.

¹⁹ V.L. Scarborough, Water management adaptations in non-industrial complex societies: An archaeological perspective, *Archaeological Method and Theory*, 3(1), (no month) 1991, p. 109.

²⁰ L.W. Mays *et al.*, A brief history of urban water supply in the antiquity, *Water Science and Technology*, 7(1), March 2007, p. 1.

contributed to the collapse of these societies, there is consensus over the fact that early water resource developments already had an impact on surrounding natural systems.²¹ As water resource exploitation proficiency increased so did communities' ability to support larger populations, and many societies ultimately experiencing a situation in which the demand for natural resources outstripped supply.²² When overpopulation and dwindling natural resources were combined with environmental calamities such as drastic climate change as well as political and economic instability, it resulted in the decline of many of these ancient societies.²³ As population densities increased so did water resource development for urban water use. Higher densities of people required more water, more food, and more systems to get rid of waste.

The appearance of the first cities spurred on the construction of advanced urban water-supply systems, including the first wastewater systems and the relay of water through pipes and canal systems for home use and public baths. In Greek and Roman cities water was transported over mountainous terrain using large aqueducts.²⁴ Most of these sophisticated water technologies disappeared into obscurity following the decline of the Roman Empire, but some, such as the water wheel, a technology brought to Europe from the Middle East, endured.²⁵ Even before large-scale industrial development, advances in agricultural technologies and the concomitant increase in grain mills led to greater impact on receiving water bodies. Hoffman studied the impact of economic development on European freshwater systems in medieval times.²⁶ He describes how water wheels and associated dams affected fish migrations, specifically anadromous species (fish species that spawn in freshwater but spend most of their life in the ocean). Fish populations

²¹ G.D. Middleton, Nothing lasts forever: Environmental discourses on the collapse of past societies, *Journal of Archaeological Research*, 20(3), September 2012, p. 258; M.W. Binford *et al.*, Climate variation and the rise and fall of an Andean civilisation, *Quaternary Research*, 47(2), March 1997, p. 243; T. Abate, Climate and the collapse of civilisation, *Bioscience*, 44(8), September 1994, p. 516; H.H.G. Savenije *et al.*, Evolving water science in the Anthropocene, *Hydrology and Earth System Sciences*, 18(1), January 2014, p. 321.

²² S. Solomon, *Water. The epic struggle for wealth, power and civilisation*, p. 16.

²³ G.D. Middleton, Nothing lasts forever: Environmental discourses on the collapse of past societies, *Journal of Archaeological Research*, 20(3), September 2012, p. 258.

²⁴ L.W. Mays *et al.*, A brief history of urban water supply in the antiquity, *Water Science and Technology*, 7(1), March 2007, p. 7.

²⁵ C. Rynne, The technical development of the horizontal water-wheel in the first millennium a.d: Some recent archaeological insights from Ireland, *The International Journal for the History of Engineering & Technology*, 85(1), January 2015, p.72.

²⁶ R.C. Hoffman, Economic development and aquatic ecosystems in medieval Europe, *The American Historical Review*, 101 (3), June 1996, pp. 631-669.

declined, not only because they could no longer move up and down river courses, but also due to the draining of large parts of freshwater systems for agriculture purposes, which disrupted breeding grounds. At the same time, water pollution increased as human waste and pollution of early manufacturing processes gravitated into water courses.²⁷ Similar studies have been undertaken for river systems such as the Mersey River (England), Wien River (Vienna) and the Rhine.²⁸

As of the mid-18th century the industrial revolution was spurred on, first in England and then the rest of Europe thanks to the exploitation of rivers by various means. As Tvedt points out “water was the main power source in the initial phase of the industrial revolution”.²⁹ The water wheel was at the centre of industrial development, enabling the milling of grain, the spinning of cotton, the forging of iron, and various others industrial processes. Factories were located next to rivers and streams, with small dams enabling a concentrated water supply to the water wheel.³⁰ The water wheel would later be replaced by another kind of hydraulic power, namely steam. To transport goods and services extensive use was made of waterborne transport, leading to the building of canals on a large scale between 1760 and 1840.³¹ By the end of this period Britain alone had 3 400 navigable rivers and 3 200km of canals.³² As Europeans settled on other continents they took their water technologies with them. So the USA, for example, had more than 65 000 water-milling operations by 1840, many of them associated with dams.³³

²⁷ R.C. Hoffman, Economic development and aquatic ecosystems in medieval Europe, *The American Historical Review*, 101 (3), June 1996, p. 638.

²⁸ P.D. Jones, Water quality and fisheries in the Mersey estuary, England: A historical perspective, *Marine Pollution Bulletin*, 53 (1-4), (no month) 2004, pp. 144-154; G. Pollack *et al.*, Using and abusing a torrential urban river: The Wien River before and during industrialisation, *Water History*, 8(3), September 2016, pp. 329-355; H.J.R. Lenders, Fish and fisheries in the Lower Rhine 1550-1950: A historical-ecological perspective, *Journal of Environmental Management* (in Press), 2016, pp. 1-9.

²⁹ T Tvedt, Why England and not China and India? Water systems and the history of the Industrial Revolution, *Journal of Global History*, 5(1), March 2010, p. 40.

³⁰ T Tvedt, Why England and not China and India? Water systems and the history of the Industrial Revolution, *Journal of Global History*, 5(1), March 2010, p. 41.

³¹ T Tvedt, Why England and not China and India? Water systems and the history of the Industrial Revolution, *Journal of Global History*, 5(1), March 2010, p. 34.

³² T Tvedt, Why England and not China and India? Water systems and the history of the Industrial Revolution, *Journal of Global History*, 5(1), March 2010, p. 35.

³³ R.C. Walter & D.J. Merritts, Natural streams and the legacy of water-powered mills, *Science*, 319 (5861), January 2008, p. 300.

The increase in demand for water as a result of the industrial revolution led to a proliferation of dams.³⁴ Advances in engineering and construction also saw the appearance of the first large dams, such as the 21m-high Glencore Dam, completed in 1821, outside Edinburgh.³⁵ (“Large dams” are defined by the International Committee of Large Dams (ICOLD) as dams that are at least 15m high from their lowest foundation.³⁶) In the New World of North America, the city of New York’s first large water-supply dam, the Croton, was completed in 1842 with the construction of the 15m-high weir.³⁷ By the end of the 19th century the United States was one of the major trendsetters in water-related technologies. Hydropower supplemented coal and gas to drive industrial processes. The world’s first large hydroelectric power station was constructed at Niagara Falls in 1886.³⁸ Countries such as Norway, Switzerland and Italy soon embraced hydropower as an alternative source of energy, and today receive almost all of their electricity from this source. Their systems are supported by a multitude of dams and complex water structures.³⁹ The completion of the 221m-high Hoover Dam on the Colorado River in 1936 marked the beginning of the era of mega dams (dams with a height above foundation more than 100m).⁴⁰ At the time of its construction, the Hoover Dam was the highest dam in the world. Two decades later it was overshadowed by the Mauvoisin Dam (250m high) in Switzerland, completed in 1957. In 1961, construction of the 262m-high Vaiont Dam was completed in the same country.⁴¹

ICOLD, which keeps a register of all large dams in the world, lists the five largest dams (in terms of height) as Rogun (335m) and Nurek (300m) in Tajikistan, Bakhtiyari (315m) in Iran, and Jinping 1 (305m) and Lianghekou (295m) dams in China.⁴² It is not only the height and size of dams that have increased, but also their sheer number. Water resource

³⁴ T. Turpin, *Dam*, p. 34.

³⁵ T. Turpin, *Dam*, p. 34.

³⁶ ICOLD, General synthesis of the register of dams, http://www.icold-cigb.net/GB/World_register/general_synthesis.asp?IDA=206.

³⁷ T. Turpin, *Dam*, p. 39.

³⁸ S. Solomon, *Water. The epic struggle for wealth, power and civilisation*, p. 243.

³⁹ T. Turpin, *Dam*, p. 40.

⁴⁰ D.P. Billington, *et al.*, *The history of large federal dams: planning, design and construction in the era of big dams*, p. 171.

⁴¹ T. Turpin, *Dam*, p. 137.

⁴² ICOLD, General synthesis of the register of dams, http://www.icold-cigb.net/GB/World_register/general_synthesis.asp?IDA=206.

development was greatly amplified by the technological advances of the Second World War (1939-1945). Spurred on first by the Cold War and then as part of endeavours to prompt economic growth the number of large dams around the world increased from approximately 5 000 to 45 000 between 1949 and 2000.⁴³ The majority of dams were constructed between 1970 and 1980. While global dam construction dropped sharply in the 1990s, the last two decades have seen a significant increase in the number of dams being planned or built, mostly in developing countries.⁴⁴ The top ten countries in terms of the number of large dams is provided in Table 3-1.

Table 3-1: Top ten countries in the world in terms of number of large dams⁴⁵

Ranking	Country	Number of large dams
1	China	23 842
2	USA	9 265
3	India	5 102
4	Japan	3 108
5	Brazil	1 392
6	Republic of Korea	1 306
7	Canada	1 170
8	South Africa	1 114
9	Spain	1 082
10	Turkey	972

China alone accounts for almost half the world's number of large dams today, while together the top ten account for more than 80% of the total number of dams in the world.⁴⁶ The vast majority of large dams constructed are earthen structures (64%), followed by rock-fill dams (13%), and gravity dams (12%).⁴⁷ Globally, it is estimated that as much as 60% of the world's 227 largest rivers have been altered by man-made structures.⁴⁸ The evident prolific flow modification of river systems has taken its toll on countries such as

⁴³ World Commission on Dams (WCD), Dams and development. A new framework for decision-making, p. 8.

⁴⁴ B.D. Richter *et al.*, Lost in development's shadow: The downstream human consequences of dams, *Water Alternatives*, 3(2), June 2010, p. 16.

⁴⁵ ICOLD, General synthesis of the register of dams, http://www.icold-cigb.net/GB/World_register/general_synthesis.asp?IDA=206.

⁴⁶ R.E. Tharme, A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers, *River Research and Applications*, 19 (5-6), September 2003, p. 398.

⁴⁷ ICOLD, General synthesis of the register of dams, http://www.icold-cigb.net/GB/World_register/general_synthesis.asp?IDA=206.

⁴⁸ B. Richter & S. Postel, Saving Earth's rivers, *Issues in Science and Technology*, 20(3), Spring 2004, p. 31.

the USA, where only 2% of all rivers remain free-flowing.⁴⁹ In Europe there are only three large river systems remaining which have not yet been dammed.⁵⁰ South Africa is the only African country featuring on the list of top ten dam-building countries.

3.3 Brief history of water resource development in South Africa

Modernist water storage facilities in South Africa are of fairly recent origin. Indigenous pre-colonial cultural communities were well adapted to their semi-arid environments. How exactly water was used by the hunter-gatherer and pastoral communities in South Africa remains unclear. This kind of study is made difficult by these communities' nomadic lifestyles and what has been described as their "highly perishable material culture".⁵¹ It would have been inevitable for hunter-gatherer communities to have some impact on the environment around them, but because of the small size of the family bands living and travelling together, this influence would have been small and easily dissipated. Hunter-gatherer communities travelled across the country seeking out water-rich areas, moving on when a resource became dry, and fodder depleted. By leaving land to lie fallow at times, sheep-herding communities prevented overgrazing and reduced environmental impact.⁵² Water storage as such would then have probably been confined to the volume of water that could be carried by a person. Vessels such as gourds, animal bladders and ostrich eggs have been discovered to have been used to store and carry water.⁵³ In the Northern Cape Province, caches of ostrich eggs have been discovered that could have been used to store water for later use.⁵⁴ Rivers did not only provide water, but also food. For example, in the Orange River and in the Drakensberg, there are accounts of hunter-gatherer communities using weaved baskets to catch fish.⁵⁵ The first Bantu-speaking

⁴⁹ P.M. Vitousek *et al.*, Human domination of Earth's ecosystems, *Science*, 277 (5325), July 1997, p. 497.

⁵⁰ C. Nilsson *et al.*, Fragmentation and flow regulation of the world's large river systems, *Science*, 308 (405), April 2005, p. 405.

⁵¹ A.B. Smith, Prehistoric pastoralism in the Southwestern Cape, South Africa, *World Archaeology*, 15(1), June 1983, p. 79.

⁵² J.A. Denison & L. Wotshela, An overview of indigenous, indigenised and contemporary water harvesting and conservation practices in South Africa, *Irrigation and Drainage*, 61(Supplement 2), October 2012, p. 9.

⁵³ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 15.

⁵⁴ Z. Henderson, A dated cache of ostrich-eggshell flasks from Thomas' Farm, Northern Cape, *The South African Archaeological Bulletin*, 57(175), June 2002, pp. 38-40.

⁵⁵ J. Parkington, Hunter-fisher-gatherers of the Olifants River valley, Western Cape, *The South African Archaeological Bulletin*, 32(126), December 1977, p. 152; F.A. Venter, *Water*, p. 224.

farming communities reached South Africa from the north between 350 and 450CE. Settling near rivers in the wetter, eastern parts of the country these communities used several techniques to water crops, including terracing and rainwater harvesting. Evidence of irrigation systems have been uncovered throughout southern Africa.⁵⁶ The practice of *gelesha* became common by the 18th century – this is a rainwater harvesting method where the earth is tilled after harvesting to allow precipitation to infiltrate.⁵⁷ Other traditional methods of capturing rainwater include *matamo* (also known as *ipitsi*), hand-dug pits from which furrows are led to divert precipitation.⁵⁸ However, as Tempelhoff points out, the role of water and, particularly, water infrastructure among these early farming communities, remains largely underexplored.⁵⁹

The settlement of Europeans at the southern tip of Africa launched the beginning of large-scale water resource development in South Africa. When the Dutch first settled at the Cape they diverted the small rivers from Table Mountain and constructed canals in the style of their home country in order to establish water supply to their settlement as well as to fill the water caskets of passing ships. The first recorded modern dam held around 2 000m³ of water.⁶⁰ The Waegenaar's Dam – named after Zacharias Waegenaar who succeeded Jan van Riebeeck as Dutch East India Company commander of the Cape – was completed in 1663 and is thought to be the oldest modern masonry weir structure in South Africa.⁶¹ For the farming of European crops, such as wheat and grapes, irrigation canals and small dams were constructed. As farmers moved into the drier interior of the country, they dammed wells and led irrigation furrows from streams and fountains.⁶² In addition to importing European water engineering technologies, the descendants of the

⁵⁶ J.E.G. Sutton, Irrigation and soil conservation in African agricultural history with a reconsideration of the Inyanga terracing (Zimbabwe) and Engaruka irrigation works (Tanzania), *The Journal of African History*, 25(1), (no month) 1984, p. 30.

⁵⁷ J.A. Denison & L. Wotshela, An overview of indigenous, indigenised and contemporary water harvesting and conservation practices in South Africa, *Irrigation and Drainage*, 61(Supplement 2), October 2012, p. 9.

⁵⁸ J.A. Denison & L. Wotshela, An overview of indigenous, indigenised and contemporary water harvesting and conservation practices in South Africa, *Irrigation and Drainage*, 61(Supplement 2), October 2012, p. 11.

⁵⁹ J. Tempelhoff, Exploring panarchy and social ecological resilience: Towards understanding water history in precolonial southern Africa, *Historia*, 61(1), May 2016, p. 109.

⁶⁰ SANCOLD, *Large dams and water systems in South Africa*, p. 33.

⁶¹ SANCOLD, *Large dams and water systems in South Africa*, p. 33.

⁶² W. Beinart, *The rise of conservation in South Africa – Settlers, livestock and the environment*, pp. 88-89.

first European settlers also adopted traditional African technologies. One of these traditional methods was the “zaaidam” (loosely translated as “sowing” or “planting dam”). From the 18th century farmers in the arid Northern Cape were particularly fond of this system of constructing low (one metre to two metre) earthen walls across large, shallow basins to retain floodwater over large tracts of land to plant grains and later lucerne.⁶³ This technology is still in use today.



Figure 3-1: The remains of the Waegenaar’s Dam was uncovered during excavations for the Golden Acre shopping centre in 1975. Posing at the excavation of the dam remains is SA Museum archaeologist, Michael Wilson⁶⁴

Until the unification of South Africa in 1910 bulk water supply systems were practically the exclusive pursuit of private landowners, small European village settlements in the interior, early municipalities in the Cape Colony, and missionaries who established irrigation settlements.⁶⁵ Robert Moffat led the construction of a dam near Kuruman in the Northern Cape in the 1820s, while by 1834 the use of furrows was well established at

⁶³ W. Beinart, *The rise of conservation in South Africa – Settlers, livestock and the environment*, p. 91.

⁶⁴ Photograph: National Library Visual Collection, Cape Times Collection, 1975-07-03.

⁶⁵ J.C. Brown, *Water supply of South Africa and facilities for the storage of it*, pp. 305, 472.

mission stations in the Kat River valley, in the Eastern Cape.⁶⁶ Similar water leading infrastructure was introduced at the Moravian missions at Hemel-en-Aarde and Zuurberg.⁶⁷ One of the most ambitious water infrastructure schemes attempted by missionaries was the Hankey tunnel constructed by William Philip of the London Missionary Society. This 228m-long, hand-dug irrigation tunnel, completed in 1845, was the first of its kind to be built in the country, and led water from the Gamtoos River through the Vensterhoek mountain to water irrigation lands on the other side.⁶⁸ From the 1860s first the discovery of diamonds (~1867) and gold (1873-1880) provided significant impetus to bulk water infrastructure development in South Africa. Mining activities resulted in the establishment of new towns not necessarily located near a water source, as is the case with Kimberley (anno 1871) and Johannesburg (anno 1886). These fast-growing settlements required reliable water supply for thousands of newcomers searching for riches and glory, while the demand for foodstuffs found farmers searching for innovative ways to improve their crop yield.⁶⁹ One way in which farmers sought to overcome the country's naturally erratic water supply was through the establishment of storage schemes. These erstwhile dams and weirs were most often unsophisticated earth and rock structures scraped together with the use of donkeys or oxen. There was also the "bush weir" – a loose structure of branches and stones packed across a stream, and the "wire dam", made of fencing fire anchored into the streambed and packed with stone and rubble.⁷⁰ It was not unusual for these structures to be repeatedly rebuilt as they were regularly washed away by stormflows.

In the meantime, larger towns – which had hitherto mainly depended on springs or run-of-river supplies – started constructing dams on their own steam to meet the rising demand of a growing population. South African towns grew exponentially as a result of the mineral revolution, from only 45 towns in 1845 (when the first town councils were formed) to around 369 in 1921.⁷¹ Many towns appointed municipal engineers to oversee

⁶⁶ W. Beinart, *The rise of conservation in South Africa – Settlers, livestock and the environment*, pp. 90-91.

⁶⁷ J.C. Brown, *Water supply of South Africa and facilities for the storage of it*, p. 472.

⁶⁸ L van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 35.

⁶⁹ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 36.

⁷⁰ F.D. McDermott, The district of Oudtshoorn, *Agricultural Journal of the Cape of Good Hope*, 27(3), September 1905, p. 355.

⁷¹ F. Pretorius (ed.), *Geskiedenis van Suid-Afrika. Van voortye tot vandag*, p. 197.

infrastructure development, including water. With little exception most of the country's first engineers were of British origin. Of the first 73 municipal engineers in South Africa only four were not English-speaking.⁷² Among the early municipal water schemes completed under the direction of these municipal engineers were the Frames Dam for Port Elizabeth in 1863,⁷³ the Bongolo Dam for Queenstown, in the Eastern Cape, in 1908,⁷⁴ and Maden Dam for King Williamstown in 1910.⁷⁵ An earthen dam was constructed to supply water to Durban from Umbilo River in 1905.⁷⁶ In addition to hiring their own engineers, town councils also made use of consulting engineers, the most well-known from this period being the Scotsman, Thomas Stewart. He was responsible for the construction of the first sizeable dam for Cape Town, namely the Woodhead Dam on Table Mountain (completed in 1905), as well as water-supply schemes for towns such as Port Elizabeth, Worcester, Oudtshoorn and Stellenbosch.⁷⁷ The appointment of the first hydraulic engineer at the Cape in 1875, John Gamble, as well as the passing of the 1877 Irrigation Act, which provided loans to farmers for water schemes for agricultural purposes as long as they organised themselves into so-called irrigation districts, further stimulated private investment into water resource development.⁷⁸ Economic boom sectors, such as ostrich feathers – which required lucerne as feed for the paddocked birds – also contributed to water resource development for irrigation purposes. This was particularly evident in the area of Oudtshoorn – the epicentre of the ostrich feather industry.⁷⁹

In 1905, F.D. McDermott described the district as

one huge irrigation settlement of which the town is the centre, and the bulk of the people seem to have but one object in life – viz, to bring under irrigation more

⁷² H. Mäki, *Municipal engineers in South Africa before 1910*, p. 60.

⁷³ D. Raymer, *Streams of life. The water supply of Port Elizabeth and Uitenhage*, pp. 20-21.

⁷⁴ J.R. Crawford & M.C. Dachs, Bongolo Dam, Queenstown, *The Civil Engineer in South Africa*, 22(6), June 1980, p. 169.

⁷⁵ G.C. Smith, Maden Dam reservoir, *The Civil Engineer in South Africa*, 19(8), August 1977, p. 193.

⁷⁶ W.M. Campbell, Durban Water Supply, *Minutes of Proceedings of the South African Institution of Civil Engineers*, 23(1), January 1925, p. 111.

⁷⁷ T. Murray, Past Master 19: Thomas Stewart, *Civil Engineering*, 16(10), October 2008, p. 37.

⁷⁸ F.E. Kanthack, Irrigation development in the Cape Colony: Past, present and future, *Agricultural Journal of the Cape of Good Hope*, 36(3), March 1910, p. 645.

⁷⁹ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p.83.

*and yet more of the exceedingly rich land which is absolute waste without irrigation waters.*⁸⁰

Following unification in 1910 the Union Irrigation Department was established out of the pre-South African War departments of the Cape and the Transvaal, and the Irrigation and Conservation of Water Act [Act No. 9 of 1912] (Irrigation Act) was passed. The law sought to boost further public and private investment (mostly through cooperation) into irrigation infrastructure (including dams) and further emphasised the South African government's almost exclusive focus on water for irrigated agriculture.⁸¹ The latter is illustrated by the fact that in 1910, the vast majority i.e. 96% of all water consumed in South Africa (some 3 000 million m³/a) was used for irrigation and stock watering.⁸² Forde estimated that by 1921 around half of the 5.3 million hectares under production in South Africa was under irrigation.⁸³ The country's first dams exceeding the 20m-high mark were constructed in a dam-building boom which lasted until the advent of the Second World War (1939-1945). Large dams constructed during this period include Hartbeespoort Dam (59m high), Kamanassie Dam (41m), Sundays River Dam (34m), Lake Arthur (38m), Grassridge Dam (24m) and Tygerpoort Dam (20m).⁸⁴ With the exception of Hartbeespoort Dam, constructed as part of a government irrigation settlement scheme for indigent whites, all the large dams in South Africa up to that point were constructed by private irrigation boards through loans and engineering assistance from the Irrigation Department.⁸⁵ By 1925, 27 large dams had been constructed in South Africa.⁸⁶

⁸⁰ F.D. McDermott, The district of Oudtshoorn, *Agricultural Journal of the Cape of Good Hope*, 27(3), September 1905, p. 348.

⁸¹ L. van Vuuren. *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 66.

⁸² DWA, *Water* 75, p. 15.

⁸³ C.D. Forde, Irrigation in South Africa, *The Geographical Journal*, 65(4), April 1925, p. 342.

⁸⁴ DWA, *Water* 75, p. 33.

⁸⁵ C.O. Linscott, A short history of irrigation development in South Africa, *South African Irrigation Department Magazine*, 3(2), June 1924, p. 51.

⁸⁶ SANCOLD, 2009. South African list of large dams, http://www.sancold.org.za/index.php?option=com_content&view=article&id=64&Itemid=74.



Figure 3-2: Kamanassie Dam outside Oudtshoorn, constructed between 1919 and 1925⁸⁷



Figure 3-3: Workers washing sand on the Marico-Bosveld irrigation scheme construction site in 1932⁸⁸

In 1929, South Africa started experiencing an economic tightening as a result of the aftermath of the New York stock exchange crash, which dumped the world into a severe

⁸⁷ Photograph, VVPA, DWA Photographic Archive (DWAPA), Kamanassie Dam.

⁸⁸ Photograph: VVPA, DWAPA, Sand washing at Marico-Bosveld, 1932.

economic depression.⁸⁹ At the same time, South Africa was facing one of the worst droughts in its recorded history.⁹⁰ To relieve resultant unemployment, particularly among the white population, the government announced an accelerated dam construction programme that focused on maximising job creation in the 1930s.⁹¹ This led to the construction of large dams such as Loskop, Buchberg, Clanwilliam, Rust de Winter and Bospoort, among others, which all formed part of government-run irrigation schemes. The only large dam the Irrigation Department did not construct solely for irrigation purposes during this time was the Vaal Dam. In addition to providing water to the Vaalharts irrigation scheme – the largest irrigation scheme in the country – the Vaal Dam also boosted water supply to Johannesburg.⁹² The Irrigation Department and its engineers were ill prepared for this sudden peak in construction – many of these works were completed on the fly without the necessary planning and pre-construction design.⁹³ The majority of the schemes were purposely built using manual labour to maximise job creation. As a result, large construction camps were built on site to house thousands of workers and their families.

Prompted by significant economic growth and in line with international trends, dam building reached a peak in South Africa in the post-war period up to 1980. The majority of these schemes were for irrigation purposes, in line with the National Party-government's policies of supporting and protecting the local agricultural sector.⁹⁴ At the height of the dam-building era in South Africa, the agricultural sector used as much as 84% of the country's water supply.⁹⁵ While commercial farmers were provided all the water they needed there was little focus on water use efficiency. Up until the 1960s, inefficient irrigation practices, such as flood irrigation, were the norm and many irrigation canals were unlined earthen structures, resulting in excessive water losses.⁹⁶ In 1956, a new Water Act was passed by parliament. While the Act still placed ownership of water in the hands of riparian land owners the government could now, through the minister of

⁸⁹ F. Pretorius (ed), *Geskiedenis van Suid-Afrika. Van voortye tot vandag*, p. 456.

⁹⁰ A.R. Turton *et al.*, A hydropolitical history of South Africa's international river basins, p. 50.

⁹¹ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 107.

⁹² SANCOLD, South African large dams – A century of engineering innovation, p. 158.

⁹³ Unie van Suid-Afrika, Rapport van die Direkteur van Besproeiing vir die tydperk 1 April 1931 tot 31 Maart 1932. (UG12-'33, Staatsdrukker: Pretoria, 1933).

⁹⁴ F. Pretorius, *Geskiedenis van Suid-Afrika. Van voortye tot vandag*, pp. 457-458.

⁹⁵ RSA, Report of the Commission of Enquiry into Water Matters, p. 61.

⁹⁶ RSA, Report of the Commission of Enquiry into Water Matters, p. 124.

water, declare certain catchments water control areas, and decide how water should be distributed in catchments.⁹⁷ The Act also recognised water use for industrial and domestic purposes, which had been growing steady since the Second World War, particularly through government-supported corporations, such as Iscor, Sasol and Eskom.⁹⁸ In recognition of the increasing role of mining, industrial and urban development on the country's water resources, this Act also introduced the country's first attempts at controlling water pollution.⁹⁹ The aquatic environment remained unacknowledged in South Africa's national water legislation, however. The only protection afforded to the aquatic environment at this stage was set in provincial legislation, particularly the Cape Inland Fisheries Ordinance [No 15 of 1941], the Natal Fisheries Ordinance [No. 11 of 1946] and the Transvaal Fisheries Ordinance [No. 11 of 1946], which were mainly set in place to sustain the sport fishing industry and, ironically exotic species, such as trout.¹⁰⁰

In addition, the Water Act cemented the role of the DWA (which changed its name from the Irrigation Department in 1956) as the prime dam builder in South Africa. The volume of water resource development can be seen in the number of White Papers published for the construction of new dams and the raising of existing dams for approval by parliament, which averaged 20 a year during this period.¹⁰¹ Prior to the construction of the Orange River Project in the 1960s and 1970s DWA undertook most of its own construction work, and its construction department alone employed 20 000 workers for this purpose (excluding department officials).¹⁰² By 1972 the DWA's annual expenditure on construction projects had reached R114 000 – three-and-a-half times the figure spent in 1932.¹⁰³ Subsidies were introduced for municipalities who needed to expand their bulk water infrastructure due to rising demand as a result of rapid urbanisation. This saw a number of large dams being constructed by municipalities for domestic water supply, including Wemmershoek Dam for Cape Town (completed in 1957),¹⁰⁴ Bridle Drift Dam for

⁹⁷ RSA, Report of the Commission of Enquiry into Water Matters, p. 26.

⁹⁸ F. Pretorius (ed.), *Geskiedenis van Suid-Afrika. Van voortye tot vandag*, p. 462.

⁹⁹ H.A. Strydom & N.D. King (eds.), *Fuggle and Rabie's environmental management in South Africa*, p. 858.

¹⁰⁰ National Archive Repository Pretoria (NAR), Central Archives Repository (SAB), Department of Health (1900-1973) (GES), 2069 [107/33], Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), pp. 1-3.

¹⁰¹ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p.180.

¹⁰² L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 181.

¹⁰³ DWA, *Water 75*, p.85.

¹⁰⁴ L. van Vuuren, Wemmershoek – 75 years in the making, *The Water Wheel*, 9(2), March 2010, p. 19.

East London (completed in 1967),¹⁰⁵ and Midmar Dam for Pietermaritzburg and Durban.¹⁰⁶ Large departmentally constructed dams were no longer constructed mainly for irrigation purposes, but also for power generation, industry, and mining requirements.¹⁰⁷ The first DWA-constructed scheme in which the end goal was not irrigation was the scheme to supply water from the Vaal River to the Orange Free State Goldfields.¹⁰⁸ This scheme was completed in 1951.¹⁰⁹ By 1981 South Africa had constructed dams in all of its major river systems, and had 340 large dams registered on the World Register of Large Dams.¹¹⁰ These dams stored around 46% of the country mean annual runoff. Another notable feature of dam construction in South Africa between 1960 and 1990 was the proliferation of water-transfer schemes – dams and associated pipelines designed to take water from catchments where water was in excess and convey it to other catchments where water resources were inadequate to meet demand. Transfer schemes constructed during this period include, among others, the Thukela-Vaal, Riviersonderend-Berg River, Usutu-Vaal and the Orange-Fish schemes.¹¹¹ The largest of these schemes is the Lesotho Highlands Water Project, of which the first phase was developed over a period of 20 years. Through this scheme, which includes various dams, tunnels and pipelines, water is transferred from the Senqu River in Lesotho to the Vaal River system to serve Gauteng.¹¹² There has been a steady decline in the construction of dams in South Africa since the 1980s. Today (2017), about 70% of the country's mean annual runoff (33 900 million m³) is stored by 252 large dams.¹¹³ In addition, there are more than 3 500 smaller dams on the country's Dam Safety Register.¹¹⁴ The water from these dams are used mostly for irrigation and stock watering purposes.

¹⁰⁵ T. Murray, *Ninham Shand. The man, the practice*, p. 121.

¹⁰⁶ V.W. Steinijans, Steady state probabilities for storage in Midmar Dam, Natal, *The Civil Engineer in South Africa*, 12(8), August 1970, p. 183.

¹⁰⁷ DWA, *Management of the water resources of the RSA*, p. 1.10.

¹⁰⁸ A.R. Turton, *et al.*, A hydropolitical history of South Africa's international river basins, pp. 202-203.

¹⁰⁹ L. Van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 145.

¹¹⁰ W.H.J. Hattingh (ed.), *Water Year +10 and then*, p. 1.

¹¹¹ DWA, *Management of the Water Resources of the RSA*, p. 1.11.

¹¹² Deutsche Welle, 20 August 2012, The Lesotho Highlands Water Project, <https://www.youtube.com/watch?v=f21uPDGL1dA>.

¹¹³ P. Roberts, Dams in South Africa, <http://www.sancold.org.za/index.php/about/about-dams/dams-in-south-africa>.

¹¹⁴ P. Roberts, Dams in South Africa, <http://www.sancold.org.za/index.php/about/about-dams/dams-in-south-africa>.

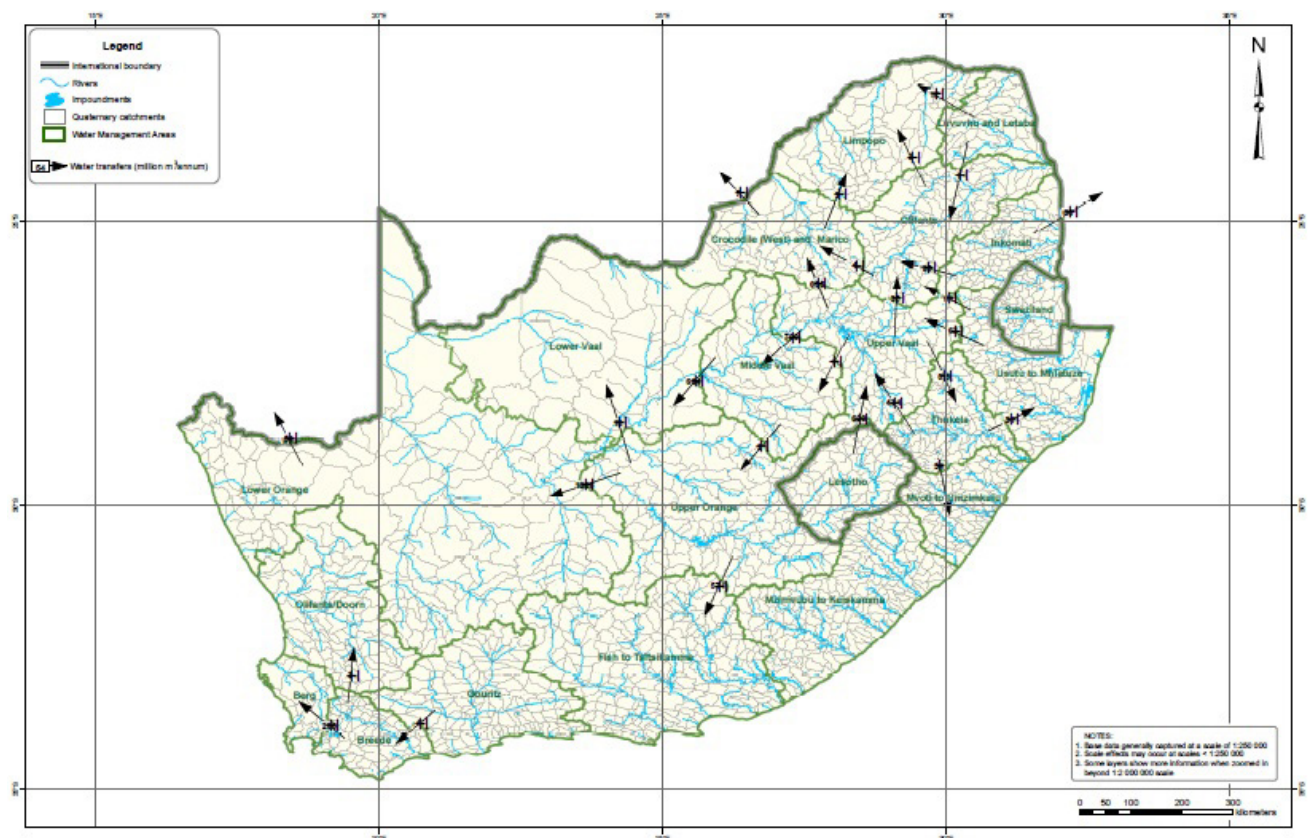


Figure 3-4: Water transfer schemes in South Africa¹¹⁵

In 1998, South Africa's first democratically-elected multiracial government passed the National Water Act [Act No 36 of 1998]. For the first time in South Africa the right of the environment to water of adequate quantity and quality was recognised in law. According to the Second National Water Resource Strategy (2012), instead of focusing on built infrastructure only the South African government is now opting for a “water mix” to balance the growing demand for water with available supply.¹¹⁶ This means that all available water augmentation options are now being considered in equal measure, including alternative technologies such as reclamation of wastewater and effluent, desalination of sea and brackish water, increased use of groundwater, along with water conservation and water demand management.

¹¹⁵ Map: Interbasin water transfers (2009), in B.J. Middleton and A.K. Bailey, Water resources of South Africa, 2005 study (WR2005) Book of maps version 1, figure 4b, p. 71.

¹¹⁶ DWA, June 2013, National Water Resources Strategy, Second Edition, https://www.dwa.gov.za/nwrs/LinkClick.aspx?fileticket=u_qFQycCIBl%3d&tabid=91&mid=496.

3.4 Historic development in river catchments of the Kruger National Park

While the majority of anthropological impact on the catchments of the Kruger National Park rivers has taken place in the last 50 years, the human footprint in these catchments dates back thousands of years. Archaeological remains date the human occupation from at least the Early Stone age (~1 million years ago).¹¹⁷ Following nomadic hunter-gatherers, the area was settled by Bantu-speaking farmers, metalworkers and traders along the main, riparian rivers from about 400 AD.¹¹⁸ Remnants of settlements have been found along all of the Kruger National Park's perennial rivers.¹¹⁹ Populations peaked at around 15 000 in the area where the park now lies.¹²⁰ Where the nomadic hunter-gatherers were thought to make use mostly of rocky outcrops near available water for shelters, the Iron Age Bantu-speaking communities lived in larger settlements where they kept livestock, practiced agriculture and smelted gold, iron ore and copper. Evidence of interaction with traders from the Far East, Middle East and Europe have been found, with sites such as Thulamela in the northern part of the Kruger National Park thought to have been an important stop along ancient trade routes.¹²¹ The confluence of the Selati and Olifants rivers – where the industrial complex of Phalaborwa is situated today – was a centre for mining, most specifically copper and iron ore, for over a 1000 years.¹²²

Little is known about the possible influence of these communities on the aquatic environment, although it is theorised that the area was better watered in the past.¹²³ Settlement remains found on the banks of ephemeral rivers, such as the Mutlumuvi River, which has its source inside the Kruger National Park, suggests that these rivers were

¹¹⁷ U. de V. Pienaar, *A cameo from the past. The prehistory and early history of the Kruger National Park*, p. 11.

¹¹⁸ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 4.

¹¹⁹ U. de V. Pienaar, *A cameo from the past. The prehistory and early history of the Kruger National Park*, pp. 35-36.

¹²⁰ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 18.

¹²¹ M.M. Küsel, A preliminary report on settlement layout and gold melting at Thula Mela, a Late Age site in the Kruger National Park, *Koedoe*, 35(1), September 1992, pp. 57-61.

¹²² C. Barnard (ed.), *Die Transvaalse Laeveld: Kamee van 'n kontrei*, p. 2; I. Plug & J.C.C. Pistorius, Animal remains from industrial iron age communities in Phalaborwa, South Africa, *The African Archaeological Review*, 16(3), September 1999, p. 155.

¹²³ I. Plug, Notes on distribution and relative abundance of some animal species, and on climate in the Kruger National Park during prehistoric times, *Koedoe*, 32(1), October 1989, p. 117.

better watered thousands of years ago than they are today.¹²⁴ Archaeologists also found the remains of large flocks of sheep inside areas of the Kruger National Park, which are thought not to have the carrying capacity for such domestic herds at the present time.¹²⁵ From excavations at these sites it is clear that these communities did not only use the water from the rivers for their daily activities, but exploited the aquatic fauna as well, with remains of animals such as hippopotamus (*Hippopotamus amphibius*), African tiger fish (*Hydrocynus vittatus*), African sharptooth catfish (*Clarias gariepinus*), Plain squeaker (*Synodontis zambezensis*), Redbreasted tilapia (*Tilapia rendalli*) and several species of freshwater crab and amphibians being uncovered during archaeological investigations at the remains of these settlements.¹²⁶ Stevenson-Hamilton describes how, up to the early 20th century, communities caught fish in the Kruger National Park rivers using the traditional method of woven baskets.¹²⁷

The attraction of rivers and waterholes to terrestrial animals was exploited through the digging of game capturing pits on game trails near water resources.¹²⁸ Remnants of the exploitation of hot springs, such as those occurring in the Letaba River catchment, have also been found.¹²⁹ It is postulated that due to their economic activities (metalworking, agriculture) and larger settlements the Iron Age communities would have had a larger impact on their surroundings than the nomadic hunter-gatherer communities. Apart from the species mentioned above, archaeological studies have revealed exploitation of game by especially Late Iron Age communities, probably for food and hides, although it is thought that the low population densities and absence of firearms prevented the over-exploitation of wildlife.¹³⁰ African communities lived throughout the catchments of the

¹²⁴ I. Plug, Notes on distribution and relative abundance of some animal species, and on climate in the Kruger National Park during prehistoric times, *Koedoe*, 32(1), October 1989, p. 117.

¹²⁵ I. Plug, Aspects of life in the Kruger National Park during the Early Iron Age, *South African Archaeological Society: Goodwin Series* 6, June 1989, p. 67.

¹²⁶ I. Plug, Notes on the distribution and relative abundance of some animal species, and on the climate in the Kruger National Park during prehistoric times, *Koedoe*, 32(1), October 1989, p. 103.

¹²⁷ J. Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense*, p. 146.

¹²⁸ F. Morton & R. Hitchcock, Tswana hunting: Continuities and changes in the Transvaal and Kalahari after 1600, *South African Historical Journal*, 66(3), September 2014, pp.421-422.

¹²⁹ C.W. Bates, A preliminary report on archaeological sites on the Groot Letaba River, North Eastern Transvaal, *South African Journal of Science*, 43(1), July 1947, p. 204.

¹³⁰ M.M. Küsel, A preliminary report on settlement layout and gold melting at Thula Mela, a Late Age site in the Kruger National Park, *Koedoe*, 35(1), September 1992, p. 57; I. Plug, Notes on the distribution and relative abundance of some animal species, and on the climate in the Kruger National Park during prehistoric times, *Koedoe*, 32(1), October 1989, p. 115.

Kruger National Park rivers. As white settlement increased in the Transvaal from the middle of the 19th century, these African communities were increasingly squeezed off prime agricultural and mining land into denser settlements, and even forcibly removed as in the case of communities living in the Kruger National Park, where up to 3000 people had been forcibly removed by 1903.¹³¹ The Natives Land Act of 1913 further deprived African communities from owning land.¹³² After 1948 a number of “territorial authorities” were established in the river catchments under the National Party “homeland” system, with some, such as Gazankulu, KaNgwane and Lebowa, bordering on the Kruger National Park.¹³³ This led to the further resettlement of communities to these areas. Agricultural development was considered an important driver for economic development in the former homeland areas. Both the rearing of livestock and irrigated agriculture (mostly at a subsistence scale) are still practiced in these areas today. However, the dense settlement of communities in areas with little or no infrastructure have had a profound impact on the river catchments of the Kruger National Park. Overgrazing and clearing of riparian vegetation for agricultural purposes, along with poor agricultural practices, have led to erosion and increased sedimentation of rivers, particularly in the Sabie River and Olifants River catchments.¹³⁴

Economic development in the Kruger National Park catchments was given a jumpstart by the discovery of gold in the Olifants and Sabie river catchments from ~1867.¹³⁵ Fortune seekers were drawn to the goldfields from all over the world, leading to the establishment of mining towns such as Pilgrims Rest (1873) and Barberton (1884).¹³⁶ The exploitation of precious metal also led to the fast-tracking of trade routes and railways from the interior through to the East coast of Southern Africa, providing not only gold prospectors but also

¹³¹ J.S. Berg & H.M. Feinberg, Trusteeship and black land ownership in the Transvaal during the nineteenth and twentieth centuries, *Kleio*, 36(1), 2004, p. 170.; B.H. King, Developing KaNgwane: Geographies of segregation and integration in the New South Africa, *The Geographical Journal*, 173(1), March 2007, pp. 15-17; J. Carruthers, *The Kruger National Park. A social and political history*, p. 43.

¹³² M. Hay, A tangled past: Land settlement, removals and restitution in Letaba district, 1900-2013, *Journal of Southern African Studies*, 40(4), July 2014, p. 750.

¹³³ RSA. Report of the interdepartmental committee concerning the division of water between black states, the remainder of the Republic of South Africa and the Republics of Bophuthatswana and Transkei, pp. 40-42.

¹³⁴ Anon, State of the rivers report. Crocodile, Sabie-Sand and Olifants River systems, p. 23.

¹³⁵ F. Pretorius (ed.), *Geskiedenis van Suid-Afrika. Van voortye tot vandag*, p.187.

¹³⁶ H. Bornman, *Baanbrekers van die Laeveld*, p. 9.

farmers with a faster route to market.¹³⁷ Land speculation became rife as Lowveld agricultural properties were sold to Johannesburg mining prospectors.¹³⁸ The railway line from Pretoria to Maputo was completed in 1889, followed by the construction of the Selati line which was supposed to connect Komatipoort to the Selati goldfields in 1915. From 1881 individual diggings were replaced by a number of gold-mining companies who owned concessions in both the Sabie and Olifants river catchments.¹³⁹ Pollution from the gold mines had a profound impact on the Kruger National Park's main artery, the Sabie River. In 1921 mine pollution was first recorded in the park after it was discovered that a number of gold mines were dumping their tailings directly into the Sabie River.¹⁴⁰ Subsequent studies found that all biological life in the river had been wiped out. While there were repeated calls from the Kruger National Park on the South African government to act against this pollution, it was only once farmers reported livestock losses in 1944 that the mines were forced to cease the dumping of tailings into the Sabie River.¹⁴¹ The gold mines of Mpumalanga were never as profitable as those on the Witwatersrand, and mining lasted for only a century, with the last of the gold-mines closing in the Sabie area in 1967.¹⁴² However, these mines left an unfortunate legacy. Cyanide leaching from old mine dumps disrupted ecological processes in the Sabie River for decades after the mines ceased to operate, so that even by 1985 no fish could be found in a 20km stretch of the river below Sabie town.¹⁴³

Outside the Kruger National Park border modern commercial mining activities commenced at Phalaborwa, at the confluence of the Olifants and Selati rivers, following the establishment of the Phosphate Development Corporation (Foskor) and the Palabora

¹³⁷ S.C.J. Joubert, The Kruger National Park – An introduction, *Koedoe*, 29(1), November 1986, p. 3.

¹³⁸ Sanparks, A/1[1], J. Stevenson-Hamilton, The Kruger National Park, Transvaal. The game sanctuary of South Africa, 1928, p.1.

¹³⁹ A.R.C. Fowler, Mining at Transvaal Gold Mining Estates, *Journal of the South African Institute of Mining and Metallurgy*, 68(7), February 1968, p. 291.

¹⁴⁰ Sanparks, B/8 [9-2], S.C.J. Joubert *et al.*, Besoedeling – 'n Bedreiging vir lewens- en omgewingskwaliteite in die Laeveld, 1985, p. 6.

¹⁴¹ Sanparks, B/8 [9-2], S.C.J. Joubert *et al.*, Besoedeling – 'n Bedreiging vir lewens- en omgewingskwaliteite in die Laeveld, 1985, p. 6.

¹⁴² A.R.C. Fowler, Mining at Transvaal Gold Mining Estates, *Journal of the South African Institute of Mining and Metallurgy*, 68(7), February 1968, p. 291.

¹⁴³ Sanparks, B/5 [1], J. O'Keeffe, Report to Sanparks on the conservation status of the Sabie and Groot Letaba rivers within the Kruger National Park, p. 5.

Mining Company in 1951 and 1956 respectively.¹⁴⁴ By 1989 in addition to copper this complex was responsible for 95% of phosphate production in South Africa.¹⁴⁵

The town of Phalaborwa was established around the mining complex, and in 1963 this was followed by the founding of the Phalaborwa Water Board to supply water to the town and mines from the Olifants River.¹⁴⁶ Water was initially drawn through pipelines from the Olifants River, but in 1968 the 235m-long Phalaborwa Barrage was constructed to secure water for the water board.¹⁴⁷ A condition of the board's water permit was that it release at all times at least 0.57m³/s to flow in the Olifants River for the Kruger National Park.¹⁴⁸ This is possibly the earliest example of water left in the system for ecological purposes in South Africa. In anticipation of siltation impeding the storage capacity of the Phalaborwa Barrage, a series of sluice gates were constructed at the bottom of the structure. This allows for the periodic release of silt-laden water downstream into the Olifants River. While normal sediment levels in the Olifants River range between 10 and 30 000 mg/ℓ water released from the Phalaborwa barrage have reached silt levels of nearly 25 000 mg/ℓ.¹⁴⁹ On occasion these high silt levels have led to fish kills in the Kruger National Park as the silt reduces oxygen levels in the river system.¹⁵⁰ This has not only resulted in a decline in fish species in the Olifants River but also of the number of fish-eating birds.¹⁵¹

Agriculture, which is today the main water user in the Kruger National Park river catchments, had been practiced from pre-colonial times. Communities practiced both dryland and irrigated agriculture. Tempelhoff relates the irrigation activities of the Venda

¹⁴⁴ E.H. Roux *et al.*, Phosphate in South Africa, *Journal of the South African Institute of Mining and Metallurgy*, 89(5), May 1989, p. 129.

¹⁴⁵ E.H. Roux *et al.*, Phosphate in South Africa, *Journal of the South African Institute of Mining and Metallurgy*, 89(5), May 1989, p. 129.

¹⁴⁶ D.C. Midgley *et al.*, The Phalaborwa Barrage, *The Civil Engineer in South Africa*, 12(5), May 1970, p. 111.

¹⁴⁷ D.C. Midgley *et al.*, The Phalaborwa Barrage, *The Civil Engineer in South Africa*, 12(5), May 1970, p. 111.

¹⁴⁸ D.C. Midgley *et al.*, The Phalaborwa Barrage, *The Civil Engineer in South Africa*, 12(5), May 1970, p. 111.

¹⁴⁹ SAWHAR, Waterlit Collection, C.A. De Moore, Water quality requirements of the biota of the Kruger National Park, p. 13.

¹⁵⁰ Y. Buermann *et al.*, Suspended silt concentrations in the lower Olifants River (Mpumalanga) and the impact of silt releases from the Phalaborwa Barrage on water quality and fish survival, *Koedoe*, 38(2), August 1995, p. 12.

¹⁵¹ SAWHAR, Waterlit Collection, C.A. De Moore, Water quality requirements of the biota of the Kruger National Park, p. 13.

people in the Limpopo catchment that included irrigation canals, terraces and small irrigation dams.¹⁵² Similar activities have been described in various parts of Mpumalanga.¹⁵³ White communities temporarily settled in the catchments of the Kruger National Park rivers from the 1840s and early towns such as Ohrigstad in the Lowveld, and Lydenburg on the Mpumalanga Highveld were provided with earthen furrows.¹⁵⁴ Settlement was initially limited to those areas not plagued excessively by tsetse fly and malaria-carrying *Anopheles* mosquitoes. Agricultural activities were limited initially, particularly in the Lowveld, which was used mostly as winter pasture for Highveld livestock farmers.¹⁵⁵ Among the first crops to be cultivated on a larger scale in the catchments of the Kruger National Park rivers were tobacco, citrus and cotton.¹⁵⁶ This was later followed by vegetables and wheat crops. Early reports of the Transvaal Department of Agriculture point to the use of small-scale irrigation, such as earthen canals, that lead water directly from the rivers onto crops and orchards.¹⁵⁷

After the South African War (1899-1902) the British High Commissioner, Sir Alfred Milner, established an irrigation settlement on the banks of the White River (a tributary of the Crocodile River), with a 28km-long canal leading water from the river. While the initial settlement was unsuccessful, citrus was later successfully planted and farming plots given to soldiers returning after the First World War (1914-1919).¹⁵⁸ Another early scheme was the construction of a diversion weir in the Politsi River, a tributary of the Letaba River, in 1911 to irrigate crops outside what would become the settlement of Tzaneen. This scheme was later placed under the management of the Tzaneen Irrigation Board,

¹⁵² J.W.N. Tempelhoff, Historical perspectives on pre-colonial irrigation in Southern Africa, *African Historical Review*, 40(1), July 2008, p. 16

¹⁵³ J.W.N. Tempelhoff, Historical perspectives on pre-colonial irrigation in Southern Africa, *African Historical Review*, 40(1), July 2008, pp. 137-142.

¹⁵⁴ U. de V. Pienaar, Indications of progressive desiccation of the Transvaal Lowveld over the past 100 years and implications for the water stabilisation programme in the Kruger National Park, *Koedoe*, 28(1), November 1985, p. 107.

¹⁵⁵ Sanparks, A1 [1], Notes of James Stevenson-Hamilton on the establishment of the Kruger National Park (undated).

¹⁵⁶ H. Bornman, *Baanbrekers van die Laeveld*, p. 35; R. Packard, Malaria blocks development revisited: The role of disease in the history of agricultural development in the Eastern and Northern Transvaal Lowveld, *Journal of Southern African Studies*, 27(3), September 2001, p. 593.

¹⁵⁷ See for example, C.D.H. Braine, Farm irrigation in the Transvaal, *Transvaal Irrigation Journal*, 5(18), January 1907, p. 354-361; C.D.H. Braine, Private irrigation achievements, *Agricultural Journal South Africa*, 15(1), November 1924, pp. 66-71.

¹⁵⁸ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, pp. 62-63.

established in 1918.¹⁵⁹ In 1929, the Pusela Irrigation Board was established to control irrigation activities along the right bank of the Letaba River. The establishment of the Union Irrigation Department and the Irrigation Act in 1912 encouraged the establishment of irrigation settlements and increased state funding for especially irrigation infrastructure. Agricultural development was further driven by strong economic growth experienced following the Second World War. Neilson and Botha point to the haphazard development of the bulk water development schemes constructed before 1980 – mostly without any consequence for the impact downstream.¹⁶⁰

One of the first large dams to be constructed in the catchment of the Kruger National Park rivers was Loskop Dam. This dam was completed in 1938 in the upper Olifants River catchment to serve the Olifants River and Hereford irrigation boards.¹⁶¹ Raised in 1979 to a height of 54m, Loskop Dam is one of the largest dams in South Africa, with a gross storage capacity of 361 million m³.¹⁶² The dam provides water for the cultivation of produce such as wheat, vegetables, tobacco, peanuts, cotton and citrus fruit. In addition to providing water to the Loskop, Olifants River and Hereford irrigation boards, Loskop Dam's water is also used by the Groblersdal and Marble Hall municipalities.¹⁶³ Citrus farming took off in the Olifants and Crocodile river catchments following the First World War, with citrus companies, such as Zebediela near Polokwane, leading the way. An important impetus to the growth of the sector was the establishment of the citrus board in 1939.¹⁶⁴ In the Blyde River Valley (part of the Olifants River catchment) the 71m-high Blyderivierspoort Dam was completed in 1975. The dam, which has a maximum storage capacity of 54 million m³, was constructed below the confluence of the Blyde and Ohrigstad rivers to satisfy the water needs of irrigators in the valley.¹⁶⁵

¹⁵⁹ Department of Irrigation, A regional report on the conservation and use of water from the Groot Letaba River, p. 7.

¹⁶⁰ I.D. Neilson & M.L.J. Botha, Water resources of the Luvuvhu River basin (In EPPIC, Environmental conference: Water, 16-17 May, 1991, Mintek, Randburg, pp. 1-11.)

¹⁶¹ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, pp. 122-123.

¹⁶² DWA Dam Safety Office, 2016, List of registered dams, <https://www.dwa.gov.za/dso/Publications.aspx>.

¹⁶³ L van Vuuren, Loskop Dam – Early local engineering ingenuity, *The Water Wheel*, 7(5), September/October 2008, p. 21.

¹⁶⁴ M.M. Cole, The growth and development of the South African citrus industry, *Geography*, 39(2), April 1954, p.108.

¹⁶⁵ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 166.

Dam construction has been prolific in the Olifants River catchment. Around 30 large dams have been constructed in the catchment, mostly for irrigation purposes. Together, these dams store 1 067 million m³ of the river's water behind their walls.¹⁶⁶ In addition to the Loskop and Blyderivierspoort dams, large dams such as Bronkhorstspuit, Witbank, Middelburg, Rust de Winter, Ohrigstad, Klaserie, Vygenhoek and Flag Boshielo (previously called Arabie) dams have been completed in the Olifants River catchment. The latter dam was constructed in the Olifants River by the Lebowa government for irrigation purposes in 1987.¹⁶⁷ The dam was raised in 2006 by the South African government (under whose ownership it now falls). This has increased the storage capacity of the dam to 184 million m³. The latest large dam to be constructed in the Olifants River catchment is De Hoop Dam, which was constructed in the Steelpoort River – a tributary of the Olifants River. This 88 m-high dam was officially opened by South African President, Jacob Zuma, in 2014.¹⁶⁸ The exact number of smaller dams that have been constructed in the catchment is not known, but the upper Olifants catchment alone was estimated to have 2000 small dams in 1997.¹⁶⁹

The largest dam in the Letaba river catchment is the Tzaneen Dam (formerly known as the Fanie Botha Dam). This dam, which has a gross storage capacity of 159 million m³, was initially constructed for the Groot Letaba government water scheme in 1976, but water is now also provided to the town of Tzaneen.¹⁷⁰ The smaller Magoebaskloof Dam was constructed in the Politsi River, a tributary of the Letaba River, in 1971 to provide water to the Tzaneen Irrigation Board. Another irrigation dam, the 61m-high Ebenezer Dam, was built in the main stem of the Letaba River system near Tzaneen in 1959.¹⁷¹ This dam has a capacity of 70 million m³, and in addition to water for irrigation, also supplies water to the town of Polokwane. The smaller Nsami Dam was constructed in

¹⁶⁶ DWA. Water resources planning of the Olifants River basin. Study of development potential and management of the water resources, p 7.

¹⁶⁷ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 226.

¹⁶⁸ Office of the President of South Africa (Presidency), Address by the President of South Africa, His Excellency Mr Jacob Zuma at the official opening of the De Hoop Dam, Sekhukhune district, 2014-03-14, <http://www.gov.za/address-president-south-africa-his-excellency-mr-jacob-zuma-official-opening-de-hoop-dam-sekhukhune>.

¹⁶⁹ P.J Kotze, Aspects of water quality, metal contamination of sediment and fish in the Olifants River, Mpumalanga, MSc, RAU, 1997, p. 8.

¹⁷⁰ B. Grobbelaar & B. Oosthuizen, Die Groot Letaba Staatwaterskema, *The Civil Engineer in South Africa*, 19(2), December 1977, p. 287.

¹⁷¹ DWA Dam Safety Office, 2016, List of registered dams, <https://www.dwa.gov.za/dso/Publications.aspx>.

1976 to supply water for irrigation in the Giyani area.¹⁷² The dam has a gross storage capacity of 24 million m³ and was constructed in the Nsama River, a tributary of the Letaba River. The Modjadji Dam, which has a gross storage capacity of 8,2 million m³, was constructed outside the town of Duiwelskloof, and supplies water for irrigation and domestic water supply purposes.¹⁷³ This dam was built in the Molototsi River in 1997.

Irrigated agriculture in the Sabie River catchment is dominated by the Sabie River Irrigation Board, established in 1953. Farmers on this scheme irrigate directly from the river.¹⁷⁴ Another irrigation board, the White Waters Main Irrigation Board, controls distribution of water from the Da Gama Dam, built in 1967. Until the completion of the Inyaka Dam in 2000, the Da Gama Dam was the largest dam in the Sabie River catchment in South Africa, with a total storage capacity of 14 million m³.¹⁷⁵ It is not the largest dam in the catchment, however, as the Corumana Dam was completed across the border in Mozambique in 1988, with a total storage capacity of 879 million m³.¹⁷⁶ This dam even overshadows the Inyaka Dam, which has a total storage capacity of 120 million m³. In 1993, the Lebowa government completed the Zoeknag Dam in the Mutlumuvi River – part of the Sabie River system. The dam was meant to supply water for irrigation purposes, but failed after its first filling.¹⁷⁷ The dam was never rebuilt. This former homeland had also constructed two other dams in tributaries of the Sabie River, namely the Orinoco Dam, located in the Mutlumuvi River, and the Kasteel Dam, located in the Klein Sand River. These dams were mostly used for irrigation purposes, as a number of agricultural programmes were established in the former homelands to boost economic development and provide jobs in these areas, among others the Lebowa Agricultural Corporation and the Gazankulu Development Corporation.¹⁷⁸

¹⁷² DWA Dam Safety Office, 2016, List of registered dams, <https://www.dwa.gov.za/dso/Publications.aspx>.

¹⁷³ DWA Dam Safety Office, 2016, List of registered dams, <https://www.dwa.gov.za/dso/Publications.aspx>.

¹⁷⁴ P. Woodhouse, Water rights and rural restructuring in South Africa: A case study from Eastern Transvaal, *International Journal of Water Resources Development*, 11(4), December 1995, p. 537.

¹⁷⁵ DWA Dam Safety Office, 2016, List of registered dams, <https://www.dwa.gov.za/dso/Publications.aspx>.

¹⁷⁶ A.M.L. Saraiva Okello *et al.*, Drivers of spatial and temporal variability of streamflow in the Incomati River basin, *Hydrology and Earth System Sciences*, 19(2), July 2014, p. 659.

¹⁷⁷ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 271.

¹⁷⁸ R.L. Mann, Homeland agriculture in the era of liberalisation: High-value fruit exports from parastatal projects, *South African Geographical Journal*, 83(3), (no month) 2001, p. 215.



Figure 3-5: The Zoeknag Dam shortly after it failed in 1993¹⁷⁹

Irrigated agriculture became more organised in the Malelane area following the establishment of an irrigation district in 1947. The production of sugarcane was stimulated by the establishment of the Transvaalse Suikerkorporasie Beperk in 1965. The Malelane sugar mill was constructed in 1967, and 20 years later more than 19 000ha of sugarcane had been planted in the area, irrigated from the Crocodile, Komati and Lomati rivers.¹⁸⁰ In addition to sugarcane, subtropical fruit and citrus are the main produce cultivated in the Crocodile River catchment. Irrigated water use accounts for close to 50% of water use in the catchment.¹⁸¹ Irrigation is concentrated on the downstream sections of the river, outside the borders of the Kruger National Park. River flow in the Crocodile River is regulated by eight large dams, which have capacities of more than a million cubic metres, and around 200 smaller dams – mostly constructed for irrigation purposes. The largest dam in the catchment is the 52m-high Kwenya Dam (formerly called the Braam Raubenheimer Dam). This dam was completed in the Crocodile River in 1985, and has a

¹⁷⁹ Photograph: VVPA, DWAPA, Zoeknag Dam after failure, 1993.

¹⁸⁰ C.A. Lewis, The South African sugar industry, *The Geographical Journal*, 156(1), March 1990, p. 72.

¹⁸¹ Anon, State of the rivers report. Crocodile, Sabie-Sand and Olifants River systems, p. 10.

capacity of 167 million m³ or around 10% of the mean annual runoff.¹⁸² While this dam was constructed almost exclusively to supply in the irrigation needs of the Crocodile River Major Irrigation District, it now also supplies the town of Nelspruit with water, as well as industrial clients, such as the sugar mill at Malelane.¹⁸³



Figure 3-6: Sugarcane field at Malelane in the Crocodile River catchment, with the Malelane sugar mill in the background¹⁸⁴

In the Luvuvhu River catchment water for irrigation purposes is in most cases still abstracted directly from the river, and compared to the other Kruger National Park river catchments bulk water resource development is still limited.¹⁸⁵ Prior to the construction of Nandoni Dam in 2004, the largest dam in the catchment was Albasini Dam. Originally completed in 1953, Albasini Dam was raised in 1971 to a full storage capacity of 28.2

¹⁸² C.J. Kleynhans, The development of a fish index to assess the biological integrity of South African rivers, *Water SA*, 25(3), July 1999, p. 267.

¹⁸³ DWA, Braam Raubenheimer Dam, p. 6.

¹⁸⁴ Photograph: VVPA, PF2, Malelane sugarcane, 2011-07-20.

¹⁸⁵ SAWHAR, Waterlit, C. Breen, *et al.*, A description of the Kruger National Park River Research Programme Phase 3, p. 5.

million m³.¹⁸⁶ Nandoni Dam was constructed as one of the first bulk water development schemes of the post-1994 government to serve the urban centre of Thohoyandou. The dam was completed in 2005, and has a gross storage capacity of 160 million m³.¹⁸⁷ The only other significant dam in the Luvuvhu River catchment is the Vondo Dam, which was constructed in the Mutshindudi River, a tributary of the Luvuvhu River, in 1982. Raised in 1992, this dam serves the towns of Makhado and Thohoyandou and surrounding irrigation areas.¹⁸⁸

After agriculture, forestry is the largest water user in the river catchments feeding the Kruger National Park. Forestry plantations are limited to upper catchment areas where rainfall is higher than 700mm/year.¹⁸⁹ The planting of exotic trees, including pine and eucalyptus, started at the turn of the 19th century after early mining activities stripped the Lowveld region of its natural wood supplies.¹⁹⁰ The South African government starting planting exotic plant species on a large scale in Limpopo and Mpumalanga after the First World War as a way of decreasing poverty and joblessness among the white population.¹⁹¹ The need for timber by the railways and mining sector further prompted afforestation of large sections of the upper catchments of the riparian rivers. Once it was discovered that the planted exotic trees greatly outgrew their indigenous counterparts plantations rose sharply, with the area under pines and eucalyptus expanding as much as 367% between 1929 and 1950.¹⁹² By 1986, the eastern and northern Transvaal Escarpment and the Soutpansberg accounted for 51% of the country's total forestry plantations.¹⁹³ As far back as 1948, Gevers drew conclusions between the planting of large tracts of exotic plantations and the decrease in streamflow in river systems such as

¹⁸⁶ H. Griscom, The drying of the Luvuvhu River, South Africa: Distinguishing the roles of dams and land cover change, MSc University of Wyoming, 2007, p. 34.

¹⁸⁷ Van Vuuren, L., *In the footsteps of giants – Exploring the history of South Africa's large dams*, pp. 274-276.

¹⁸⁸ H. Griscom, The drying of the Luvuvhu River, South Africa: Distinguishing the roles of dams and land cover change, MSc University of Wyoming, 2007, p. 34.

¹⁸⁹ Lowveld Regional Development Association, A survey of the resources and development of the southern region of the Eastern Transvaal Lowveld, p. 87.

¹⁹⁰ Lowveld Regional Development Association, A survey of the resources and development of the southern region of the Eastern Transvaal Lowveld, p. 87.

¹⁹¹ A.C. Mkwalo, Assessment of potential and impacts of afforestation in the Letaba catchment, Limpopo Province, South Africa, MA, UNISA, p. 8.

¹⁹² Lowveld Regional Development Association, A survey of the resources and development of the southern region of the Eastern Transvaal Lowveld, p. 88.

¹⁹³ DWA, Management of the water resources of the Republic of South Africa, p. 3.6.

the Groot Letaba.¹⁹⁴ Forestry has resulted in reduced stream flows in all of the catchments feeding the Kruger National Park.¹⁹⁵

3.5 Conclusion

Humankind has depended on the ecological services provided by river systems for thousands of years. This has resulted in the alteration of flow to meet the demands of increasingly large settlements, first through simple canals and flow alteration systems and later through sophisticated pipelines and aqueducts. These anthropogenic actions have impacted the way in which river ecosystems function, and evidence suggests that the resulted altered ecosystems may have influenced the sustainability of ancient civilisations. Thus the impact of people on aquatic ecosystems began long before the industrial revolution, although this period in history did see an acceleration of water resource development as technological advances allowed for larger and more complex systems to be constructed allowing for disruption of natural processes on a larger scale. Today, the world's people are served by an estimated 45 000 large dams, which have left few rivers in their natural state. While its history of dam-building is relatively recent compared to other countries, South Africa is considered one of the major dam-building nations in the world. South Africa's freshwater resources were exploited on a small scale for thousands of years before the arrival of European settlers in the 17th century. Once Dutch and British settlers established themselves at the Cape, and later inland, the development of South African water resources took off – first for agriculture and domestic use and later also for industrial needs. The peculiarity of South Africa's rivers systems – and their tendency towards erratic flow patterns – prompted the construction of complex water engineering systems to regulate South Africa's water supply.

People have lived in the Lowveld catchments for thousands of years, but it was not until the late 19th century that water resource development started to be implemented at a larger scale. The discovery of gold prompted the development of towns and stimulated growth in sectors such as agriculture and forestry. Agriculture, mining and forestry have all had an impact on the Lowveld river systems in terms of flow disruption in the forms of

¹⁹⁴ T.W. Gevers, Drying rivers in the North-eastern Transvaal, *The South African Geographical Journal*, 30, April 1948, pp. 17-44.

¹⁹⁵ W. Vlok & J.S. Engelbrecht, Some aspects of the ecology of the Groot Letaba River in the Northern Province, *South African Journal of Aquatic Science*, 25(1), (no month) 2000, pp. 76-83.

dams and weirs as well as pollution, although the rivers have been impacted in varying degrees. These developments have affected the river water that reaches the Kruger National Park located downstream from these activities both in terms of quantity and of quality. The following chapter explores how scientific curiosity about South Africa's rivers systems as well as threats on these systems stimulated the advance of aquatic science in South Africa. In particular this chapter considers the impact of collaborative science programmes in growing the aquatic science community and providing the necessary impetus for the discipline to grow in South Africa.

Chapter 4 The foundations of aquatic science in South Africa (1652-1987)

4.1 Introduction

The ecological flow science that led to the methodologies and tools to determine the ecological reserve is a relatively young discipline in South Africa, and grew out of the broader study of aquatic ecosystems. To understand how ecological flow science evolved in South Africa to the point where it influenced the inclusion of the environmental reserve in the NWA, this chapter explores the origins of aquatic science in South Africa that eventually fed into the discipline of ecological science that later found application in the Kruger National Park's rivers. The overview starts with the contribution of European travelling scientists in the 18th century. The chapter then goes on to describe the contributions of taxonomic studies on the broader aquatic science discipline in South Africa and, in particular, the influence of medical entomology. The role of institutions such as the Council for Scientific and Industrial Research (CSIR) is explored, particularly its leading role in the evolution of the aquatic science discipline in South Africa towards more holistic studies. Finally, the chapter delves into the contribution of the collaborative science programmes of the 1960s and 1970s, particularly focusing on how these programmes influenced thinking around the aquatic environment at a policy level.

4.2 Aquatic science in South Africa – where it all began

South Africa's water law and, in particular, the environmental reserve, are based on a sound scientific basis as established by the local aquatic science community. Ecological flow science, which refers to the study of development and application of methods to determine the quantity, quality and timing of flows required to sustain aquatic ecosystems, has only been practiced by South African scientists for the last 30 years.¹ The study of ecological flows evolved out of the broader exploration of aquatic ecosystems, however, which has a slightly longer history in South Africa. The studies of Ashton et al. (2012) and Allanson et al. (1990) identified the narrower disciplines of zoology and taxonomy as the nucleus from which aquatic science evolved in South Africa. However, these studies fail to appreciate the importance of early zoological endeavours, particularly those of traveller

¹ VVPA, Oral Archive File 1 (OA1), J. King, Ecological flow scientist, 2016-10-31.

scientists since the 18th century in creating a curiosity about the South African freshwater landscape.² This peculiarity was fuelled by the fact that, in contrast to the well-watered countries of Europe, South African freshwater systems are quite fickle, with many rivers being dry for most parts of the year only to come down in torrents after a rain storm. It is through the reports of early scientists that the scarcity of South Africa's water resources, in particular, the lack of perennial rivers and the irregularity of flow, first became known. Scientifically informed explorers and travellers – almost exclusively of European origin – became a regular feature on the cultural landscape of South Africa, after the establishment of the Cape settlement in 1652.³ These travellers took back to the northern hemisphere a glimpse of the South African interior of South Africa beyond Cape Town, the first urban settlement. In this way they contributed to the accumulation of scientific knowledge about South Africa's freshwater aquatic systems. These early scientists gathered information not only about zoological and botanical finds but also about climatic conditions, topography, water resources, geography, and anthropogenic information about communities they came across. In this way they contributed to growing the overall pool of knowledge about what the western world knew about Africa.⁴ William Burchell was the first to describe freshwater fish in South Africa in 1811, namely the smallmouth yellowfish (*Labeobarbus aeneus*) and the sharptooth catfish (*Clarias gariepinus*).⁵ Fifty years later Count F. Castelnau described more species, including the tiger fish (*Hydrocynus vittatus*).⁶ South Africa's general aridity was known from the time Europeans settled at the Cape and various writers commented on the country's unfortunate water situation. Livingstone, who was both an explorer and a missionary, frequently mentions what he thought was the drying out of South Africa.⁷ Swedish traveller scientist, Anders Sparrman described the Cape as the “most thirsty and dry tract of land” he had ever seen.⁸ Cape colonial botanist, John Brown, like many scholars of the time, was of the

² P. Ashton *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 1; B. Allanson *et al.*, *Inland waters of Southern Africa: An ecological perspective*, p. 97.

³ S. Huigen, *Knowledge and colonialism: Eighteenth-century travellers in South Africa*, p. 4.

⁴ S. Huigen, *Knowledge and colonialism: Eighteenth-century travellers in South Africa*, p. 3.

⁵ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 3.

⁶ P. Skelton, *A complete guide to the freshwater fishes of Southern Africa*, p. 3.

⁷ D. Livingstone, *Missionary travels and researches in South Africa*, pp. 17, 19, 34, 66, 75.

⁸ A. Sparrman, *A voyage to the Cape of Good Hope Volume 1*, p. 147.

opinion that Africa was gradually drying out, a phenomenon he blamed partially on anthropogenic actions, such as deforestation and overstocking. Writes Brown,

*A drop of water in most of our African soil will produce a blade of grass, or nourish an ear of corn, and is far more valuable to the colonial farmer than manure is to the English.*⁹

Brown's remedies for the situation included the creation of storage works to store surplus water flow, halting the practice of veld burning, and replanting trees in deforested areas.¹⁰ Most scientific travellers disregarded local communities' knowledge of the environment, speaking of indigenous people in inferior tones.¹¹ Sparrman was an exception. In his travels to South Africa between 1772 and 1776 he made copious notes about the ways in which Khoi people used plants and animals. He also recorded some of the local language, and advocated for the preservation of this vast indigenous knowledge.¹²

Despite their general descriptions of South African rivers, traveller scientists rarely spent time studying these freshwater resources in detail other than to describe the animals and plants found near them. The first in-depth studies of South African rivers, albeit from a hydrological point of view, were made by the engineers who arrived in the 19th century when the Cape became a British territory. For hydraulic engineers such as John Gamble, employed by the Cape colonial government between 1875 and 1886, knowledge about the area's rivers was crucial, in order to build the right kind of water infrastructure to serve the burgeoning human settlements of the colony. He was a prolific writer, and contributed a number of papers to the *Transactions of the Royal Society of South Africa* (known as the *Transactions of the Philosophical Society* before 1908), one of the first scientific journals to be published in the country. Scrutiny of the early volumes of the journal between 1877 and 1884 reveal that Gamble's articles not only dealt with the subject of rivers and artificial storage possibilities, but also with meteorology and climate.¹³ Gamble left South Africa in 1886 when his post was abolished by the Cape government. However,

⁹ J.C. Brown, *Water supply of South Africa and facilities for the storage of it*, p. 647.

¹⁰ J.C. Brown, *Water supply of South Africa and facilities for the storage of it*, p. 647.

¹¹ W. Beinart, Men, science, travel and nature in the Eighteenth and Nineteenth century Cape, *Journal of Southern African Studies*, 24(4), (no month) 1998, p. 777.

¹² W. Beinart, *The rise of conservation in South Africa – Settlers, livestock and the environment*, p. 35.

¹³ See for example, J.G. Gamble, Rainfall of South Africa, *Transactions of the Philosophical Society*, 1(2), (no month) 1877, pp. 13-21; J.G. Gamble, Proposals of the Table Mountain Water Supply Company, *Transactions of the Philosophical Society*, 3(2), (no month) 1881, pp. 5-6; J.G. Gamble, Meteorological notes, *Transactions of the Philosophical Society*, 4(1), (no month) 1884, pp. 10-14.

he lay a firm foundation for hydrological science that would be continued by water engineers, especially after the establishment of the Irrigation Department in 1912.¹⁴ The production of hydrographic maps was one of the duties of the department under the Irrigation Act and a specialised unit was established in the department for this purpose.¹⁵ Freshwater scientists would later build on this knowledge of the hydrological behaviour (i.e. the flow) of rivers to study the associated behaviour of aquatic fauna and flora.

4.3 South African aquatic science in the 20th century

Following the establishment of the first zoological departments at the universities of Cape Town (1903) and Rhodes in Grahamstown (1905) as well as the unification of South Africa (1910), aquatic science slowly developed out of the description of freshwater fauna and flora. Described as the “collect them, count them and name them” phase this lasted up until the Second World War, and was mainly driven by the effort of individuals.¹⁶ One person who made an exceptional contribution to expanding knowledge about freshwater biota in South Africa was Keppel Barnard, who published over 200 scientific articles on aquatic fauna during his 53-year tenure at the South African Museum (1911-1964).¹⁷ Contributions to knowledge of South African freshwater algae and phytoplankton were made by scientists such as Mary Agard Pocock, most well known for her studies in Volvocales (green algae).¹⁸

Medical entomology – most notably malaria and schistosomiasis – received increased attention at the start of the 20th century, mainly as a result of the establishment of the South African Institute for Medical Research in 1914.¹⁹ In 1925, the institute established its Department of Medical Entomology, managed between 1930 and 1962 by

¹⁴ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 40.

¹⁵ D.C. Midgley, The water conservation aspects of planned resource utilisation in the Union of South Africa, *Minutes of Proceedings of the South African Institution of Civil Engineers*, 47(1), January 1949, p. 116.

¹⁶ P. Ashton *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 1.

¹⁷ I. Gordon, Keppel Harcourt Barnard, *Crustaceana*, 10(2), March 1966, p. 220.

¹⁸ See for example M.A. Pocock, Studies in SA Volvocales, *Proceedings of the Linnean Society of London*, 149, June 1937, pp. 55-58, doi: 10.1111/j.1095-8312.1937.tb01183x; M.S. Cave & M.A. Pocock, The Aceto-Carmine technic applied to the colonial Volvocales, *Stain Technology*, 26(3), (no month) 1951, pp. 173-174; M.S. Cave & M.A. Pocock, Karyological studies in the Volvocaceae, *American Journal of Botany*, 38(10), December 1951, pp. 800-811.

¹⁹ Anon, s.a., Malaria entomology research unit, <https://www.wits.ac.za/health/research-entities/malaria-entomology-research-unit/malaria-entomology-research-unit/>.

internationally known medical entomologist, Dr Botha de Meillon.²⁰ De Meillon identified and recorded the entomology of the Anopheles mosquito that carries malaria in southern Africa and pioneered the use of indoor spraying of pyrethrum/kerosene as a method of vector control.²¹ In addition to malaria, South African scientists also began studying schistosomiasis-carrying snails in the early 20th century. In 1921, Cawston published the results of his studies into schistosomiasis-carrying freshwater snails in which he underlined the importance of natural floods to keep rivers clean from pollution and wash away disease-carrying snails.²² This paper was followed in 1948 by a paper of De Meillon in which he warned that the damming of rivers in South Africa could lead to an increase in schistosomiasis as the vectors preferred still water over flowing water.²³ In a later report to the World Health Organisation (1958), De Meillon and his co-authors expressed their concern that any method to curb the disease would have to be tested thoroughly so as not to cause harm to other river biota or downstream water users.²⁴

The Second World War provided an important stimulus to South Africa's burgeoning economy, boosted by the creation of government-funded industrial entities such as Sasol and Foskor.²⁵ The multiplication of industries was so rapid that the period directly after the war was dubbed an era of "industrial explosion."²⁶ However, the formation of new factories and mines also meant the creation of additional effluent that ended up in South Africa's river systems. By the early 1950s South African scientists and water engineers alike started to express publicly their concern over the state of South Africa's water resources and the impact of intensified industrial development on this scarce local resource.²⁷ Up until 1956 legislation preventing water pollution was wholly inadequate and

²⁰ M. Coetzee, *et al.*, Malaria in South Africa: 110 years of learning to control the disease, *South African Medical Journal*, 103(10), October 2013, p. 771.

²¹ M. Coetzee, Obituary: Botha de Meillon 1902-2000, *African Entomology*, 9(1), March 2001, p. 95.

²² F.G. Cawston, Some infections due to freshwater snails and their eradication, *South African Medical Record*, 19(7), April 1921, pp. 125-126.

²³ B. de Meillon, Aspects of the natural history of bilharzia in South Africa, *The South African Medical Journal*, 22(7), April 1948, p. 258.

²⁴ B. de Meillon *et al.*, Some aspects of snail ecology in South Africa. A preliminary report, *Bulletin of the World Health Organisation*, 18(5-6), (no month) 1958, p. 772.

²⁵ A.R. Turton *et al.*, A hydropolitical history of South Africa's international river basins, p. 73.

²⁶ G.J. Stander, Water pollution research: A key to wastewater management, *Journal of the Water Pollution Control Federation*, 38(5), May 1966, p. 774.

²⁷ See A.L. Mackenzie, Presidential address, *Minutes of Proceedings of the South African Institution of Civil Engineers*, 47(1), 1949, pp. 6-26; G.J. Stander, The quality requirements of water for the maintenance of aquatic flora and fauna and for recreational purposes, *The South African Industrial*

by the early 1950s several hotspots had been identified where river systems were being increasingly threatened by industrial and mining pollution, including the Swartkops River system serving Uitenhage, the Olifants River above Witbank, the rivers serving the coal-mining areas of northern KwaZulu-Natal and the Vaal River.²⁸ The latter river was of particular concern, not only because of its increasing salinity due to discharge from gold mines, but also because of reports of toxic microcystis (blue-green) algae on the Vaal dam as a result of eutrophication.²⁹ Botanist, Edith Stephens identified the algae (*Microcystis Toxica Sp.*) in the Vaal River in 1942 after livestock died drinking the water after the construction of the Vaal Dam.³⁰ She theorised that the algal growth was stimulated by fertiliser wash-off into the dam.³¹ Various treatments were considered to deal with the algae problem, including the application of copper sulphate.³²

Growing concerns over the pollution of South Africa's water resources led to the appointment of a committee of enquiry by the Minister of Welfare and Demobilisation on 2 June, 1944.³³ The committee of enquiry on the bacterial and chemical pollution of water supplies, which included members representing the departments of irrigation, agriculture and health, was to investigate incidence of bacterial and chemical pollution of the country's water.³⁴ Seven meetings were held between February and October 1945, with oral evidence provided by the Institute of Sewage Purification (an organisational body of water professionals that preceeded the Water Institute of Southern Africa), the Rand Water Board, Johannesburg Municipality, the Local Health Commission of Natal, as well

Chemist, 6(6), June 1952, pp. 118-119; N. Shand, The role of the civil engineer in the daily life of the community, *The transactions of the South African Institution of Civil Engineers*, 3(12), December 1953, pp. 381-391.

²⁸ NAR, SAB, Archive of the Private Secretary of the Minister of Lands and Water Affairs (1948-1971) (MLW), 149 [314/25], Letter from the Director of Irrigation, S. Marais, to the Minister of Irrigation, J.G. Strijdom, on the upcoming conference of the Institute of Sewage Purification, Pretoria, 1954-08-03, p.2.

²⁹ NAR, SAB, GES, 2069 [107/33], Correspondence: D.G. Steyn, Department of Agriculture – Committee on Enquiry on the bacterial and chemical pollution of water supplies, Onderstepoort, 1946-02-01, p. 4.

³⁰ E.L. Stephens, *Microcystis Toxica Sp. Nov: A poisonous algae from the Transvaal and Orange Free State*, *Transactions of the Royal Society of South Africa*, 32(1), (no month) 1949, p. 105.

³¹ E.L. Stephens, *Microcystis Toxica Sp. Nov: A poisonous algae from the Transvaal and Orange Free State*, *Transactions of the Royal Society of South Africa*, 32(1), (no month) 1949, p. 105.

³² NAR, SAB, GES, 2069 [107/33], Correspondence: D.G. Steyn, Department of Agriculture – Committee on Enquiry on the bacterial and chemical pollution of water supplies, Onderstepoort, 1946-02-01, p. 4.

³³ NAR, SAB, GES, 2069, 107/33, Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p.1.

³⁴ NAR, SAB, GES, 2069, 107/33, Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p.1.

as several mining engineers, botanists and plant pathologists. Written evidence was also considered from several public bodies and private individuals. The committee heard accounts of fish kills as a result of effluent from jam factories in the Cape and sugar mills in Natal, bacteriological pollution from faecal sources in several towns and chemical discharges from coal and gold mines which had “caused acute and chronic poisoning in stock and [had] also rendered excellent arable land totally unsuitable for agricultural purpose”.³⁵

The committee noted that water pollution was covered by six acts of legislation of the Union, namely the Public Health Act (Act no. 36 of 1919), the Gold Law Act (Act no. 35 of 1908), the Irrigation Act (no. 8 of 1912), the Cape Inland Fisheries Ordinances no. 15 of 1941 and the Transvaal Fisheries Preservation Ordinance (No. 10 of 1921) and the Natal Fisheries Ordinance (No. 11 of 1916).³⁶ However, they contained many loopholes for industries, for example, the onus fell on local authorities to prosecute individuals or companies who made themselves guilty of water pollution, but provided no regulations for doing so. Furthermore, laws such as the Irrigation Act provided immunity to certain mines which allowed them to discharge their effluent directly into streams without any form of treatment.³⁷ With regards to pollution by domestic sewage there were no regulations for municipal sewage treatment plants to adhere to other than a curious rule that final sewage effluent was not be discharged into rivers but over municipal land. City councils purchased large tracts of land for this purpose, resulting in large volumes of sewage seeping into the ground and polluting groundwater sources.³⁸ To remedy the situation, the committee called for more stringent legislation, including the passing of regulations based on British and US standards, as well as the formation of “regional control boards” to provide a policing function with regards to water pollution.³⁹ Stricter action was also advocated against mining companies.

³⁵ NAR, SAB, GES, 2069, 107/33, Correspondence: D.G. Steyn, Department of Agriculture - Committee on Enquiry on the bacterial and chemical pollution of water supplies, Onderstepoort, 1946-02-01, p. 2.

³⁶ NAR, SAB, GES, 2069, 107/33, Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p. 3.

³⁷ NAR, SAB, GES, 2069 [107/33], Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p. 3.

³⁸ NAR, SAB, GES, 2069 [107/33], Report of the Institute of Sewage Purification (South African branch) to the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a., p. 4.

³⁹ NAR, SAB, GES, 2069 [107/33], Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p. 4.

The committee concluded that South Africa's economic prosperity was bound to the health of its water supplies and recommended urgent action to address pollution of river courses, including legislation which would allow government to more effectively act against polluters. The committee was aware of the fact that South Africa was a water scarce country and feared that people would be forced to move away from certain areas if water resources were rendered useless by anthropogenic activities. In particular, the committee noted that aquatic studies in South Africa's rivers had been limited up to that time, particularly "the changes in the fauna and flora and chemical composition of the water and deposits" that occurred as a result of human impact.⁴⁰ Given this lack of knowledge about the extent and impact of pollution on South Africa's freshwater sources the committee noted that

*[i]t is imperative, therefore, that a systematic bacteriological investigation, in conjunction with chemical, zoological and botanical observations and experiments be instituted, as it would provide information on the value of the cycle of life in fresh waters, not only in rivers and impounding dams but also in water supply reservoirs.*⁴¹

To gain the necessary knowledge about South Africa's river systems, the committee suggested that a neutral research body be created under the auspices of the Council for Scientific and Industrial Research (CSIR), established in 1945. The CSIR was a direct result of the need for increased scientific support to the country's rapidly industrialising economy, a long-cherished desire of the South African government to grow its own scientific solutions and prove its independence and ability to compete internationally. Following on other councils established in countries such as Britain, Australia and Canada, the CSIR had the main objective of

*[a]dvis[ing] government on all questions affecting the utilisation of the natural resources of the country, the development of its industries and the proper coordination and employment of scientific research to these ends.*⁴²

⁴⁰ NAR, SAB, GES, 2069 [107/33], Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p. 14.

⁴¹ NAR, SAB, GES, 2069 [107/33], Final report of the Committee of Enquiry on the bacterial and chemical pollution of water supplies, s.a. (circa 1945), p. 15.

⁴² B.F.J. Schonland, Recent developments in scientific and industrial research in South Africa, *Journal of the Royal Society of Arts*, 97(4784), December 1948, p. 73.

While no evidence could be found that the committee of enquiry on the bacterial and chemical pollution of water supplies' final report had, in fact, ever been published and while it would take some years for the laws to be changed, the recommendation towards the establishment of a research body did bear fruit in the form of the water treatment research unit, established under the CSIR's National Chemical Research Lab in 1948.⁴³ The objectives of the unit can be linked directly to the recommendations of the committee in that it provided *inter alia* basic research with the object of improving water and wastewater and effluent treatment, while providing assistance to authorities in the form of biological information on rivers where water resource developments were planned.⁴⁴ The CSIR provided great stimulus to the development of aquatic science in South Africa, not only in terms of its own research but also by providing much needed funding to other research institutions, such as the Department of Zoology at the University of Cape Town (UCT) who then switched their research focus from marine to estuarine research under the leadership of John Day.⁴⁵

Initially, the CSIR water treatment research unit was almost exclusively focused on developing improved methods to treat industrial effluent and domestic wastewater to better standard.⁴⁶ From a humble prefabricated hut borrowed from the University of the Witwatersrand the unit grew to have its own large laboratory in Pretoria along with regional laboratories in Durban, Bellville, Bloemfontein and Windhoek.⁴⁷ By 1958 the water unit had grown to such an extent that it warranted its own stand-alone division, namely the National Institute for Water Research (NIWR), headed by G.J. Stander, who gained international recognition when he pioneered the first water reclamation plant at Windhoek.⁴⁸ The institute commenced a series of in-depth hydrobiological studies in South Africa's rivers in 1950 starting with the Vaal and Berg rivers.⁴⁹ Never before had the country's aquatic ecosystems been studied in such detail. The objective of these

⁴³ D.G. Kingwill, *The CSIR. The first 40 years*, p. 212.

⁴⁴ D.G. Kingwill, *The CSIR. The first 40 years*, p. 213.

⁴⁵ A.C. Brown, Centennial history of the Zoology Department, University of Cape Town, 1903-2003. A personal memoir, *Transactions of the Royal Society of South Africa*, 58(1), (no month) 2003, p. 18.

⁴⁶ D.G. Kingwill, *The CSIR. The first 40 years*, p. 213.

⁴⁷ G.J. Stander, Water pollution research: A key to wastewater management, *Journal of the Water Pollution Control Federation*, 38(5), May 1966, p. 774.

⁴⁸ D.G. Kingwill, *The CSIR. The first 40 years*, p. 30.

⁴⁹ See, for example, A.D. Harrison & J.F. Elsworth, Hydrobiological studies on the Great Berg River, Western Cape Province, *Transactions of the Royal Society of South Africa*, 35(3), (no month) 1958, pp. 125-226.

studies, according to Stander (1966), was to provide a picture of the natural ecological conditions of South Africa's rivers in order to more accurately measure the impact of pollution and thus improve ways to address it.⁵⁰ A Research Group for Hydrobiology was established at Rhodes University for this purpose.⁵¹ By this time aquatic science had evolved from mere taxonomic work, influenced as it were by the growing concept of trophic dynamics as first described by R.L. Lindeman.⁵² The young South African aquatic science community started considering not only the biology of individual species but how they interacted with each other and their physical surroundings (known as freshwater ecology). The CSIR river studies made some startling revelations in terms of how human actions had already influenced aquatic ecosystems. Chutter's studies on the Vaal River determined that increases in the pest blackfly (*Diptera: Simuliidae*), which plagues livestock, was a direct result of increased flows from the Vaal Dam.⁵³ The rapid release of water downstream of the dam creates a suitable environment for these livestock pests to multiply, replacing more benign species. In turn, studies like those of Crass pointed to the impact of man-made structures on the country's freshwater fish,⁵⁴ while Allanson and Gieskes's studies looked to the impact of sewage and other runoff on the river biota of the rivers of the Transvaal.⁵⁵

The CSIR also undertook took hydrobiological studies on Natal's rivers in partnership with the Natal Provincial Town and Regional Planning Commission and the University of Natal. Surveys on rivers, such as the Thukela, Umgeni, Bushmans, Buffalo, Mooi and Sundays were undertaken between 1953 and 1963 and formed part of broader catchment studies aimed at determining the potential of the area for economic development.⁵⁶ These

⁵⁰ G.J. Stander, Water pollution research: A key to wastewater management, *Journal of the Water Pollution Control Federation*, 38(5), May 1966, p. 786.

⁵¹ G.J. Stander, Water pollution research: A key to wastewater management, *Journal of the Water Pollution Control Federation*, 38(5), May 1966, p. 774.

⁵² R.L. Lindeman, The trophic aspect of ecology, *Ecology*, 23(4), October 1942, pp. 399-417.

⁵³ F. M. Chutter, On the ecology of fauna found on stones in the current in a South African river supporting a very large simulium (*Diptera*) population, *Journal of Applied Ecology*, 5(1), December 1968, pp. 531-561.

⁵⁴ R.S. Crass, The effects of land use on freshwater fish in South Africa, with particular reference to Natal, *Hydrobiologia*, 34(1), September 1969, pp. 38-56.

⁵⁵ B.R. Allanson & G.M.T.M. Gieskes, Investigations into the ecology of polluted inland waters of the Transvaal, *Hydrobiologia*, 18(1), October 1961, pp. 1-76.

⁵⁶ NAR, SAB, Department of Water Affairs (WW), 435 [K52/4/1], Letter from the Administrator of Natal, T. Gerdener, to Minister of Water Affairs, J.J. Fouché, on abatement of pollution in rivers in Natal, Pietermaritzburg, 1966-07-07, p. 1.

investigations focused on both the quality and quantity of water found in KwaZulu-Natal's river systems.⁵⁷ Flow was measured through the addition of gauging weirs with the assistance of DWA, while physical, chemical, biological and bacterial samples were taken along the river courses. The hydrobiological studies were some of the most extensive that had been undertaken in South Africa up to that time. In the Umgeni River alone, more than 2000 samples of instream biota were taken over a period of two years.⁵⁸ The intensity of the studies allowed a deeper understanding to form among aquatic scientists of South African river systems. The studies did not have an ecological focus, rather the Natal provincial administrators wanted a baseline on current natural resource potential with the eye on developing industrial areas similar in size to the Pretoria-Witwatersrand-Vereeniging area. However, the collection of ecological data on the province's rivers had an important role to play in: determining sources of pollution; formulating indices of pollution; and providing a basis for formulating standards for industrial wastes and effluents.⁵⁹

Thus, these investigations are seen as an important milestone in the development of aquatic science in South Africa, as they started to draw a clear line between land use practices in a catchment and the impact on the receiving river system. This link was particularly prevalent in the Umgeni River studies where persistent industrial pollution into the river estuary was linked to the decimation of the local shrimp and prawn industry.⁶⁰ The Natal Provincial Town and Regional Planning Commission used the data gathered during the hydrobiological study to appeal to the DWA to take action against polluters.⁶¹

⁵⁷ E. Thorington-Smith, 1960, Towards a plan for the Tugela basin. Second interim report of the regional survey of the Tugela basin, p. 27.

⁵⁸ H.J. Schoonbee, The role of ecology in the species evaluation of the genus *Afronurus* Lestage (Heptageniidae) in South Africa (In W.L. Peters & J.G. Peters (eds.), Proceedings of the first international conference on Ephemeroptera, Floral Agricultural and Mechanical University, August 17-20, 1970, pp. 89-112.)

⁵⁹ NAR, SAB, WW, 435 [K52/4/1], Letter from the Administrator of Natal, T. Gerdener, to Minister of Water Affairs, J.J. Fouché, on abatement of pollution in rivers in Natal, Pietermaritzburg, 1966-07-07, p. 1.

⁶⁰ NAR, SAB, WW, 435 [K52/4/1], Letter from the Administrator of Natal, T. Gerdener, to Minister of Water Affairs, J.J. Fouché, on abatement of pollution in rivers in Natal, Pietermaritzburg, 1966-07-07, p. 2.

⁶¹ NAR, SAB, WW, 435 [K52/4/1], Letter from the Administrator of Natal, T. Gerdener, to Minister of Water Affairs, J.J. Fouché, on abatement of pollution in rivers in Natal, Pietermaritzburg, 1966-07-07, p. 2.

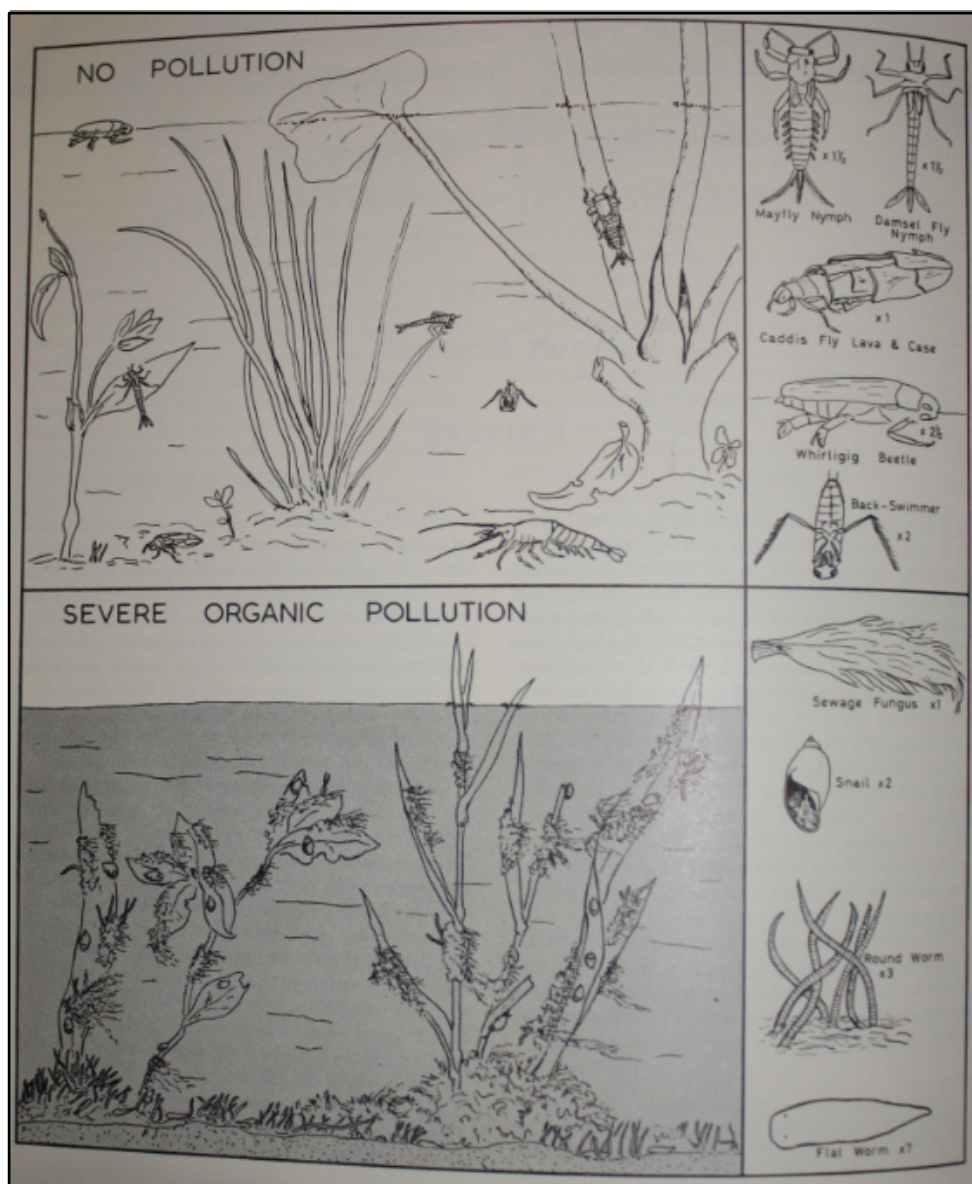


Figure 4-1: A healthy river versus an unhealthy river as illustrated by the Natal Provincial Town and Regional Planning Commission in its second report on the Thukela River⁶²

Just as aquatic science in upstream catchments evolved from more simplistic zoological studies to more complex hydrobiological investigations, aquatic science in South Africa's estuaries played the same role. Estuarine systems also started receiving increased attention from the 1950s. One of the first studies to be published on the ecology of South

⁶² Illustration: E. Thorington-Smith, 1960, Towards a plan for the Tugela basin. Second interim report of the regional survey of the Tugela basin, p. 28.

African estuaries was a study by Day, published in 1951.⁶³ The study covered everything regarding the inner workings of South African estuaries from how they were shaped geographically as well as their physical environment and the influence of aspects such as turbidity, temperature and nutrients on prevailing fauna and flora.⁶⁴ This was followed by more specific ecological studies on the Klein River, Knysna, St Lucia, Richards Bay, and Orange River estuaries, published between 1951 and 1959.⁶⁵ From these studies the importance of freshwater intake to the optimal functioning of estuarine environments became apparent.

By 1950 it had become clear that the Irrigation Act – with its focus on agriculture – was no longer serving the needs of the South African water sector, and a review process began towards the implementation of a new water Act. For this purpose, a commission of enquiry was appointed, which published its final report in 1952.⁶⁶ Submissions were welcomed from a range of institutions and individuals, and the commission travelled across the country, holding 54 meetings and seeing 451 witnesses.⁶⁷ The commission's recommendations led to the establishment of a new water bill put before Parliament in 1954.⁶⁸ The bill, which in 1956 became the Water Act [No. 54 of 1956] consolidated legislation regarding the pollution of the country's rivers and provided the first real regulations attempted at controlling the release of sewage and effluent into South Africa's

⁶³ J.H. Day, The ecology of South African estuaries, *Transactions of the Royal Society of South Africa*, 33(1), (no month) 1951, pp. 53-91.

⁶⁴ J.H. Day, The ecology of South African estuaries, *Transactions of the Royal Society of South Africa*, 33(1), (no month) 1951, pp. 53-91.

⁶⁵ K.M.F. Scott *et al.*, The ecology of South African estuaries part II. The Klein River estuary, Hermanus, Cape, *Transactions of the Royal Society of South Africa*, 33(3), (no month) 1951, pp. 283-331; J.H. Day *et al.*, The ecology of South African estuaries part III. Knysna: A clear and open estuary, *Transactions of the Royal Society of South Africa*, 33(3), (no month) 1951, pp. 367-413; J.H. Day *et al.*, The ecology of South African estuaries: Part IV. The St Lucia system, *Transactions of the Royal Society of South Africa*, 34(1), (no month) 1954, pp. 129-156; N.A.H. Millard & A.D. Harrison, The ecology of South African estuaries: Part V. Richards Bay, *Transactions of the Royal Society of South Africa*, 34(1), (no month) 1954, pp. 157-179; N.A.H. Millard & K.M.F. Scott, The ecology of South African estuaries: Part VI. Milnerton estuary and the Diep River, Cape, *Transactions of the Royal Society of South Africa*, 34(2), (no month) 1954, pp. 279-324; A.C. Brown & J.H. Day, The ecology of South African estuaries part VII. Notes on the estuary of the Orange River, *Transactions of the Royal Society of South Africa*, 35(5), (no month) 1959, pp. 463-473.

⁶⁶ Union of South Africa, Report of the Commission of Enquiry into the water laws of the Union. (Report No. U.G. 11-1952, Government Printer: Pretoria, 1952).

⁶⁷ Union of South Africa, Report of the Commission of Enquiry into the water laws of the Union, 1952, p.2.

⁶⁸ NAR, SAB, MLW, 149 [314/25], Letter from the Director of Irrigation, S. Marais, to the Minister of Irrigation, J.G. Strijdom, on the upcoming conference of the Institute of Sewage Purification, Pretoria, 1954-08-03, p.3.

river systems.⁶⁹ While the regulations introduced by the Water Act provided the first real attempts at protecting water quality, it made no attempt at curbing the impact on water flow. The Water Act made no mention of environmental impact assessment or stakeholder consultation, and the first public notice of the government's intention to build a dam was when a published White Paper was presented in Parliament for budgetary approval. By that time project planning would typically have been well advanced and construction usually followed shortly after parliamentary approval of the white paper. Since few of South Africa's rivers were studied while still in their natural state, it was difficult to pinpoint the impact of structures such as dams and weirs on aquatic systems. Even with the construction of South Africa's biggest water resource infrastructure – the Orange River Development Project – detailed hydrobiological studies were undertaken only after the project was announced in 1962.⁷⁰

Aquatic scientists did not seem to be against the project, and no record of resistance has been recorded, although some scientists did express a desire to collect data and samples on the Orange River before its impoundment and in this way pre-empt any impacts that may occur.⁷¹ While initial fears, such as an increase of schistosomiasis, did not materialise following the completion of the project, the engineering works did have a profound environmental impact on the freshwater system. Shortly after the completion of the Orange-Fish Tunnel, it was discovered that fish species were being translocated from the Orange River to the Great Fish and Sundays River, causing inter-breeding of formerly isolated species.⁷² Hardy fish species, such as the sharptooth catfish (*Clarias gariepinus*) made its way through the Orange-Fish Tunnel into the Great Fish and Sundays rivers where it did not occur before and where it impacted other, more localised fish species.⁷³ Studies undertaken in 1985 on the fish of the Orange River indicated how the cold water releases from the Gariep Dam negatively influenced breeding of endemic species such

⁶⁹ NA Pretoria, SAB, MLW, 149 [314/25] Letter from the Director of Irrigation, S. Marais, to the Minister of Irrigation, J.G. Strijdom, on the upcoming conference of the Institute of Sewage Purification, Pretoria, 1954-08-03, p.3.

⁷⁰ B.R. Allanson *et al.*, *Inland waters of Southern Africa: An ecological perspective*, p. 105.

⁷¹ S. Biesheuvel, Orange River Development Conference: A summary of proceedings, *South African Journal of Science*, 59(7), July 1963, p. 308.

⁷² J.A. Cambray & R.A. Jubb, Dispersal of fishes via the Orange-Fish Tunnel, South Africa, *Journal of the Limnological Society of Southern Africa*, 33(1), (no month) 1977, pp. 33-35.

⁷³ J.A. Cambray, The need for research monitoring on the impacts of the translocated sharptooth catfish, *Clarias gariepinus*, in South Africa, *African Journal of Aquatic Science*, 28(2), (no month) 2003, p. 192.

as the smallmouth yellowfish (*Barbus aeneus*), while rare species such as the slender redbfin (*Barbus tenuis*) became confined to smaller reaches of the river as a result of their migratory path being blocked with the construction of the dams in the Orange River.⁷⁴

The first notable expression of resistance towards the construction of a dam in South Africa occurred in KwaZulu-Natal in 1963 when the government announced the construction of Hluhluwe Dam to provide irrigation water for sugarcane farmers. The concern, voiced by scientists and environmentalists, stemmed over the potential impact the dam would have on the St Lucia estuary, one of the largest estuarine systems in Africa and an important nursery area for fish and invertebrates in the region.⁷⁵ St Lucia is one of the oldest conservation areas in South Africa, and was first declared a reserve in 1895.⁷⁶ The estuarine system is dependent on streamflow from the Hluhluwe River, along with five other river systems, namely Mkhuze, Nyalazi, Mpate, Mzinene and Mfolozi (the latter system was artificially separated from St Lucia in 1950 but has since been reconnected).⁷⁷ The studies of Day *et al.* on the ecology of St Lucia, published in 1954, already pointed to siltation and salinity problems as a result of reduced flow caused by upstream anthropogenic activities (most notably sugar cane farming).⁷⁸ Following the publication of the White Paper by DWA on its intention to build Hluhluwe Dam, the South African Association for the Advancement of Science called for thorough investigations into the ecological impact the Hluhluwe Dam would have on St Lucia. The aim of these studies would be to make recommendations towards remedial actions to save 'this precious natural asset from further deterioration'.⁷⁹

The matter was debated in Parliament in May 1963. While DWA defended its decision to build the dam, insisting that the construction of the dam would only reduce flow to the St Lucia system by 2,2%, Parliament made a decision in December 1963 to appoint a

⁷⁴ B. Davies & J. Day, *Vanishing waters*, pp. 74-75.

⁷⁵ A.K. Whitfield & R. Taylor, A review of the importance of freshwater inflow to the future conservation of Lake St Lucia, *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19(7), November/December 2009, p. 838.

⁷⁶ B. Bainbridge, Lake St Lucia and the Eastern Shores – The Natal Parks Board's role in the environmental impact report, *Natalia*, 23 and 24 (1), December 1994, p. 47.

⁷⁷ L. van Vuuren, Intensive operation on cards to save SA's top estuary, *The Water Wheel*, 8(3), July/August 2009, pp. 18-22.

⁷⁸ J.H. Day *et al.*, The ecology of South African estuaries part IV, The St Lucia system, *Transactions of the Royal Society*, 34(1), (no month) 1954; pp. 129-156.

⁷⁹ NAR, SAB, WW, 12 [K1/8], Letter to the Private Secretary of the Minister of Lands from the South African Association for the Advancement of Science on Hluhluwe Dam, 1963-02-02.

commission of enquiry into the impact of reduced flows due to upstream dams on the estuarine system.⁸⁰ The commission was chaired by Dr J.P. Kriel of the DWA. Meanwhile construction continued on the Hluhluwe Dam. Hluhluwe Dam was one of three dams being constructed in the rivers feeding St Lucia at that time, the others being Pongolapoort Dam and Mfolozi Dam. The commission confirmed the importance of St Lucia and its ecosystem benefits to South Africa and, among others, proposed that for every storage dam constructed in future in the catchment a proportion of the yield should be reserved for supply to the system during dry periods.⁸¹ As a first step, the commission recommended a canal system be constructed from Pongolapoort Dam to allow water from the Mkhuze River to still reach St Lucia. The commission went so far as to suggest that dams be especially built for St Lucia to guarantee its supply during dry periods. A more balanced approach to the management of water resources in the catchments feeding the system (between water for human use and water for the system) was also recommended.

The St Lucia example is perhaps the first case in South Africa where the impact of upstream anthropogenic activities, such as the construction of dams, on the flow of rivers, and especially to the availability of freshwater to estuarine systems at the bottom of these river systems was publicly acknowledged by the government. The results of the St Lucia commission of enquiry would later influence the findings of the commission of enquiry into water matters, which was approved by parliament in 1970.⁸² This was the first official document in which the need to allocate water for the environment was expressed, in this case for the country's most iconic nature reserves, namely Lake St Lucia and the Kruger National Park.⁸³

Despite this victory for the aquatic environment, in 1973, Chutter lamented the South African scientific community's general lack of knowledge, which prevented it from playing a more meaningful role in the sustainable development of the country's rivers, saying

⁸⁰ NAR, SAB, WW, 13 [K1/8/3], RSA, Report of the Commission of Inquiry into the alleged threat to animal and plant life in St Lucia Lake, p. 1.

⁸¹ NAR, SAB, WW, 13 [K1/8/3], RSA, Report of the Commission of Inquiry into the alleged threat to animal and plant life in St Lucia Lake, p. 186.

⁸² RSA. Report of the Commission of Enquiry into Water Matters. (Report No. RP 34-1970z, Government Printer: Pretoria, 1970).

⁸³ R.D. Walmsley & B.R. Davies, An overview of water for environmental management, *Water SA*, 17(1), January 1991, p. 68.

[t]he river biologist should ideally be equipped with sufficient knowledge to enable him to critically assess the consequences of proposed engineering and water quality modifications in our rivers so that he may play a useful role in planning. It is my opinion that existing knowledge is not sufficient to meet this challenge.⁸⁴

It is theorised that a possible reason for this apparent lack of involvement from the side of aquatic scientists in water resource development was the fact that they remained rather removed from developers and engineers – with the two groups operating largely in isolation from one another up to that point. The era of collaborative science that followed in the 1970s and 1980s would go a long way towards breaking the barriers between scientists and engineers towards onto a new path of cooperation.

4.4 The impact of collaborative science

In the 1960s South Africa entered the era of collaborative science, most notably through the International Council of Scientific Unions (ICSU) – a global conglomerate of science bodies. In 1957, ICSU organised the first year of collaborative science under the theme “International Year of Geophysics”.⁸⁵ The apparent success of this effort led to the launch, in 1964 of the International Biological Programme (IBP).⁸⁶ The IBP focused on research that investigated man’s relationship with his environment, and over the next decade projects were funded in 60 countries around seven themes, the ultimate objective being to use the results from these projects to make recommendations for the improvement of society’s well-being.⁸⁷ The seven themes were:

- The productivity of terrestrial communities;
- Production processes;
- Conservation of terrestrial communities;
- Productivity of freshwater communities;
- Productivity of marine communities;
- Use and managements of biological resources; and

⁸⁴ F.M. Chutter, An ecological account of the past and future of South African rivers, *Limnological Society of Southern African Newsletter*, No. 21, 1973, p. 31.

⁸⁵ D.G. Kingwill, *The CSIR. The first 40 years*, p. 30.

⁸⁶ D.G. Kingwill, *The CSIR. The first 40 years*, p. 30.

⁸⁷ Anon, The National Academies, The International Biological Programme (1964-1974), http://www7.nationalacademies.org/archives/International_Biological_Program.html.

- Human adaptability.⁸⁸

In 1987 Huntley emphasised the importance the IBP placed on the understanding of entire ecosystems and their functioning as a way of addressing the impacts of environmental pollution.⁸⁹ The programme also encouraged cooperation among scientific disciplines as a way of tackling the consequences of anthropogenic impact on nature from all angles. South Africa's participation in the IBP was largely limited to limnological studies on Lake Sibaya, a coastal lake located in Zululand. The Lake Sibaya studies (conducted between 1964 and 1976) were undertaken by the Zoology and Entomology Department at Rhodes University, and the accumulated results of research on the lake was published as a single volume in 1979.⁹⁰ While South Africa's participation in the IBP was limited, the programme did, however, inspire the South African government to launch its own cooperative research programmes – aimed at bringing researchers together from different institutions and from different disciplines to grow the country's scientific knowledge on various themes, including freshwater. Most notable of these was the National Programme for Environmental Sciences (NPES), which was established in 1972 by the CSIR just as the IBP started to wind down.⁹¹ The NPES had six sub-programmes, including a sub-programme on inland water ecosystems (IWE).⁹²

The National Committee for Environmental Sciences managed the NPES, with administrative services being provided by the CSIR. Among the organisations represented on the committee were the departments of Water Affairs, Health, Agriculture, Environment, as well as provincial administrations, various universities and the WRC.⁹³ The main objective of the NPES was the pooling of South Africa's scarce scientific

⁸⁸ Anon, The National Academies, The International Biological Programme (1964-1974), http://www7.nationalacademies.org/archives/International_Biological_Program.html.

⁸⁹ B.J. Huntley, Ten years of cooperative ecological research in South Africa, *South African Journal of Science*, 83(2), February 1987, p. 72.

⁹⁰ B.R. Allanson (ed.), *Lake Sibaya*. (Dr W. Junk bv Publishers: the Hague, 1979).

⁹¹ NAR, SAB, Archives of the Minister of Constitutional Development and Planning (DCD), 2468, 27/2/3, National Programme for Environmental Sciences (Inland Water Ecosystems Section) (NPES/IWES), Memorandum oor die wedersydse inskakeling van die aktiwiteite van die nasionale program vir omgewingswetenskappe en die van die Waternavorsingskommissie, 1976-10-20, p. 5.

⁹² D.G. Kingwill, *The CSIR. The first 40 years*, p. 73.

⁹³ Ecosystems Programmes (Compiler), *Environmental research perspectives in South Africa*, p. 2.

resources towards growing knowledge in the field of environmental management.⁹⁴ The cooperative nature of the programme was said to

*[involve] close collaboration of all members of our scientific community concerned with environmental matters – drawn together in committees, seminars, workshops and active research projects, through a common interest in maintaining renewable natural resources and environmental quality in South Africa.*⁹⁵

The aquatic research projects executed under the programme were aimed at growing knowledge on the ecological processes within rivers, wetlands and estuaries.⁹⁶ The programme budget was drawn from several government departments, including those of water and environmental affairs, as well as provincial administrations. However, the main funders of the programme were the CSIR (34.2%), the Department of Environmental Affairs (which between 1980 and 1984 included DWA as a directorate) (58.4%) and the WRC (7.4%).⁹⁷ The NPES grew exponentially judging by the annual growth in its budget, from an allocation of R60 000 in its starting year (1972) to R2 million a year by 1982.⁹⁸ Ten years after the establishment of the NPES the programme had managed to attract over 300 scientists working on various research projects.⁹⁹ The impact of the NPES on the South African aquatic science sector was outstanding. By 1984, 69 of 422 nationally-listed research projects were on freshwater.¹⁰⁰

The NPES freshwater studies were managed by the committee for inland waters, which was chaired by DWA.¹⁰¹ For the most part these studies had a strong focus on water quality issues (including among others, studies on mineralisation of inland waters and problems around eutrophication and aquatic macrophytes).¹⁰² Research was almost exclusively undertaken in artificial lake environments, reflecting South Africa's focus on dams at the time. A number of reasons are put forward for this research focus on dams

⁹⁴ Ecosystems Programmes (Compiler), Environmental research perspectives in South Africa, p. 2.

⁹⁵ Annual Report to the National Committee for Environmental Sciences, July 1981 to June 1982, p. 2.

⁹⁶ G.G. Cillie *et al.*, Water pollution research in South Africa, *Journal of Water Pollution Control Federation*, 51(3), March 1979, p. 464.

⁹⁷ B.J. Huntley, Ten years of cooperative ecological research in South Africa, *South African Journal of Science*, 83(2), February 1987, p. 77.

⁹⁸ Annual Report to the National Committee for Environmental Sciences, July 1981 to June 1982, p. 2.

⁹⁹ Annual Report to the National Committee for Environmental Sciences, July 1981 to June 1982, p. 2.

¹⁰⁰ J.H. O'Keeffe (ed.), Conservation of South African rivers, p. 91.

¹⁰¹ NAR, SAB, DCD, 2468, 27/2/3/1, NPES/IWES, Minutes of the ninth meeting of the Committee for Inland Waters, held on 1 July 1976 at CSIR, Pretoria.

¹⁰² NAR, SAB, DCD, 2468 [27/2/3/1], NPES/IWES, Minutes of the ninth meeting of the Committee for Inland Waters, held on 1 July 1976 at CSIR, Pretoria.

and water quality as opposed to rivers. The nucleus of the early research groups of the IWE sub-programme were researchers who had worked previously on the dams (i.e. the Gariep and Vanderkloof dams) of the Orange River Development Project.¹⁰³ Furthermore, each research project was overseen by a so-called “working committee” made up of the researchers themselves as well as various stakeholders – invariably government officials, who played a leading role in determining the direction of the research project.¹⁰⁴ Since a major function of the research undertaken under the auspices of the IWE programme was to advise government (who also provided all of the funding), it would make sense for research topics to be geared towards government focus areas, particularly those of DWA, who was a major funder.¹⁰⁵ Even the WRC dealt almost exclusively with water quality-related research between two decades of existence.¹⁰⁶ Having research and decision-makers cooperating so closely on research projects for the first time in South Africa allowed for a meaningful exchange of information. The influence that this programme had on government officials can be seen in the fact that they themselves started calling for improved monitoring systems to reduce the impact of development on the aquatic environment.¹⁰⁷ It is postulated that this also planted the seed for DWA to recognise environmental water use in 1986.¹⁰⁸

One collaborative project stood out during this period, namely the Pongolo floodplain research programme. Pongolapoort Dam is one of South Africa’s largest dams. First announced in 1960, the 89m-high dam was built at the lower end of the Pongolapoort through the Lebombo Mountains and has a gross storage capacity of 2 500 million m³.¹⁰⁹ The main aim of the dam is to serve the water needs of sugarcane irrigators in the Pongolo area. When the dam was completed in 1973 it flooded a significant section of

¹⁰³ NAR, SAB, DCD, 2468 [27/2/3/1], NPES/IWES, Memorandum oor die wedersydse inskakeling van die aktiwiteite van die nasionale programme vir omgewingswetenskappe en die van die Waternavorsingskommissie, 1976-10-20.

¹⁰⁴ NAR, SAB, DCD, 2468 [27/2/3/1], NPES/IWES, Minutes of the tenth meeting of the Committee for Inland Waters, held on 20 October 1976 at CSIR, Pretoria.

¹⁰⁵ NAR, SAB, DCD, 2468 [27/2/3/1], NPES/IWES, Minutes of the tenth meeting of the Committee for Inland Waters, held on 20 October 1976 at CSIR, Pretoria.

¹⁰⁶ M. Uys (ed.), Classification of rivers and environmental health indicators. A joint SA/Australian workshop, February 1994, p. 5.

¹⁰⁷ See, for example, W.J.R. Alexander, Proposed programme for monitoring pollutants in the water environment. (DWA Technical Note No. 38, DWA: Pretoria, 1972).

¹⁰⁸ RSA, *Management of the water resources of the Republic of South Africa*, p. 2.25.

¹⁰⁹ Union of South Africa, Report on the proposed Pongolapoort-Makatini Flats Government Water Scheme. (Report No. WP F-1960, Government Printer: Pretoria, 1960)

the Pongolo floodplain, considered one of the most biologically diverse freshwater habitats in South Africa.¹¹⁰ Prior to the construction of the dam, the annual inundation of the 13 000ha floodplain by summer floods re-energised a rich variance of ecosystems services that not only supported fish and animal life, but also a large community of people who had depended on the floodplain for their livelihood for thousands of years.¹¹¹ At that stage the South African government did not liaise, or in many instances, even inform stakeholders of new bulk water infrastructure projects before they started. Thus, organisations such as the Natal Parks Board, who had an interest in the floodplain from a conservation point of view, only got to know about the Pongolapoort Dam when construction had already begun.



Figure 4-2: The Pongolapoort Dam wall outside Jozini, Kwazulu-Natal¹¹²

With construction of the Pongolapoort Dam underway, the Natal Parks Board became concerned over the impact of the regulation of the water of the Pongolo River on the fish

¹¹⁰ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 160.

¹¹¹ Walmsley, R.D. & Roberts, C.P.R. (eds.), *Changing patterns of resource use on the Pongolo river floodplain*. Proceedings of a symposium convened by the Foundation of Research and Development and the Institute for Natural Resources, held at University of Natal, Pietermaritzburg, 9-10 February, 1988, p. 33.

¹¹² Photograph: VVPA, PF2, Pongolapoort Dam, 2012-08-15.

of the floodplain. In 1967, Natal Parks Board employee, Mike Coke, started conducting research on the fish ecology of the floodplain lakes with a view of determining the effect of the dam.¹¹³ Coke's research subsequently underlined the importance of natural flooding to the life history of the fish species supported by the floodplain. Negotiations between the DWA and the Natal Parks Board followed and, in 1974, the University of Natal established a research site at the Pongolo floodplain with funding from the IWE sub-programme.¹¹⁴ The Pongolo Floodplain Research Programme would go on to become the longest and most intensive research programme undertaken under the IWE, with over 50 individual research projects being undertaken on the floodplain between 1967 and 1987.¹¹⁵ Together, the aim of these multidisciplinary studies was to understand the ecological and social processes of the floodplain, and to provide a scientific foundation for allocating releases from the dam to sustain ecosystem processes on the floodplain.¹¹⁶ The Pongolo floodplain research programme was the first comprehensive study in South Africa focusing on water releases for human and environmental benefit and remains unequalled in terms of scope and value. A synthesis report was published in 1982 that captured the main results of all the individual projects undertaken.¹¹⁷ While challenges were later experienced in implementing the prescribed releases from the dam to sustain the ecological processes in the floodplain, the research had an enduring effect on the management of freshwater systems in South Africa.¹¹⁸

According to programme manager Charles Breen, who would later go on to lead the Kruger National Park rivers research programme

¹¹³ M. Coke [mdcoke@futurenet.co.za], Ecological research on the Pongolapoort floodplain, private email message to L. van Vuuren [laniv@wrc.org.za], 2012-12-11.

¹¹⁴ Walmsley, R.D. & Roberts, C.P.R. (eds.), Changing patterns of resource use on the Pongolo river floodplain. Proceedings of a symposium convened by the Foundation of Research and Development and the Institute for Natural Resources, held at University of Natal, Pietermaritzburg, 9-10 February, 1988, p. 7.

¹¹⁵ Walmsley, R.D. & Roberts, C.P.R. (eds.), Changing patterns of resource use on the Pongolo river floodplain. Proceedings of a symposium convened by the Foundation of Research and Development and the Institute for Natural Resources, held at University of Natal, Pietermaritzburg, 9-10 February, 1988, p. 7.

¹¹⁶ NA, SAB, DCD, 2468 [27/2/3], NPES/IWES, Minutes of the tenth meeting of the Committee for Inland Waters, 20 October 1976.

¹¹⁷ J. Heeg and C.M. Breen. Man and the Pongolo Floodplain (South African National Scientific Programmes Report No. 56, CSIR: Pretoria, 1982).

¹¹⁸ K.H. Rogers, Kilham memorial lecture: Limnology and the post-normal imperative: An African perspective, *International Limnology*, 30(2), April 2008, p. 173.

*[the research programme] set the platform for the DWA to begin to appreciate the importance of environmental flows and to collaborate with aquatic ecologists...It introduced people as integral parts of river ecosystems – a concept that would later become formulated as ‘socio-ecological systems’.*¹¹⁹

In its totality, the NPES, particularly the IWE programme, played a significant role in advancing aquatic science in South Africa.¹²⁰ The research undertaken under this programme provided valuable knowledge in terms of the functioning and management of South Africa’s freshwater systems, and built significant scientific capacity for the country as illustrated by the number of water research units and institutes established in the 1960s and 1970s. These included the Institute for Freshwater Studies established at Rhodes University (established in 1964), J.L.B. Smith Institute for Ichthyology (1968), the Hydrological Research Unit at the University of the Witwatersrand (1970), the Pollution Research Group at the University of KwaZulu-Natal (1971), the Institute for Groundwater Studies at the University of the Free State (1974), and the Hydrological Research Unit at Rhodes University (1974).¹²¹ In spite of South Africa’s political isolation, particularly in the 1980s, the local aquatic science community held high international prestige, as illustrated by the number of international conferences hosted in the country, such as the Southern Hemisphere Limnology Conference, held at Wilderness in 1984.¹²² Although it became increasingly difficult for South African aquatic scientists to publish their research in international journals.¹²³ As a consequence the South African aquatic science sector developed its own scientific journal, currently known as the *African Journal of Aquatic Science*, which grew out of the newsletter of the Limnological Society of Southern Africa (now known as the Southern African Society of Aquatic Scientists or SASAQS).¹²⁴

¹¹⁹ C. Breen [breenc39@gmail.com], The Pongola research programme, private email message to Lani van Vuuren [laniv@wrc.org.za], 2011-07-25.

¹²⁰ P. Ashton, *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 49.

¹²¹ P.E. Odendaal, Water research in South Africa (In National Institute for Water Research. Symposium on Water for the Future, CSIR Conference Centre, 1 October 1986, pp. 1-21.)

¹²² P. Ashton, *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 38.

¹²³ P. Ashton, *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 46.

¹²⁴ P. Ashton, *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 48.

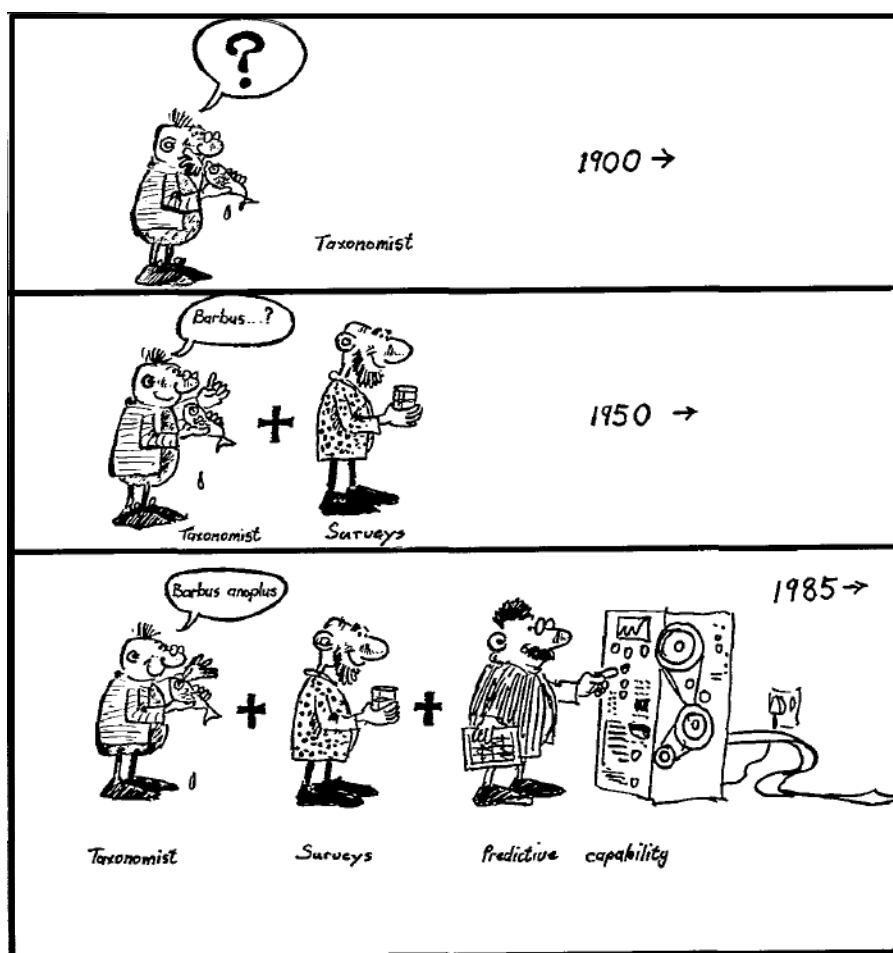


Figure 4-3: This figure illustrates the evolution of the South African aquatic science sector from the first taxonomic studies (up to the 1950s) evolving into larger surveys and eventually more comprehensive studies towards predicting the effects of anthropogenic impact from the 1980s¹²⁵

Aquatic science lost momentum when the programme was suddenly ceased in the mid-1980s due to a restructuring of its main funder, the CSIR. Funding for the NPES moved out from the CSIR and into a separate organisation, the Foundation for Research and Development (FRD) in 1984. Former research partners from different institutions now had to compete for the same, smaller pool of funding, and also had to compete with researchers from the CSIR.¹²⁶ Researchers drew back into their silos, and knowledge integration became more difficult. By 1988 the FRD completely ceased funding cooperative programmes.¹²⁷ It would take another research programme, namely the

¹²⁵ J.H. O' Keeffe (ed.), Conservation of South African rivers, p. 93.

¹²⁶ W.J.R. Alexander [alexwj@iafrica.com]. Your questions for water history thesis, private email message to Lani van Vuuren [laniv@wrc.org.za], 2012-06-02.

¹²⁷ P. Ashton *et al.*, The freshwater science landscape in South Africa, 1900-2010, p. 27.

Kruger National Park rivers research programme, for these streams of knowledge between institutions to be rekindled.

4.5 Conclusion

In order to understand why the Kruger National Park played a role in the reserve legislation in South Africa, it is sensible to contemplate the history of aquatic science in South Africa and its influence on the evolution of ecological flow science. South African ecological flow science has its foundation in aquatic science, which evolved out of early taxonomic studies from the 17th century undertaken by individuals into collaborative science efforts reaching across disciplines starting from the 20th century. These latter studies were aimed at building knowledge of aquatic ecology, rather than merely looking at the description and habits of individual species. Concern over the increasing polluted state of South African river systems following industrial expansion after the Second World War, propelled aquatic science forward as scientific answers were sought to deal with human impacts on ecological systems. A significant highlight in the history of aquatic science in South Africa was the establishment of the CSIR and its water unit, which provided a valuable incubator for freshwater science in the country. While erstwhile studies by the CSIR focused on water and sewage treatment, the institution also launched the first hydrobiological studies in selected rivers across South Africa. These studies provided an important baseline against which future human impact could be measured.

The South African aquatic science community's involvement in international collaborative studies advanced local knowledge and built capacity in the form of dedicated freshwater research units within universities. The collaborative nature of multi-institutional studies did much to enhance the flow of information between government departments and researchers, culminating in the first ecological flow studies in the Pongolo River in the 1970s. The abrupt withdrawal of funding for these programmes in 1988 dealt a severe blow to the advancement of South African aquatic science as researchers now competed for funding and retreated to their individual silos. The Kruger National Park would play an important role in rekindling the collaborative spirit of the aquatic science sector.

Chapter 5 The Kruger National Park as a starting point for ecological flow science in South Africa

5.1 Introduction

The Kruger National Park has played a significant role in the aquatic science history of South Africa. The dependence of South Africa's largest nature reserve on its perennial rivers turned the Kruger National Park into a practical space for new scientific theories and management approaches to be studied and tested. The park's reputation as a world-class tourist destination meant that these experiments took on a significance it might not otherwise have had. Described as an "iconic national park" the Kruger National Park is a well-established international eco-tourist attraction, with an average of 1.4 million people visiting the park each year.¹ This makes the park an important focus area not only from a biodiversity protection perspective, but also from an economic perspective as a generator of income for the region.

The Kruger National Park is highly dependent on its natural water resources, and it is estimated that as much of 50% of the park's biodiversity is directly dependent on its river systems.² The location of the park at the downstream end of the river catchments has meant that the Kruger National Park has had to increasingly cope with water diminishing in quantity and quality as a result of upstream anthropogenic activities. These impacts, along with the fact that, before 1998 the environment had no right to water in South Africa, drove the park to seek alternative ways to ensure water for tourists and animals. There is a clear similarity, up to the 1990s, between the status of the park's water and the adjacent area to its west. Typically, it all started with a period of little to no interference with the natural system, and then progressing towards a steady increase in the magnitude of development to equalise and control the natural variability in the freshwater systems feeding into the Kruger National Park as will be illustrated in this chapter.

¹ S. Ferreira & A. Harmse, Kruger National Park: tourism development and issues around the management of large numbers of tourists, *Journal of Ecotourism*, 13(1), June 2014, p. 16.

² VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

5.2 Short overview of the establishment of the Kruger National Park

The Kruger National Park traces its history back to the various measures undertaken by the governments of South Africa from the 17th century to protect its wildlife from overzealous hunters. The sparse settlement and frugal hunting practices of pre-colonial communities had little impact on their surrounding natural environment. However, the arrival of permanent European settlers at the Cape after 1652 soon led to an overexploitation of local game.³ The first conservation measure – in the form of a ban on the excessive hunting of penguins – was passed only two years after Jan van Riebeeck landed at the Cape to establish a halfway station for Dutch shipping firm, the *Vereenigde Oostindische Compagnie* (VOC).⁴ Legislation governing hunting practices was introduced at the Cape settlement as early as 1669.⁵ As white settlers reached deeper into the interior of the country several attempts at curbing hunting through legislation followed in all of South Africa's erstwhile territories – the Cape, Natal, Orange Free State and Transvaal.⁶

By the early 19th century four types of hunters could be distinguished in the interior of South Africa – rural white people and African people who hunted mainly for subsistence, British sportsmen who hunted for pleasure, and commercial hunters who profited from skins and ivory.⁷ Freshwater fauna were not exempt from mass hunting exploits. The arrival of prospectors and delvers in the Transvaal from the 1870s led to an increase in the availability of explosives which were used to remove vast quantities of fish from the province's rivers.⁸ The hunting laws seemingly had little effect on curbing over-exploitation of game, as illustrated by the fact that the area which was later to become the Kruger National Park was devoid of species such as elephant, white rhinoceros, and

³ D. Hey, Man, nature and conservation, *Supplement to Koedoe*, 20(1), August 1977, p. 51.

⁴ U. de V. Pienaar, An overview of conservation in South Africa and future perspectives, *Koedoe*, 34(1), September 1991, p. 73.

⁵ A.M. Brynard, Die nasionale parke van die Republiek van Suid-Afrika, *Supplement to Koedoe*, 20(1), August 1977, p. 24.

⁶ A.E. Cubbin, An outline of game legislation in Natal 1866-1912, *Journal of Natal and Zulu History*, 14(1), (no month) 1992, pp. 37-47; A.M. Brynard, Die nasionale parke van die Republiek van Suid-Afrika, *Supplement to Koedoe*, 20(1), August 1977, pp. 24-25.

⁷ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 6.

⁸ J. Carruthers, *The Kruger National Park. A social and political history*, p. 14.

eland by the early 20th century.⁹ The failure of hunting laws led to the establishment of the first wildlife sanctuaries in South Africa between 1894 and 1898, including the Pongolo, Hluhluwe, uMfolosi and Mkhuze reserves.¹⁰ This model of keeping humans and wildlife apart (rather than promoting sustainable use) was based on international trends at the time, with similar game reserves being established in countries such as Australia, Canada and Kenya.¹¹ In 1898 the predecessor of the Kruger National Park, the Sabi game reserve, was established in the Transvaal between the Olifants and Letaba rivers.¹² The reserve was extended in 1903 to include an area west of the Nsikazi River, resulting in a nature reserve 31 080km² in size.¹³ A neighbouring reserve, Shingwedzi (also spelled Singwitsi), followed in 1903 and was located between the Letaba and Limpopo rivers.¹⁴ According to erstwhile warden of Sabi (and later the Kruger National Park), Colonel James Stevenson-Hamilton, the motivation for the establishment of the game reserves was

*to effect the rescue from complete destruction of the last of the big game by providing a surer, more special, and efficient method of protection than was possible in the rest of the country, and under the ordinary game laws.*¹⁵

Thus, in these game sanctuaries it was forbidden

*to hunt, shoot, seek, or in any way to disturb, intimidate, chase or drive any game or birds.*¹⁶

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- ⁹ J.T. du Toit, K.H. Rogers & H.C. Biggs (eds.), *The Kruger experience. Ecology and management of savanna heterogeneity*, p. 7; J. Stevenson-Hamilton. Tsetse fly and the Rinderpest epidemic of 1896, *South African Journal of Science*, 53(8), March 1957, p. 216.
- ¹⁰ A. Rabie, South African law relating to conservation areas, *The Comparative and International Law Journal of Southern Africa*, 18(1), March 1985, p.52; W. Beinart & P. Coates, *Environment and history. The taming of nature in the USA and South Africa*, p. 75.
- ¹¹ J. Carruthers, *The Kruger National Park. A social and political history*, p. 32.
- ¹² A.M. Brynard, Die nasionale parke van die Republiek van Suid-Afrika, *Supplement to Koedoe*, 20(1), August 1977, p. 24.
- ¹³ U. de V. Pienaar, Indications of progressive desiccation of the Transvaal over the past 100 years, and implications for the water stabilisation programme in the Kruger National Park, *Koedoe*, 28(1), November 1985, p. 130.
- ¹⁴ S.C.J. Joubert, The Kruger National Park – An introduction, *Koedoe*, 29(1), November 1986, p.3.
- ¹⁵ J. Stevenson-Hamilton, Notes on the Sabie Game Reserve, *Transvaal Agricultural Journal*, 5(19), April 1907, p. 606.
- ¹⁶ J. Stevenson-Hamilton, The Transvaal Game Reserve: An animal sanctuary for the Union. *Journal of the Royal African Society*, 25(9), April 1926, p. 211.

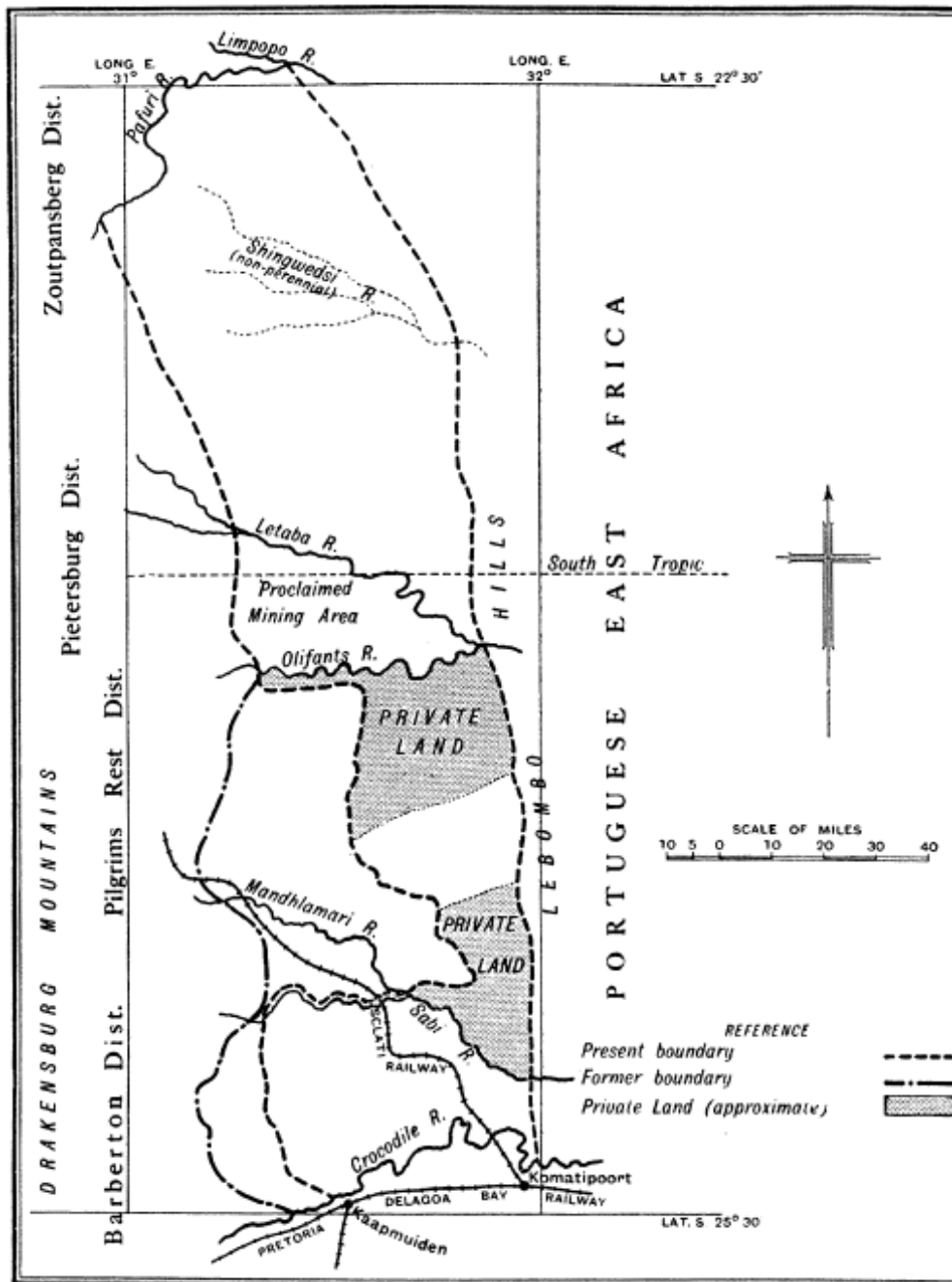


Figure 5-1: The Sabi game reserve in 1903.The map shows the boundaries of the original reserve as proclaimed in 1898 as well as boundaries when the reserve was re-proclaimed in 1903¹⁷

In 1926 the South African government passed the National Parks Act [Act no 56 of 1926]. This led to the amalgamation of the Sabi and Shingwedzi reserves into the Kruger National Park. The park, and all subsequent national parks, was managed by the National

¹⁷ J. Stevenson-Hamilton, The Transvaal Game Reserve: An animal sanctuary for the Union, *Journal of the Royal African Society*, 25(9), April 1926, p. 214.

Parks Board of Trustees (NPB) – located in Pretoria. After 1994, the NPB was renamed South African National Parks (Sanparks).¹⁸ The area occupied by the Kruger National Park was selected for the sole purpose of conserving game as it was thought to have no other economic value.¹⁹ Like many conservation areas of the time, the Kruger National Park was established for the purpose of conserving terrestrial animals (particularly game), with little thought to the needs of the river ecosystems feeding the park or the aquatic fauna within them.²⁰ This is illustrated by the north-south orientation of the Kruger National Park, whereas the park's main rivers run from west to east. This effectively means that only 4% of the water in the park's rivers is generated by runoff within the Kruger National Park itself.²¹ As a result, the Kruger National Park's water resources are vulnerable to anthropogenic impacts in the catchment upstream of the park fence. The early days of the Kruger National Park were precarious, with industrialists and agriculturalists constantly threatening to unravel the conservation effort. The Selati railway line was constructed by the Transvaal government to serve the Selati goldfields at Gravelotte, Leydsdorp and Rubbervale. After much interruption, the line was completed in 1915 with a section running through the Kruger National Park at Skukuza.²² When the gold ran out, the railway line brought tourists (and therefore valuable economic income) to the Kruger National Park, which provided enough motivation for the park's continued existence.²³ The railway line was also used to bring provisions to the park. The line ceased operation in 1972.²⁴ Today, the Kruger National Park is a key destination for tourists, both national and international.

¹⁸ Anon, Brief history of Sanparks, <https://www.sanparks.org/about/history.php>. To avoid confusion, Sanparks will be used throughout.

¹⁹ Sanparks, NK/18[1], Transvaal Native Affairs Department, Annual Report 1906, pp. 606-607.

²⁰ J. Carruthers, Creating a national park, *Journal of Southern African Studies*, 15(2), January 1989, p. 191.

²¹ A. Pike & R. Schulze, Development of a distributed hydrological modelling system to assist in managing the ecological reserve to the Sabie River system within the Kruger National Park, p. 2.

²² Sanparks, A/1 [1]. The Selati railway line, s.a., n.p.

²³ U. de V. Pienaar, *A cameo from the past. The prehistory and early history of the Kruger National Park*, pp. 363; M.J.L. Akeley, The Kruger National Park of the Transvaal, *The Scientific Monthly*, 45(3), September 1937, p. 209.

²⁴ Sanparks, A/1 [1]. The Selati railway line, s.a., n.p.



Figure 5-2: Remnants of the Selati railway line, which can be viewed from the Skukuza tourist camp in the Kruger National Park²⁵

5.3 Evolution of water management in the Kruger National Park as a forerunner to the Skukuza workshop and the birth of ecological flow science in South Africa (1898-1988)

5.3.1 Low intervention (1898-1945)

Where other conservation areas of the time, such as Yellowstone National Park established in the USA in 1872, had a central focus on conserving nature for the distinct pleasure of visiting tourists,²⁶ the Sabi Game Reserve was established as a safe haven for game away from hunters' guns.²⁷ In the words of Stevenson-Hamilton, the Sabi Game Reserve was "a wild, trackless, primitive bit of Africa".²⁸

²⁵ Photograph: VVPA, PF1, Sabie railway bridge, 2006-10-10.

²⁶ Anon, Why wilderness must come first, *National Geographic*, 229(5), May 2016, p. 6.

²⁷ J. Stevenson-Hamilton, The Transvaal Game Reserve: An animal sanctuary for the Union, *Journal of the Royal African Society*, 25(99). April 1926, p. 211.

²⁸ J. Stevenson-Hamilton, *South African Eden*, p. 263.

The warden had every intention of keeping it so. There was originally no plans of turning this conservation area into a tourist attraction. In fact, the first warden made it his mission to keep people out of the reserve, whether they be local African communities, biltong hunters, farmers, mining companies or treasure seekers. It was only after the establishment of the Kruger National Park in 1926 that Stevenson-Hamilton started to see the role that tourists could play in keeping the nature reserve intact by providing a public voice that he started to become more amenable to the idea of tourists in the park.²⁹ While nature was largely left to regulate itself during Stevenson-Hamilton's tenure, he did for a while bow to pressure from agriculturalists outside the borders of the Kruger National Park and slayed thousands of predators, such as lions and wild dogs, which were then considered vermin and a threat to livestock farmers surrounding the then unfenced Kruger National Park.³⁰ The increasing attractiveness of these animals to tourists later put a stop to this slaughter.³¹ The warden became a strong advocate for the conservation of nature with minimal human interference, believing that, if left alone, nature would establish its own equilibrium.³²

While the Sabi Game Reserve, and its successor, the Kruger National Park, were established for the exclusive conservation of terrestrial species, the richness and, in some instances, the rarity, of the river fauna in the park was recognised from the time of the establishment of the reserve. Stevenson-Hamilton was especially taken with the diversity of species found in the Sabie River.³³ During his time as warden of the Kruger National Park he assisted in collecting specimens from the park's rivers for description by the South African Museum.³⁴ By 1949, at least 11 *Barbus* species, four *Labeo* species, two *Clarias* species, and three *Anguilla* species had been described.³⁵ Stevenson-Hamilton was particularly impressed with the majestic qualities of the African tiger fish (*Hydrocynus vittatus*), a favourite angling fish.³⁶ Despite the recognition of the richness of aquatic fauna

²⁹ J. Stevenson-Hamilton, *South African Eden*, p. 188.

³⁰ J. Carruthers, Conservation and wildlife management in South African National Parks 1930s-1960s, *Journal of the History of Biology*, 41(2), Summer 2008, p. 209.

³¹ J. Carruthers, Conservation and wildlife management in South African National Parks 1930s-1960s, *Journal of the History of Biology*, 41(2), Summer 2008, p. 209.

³² J. Stevenson-Hamilton, *South African Eden*, p. 297.

³³ J. Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense*, p. 146.

³⁴ J. Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense*, p. 146.

³⁵ J. Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense*, pp. 148-149.

³⁶ J. Stevenson-Hamilton, *Die Laeveld. Sy natuurlewe en sy mense*, p.149.

in the rivers of the Kruger National Park the aquatic ecosystem sustained by these rivers were not considered during its early history. Rather the rivers of the Kruger National Park were valued only for the water they supplied to sustain the terrestrial fauna of the park.

Even before the Kruger National Park came into being the semi-arid climate of the area and lack of water resources were well understood. Stevenson-Hamilton kept meticulous climate and rainfall records from the time he came to the area.³⁷ The perennial rivers are the mainstay of the park's water resources, particularly during the long dry season (April to February) when the smaller, seasonal rivers in the park generally cease to flow.³⁸ Stevenson-Hamilton took particular note of the oscillations between wet and dry seasons and the variations in water resource availability these brought to the park.³⁹ A popular theory held at the time was that South Africa's rainfall was becoming progressively less and that the country was in fact "drying up". Despite being dismissed by, among others, engineers of the then Department of Irrigation, Stevenson-Hamilton and others held the theory that South Africa was becoming desiccated, and that it held catastrophic consequences for the country's water resources, particularly those in the Lowveld.⁴⁰ In his annual report on the Sabi and Singwitsi Game Reserves in 1912, Stevenson-Hamilton writes about the increasing siltation in the rivers of the park and the gradual, permanent, withering of natural lakes and pans.⁴¹ He adds that in

*[his] opinion based on continual observation since 1902, there is a gradual desiccation of the whole eastern low country in progress, which an occasional season of heavy rains only temporarily alleviates.*⁴²

Stevenson-Hamilton held the theory that increasing deforestation of the upper catchments of the perennial rivers of the Kruger National Park as well as fires within the park were the main causes of this increasing lack of water. No correlation was made between increasing water use in the upper catchments by, among others, agriculture and industry, at this stage. In later years, as more knowledge was accumulated on the Kruger

³⁷ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07, p.3.

³⁸ Sanparks, NK/18 [1], Transvaal Native Affairs Department, Annual Report 1906, p. 604.

³⁹ J. Stevenson-Hamilton, Notes on the Sabi Game Reserve, *Transvaal Agricultural Journal*, 5(19), April 1907, p. 604.

⁴⁰ D.F. Kokot, *An investigation into the evidence bearing on recent climatic changes over southern Africa*, p. 135.

⁴¹ Sanparks, NK/28 [1], Government Game Reserves, Sabi and Singwitsi Annual Report, 1912, p. 1.

⁴² Sanparks, NK/28 [1], Government Game Reserves, Sabi and Singwitsi Annual Report, 1912, p. 1.

National Park's ecosystems and their response to climate, this theory was dismissed in favour of the increasing knowledge on the impact of upstream water use.⁴³

In the early years of the park, wildlife numbers were sufficiently low as to not put too much pressure on available water (or grazing) resources. A series of seasons of below average rainfall (1912-14, 1926-1928, 1929-1933) and consequent game losses prompted Stevenson-Hamilton to launch an investigation into possible ways of augmenting water storage both for human consumption (rangers and tourists) and for game.⁴⁴ Since the park was unfenced at that time, Stevenson-Hamilton was particularly concerned about the migration of animals out of the safety of the park eastwards into what is now Mozambique and westwards onto agricultural land where they would be vulnerable to hunting.⁴⁵ Stevenson-Hamilton noted the link between the availability of water resources and grazing. This was particularly noticeable during times of drought when the veld in the vicinity of available water would be stripped bare of grazing by wild animals while relatively untouched areas remained further away from available water supplies.⁴⁶ Grass-dependent animals, such as impala, would become weak as they travelled between water points, thus becoming easier prey for carnivores. This was of particular concern as the Sanparks was trying to increase the game population of the Kruger National Park.⁴⁷ As a result, early (and consequent) attempts at enhancing water supplies through artificial means were aimed at providing water supplies in these food-rich areas located in between the perennial rivers.

Stevenson-Hamilton describes the situation in the Olifants River section of the Kruger National Park in his 1933 report to the National Parks Board of Trustees as

South of Olifants River, water became so scarce towards the end of winter that all the animals tended to congregate near the few permanent water supplies, with

⁴³ S. Joubert, *The Kruger National Park – A history Vol I*, p. 54.

⁴⁴ Sanparks, NK/18/1 [1], Letter from Kruger National Park Warden, James Stevenson-Hamilton, to National Parks Board of Trustees on increasing water supply in the park, Skukuza, 1930-02-06.

⁴⁵ Sanparks, NK/18/1 [1], Letter from Kruger National Park Warden, James Stevenson-Hamilton, to National Parks Board of Trustees on increasing water supply in the park, Skukuza, 1930-02-06.

⁴⁶ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07, p. 1.

⁴⁷ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07, p. 1.

*the result that every particle of pasture was eaten off for many miles around; the veld resembled a roadway and the animals had to trek far to find food.*⁴⁸

Among the first attempts at enhancing water supplies in the Kruger National Park through artificial means was by way of drilling boreholes. One of the first boreholes to be sunk was at the warden's headquarters at Skukuza. The borehole, attached to a windmill, was drilled in 1913 in the riverbed of the Sabie River.⁴⁹ A few years after the establishment of the Kruger National Park, in 1932, a public outreach campaign raised funds for the drilling of more boreholes for the watering of game and, by 1935, 14 such boreholes had been constructed in the park.⁵⁰ Most of these early boreholes were drilled by the DWA on behalf of Sanparks. In 1930 investigations began into the possibility of constructing dams in the Kruger National Park in order to augment available water supply.⁵¹ The park warden also considered the augmentation of existing watering holes in order for them to hold water for longer periods of time. In 1933, DWA Northern Transvaal Circle Engineer, T. Hopwood, visited the park with the view of identifying potential dam sites.⁵² He was followed in May 1937 by Northern Transvaal Assistant Circle Engineer, W.A. Lignau, who made further recommendations on proposed dam sites in the Kruger National Park.⁵³

⁴⁸ Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park to the Board of Trustees, 1933, p. 1.

⁴⁹ Sanparks, NK/28 [1], Government Game Reserves, Sabi and Singwitsi, 1914, Annual Report, p. 1.

⁵⁰ Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park to the National Parks Board of Trustees (1933 to 1939).

⁵¹ Sanparks, NK/18/1 [1], Letter from Kruger National Park Warden, James Stevenson-Hamilton, to National Parks Board of Trustees on increasing water supply in the park, Skukuza, 1930-02-06.

⁵² Sanparks, NK/18/1 [1], Letter from T. Hopwood to the Secretary of the Kruger National Park on available dam sites, Pretoria, 15 May 1933.

⁵³ Sanparks, NK/18/1 [1], Report by W.A. Lignau, Department of Irrigation, to the National Parks Board of Trustees on possible dam sites in the Kruger National Park, 1937-03-04.



Figure 5-3: The Eileen Orpen Dam, located near Tshokwane in the central section of the Kruger National Park, was completed in 1944⁵⁴

Since the focus was on providing water away from the perennial rivers, the latter were not considered for damming at that stage. Rather, the attention turned to the smaller, non-perennial rivers criss-crossing the Kruger National Park.⁵⁵ Even in those early years there was an awareness that constructing sustainable dams would be a difficult task in the park due to the hydrology (oscillating between low to no flows during arid periods to high flows during floods), the flat topography (resulting in there being no suitable sites for large dams), general high evaporation and high siltation rates.⁵⁶ The warden first experimented with an earth dam constructed at Satara in 1925.⁵⁷ This was followed by the Ntomeni Dam in the area of Pretoriuskop in 1931.⁵⁸ By the time Stevenson-Hamilton retired in 1945

⁵⁴ Photograph: VVPA, PF1, Orpen Dam, 2016-07-27.

⁵⁵ Sanparks, NK/18/1 [1], Report by W.A. Lignau, Department of Irrigation, to the National Parks Board of Trustees on possible dam sites in the Kruger National Park, 1937-03-04.

⁵⁶ Sanparks, NK/28 [1]. Annual Report of the Warden of the Kruger National Park to the National Parks Board of Trustees (1933 to 1939).

⁵⁷ Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park Board of Trustees, 1933, p. 8.

⁵⁸ Sanparks, NK/28 [1], Annual Report of the Warden of the Kruger National Park Board of Trustees, 1932, p. 15.

eight small concrete and earth dams had been constructed in the Kruger National Park along with a growing number of boreholes.⁵⁹ One of these dams, the Eileen Orpen Dam (named after a benefactor of the park) was completed in the Manzentondo River in 1944, and remains a favourite game viewing spot for tourists to this day.⁶⁰

5.3.2 Water for game (1946-1960)

In 1946, Colonel J.A.B. Sandenbergh became the warden of the Kruger National Park when Stevenson-Hamilton retired. In the same year the South African government passed the Soil Conservation Act [Act no. 45 of 1946], which allowed for the establishment of soil conservation committees in an effort to safeguard soil and water resources and reduce soil erosion in South Africa.⁶¹ Shortly after the legislation was passed, Sanparks started corresponding with the Soil and Conservation Board over the possibility of declaring the Kruger National Park a soil conservation area.⁶² This would provide the necessary state funding for the park to pursue an accelerated artificial water provisioning programme.⁶³ At this stage it was estimated that the park required about £27 000 to improve its water situation. Sanparks' intention, as stated in a letter to the Board dated 12 December 1946 to the Soil and Conservation Board on the matter of declaring the park a soil conservation area was to

*[c]reate water storage by all means at [its] disposal with the object of providing permanent water so dispersed as to ensure the maximum possible spread of grazing.*⁶⁴

The Board planned to do this through various means, namely by establishing dams and boreholes, enlarging existing pans and digging wells. Similar to Stevenson-Hamilton, Sandenbergh maintained that providing sufficient water (and therefore access to grazing)

⁵⁹ Sanparks, NK/18/1 [K39/A]. A.M. Brynard, Interne memorandum oor water vir wild. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in die Nasionale Krugerwildtuin, s.a., p. 11.

⁶⁰ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07. p. 7.

⁶¹ W. Beinart, The rise of conservation in South Africa – Settlers, livestock and the environment, p. 381.

⁶² NAR, SAB, Archive of the Land Protection Board (1910-1963) (GBR) 8, SCB6/01, Kruger National Park Soil and Water Conservation, correspondence between the National Parks Board of Trustees and the Soil and Conservation Board on declaring the Kruger National Park a soil conservation area, 1946-1951.

⁶³ NAR, SAB, GBR 8, SCB6/01, Minutes of the eighth meeting of the Executive Committee of the Soil Conservation Board, Cape Town, 1948-09-01.

⁶⁴ NAR, SAB, GBR 8, SCB6/01, Letter from the National Parks Board to the Soil and Conservation Board on soil and water conservation in the Kruger National Park, Pretoria, 1946-12-12.

in the Kruger National Park would prevent the migration of animals onto adjacent land (and across the border) in drier times.⁶⁵ In 1947 it was estimated that of the 20 720km² of grazing available in the park, 5 180km² was not in the close vicinity of any water supply, and therefore remained virtually untouched by the animals of the park.⁶⁶ It was also estimated that, due to the Kruger National Park's precarious water situation, as much as a third of its antelope had migrated permanently out of the park. Sanparks was also increasingly concerned about the state of the perennial rivers of the park. Rivers such as the Luvuvhu had by that time already been affected negatively by upstream anthropogenic impacts as poor agricultural practices upstream caused the river's water to become more turbid. The Letaba River ceased flowing for the first time in 1949.⁶⁷ In the winter months of 1947 the first significant fish kills were reported in the Kruger National Park.⁶⁸ While there were police investigations into the factors leading to this incident no evidence of pollution could be established.

Sandenbergh was not convinced that the reasons behind the increased lack of water was a steady decrease in rainfall, as had been believed by his predecessor. Rather, he was of the opinion that it was an unusually wet period, between 1890 and 1995 that created this illusion in later, drier years, that the country was becoming desiccated.⁶⁹ Pans, lakes and wetlands were filled during the time the park received excess rainfall. As the climate around the park returned to normal these water bodies started drying naturally, creating the impression that the landscape was becoming more arid. While there was now seemingly increased appreciation for the fact that, lying downstream in the catchments of its perennial rivers, the Kruger National Park was on the receiving end of upstream impacts to its water resources, park management still looked at remedies inside its borders rather than engaging with other users upstream. It is theorised that the possible reason for this is the dearth of environmental legislation that existed in South Africa at the

⁶⁵ NAR, SAB, GBR 8 [SCB6/01], Minutes of the fifth meeting of the Executive Committee of the Soil and Conservation Board, Cape Town, 31 August, 1948.

⁶⁶ NAR, SAB, Archive of the Secretary of Native Affairs (1880-1975) (NTS) 8075, 626/337, Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947, p. 7.

⁶⁷ Sanparks, B/8, 9-1, Internal notes on the rainfall and streamflow data for the Kruger National Park, s.a.

⁶⁸ National Parks Board of Trustees (NPB), Annual Report for the year 1947, p. 25.

⁶⁹ NAR, SAB, NTS 8075, 626/337, Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947.

time, which would have left Sanparks with little influence outside its borders. While the Kruger National Park was appreciated by the South African government as a game sanctuary and an income generator through tourism, the park had no “teeth” to take on economically important water users such as commercial farmers and mining companies.

The Soil and Conservation Board responded to the park’s request by establishing a multi-departmental committee to investigate conditions in the Kruger National Park with the view of declaring the park a soil conservation area. The committee, comprising various officials from the DWA, the Department of Lands, Department of Agriculture and the Department of Native Affairs, reported back to the Soil and Conservation Board in 1947 following its investigations.⁷⁰ The committee confirmed the deteriorating state of the perennial rivers of the Kruger National Park:

*Perennial rivers, which would be relied upon for a permanent strong flow of crystal-clear water, today have a dry-weather flow estimated at about a fifth of the former flow and in the case of the Levubu [sic] river, this consists of heavily silt-laden water.*⁷¹

The committee also appreciated the fact that the areas upstream of the Kruger National Park were still developing, and that this would increasingly impact on the park’s perennial water supplies:

*There is no doubt that as the country develops, the water of these rivers will be drawn off for irrigation at an ever increasing extent. The importance of maintaining the perennial flow of these rivers throughout the [p]ark cannot be overstressed.*⁷²

The committee recommended that the Kruger National Park be declared a soil conservation area and that measures be taken to improve water supply in the park by means of drilling more boreholes and constructing more dams. Despite the positive response by the Soil and Conservation Board the Minister of Agriculture, with whom the decision ultimately rested, rejected Sanparks’s request, saying that, since the Kruger National Park generated its own income, the park had to fund its own water conservation

⁷⁰ NAR, SAB, NTS 8075 [626/337], Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947.

⁷¹ NAR, SAB, NTS 8075 [626/337], Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947, p. 8.

⁷² NAR, SAB, NTS 8075 [626/337]. Report on soil and water conservation in the Kruger National Park by an inter-departmental committee for submission to the Soil Conservation Board, September 1947, p. 16.

efforts.⁷³ This led to the launch of the water-for-game fund in 1949 – with Sandenbergh travelling across the country to appeal to the general public to donate funds for the establishment of artificial water points in the Kruger National Park.⁷⁴ In the first year the park managed to raise £14 000, resulting in 33 boreholes being sunk as part of stage one of the water-for-game project. The warden states in the Annual Report of 1949 about the success of the water-for-game fund that

*[t]he shortage of drinking water for game has been one of the park's greatest handicaps. Thanks to the generosity of the public of South Africa, this handicap should be reduced by the end of 1951.*⁷⁵

By the end of the 1951 financial year, the number of water points in the Kruger National Park had been increased to 54.⁷⁶ Water from some boreholes were let into natural waterholes while around others concrete reservoirs were constructed to store excess water.⁷⁷ By 1961 there were 63 windmills in the park.⁷⁸

In July 1950, the Kruger National Park started investigations around stage 2 of its water plan, namely the construction of dams.⁷⁹ For this part of the project assistance was called from DWA engineers. The first two dams constructed under the water-for-game Fund in 1951 were the Mlondozi Dam, followed by the Ngwanetsi Dam, constructed in 1952.⁸⁰ A further nine dams were completed that same year.⁸¹ While Sandenbergh left the service of the Kruger National Park in 1954 the water-for-game programme continued. By 1960 a further 13 dams of various sizes had been constructed in the rivers of the Kruger National Park.⁸² These early dams and boreholes were constructed without any consideration of their impact on the aquatic ecosystem or on the faunal and floral species

⁷³ NAR, SAB, GBR 8 [SCB6/01], Letter from the Secretary of Agriculture to the Soil Conservation Board on the Kruger National Park, Pretoria, 1948-12-23.

⁷⁴ Sanparks, A/1 [1], Letter from the warden of the Kruger National Park to the National Parks Board on the development of water in the Kruger National Park, 1946-1950, Skukuza, 1950-07-24.

⁷⁵ NPB, Annual Report, 1949, p. 12.

⁷⁶ NPB, Annual Report, 1951, p. 7.

⁷⁷ Sanparks, A/1 [1], Letter from the warden of the Kruger National Park to the National Parks Board on the development of water in the Kruger National Park, 1946-1950, Skukuza, 1950-07-24.

⁷⁸ NPB, Annual Report, 1961, p. 23.

⁷⁹ NPB, Annual Report, 1951, p. 7.

⁸⁰ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07.

⁸¹ NPB, Annual Report, 1952, p. 7.

⁸² Sanparks, NK/18/1 [K39/A]. A.M. Brynard, Interne memorandum oor water vir wild. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in die Nasionale Krugerwildtuin, s.a., p. 16.

of the Park.⁸³ In addition, many of the dams and artificial waterholes were constructed without proper investigation as to their sustainability, and many of these artificial water points silted up as fast as they were being constructed.⁸⁴ The majority of the water infrastructure constructed at this point was per the preference of the warden and the rangers running the different sections of the Kruger National Park.⁸⁵ Preference was given to sites that allowed for good game viewing by tourists. The late 1950s were good rainfall years for the park, and the demand for artificial water reduced slightly in the last five years of the decade.



Figure 5-4: Elephants at a concrete reservoir established near a borehole outside Letaba tourist camp⁸⁶

⁸³ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07, p. 2.

⁸⁴ Sanparks, B/5 [1], Report to the National Parks Board by J. Dommissie, consulting engineer, on the supplies of the Kruger National Park with special emphasis on game requirements, 1957-09-07.p. 2.

⁸⁵ Sanparks, B/5 [1], U. de V. Pienaar, Internal report on the water resources of the Kruger National Park – past and present, s.a.

⁸⁶ Photograph: LVPA, PF1, Elephants at Letaba camp, 2007-07-05.

5.3.3 Management through intervention (1960 to 1980)

From the time the Kruger National Park had been established its human managers had interfered in the natural state of the things. From the hunting of lions and other predators to improve game numbers to the sinking of wells and boreholes to increase the availability of water, park management had not left nature to establish its own equilibrium. Following the appointment of the park's first scientist in 1951, this management by intervention took on a new intensity, the objective being to stabilise the unpredictable nature of the ecosystems in the park.⁸⁷ Interventions became pronounced once the park fence was completed in 1963, as animals that once migrated freely were now contained. From then on the Kruger National Park was managed as an isolated area, detached from its surroundings.⁸⁸ Between 1960 and 1990 interventions were purposefully aimed at subduing the inherent variability of nature inside the park's borders towards a target of equilibrium. This was achieved through management programmes such as controlled burning, culling of excess animals based on pre-determined population ceilings, and the acceleration of the artificial water-supply programme.

Pienaar sums up park management's philosophy during this period, saying that

*[n]ational parks and nature reserves are in fact ecological islands which can rarely be self-regulatory...Few, if any, of our South African national parks and nature reserves are completely self-contained ecological units...Maintenance of most natural park ecosystems requires management in some form or other in order to prevent or compensate for man's altering of natural ecological relations.*⁸⁹

In the National Parks Board of Trustees' Annual Report for the 1962 financial year it was reported that

*[n]ature's natural preserves have been interfered with to such an extent that we have to manage the park on a scientific basis, and cannot rely on nature to keep a natural balance as too many extraneous factors are present.*⁹⁰

⁸⁷ J. Carruthers, Conservation and wildlife management in South African National Parks 1930-1960s, *Journal of the History of Biology*, 41(2), Summer 2008, p. 226; J. Carruthers, *The Kruger National Park. A social and political history*, p. 115.

⁸⁸ NPB, Annual Report, 1963, p. 29.

⁸⁹ U. de V. Pienaar, Research objectives in South African national parks, *Supplement to Koedoe*, 1977, p. 38.

⁹⁰ NPB, Annual Report, 1962, p. 10.

The wet cycle experienced between 1953 and 1961 concealed the increasing impact upstream anthropogenic activities were having on the availability of water downstream where the Kruger National Park was located. When the next dry climatic cycle started in 1962 it became evident that activities, such as agriculture, deforestation, industry and mining, were causing water flow to the park to dwindle.⁹¹ Sanparks' annual reports from the period reveal that from 1963 the Letaba River ceased to flow every dry winter season, while the Olifants, Crocodile, and Sabie rivers reached their lowest levels in recorded history during the 1960s.⁹² In 1964, the Luvuvhu River stopped flowing for the first time since the park's creation.⁹³

In answer to its dwindling natural water supplies the Kruger National Park accelerated its water-for-game programme, spending more on the establishment of boreholes and dams between 1961 and 1969 than it had in the previous three decades.⁹⁴ From 1961 to 1972 the number of (water-giving) boreholes were increased from 63 to 230.⁹⁵ This is significant, considering that only one out of every three boreholes drilled struck water.⁹⁶ Park management also started investigations into a series of small water transfer schemes to pump water from perennial rivers via pipelines to non-permanent rivers to provide additional water to tourist camps.⁹⁷ The artificial water-supply programme was also put to work to increase the number of rare animal species. This meant that dams were erected in the Nwaswitshaka River, frequented by white rhinoceros, while windmills were erected around Pretoriuskop, Tsutsi and Mbyashishe to serve sable antelope populations.⁹⁸ In 1969, Sanparks adopted a 10-year water-for-game programme.⁹⁹

⁹¹ Sanparks, B/5 [1], U. de V. Pienaar, interne verslag oor die waterbronne van die Krugerwildtuin – 'n opsomming van die huidige toestand, asook die waterverskaffingsprogram – wat reeds vermag is en die pad vorentoe, 1969-05-30.

⁹² NPB, Annual Reports, 1960-69.

⁹³ NPB, Annual Report, 1964, p. 11.

⁹⁴ Sanparks, NK/18/1 [K39/A], A.M. Brynard, Interne memorandum oor water vir wild. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in die Nasionale Krugerwildtuin, undated.

⁹⁵ Sanparks, NK/18/1 [K39/A], A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

⁹⁶ Sanparks, NK/18/1 [K39/1], R. Knobel, Interne memorandum aan Nasionale Parkeraad oor water vir wild in die Kruger wildtuin en ander nasionale parke, 1969-08-28, p. 4.

⁹⁷ Sanparks, NK/18/1 [K39/1], A.E. Kuschke, 'n Oorsig van bestaande en moontlike addisionele waterbronne in wildsuiping in die Krugerwildtuin, 1969-06-17.

⁹⁸ Sanparks, B/5 [1], U. de V. Pienaar, Internal report on the water resources of the Kruger National Park – past and present, s.a., p. 10.

⁹⁹ Sanparks, NK/18/1 [K39/1], Extracts from the agenda and minutes of the ordinary meeting of the National Parks Board of Trustees held at Skukuza, Kruger National Park, 1969-06-26.

Dependent on the availability of funds, the aim of the programme was to stabilise the water-supply of the Kruger National Park further through the construction of 150 boreholes, at least 100 smaller dams, four large dams and 25 smaller dams in the perennial rivers, as well as 10 large dams in the non-perennial rivers of the Park.¹⁰⁰ Also on the cards were 12 pumping schemes to transfer water between the different river systems of the park.¹⁰¹

The water transfer schemes never materialised, but Sanparks made a good start on the rest of the water infrastructure. By 1972, 30 earthen and 24 concrete dams had been constructed all over the park.¹⁰² In 1970, the Kruger National Park completed its first dam in a perennial river, namely the Engelhard Dam, which is located in the Letaba River, downstream of the Letaba tourist camp. The dam, which has a capacity of 3.75 million m³, was the most expensive dam the park had constructed up to that time, and formed part of a set of four weirs (the others being Shimuwini, Mingerhout and Black Heron) built in the Letaba River to enable the lower reaches to hold more water during the dry months.¹⁰³ These weirs were not successful. They silted up within 10 years of their construction, which dramatically reduced their storage capacity and rendered them practically worthless.¹⁰⁴ Despite the investment in artificial water infrastructure, the Kruger National Park remained dependent on the water of its perennial rivers. The dams constructed in the seasonal rivers tended to dry up in winter, and during the drought years of the 1960s, park management spent much time pumping and tanking water through to these dams from boreholes. By this time the park's mammalian population had grown to around a million. The lack of water – and concomitant lack of grazing – led to large-scale animal fatalities, including hundreds of hippopotami.¹⁰⁵ To counteract the apparent man-

¹⁰⁰ Sanparks, NK/18/1 [K39/1], Extracts from the agenda and minutes of the ordinary meeting of the National Parks Board of Trustees held at Skukuza, Kruger National Park, 1969-06-26.

¹⁰¹ Sanparks, NK/18/1 [K39/1], Extracts from the agenda and minutes of the ordinary meeting of the National Parks Board of Trustees held at Skukuza, Kruger National Park, 1969-06-26.

¹⁰² Sanparks, NK/18/1 [K39/A]. A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

¹⁰³ Sanparks, NK/18/1 [K39/A], A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

¹⁰⁴ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

¹⁰⁵ Sanparks, NK/18/1 [K39/A], A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

made disaster, the park began with the culling of animals in 1965.¹⁰⁶ Large animals were targeted, such as buffalo and elephant, although the 1960s drought also led to the culling of animals such as wildebeest and zebra in an attempt to save grazing for other species.¹⁰⁷ Overcrowding in the Kruger National Park rivers also led to the culling of around 500 hippopotami between 1974 and 1981.¹⁰⁸



Figure 5-5: Black Heron weir – constructed in the Letaba river inside the Kruger National Park – had completely silted up by 1986. It has since been converted into a measuring weir¹⁰⁹

The Kruger National Park was not the only area experiencing drought in South Africa at the time. The drought that lasted through the 1960s had a far-reaching impact on the management of water in the country. In 1966, the South Africa government appointed a commission of enquiry into water matters in South Africa under the leadership of Prof

¹⁰⁶ B.H. Walker *et al.*, To cull or not to cull: Lessons from a Southern African drought, *Journal of Applied Ecology*, 24(2), August 1987, p. 385.

¹⁰⁷ B.H. Walker *et al.*, To cull or not to cull: Lessons from a Southern African drought, *Journal of Applied Ecology*, 24(2), August 1987, p. 386.

¹⁰⁸ B.H. Walker *et al.*, To cull or not to cull: Lessons from a Southern African drought, *Journal of Applied Ecology*, 24(2), August 1987, p. 385.

¹⁰⁹ Photograph, VVPA, Sanparks Photographic archive (SPA), Black Heron Weir.

Stephanus Petrus du Toit Viljoen.¹¹⁰ The commission had the task of investigating the availability of water in South Africa as well as the present and future demand for water by all sectors with a view of making recommendations towards the improved management of water in South Africa.¹¹¹ The commission's final report was accepted by parliament in 1970.¹¹² Different sectors made submissions before the commission, including the Kruger National Park. At the same time the commission considered the final report of a commission of enquiry, published in 1967, which investigated the water needs of the Lake St Lucia nature conservation area.¹¹³ Along with the Kruger National Park, Lake St Lucia was considered the most important nature conservation area in South Africa. For its submission to the commission of enquiry into water matters, the Kruger National Park made an attempt to determine its exact water requirements.¹¹⁴ The figures that were submitted included estimates based on the water requirements of fauna and riparian flora in terms of drinking and habitat, as well as for tourists visiting the park.¹¹⁵ The scientific basis for these figures is unclear, other than that they were made by the park engineer.

The following figures were put forward to the commission:

Table 5-1: The total water requirement proposed for the Kruger National Park.¹¹⁶

Minimum water requirements	
Water use for drinking by game	2 million gallons (9 092.18 m ³) a day
Water needed to maintain habitat	26 million gallons (118 198.34 m ³) a day
Water needs of riparian vegetation	26 million gallons (118 198.34 m ³) a day
Water for human needs	1 million gallons (4 546.09 m ³) a day
Total water requirement	55 million gallons (250 034.95 m³) a day

¹¹⁰ NAR, SAB, Decisions of the Executive Council (URU), 5157 [1100], Appointment of the Commission of Enquiry into Water Matters by C.S. Swart, 1966-06-23.

¹¹¹ NAR, SAB, URU, 5157 [1100], Appointment of the Commission of Enquiry into Water Matters by CS Swart, 1966-06-23.

¹¹² RSA, Report of the Commission of Enquiry into Water Matters (Report No. RP 34/1970. Government Printer: Pretoria).

¹¹³ J.P. Kriel. Report of the Commission of Inquiry into the alleged threat to animal and plant life in St Lucia Lake. (Government Printer: Pretoria, 1967).

¹¹⁴ Sanparks, NK/18/1 [K39/1], A.E. Kuschke, 'n Oorsig van bestaande en moontlike addisionele waterbronne in wildsuiping in die Krugerwildtuin, 1969-06-17.

¹¹⁵ Sanparks, NK/18/1 [K39/1], A.E. Kuschke, 'n Oorsig van bestaande en moontlike addisionele waterbronne in wildsuiping in die Krugerwildtuin, 1969-06-17.

¹¹⁶ Sanparks, NK/18/1 [K39/1], A.E. Kuschke, 'n Oorsig van bestaande en moontlike addisionele waterbronne in wildsuiping in die Krugerwildtuin, 1969-06-17.

Based on these figures, as well as the figure of 78 million gallons a day (354 595 m³/day) recommended as the minimum daily water requirement of St Lucia, the commission of enquiry into water matters determined that conservation water requirements made up around 1% of the total water consumption in South Africa.¹¹⁷ In its recommendations the commission noted that

*[i]t would be disastrous both for nature conservation and for our tourist industry if too little water were to be made available for wild life [sic] in the Kruger [National] Park...The Commission recommends that, in the utilisation of our water resources, provision be made for the reasonable needs of nature conservation areas, but that in each case a thorough investigation be undertaken to ensure that waste of water is avoided.*¹¹⁸

This was the first official document in South Africa in which the need to allocate water for the environment was expressed. While aquatic scientists later argued that the figure of 1% of total water consumption as suggested by the commission was far too low, it provided a useful point of departure for further debate and study during the awakening of ecological research in the early 1980s. This was the foundation on which the 1998 reserve legislation was based.¹¹⁹ The outcome of the commission of enquiry into water matters did not immediately improve the Kruger National Park's water situation. In 1972, a further submission was made to the water planning committee of the Eastern Transvaal in an effort to secure water for the Park from its perennial rivers.¹²⁰ This was part of a larger exercise by the water planning committee, which had been appointed by the minister of water affairs to determine the present and future water needs of all water users in the Lowveld river catchments.¹²¹ It was the opinion of park management that the only way to improve the situation was to declare the Sabie, Olifants, Crocodile, Luvuvhu and Letaba rivers as state-controlled areas, and to guarantee minimum flows to the Kruger National

¹¹⁷ RSA, Report of the Commission of Enquiry into Water Matters, p. 63.

¹¹⁸ RSA, Report of the Commission of Enquiry into Water Matters, p. 17.

¹¹⁹ J. King and H. Pienaar (eds.), Sustainable use of South Africa's inland water, p. 59.

¹²⁰ Sanparks, NK/18/1 [K39/A]. A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefte van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

¹²¹ Sanparks, NK/13[14], Brief van Minister van Waterwese aan Sanparke, Waterbeplanningskomitee vir Oos-Transvaal. Inligting oor waterverbruik en verwagte toekomstige waterbehoefte, 1972-11-16.

Park.¹²² In this memorandum park management called for a minimum flow of 1 m³/s from each of the five perennial rivers to sustain water resources in the Kruger National Park.¹²³

In the 1970s the Kruger National Park entered another wet period. The water-for-game programme slowed, but did not stop altogether. The intense drought of the 1980s would bring an evolution in the management of water – not only in the park, but also in South Africa. It would prompt the country's first ecological flow studies and influence the country's eventual decision to include the ecological reserve in the National Water Act.

5.4 Interaction with DWA and the Skukuza workshop (1983-1987)

The first voices against the artificial water-for-game programme were heard in 1981.¹²⁴ In addition to disrupting the natural flow processes of the rivers in which they were constructed, the artificial water points had other unexpected consequences. Arguably the most significant consequence was that the artificial availability of water in previously waterless areas resulted in overgrazing, since artificial water points now greatly decreased the walking distance between water sources, allowing access to grazing that would otherwise only be accessible to stronger animals.¹²⁵ Many of the erstwhile artificial water points had also become inadequate as a result of siltation.¹²⁶ Management's good intentions of establishing artificial water points in areas where rare antelope species browsed did not have the desired effect. Instead of assisting the population growth of rare species of antelope, the establishment of water had the opposite effect – since easy access to water artificially increased the numbers of herding grazers such as zebra and impala, carnivores were more likely to attack lower density, rare antelope species.¹²⁷

¹²² Sanparks, NK/18/1 [K39/A]. A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

¹²³ Sanparks, NK/18/1 [K39/A]. A.E. Kuschke & U. de V. Pienaar, Memorandum oor waterverbruik en toekomstige waterbehoefes van die Krugerwildtuin vir die Waterbeplanningskomitee vir Oos-Transvaal, 1972-12-08.

¹²⁴ See for example, W.P.D. Gertenbach, Artificial water – yes or no?, *Custos*, 10(6), September 1981, pp. 37-38.

¹²⁵ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹²⁶ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹²⁷ I.P.J. Smit, Systems approach towards surface water distribution in Kruger National Park, South Africa, *Pachyderm*, 53(1), January-June 2013, p. 91.

Despite these misgivings, the establishment of dams and boreholes would be continued for at least another decade.

In 1979, the Kruger National Park again entered a drought period, which lasted until around 1987 – this time the most severe in its recorded history.¹²⁸ The natural situation was greatly exacerbated by increased upstream abstraction, most notably for irrigation purposes. By 1982, the Sabie River reached its lowest flow on record (1.51m³/s), resulting in the park having to construct emergency water-supply schemes for its tourist facilities at Sabie, Onder-Sabie and Pretoriuskop.¹²⁹ To improve the situation in the Sabie River Sanparks called on the DWA to help fund the construction of a series of weirs in the river. According to Tol Pienaar, this was the only way in which water could be secured for the park from the river in the long term.¹³⁰ The Kruger National Park's largest dam, namely Piet Grobler Dam, was completed in the Timbavati River, in 1988. The dam had an original capacity of 700 000m³.¹³¹ By the time the park's water policy was reviewed in 1997 the park had 365 boreholes and around 50 earth dams, leaving less than a fifth of the park more than 5km away from a permanent water source.¹³² This caused large-scale starvation and death among mammalian populations during the drought periods of the 1980s. There was a marked depletion in the park's animal numbers.¹³³ In 1982-83 – when the drought reached its peak – an estimated 10 000 impala died from starvation as a result of lack of grazing.¹³⁴

A voice that was becoming progressively stronger in the 1980s was that of the aquatic environment itself. Despite the importance of the perennial rivers to the sustainability of the park the Kruger National Park only started considering the importance of its rivers as aquatic ecosystems (as opposed to mere sources of water for terrestrial systems) of the 1960s. The catalyst for this change in thinking was the first comprehensive fish survey

¹²⁸ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

¹²⁹ Sanparks, NK/28[1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1980/81, p. 19.

¹³⁰ Sanparks, NK/18[1], Parkhoof, Nasionale Krugerwildtuin – Hoofdirekteur van die Nasionale Parkeraad, 1982-08-23.

¹³¹ Anon, New dam named, *Custos*, 17(8), November 1988, p. 14.

¹³² I.P.J Smit, Systems approach towards surface water distribution in Kruger National Park, South Africa, *Pachyderm*, 53(1), January-June 2013, p. 92.

¹³³ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹³⁴ Sanparks, NK/28 [1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1982/83, p. 3.

undertaken in the park, which started in 1957.¹³⁵ This survey underlined the richness of the Lowveld rivers feeding the Kruger National Park in terms of the number of freshwater species present, with many fish species being endemic to the park. In the Sabie River alone, at least 38 species were recorded, more than in any other river in South Africa.¹³⁶ Apart from these early studies into fish species, no other monitoring of the Kruger National Park rivers took place until 1983. In this year, massive fish kills (at least 100 000) were reported in the Olifants River after sediment laden water was released from the Phalaborwa Barrage.¹³⁷ The incident was considered an ecological disaster. Head of the park, Dr Tol Pienaar wrote the following of the incident:

*Die mortaliteit [moet] in baie miljoene gemeet word en verteenwoordig 'n ramp waarvan die rivier nie gou sal herstel nie. Van die groter palings wat dood aangetref is, was volgens lengte 20 jaar en ouer en verskaf 'n aanduiding van die tyd wat dit sal neem om weer die oorspronklike toestand en kwaliteit van die waterlewe te herwin.*¹³⁸

(Translated as: The mortality must be measured in millions and represents a disaster from which the river will not recover quickly. Some of the bigger eels found dead were, according to length, 20 years and older, and provide an indication of how long it will take for the river to reach its original ecological condition).

The fish mortality incident sparked concern over the ecological condition of the other rivers of the Kruger National Park. Sanparks requested the Hydrological Research Institute (HRI) of the DWA to assist the park with a water quality monitoring programme.¹³⁹ Then negotiations with the CSIR's NIWR led to the first comprehensive invertebrate studies undertaken in the rivers of the park. The two-year study, undertaken by the scientists from the CSIR, not only confirmed the pristine nature of rivers such as the Sabie, but also the threats to the Kruger National Park's rivers by upstream developments.¹⁴⁰ In 1985 and 1987, respectively, the park was visited by two more

¹³⁵ S. Joubert, *The Kruger National Park – A history Vol I*, p. 160.

¹³⁶ Sanparks, B/8 [9-1]. U. de V. Pienaar, *Die huidige en toekomstige waterbehoefte van die Krugerwildtuin uit die Sabie- en Krokodilriviersisteme*, s.a., p. 3.

¹³⁷ Sanparks, NK/28 [1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1982/83, p. 41.

¹³⁸ Sanparks, NK/28 [1], Jaarverslag van die Nasionale Krugerwildtuin aan die Nasionale Parkeraad, 1982/83, p. 41.

¹³⁹ VVPA, OA1, C. Bruwer, independent consultant (former head of DWA HRI), 2015-03-20.

¹⁴⁰ Sanparks, B/5 [1], F.M. Chutter & F.C. de Moore, Preliminary report on a survey of the conservation status of the major rivers in the Kruger National Park, 1983.

renowned South African aquatic researchers, Jay O’Keeffe and Bryan Davies. They conducted surveys of the park’s perennial rivers in their personal capacity. Both experts confirmed the earlier findings of the CSIR.¹⁴¹

Sanparks have a long-standing relationship with the DWA on water management issues. During the intense nationwide drought of the 1980s, this interaction became of great importance in relating the urgent need for potential interventions. In 1982, the DWA agreed to assist the park with the construction of several measuring weirs to more accurately measure flow in the park’s perennial rivers. The park was now becoming increasingly dependent on water releases from the Phalaborwa Barrage in the Olifants River and the stabilised flow of the Crocodile River, thanks to the construction of the Kwenia Dam.¹⁴² In the same year Sanparks also successfully negotiated with the Minister of Water Affairs to gain a portion of water from the Tzaneen Dam. In order to achieve this, the park called on Section 9(1) of the Water Act, which regulated riparian water use and allowed for downstream water users to be compensated with water for “domestic use and livestock watering” when dams were built upstream.¹⁴³ Using formulas normally applied to determine irrigation water allocations, it was estimated that the Kruger National Park would be eligible for a share of 14.7 million m³ from the Tzaneen Dam.¹⁴⁴ In 1985, the DWA announced a series of comprehensive catchment studies starting with three of the Lowveld rivers that feed the Kruger National Park, the Sabie, Luvuvhu and Letaba.¹⁴⁵ The studies were part of a first attempt by the department to move away from *ad hoc* water resource development towards a more integrated catchment management approach.¹⁴⁶ A particular concern regarding the rivers of the Eastern Transvaal (of which the Kruger National Park formed a part) was that water demand had already outstripped supply in

¹⁴¹ Sanparks, B/5 [1], J. O’Keeffe, Report to Sanparks on the conservation status of the Sabie and Groot Letaba rivers within the Kruger National Park, pp. 12-13; Sanparks, B/5 [1], B. Davies, Sabbatical research and study leave reports, Kruger National Park, July 11 – September 8, 1987, pp. 4-5.

¹⁴² Sanparks, NK18[1], Parkhoof, Nasionale Krugerwildtuin – Hoofdirekteur van Nasionale Parkeraad, 1982-08-23.

¹⁴³ RSA, Water Act 54 of 1956.

¹⁴⁴ Sanparks, B8/3 [2], Letter from Department of Environmental Affairs to Groot Letaba Main Irrigation Board, ‘Gratis watertoekenning uit die Fanie Botha Dam aan die Nasionale Krugerwildtuin’, 1983-11-14.

¹⁴⁵ Sanparks, B/8 [9-1], Background document for ad hoc study on water requirements for water conservation in the catchments of the Sabie, Letaba, Shingwidzi and Luvuvhu rivers, 1987, p. 1.

¹⁴⁶ F.C. van Zyl, Integrated catchment management: Is it wishful thinking or can it succeed? (in Water Institute of Southern Africa, River basin conference for sustainable development Volume 1, Kruger National Park, 15-17 May, 1995, pp. 1-13.)

many catchments.¹⁴⁷ Consultants were appointed to undertake each of these studies. The task was made particularly difficult by the fact that these rivers crossed various homelands, and were therefore considered transboundary rivers.¹⁴⁸ This meant that negotiations with the homeland governments would have to be undertaken to ensure equal distribution of river resources between South Africa and these areas. Led by DWA engineer, Fred van Zyl, these catchment studies were the most comprehensive investigations of their kind ever undertaken in South Africa up to that time, and included studies on, among others, the general characteristics of the catchment, the current water use and future water requirements of all water users (including the environment), the current state of the natural water resources and potential future water resource development possibilities.¹⁴⁹ In 1995, Van Zyl pointed to the changes these catchments studies brought within the department, saying

*[t]he feeling experienced when one started to understand a system and how it works, was incredible. Everything started to make sense and complex problems became simple and understandable. Getting people together from different cultures, backgrounds and attitudes and transforming them into a joint and positive team was like winning a test match. The whole process was a learning experience of thinking, listening and doing. Suddenly everybody wanted to be part of the team.*¹⁵⁰

While the water laws of the time did not yet reflect it, the department had started acknowledging the environment as a rightful water user, albeit in competition with other water users, such as irrigation and domestic and industrial water supply.¹⁵¹ The Kruger National Park was requested to provide information on the minimum water needs of its ecosystems so that it could be provided a share of the Lowveld's water resources. South

¹⁴⁷ Sanparks, B/8 [8-1], Motivation for a cooperative multidisciplinary research programme on the Kruger National Park river systems, document drawn up by the Working Group on behalf of the National Parks Board, 19 July 1988.

¹⁴⁸ Sanparks, B/8 [9-1], Background document for ad hoc study on water requirements for water conservation in the catchments of the Sabie, Letaba, Shingwidzi and Luvuvhu rivers, 1987, p. 1.

¹⁴⁹ Sanparks, B/8 [9-1], Background document for ad hoc study on water requirements for water conservation in the catchments of the Sabie, Letaba, Shingwidzi and Luvuvhu rivers, 1987, p. 1.

¹⁵⁰ F.C. van Zyl, Integrated catchment management: Is it wishful thinking or can it succeed? (in Water Institute of Southern Africa, River basin conference for sustainable development Volume 1, Kruger National Park, 15-17 May, 1995, pp. 1-13.)

¹⁵¹ Anon, Wildtuin se riviere 'n bedreigde spesie, *SA Waterbulletin*, 13(3), June 1987, p. 18; J.H. O'Keeffe & B.R. Davies, Conservation and management of the rivers of the Kruger National Park: Suggested methods for calculating instream flow needs, *Aquatic conservation: Marine and freshwater ecosystems*, 1(1), September 1991, p. 57.

Africa also has an obligation to provide water to downstream Mozambique, especially from the Crocodile River, which meant that enough water had to be allocated to the park's rivers to allow water to pass through the nature reserve and cross the South African border.¹⁵² Apart from simple calculations – mainly based on engineering formulae – the Kruger National Park had not begun to determine the ecological flow requirements of its rivers. Two symposia were held by Sanparks in 1985 and 1986 to consult with stakeholders and to share the complexity of challenges faced by the Kruger National Park in managing its rivers.¹⁵³ This was followed by an invitation by DWA and Sanparks to a number of aquatic scientists, known to be experts in their individual fields, to a special workshop held at Skukuza, on 14-19 March 1987, to provide a first estimate of the water needs of the park's aquatic ecosystems.¹⁵⁴ More than 60 individuals from various disciplines were divided into teams tasked to determine the minimum water requirements for each of the Kruger National Park's perennial rivers. Ecological flows were still part of a new science discipline at the time, and no South African methods existed to determine the quantitative and qualitative water needs of local rivers.¹⁵⁵ The principles applied at the workshop were those developed for the Pongolo River where environmental committees, representing 13 organisations and the 7000 people who depended on the floodplain system had met regularly since 1976 to negotiate releases from the Pongolapoort Dam.¹⁵⁶

The scientists at the Skukuza Workshop came up with what became known as the “Skukuza method” to determine a first estimate of the minimum flow requirements for the Kruger National Park rivers. Described as a “consumptive/non-consumptive approach”, the Skukuza method calculated environmental water needs of a river by adding up all estimated consumptive (such as animal and human water consumption) and non-consumptive (such as maintenance of natural biotic diversity and in-stream and riparian habitat) water requirements.¹⁵⁷ There was a realisation at the Skukuza workshop that this

¹⁵² Sanparks, B/8 [9-1], F. van Zyl, Oorsig van die riviere wat streke F en G van die streeksontwikkelingsadvieskomitee dreineer, 1988-07-13, p. 10.

¹⁵³ S. Joubert, Waarborge vir standhoudende riviere in die Kruger Wildtion, *Custos*, 16(1), April 1987, p. 41.

¹⁵⁴ VVPA, OA1, C. Bruwer, independent consultant (former head of DWA HRI), 2015-03-20.

¹⁵⁵ VVPA, OA1, C. Bruwer, independent consultant (former head of DWA HRI), 2015-03-20.

¹⁵⁶ VVPA, OA1, C. Bruwer, independent consultant (former head of DWA HRI), 2015-03-20.

¹⁵⁷ J.H. O' Keeffe & B.R. Davies, Conservation and management of the rivers of the Kruger National Park: suggested methods for calculating instream flow needs, *Aquatic Conservation: Marine and Freshwater Ecosystems*, 1(1), September 1991, p. 59.

crude calculation could not be accepted as the final answer to the question: How much water do the Kruger National Park rivers need? In 1988, following a meeting between DWA, Sanparks, the WRC and the NRF, it was decided to launch a collaborative programme, the Kruger National Park (KNP) rivers research programme, to fund the necessary research in order to determine the ecological flow requirements of the Lowveld rivers serving the Kruger National Park.¹⁵⁸ Initially envisaged to run over only one or two years, the KNP rivers research programme would end up running over more than a decade, and was the most comprehensive aquatic research programme ever undertaken in South Africa.

5.5 Conclusion

As South Africa's largest national park, the Kruger National Park is a prime example of national conservation efforts in South Africa. In addition to providing an important conservation function, the park also generates important income from national and international tourists. The availability (or not) of water resources has been a prime consideration for the management of the Kruger National Park since its establishment in 1926 – more than 90 years ago. While the park is fed by five perennial systems, its location at the downstream end of the river catchments, in addition to its semi-arid rainfall and non-perennial, localised water resources, has left the park vulnerable to upstream anthropogenic impacts, and has led much of its management actions. These vulnerabilities become abundantly clear during the drought cycles which the park experience every ten years or so. Prior to the passing of the NWA in 1998, there was no provision made for environmental flows in South Africa's water legislation. This left the Kruger National Park with little legal right to the water in the river systems it depends upon. As a result, all water management efforts were inwardly focused on enhancing available water supplied within the perimeters of the park's boundary fence. Shortly after the park's establishment management started a campaign to augment existing water supplies through artificial means by way of dams and boreholes. With each concomitant drought period, and with increased upstream economic development, this water-for-game programme was intensified leading to an advanced network of water points throughout the park. Many components of this infrastructure has proved unsuccessful in the long run.

¹⁵⁸ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

The park has remained dependent on the exogenous water supply flowing from perennial rivers. It has also led to other ecological disturbances in the park, including the decline of rare ungulate species.

Starting with fish surveys in the 1950s, park management became increasingly aware of the value of the Lowveld rivers transecting its boundaries – not only from the point of view of providing drinking water for terrestrial fauna, but also in terms of the rich aquatic biodiversity contained in these rivers. This prompted Sanparks to increase negotiations with DWA as the national custodian of water resources in the 1980s to come up with a solution to the Kruger National Park's water challenges. When the department's Transvaal section announced its intention to undertake catchment studies of the Lowveld river systems, it was an opportunity for the Kruger National Park to push its environmental agenda. With DWA now recognising the environment as a legitimate water user plans were put in place to determine the ecological flow requirements of the perennial rivers serving the park. A multi-stakeholder programme, the KNP rivers research programme was launched to fund the scientific enquiry needed to determine the ecological flow requirements of the rivers. This programme would springboard the South African aquatic science community into action to develop local ecological methods that would eventually influence the inclusion of the environmental reserve in the NWA. The next chapter places the Skukuza workshop in the context of the history of the development of ecological flow sciences in South Africa. It provides a short historiographical overview of ecological flow sciences in South Africa, and the role this branch of aquatic science played in writing the environmental reserve into law.

Chapter 6 Ecological flow science – South African aquatic scientists and the environmental reserve (1987-1998)

6.1 Introduction

The methods and tools to determine and monitor ecological flows did not originate in South Africa, but rather developed in the northern hemisphere as a reaction to the anthropogenic impacts of water resource development. This chapter is focused on how South Africa adapted and further developed these international ecological flow methodologies as a response to decision-makers' needs for answers around the water needs of the environment. The study then moves to the role the rivers of the Kruger National Park played in the evolution of ecological science as a discipline in South Africa, which resulted in the environmental reserve being written into law.

6.2 Global origins of ecological flow methodologies

As water resource development started to increase exponentially in the 19th century as a result of the industrial revolution gaining momentum, there was a need for scientists globally to start taking cognisance of the impact of these engineering works on the surrounding aquatic environment.¹ Knowledge of the aquatic environment grew along with the number of flow modifying infrastructure in rivers, and scientific endeavours increasingly began to link the health and abundance of aquatic species – particularly fish – with the condition of their surrounding environment.² The acceleration of dam construction after 1945 coincided with a decline in freshwater species. In North America alone, 40 taxa of fish became extinct because of anthropogenic impacts by 1989 – half of these after 1964.³ The trend of rapid decline in freshwater health drove environmental agencies and activists to push for the protection of remaining freshwater species. In 1968 the United States government passed the Wild and Scenic Rivers Act, aimed at protecting

¹ V.E. Shelford, Ways and means of measuring the dangers of pollution to fisheries, *Bulletin of the State of Illinois Department of Registration and Education*, 13(2), September 1918, p. 26.

² V.E. Shelford, Ways and means of measuring the dangers of pollution to fisheries, *Bulletin of the State of Illinois Department of Registration and Education*, 13(2), September 1918, p. 26.

³ R.R. Miller *et al.*, Extinctions of North American fishes during the past century, *Fisheries*, 14(6), November-December 1989, p. 34.

the country's remaining undammed rivers from development.⁴ The legislation prohibited dam construction in any river – or section of a river – that became protected under the Act, and opened the door to greater environmental protection of river systems.⁵ The Wild and Scenic Rivers Act was followed in 1969 by the passing of the federal National Environmental Policy Act (which wrote environmental impact assessment studies into American law) as well as the Endangered Species Act in 1973. Six years later 33% of American states had built in the need for instream flows into their respective states' legislation.⁶ Other countries, such as Australia, Canada, and New Zealand followed suit and passed their own environmental impact assessment legislation.⁷ These legislative advances increasingly called on aquatic scientists to "prove" the quantitative and qualitative requirements of river habitats and selected species, allowing for the development of the first ecological flow methods.

Initially, scientists focused on establishing minimum flow requirements – i.e. determining the smallest volume of water by which aquatic life could survive in a river, rather than by looking to mimic, as close as possible, the natural flow regime, which is the main objective of ecological flow methods developed in subsequent decades.⁸ In 1976, one of the first conferences to discuss methods of assessing ecological flows was convened by the American Fisheries Society. In the same year, the Montana method (also known as Tennant method) was published.⁹ It was arguably the first ecological flow method to be widely applied.¹⁰ Developed by biologists at United States Fisheries and Wildlife, the method used historical flow records to determine the minimum flows that should be allowed to remain in a river to sustain biological life. While the method was applied in several countries, it was rather rudimentary as it took a blanket approach to ecological

⁴ A.C. Benke, A perspective on America's vanishing streams, *Journal of the North American Benthological Society*, 9(1), March 1990, p. 82.

⁵ A.C. Benke, A perspective on America's vanishing streams, *Journal of the North American Benthological Society*, 9(1), March 1990, p. 85.

⁶ A.C. Benke, A perspective on America's vanishing streams, *Journal of the North American Benthological Society*, 9(1), March 1990, p. 85.

⁷ N.A. Robinson, International trends in environmental impact assessment, *Boston Environmental Law Review*, 19(3), (no month) 1992, p. 597.

⁸ S. Postel & B Richter, *Rivers for life. Managing water for people and nature*, p. 3.

⁹ D.L. Tennant, Instream flow regimes for fish, wildlife, recreation and related environmental resources, *Fisheries*, 1(4), (no month) 1976, pp. 6-10.

¹⁰ D.L. Tennant, Instream flow regimes for fish, wildlife, recreation and related environmental resources, *Fisheries*, 1(4), (no month) 1976, pp. 6-10.

flows, and did not take individual rivers' needs or the need for seasonal variations in river systems into account.¹¹ Rather, the Montana method calculated absolute minimum flows as a general 10% of the mean flow of the river, with 30% of the average flow considered satisfactory, and ideal flows as varying between 60% and 100% of average flows.¹² Since the method was based on historical flows, it was largely a desktop study without any field calculations.¹³

A range of ecological flow methodologies followed the publication of the Montana method. These methods are grouped into four types: hydrological methods; hydraulic rating methods; habitat simulating methods; and holistic methods.¹⁴ As ecological flow science matured each method grew more intricate and multi-disciplinary. The methods were also boosted by advances in technology. The advent of the personal computer, for example, allowed for faster, more complex calculations. Hydrological methods were those – like the Montana method – that made strict use of historic hydrological data. These methods were succeeded by hydraulic rating methods, which added field data to better define the link between flow quantities and the hydraulic movement of water in a river in a quantifiable way. While the addition was a slight improvement over the first ecological flow methods, the link between reduced flows because of human impact and the effect this had on aquatic life, remained vague.¹⁵ To better understand the link between reduced flow, habitat alteration and the impact on aquatic species, so-called habitat simulation or habitat modelling methods were developed. The most popular of these ecological flow tools was the Instream Flow Incremental Methodology (IFIM).¹⁶ IFIM selected a target species (in the USA where the methodology originated this was usually game fish, such as trout and salmon) and then sought to determine how flow impacted the species' habitat

¹¹ J. King *et al.*, A scenario-based holistic approach to environmental flow assessments for rivers, *River Research and Applications*, 19 (5-6), December 2003, p. 619.

¹² D.L. Tennant, Instream flow regimes for fish, wildlife, recreation and related environmental resources, *Fisheries*, 1(4), (no month) 1976, pp. 6-10.

¹³ J. King *et al.*, A scenario-based holistic approach to environmental flow assessments for rivers, *River Research and Applications*, 19 (5-6), December 2003, p. 619.

¹⁴ J. King *et al.*, A scenario-based holistic approach to environmental flow assessments for rivers, *River Research and Applications*, 19 (5-6), December 2003, p. 619; R.E. Tharme, A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers, *River research and applications*, 19 (5-6), September 2003, p. 401.

¹⁵ J. King *et al.*, A scenario-based holistic approach to environmental flow assessments for rivers, *River Research and Applications*, 19 (5-6), December 2003, p. 620.

¹⁶ S. Postel and B Richter, *Rivers for life. Managing water for people and nature*, p. 48.

and thus its ability to survive. A minimum flow, in which the habitat of that particular species could persist, could then be calculated using advanced computer models. The computer model, Physical Habitat Simulation Model (PHABSIM), which was developed as part of the IFIM suite, proved especially popular, and was used by ecological flow scientists worldwide to calculate the expected effect of different ecological flows on the habitat of target species.¹⁷

With the assistance of North American ecological scientists IFIM was tested on the Sabie River in the Kruger National Park in 1987.¹⁸ As far as could be established this was the first application of the method on a southern African river. It was a test case in which scientists attempted to use the methodology to determine the ideal ecological flow for more than one target species, i.e. various species of fish as well as water-dwelling mammals (in this case hippopotami). The three target fish types collected were the bow-stripe barb (*Barbus viviparous*), the Lowveld large-mouth (*Serranochormis meridianus*) and the Lowveld catlet (*Chiloglanis swierstrai*). Interestingly, the river's one game fish – the tiger fish (*Hydrocynus vittatus*) was not selected for the study. The results of the IFIM test case on the Sabie River were criticised by South African aquatic scientists as it provided conflicting data for the different target species. For example, study results suggested that a minimum ecological flow of 3.5m³/s would be enough to maintain hippopotami habitat, but not enough to maintain the habitat of the large-mouth.¹⁹ Other data were also conflicting about what was known about the river. While a 6m³/s minimum ecological flow was recommended for the catlet, flow in the river naturally fell below that volume for months during the dry season, yet thriving communities of the fish were still found.²⁰ The IFIM method was also tested on the Olifants River, in the Western Cape, which yielded similar results.²¹

¹⁷ S. Postel and B Richter, *Rivers for life. Managing water for people and nature*, p. 48.

¹⁸ Sanparks, B/8 [9-3], J.A. Gore *et al*, Technology transfer/workshop: Instream flow incremental methodology, Kruger National Park, s.a.

¹⁹ J.H. O'Keeffe & B.R. Davies, Conservation and management of the rivers of the Kruger National Park: suggested methods for calculating instream flow needs, *Aquatic Conservation: Marine and Freshwater Ecosystems*, 1(1), September 1991, p. 57.

²⁰ J.H. O'Keeffe & B.R. Davies, Conservation and management of the rivers of the Kruger National Park: suggested methods for calculating instream flow needs, *Aquatic Conservation: Marine and Freshwater Ecosystems*, 1(1), September 1991, p. 57.

²¹ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 49.

The Sabie and Olifants river studies underlined the importance of having an ecological flow methodology that could consider the need for variable flows and how this impacted aquatic ecosystems, rather than just looking at minimum flow. The failure of IFIM's application in South Africa also highlighted the importance of considering overall river health rather than just the well-being of a single target species in the South African context. Above all, for South African aquatic scientists it was crucial that any ecological flow methodology applied dealt not just with maintaining "some flow" in the river system for selected biota, but truly

*(m)anage(d) the magnitude, frequency, duration, timing and rate of change of flow events so that the mosaic of hydraulic habitat conditions is maintained through space and time.*²²

It was not only the approach to conservation that hindered the application of ecological flow methodologies such as IFIM in South Africa. In addition to being expensive, these early methodologies required huge reams of historic data of river behaviour and a high level of scientific expertise to undertake extensive flow modelling – two aspects that were not present in South Africa at the time.²³ A final blow to the use of the method in South Africa was the fact that it did not consider traditional human dependence of natural river systems, an element that was an important consideration for a developing country such as South Africa.²⁴ When it became clear that North American methodologies would not be applicable to South African circumstances, aquatic scientists abandoned the methods in exchange for a home-grown alternative.²⁵ Another country that struggled to adapt existing ecological methodologies to its own context was Australia. Considered the world's "driest inhabited continent" the climate of Australia is not unlike that of South Africa.²⁶ The country has a low average annual rainfall (455mm/year) equal to that of its African equivalent, and shares similarly high evapotranspiration rates.²⁷ While there is a considerable difference in aquatic species the two countries have equally variable climatic

²² J. O'Keeffe, Sustaining river ecosystems: balancing use and protection, *Progress in Physical Geography*, 33(3), June 2009, p. 342.

²³ VVPA, OA1, A. Arthington, ecological flow scientist, 2016-08-11.

²⁴ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

²⁵ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

²⁶ A.H. Arthington & B.J. Pusey, Flow restoration and protection in Australia rivers, *River Research and Applications*, 19(5-6), September-October 2003, p. 379.

²⁷ A.H. Arthington & B.J. Pusey, Flow restoration and protection in Australia rivers, *River Research and Applications*, 19(5-6), September-October 2003, p. 379.

features, resulting in river systems with highly variable flow regimes.²⁸ When Australian scientists starting exploring ecological flows in the 1980s they encountered similar difficulties with applying North American methods as the South African scientists. Once it seemed obvious that northern hemisphere ecological flow techniques would not be applicable in southern, semi-arid river systems, aquatic scientists in Australia and South Africa became the first to explore wider or more holistic ecological flow studies that did not target the protection of habitats for specific species, but rather sought to protect the entire aquatic ecosystems. This meant determining not just the minimum flow that a river needed, but rather seeking to roughly mimic the different kinds of flows, of different magnitudes and frequencies, flowing at different times of the year. The objective was to determine what was required to ensure a healthy ecosystem.²⁹ A significant underlying factor driving these holistic methodologies, is the philosophy that the environment should not be just another water user competing with other users, but rather be accommodated, first and foremost when water is allocated.³⁰ Thus, the application of these methodologies would mean a major shift in environmental thinking. The two southern hemisphere countries (South Africa and Australia) went on to dominate the ecological flow science scene during the 1990s, with each country developing its own holistic ecological flow methodology (namely the Building Block Methodology in South Africa and the Holistic Approach and Expert Panel Assessment Method in Australia).³¹ The advancement of ecological flow research – and the changed thinking about the importance of the aquatic environment and its flow needs – culminated in the passing of the National Water Act in South Africa in 1998, with the inclusion of the environmental reserve. It is recognised that the window of opportunity created by the post-1994 government's drive for legislation that restored human rights to the entire population, undoubtedly played a role in the legislation's environmental component.³² Australia, in comparison, did not have the same appetite for change, however, in 1994, the Council of Australian Governments (an

²⁸ VVPA, OA1, A. Arthington, ecological flow scientist, 2016-08-11.

²⁹ R.E. Tharme, A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers, *River research and applications*, 19 (5-6), September 2003, p. 398.

³⁰ A.H. Arthington, Comparative evaluation of environmental flow assessment techniques: Review of Holistic methodologies, p. 4.

³¹ R.E. Tharme & J.A. King, Development of the Building Block Methodology for instream flow assessments and supporting research on the effects of different magnitude flows on riverine ecosystems, p. 4.

³² S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 87.

intergovernmental forum comprising the prime minister, state ministers and territory chief ministers) signed into being a new water reform framework, which recognised the need to move towards sustainable use of water and greater protection of freshwater ecosystems, including the allocation of ecological flows.³³ It was now up to the individual Australian states to pass legislation to protect water resources in their individual territories. By 2003, eight Australian states had recognised the need for ecological water flows in their rivers.³⁴ Methodologies kept being improved upon – by 2003 there were an estimated 100 ecological flow methodologies being applied in about 30 countries.³⁵ However, few of these countries followed South Africa's lead to write the water needs of the environment into law. Two countries that did follow suit were Tanzania and Costa Rica.³⁶ In 2000, the European Union established a new framework for water policy that that included river flows. According to this framework, member states are required to pursue the protection of rivers in a good ecological state.³⁷

6.3 Origins of ecological flow science in South Africa

If one must pinpoint a “ground zero” for the materialisation of ecological flow science in South Africa that year would most likely be 1970. It is generally accepted that the declaration of 1970 as a National Water Year did much to advance aquatic science and conservation of aquatic systems in South Africa.³⁸ It is interesting to note that the year corresponded with Europe's Conservation Year, which had as its main objective the promotion of environment-related policies and actions among European states.³⁹ Various discussions, activities and conferences, much of it coordinated by the DWA, were held throughout 1970 in South Africa with water, and more specifically, South Africa's inherent

³³ A. Arthington, Wounded rivers, thirty land: getting water management right, p. 15; L. Godden, Water law reform in Australia and South Africa: Sustainability, efficiency and social justice, *Journal of Environmental Law*, 17(2), (no month) 2005, p. 189.

³⁴ S. Postel & B. Richter, *Rivers for life. Managing water for people and nature*, p. 88.

³⁵ J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 7.

³⁶ M.C. Acreman & A.J.D. Ferguson, Environmental flows and the European Water Framework, *Freshwater Biology*, 55(1), January 2010, p. 33.

³⁷ M.C. Acreman & A.J.D. Ferguson, Environmental flows and the European Water Framework, *Freshwater Biology*, 55(1), January 2010, p. 32.

³⁸ P.E. Odendaal, Water research in South Africa [in National Institute for Water Research *et al.*, Symposium on water for the future, CSIR, Pretoria, 1 October 1986, pp. 1-21.]

³⁹ D.C. Midgley, The impact of the water '70 campaign, *South African Journal of Science*, 67(4), April 1971, p. 269.

water scarcity, as a central theme. Midgley points to the importance of the Water Year in building a national awareness of the various role-players in managing South Africa's water resources sustainably, explaining how

[d]edication ceremonies highlighted the vital roles of scientist and engineer in providing essential water supplies while creating the attractive aquatic environments necessary for recreation and wildlife sanctuary, always with due regard to conservation and pollution control.⁴⁰

The year culminated with the approval by parliament of the findings of the commission of enquiry into water matters, which had been appointed in 1966 to undertake an in-depth investigation into the South African water sector.⁴¹ For the country to continue growing economically despite its inherent lack of water resources, the commission recommended that water resource development be optimised and planned more carefully; that water use efficiency be increased and water losses reduced among all sectors (particularly irrigated agriculture); and that alternative sources of water be actively pursued (including desalination and water reclamation).⁴² The commission's final report also included the recommendation that 1% of total water consumption be reserved for these conservation areas. This was the first time that the South African government publicly acknowledged the water needs of the environment. In addition to the general water use inefficiencies identified by the commission of enquiry the members also criticised the DWA for its general lack of planning when considering water resource developments. Up to this time, departmental infrastructure projects were mostly planned without any consideration of the water requirements of water users in the rest of the catchment.⁴³

Despite South Africa's political isolation, local water authorities were not oblivious to global developments with regard to environmental awareness, and paid close attention to international developments.⁴⁴ Environmental protection took on a global character with organisations such as the Organisation for Economic Cooperation and Development (OECD) establishing environmental committees from 1970. As members of ICOLD, DWA

⁴⁰ D.C. Midgley, The impact of the water '70 campaign, *South African Journal of Science*, 67(4), April 1971, p. 270.

⁴¹ RSA, Report of the Commission of Enquiry into Water Matters (Report No. RP 34/1970. Government Printer: Pretoria).

⁴² RSA, Report of the Commission of Enquiry into Water Matters, p. 1.

⁴³ RSA, Report of the Commission of Enquiry into Water Matters, p. 9.

⁴⁴ J.P. Kriel, Quo vadis waterboukund?, pp. 16-17.

engineers participated in the committee's conferences in 1973 and 1976 where the environmental impact of large dams was discussed at this forum for the first time.⁴⁵ In South Africa, public pressure over the environmental impact of human development led to the formation of the Environmental Planning Professions Interdisciplinary Committee (EPPIC) in 1974.⁴⁶ This was a joint initiative of several professional bodies, including the South African Institution of Civil Engineering (SAICE), Institute of South African Architects, Institute of South African Landscape Architects and South African Institute of Town and Regional Planners.⁴⁷ EPPIC's main objective was finding improved ways to, amid lack of government regulation, roll out required infrastructure without causing degradation of the surrounding landscape. Among others, the organisation advocated for the voluntary undertaking of environmental impact assessments prior to construction projects and called for increased public participation in decision-making.⁴⁸ Many of DWA's engineers were members of SAICE, and thus aware of EPPIC, and by their own admission the committee did much to raise the realisation of the importance of environmental conservation among the engineering fraternity.⁴⁹ The committee disbanded in 2000 after new laws were passed, such as the National Environmental Management Act [Act no. 197 of 1998].⁵⁰

DWA included environmental aspects in the planning and execution of its water engineering schemes for the first time in 1974, during the construction of the Drakensberg pumped storage scheme. Located in the foothills of the Drakensberg complex, the Drakensberg pumped storage scheme formed part of the second phase of the Thukela-Vaal Transfer Scheme – the first phase of which had been approved in 1970 to augment water supply to what is now Gauteng.⁵¹ The second phase involved constructing the

⁴⁵ C.P.R. Roberts & J.J. Erasmus, Environmental considerations of the Drakensberg pumped storage scheme, *The Civil Engineer in South Africa*, 24(8), August 1982, p. 361.

⁴⁶ Anon, EPPIC reports considerable progress in three years, *The Civil Engineer in South Africa*, 14(1), January 1978, p. 14.

⁴⁷ Anon, EPPIC reports considerable progress in three years, *The Civil Engineer in South Africa*, 14(1), January 1978, p. 14.

⁴⁸ Anon, EPPIC reports considerable progress in three years, *The Civil Engineer in South Africa*, 14(1), January 1978, p. 14.

⁴⁹ C.P.R. Roberts, Environmental implications of the proposed Palmiet River water and power development projects, *Veld & Flora*, 68(1), March 1982, p. 5.

⁵⁰ J. Freer, The demise of EPPIC, *Journal of the South African Institute of Mining and Metallurgy*, 100(3), May/June 2000, p. 204.

⁵¹ L. van Vuuren, Thukela-Vaal Transfer Scheme – Feeding the hungry heartland, *The Water Wheel*, 7(6), November-December 2008, p.18.

necessary dams, weirs and other infrastructure to pump water from the Tukhela River system into the Sterkfontein Dam. When water is required it is released from Sterkfontein Dam into the Wilge River system, a tributary of the Vaal River. From the Vaal River, the water flows into the Vaal Dam.⁵² Following negotiations between the DWA and Eskom, a pumped storage element was added to the scheme, which included the construction of the Kilburn and Woodhead dams, as well as a hydro-electrical power station.⁵³ While the DWA constructed the dams and related infrastructure, Eskom constructed the power station. Concern by surrounding landowners over the impact of the Drakensberg pumped storage scheme on the landscape prompted the department to establish an environmental committee as part of the project.⁵⁴ The role of the committee, comprising representatives from national and provincial government departments as well as an environmental non-governmental organisation, was to “investigate the environmental implication of the project and to make recommendations to minimise adverse effects”.⁵⁵

The presence of the committee lead to some changes on the project, for example, grassing of the downstream slope of the Kilburn Dam (as opposed to conventional stone pitching), rehabilitation of borrow areas and general landscape restoration.⁵⁶ While most of these efforts were orientated towards mitigating the environmental impact of the engineering infrastructure on the terrestrial landscape rather than on the receiving aquatic ecosystem, the project did have a significant impact on the way the DWA approached water resource development projects going forward. According to former DWA Deputy Director-General: Water resources, Paul Roberts, the project was directly responsible for the “environmental awakening” within the department.⁵⁷ Due to the positive experience of the Drakensberg pumped storage scheme, the DWA started including environmental considerations in all its subsequent projects, and in 1980 environmental impact

⁵² L. van Vuuren, Thukela-Vaal Transfer Scheme – Feeding the hungry heartland, *The Water Wheel*, 7(6), November-December 2008, pp.18-19.

⁵³ L. van Vuuren, Thukela-Vaal Transfer Scheme – Feeding the hungry heartland, *The Water Wheel*, 7(6), November-December 2008, p.19.

⁵⁴ C.P.R. Roberts & J.J. Erasmus, Environmental considerations of the Drakensberg pumped storage scheme, *The Civil Engineer in South Africa*, 24(8), August 1982, p. 362.

⁵⁵ C.P.R. Roberts & J.J. Erasmus, Environmental considerations of the Drakensberg pumped storage scheme, *The Civil Engineer in South Africa*, 24(8), August 1982, p. 362.

⁵⁶ C.P.R. Roberts & J.J. Erasmus, Environmental considerations of the Drakensberg pumped storage scheme, *The Civil Engineer in South Africa*, 24(8), August 1982, pp. 365-373.

⁵⁷ C.P.R. Roberts, Development and conservation go hand in hand at Water Affairs, *The Civil Engineer in South Africa*, 26(9), September 1984, p. 419.

assessments became departmental policy.⁵⁸ Environmental impact assessments were undertaken prior to every water resource development project – either by the DWA itself or by an appointed committee of various stakeholders. Projected environmental impacts were then considered and mitigation measures put in place against possible impacts.⁵⁹

The Palmiet pumped storage scheme is highlighted as another landmark project in the DWA's journey towards increased environmental consciousness. This was the first project in which environmental considerations influenced the design of a water resource development project and the siting of a dam in South Africa.⁶⁰ The first studies to construct a hydropower scheme in the Palmiet River in the Western Cape were undertaken by Eskom in 1979.⁶¹ During the same period, the DWA was investigating additional schemes to augment Cape Town's water-supply system to meet increasing demand. Various options were considered, including construction of the so-called Hangklip Dam, about 2km above the Palmiet estuary.⁶² The estuary, located next to the town of Kleinmond, is not only considered important from a tourist point of view, but also in terms of its function as a fish nursery area.⁶³ Public opposition to the construction of Hangklip Dam resulted in the appointment by the Minister of Environment Affairs of an environmental committee in 1981 to investigate various options and select a configuration that would have the least impact on the environment.⁶⁴ An ecological impact study on the Palmiet estuary highlighted just what a significant impact a dam so close to the estuary would have on environmental processes within the estuarine system.⁶⁵ In addition to the estuary, the committee also had to consider the possible inundation of valuable agricultural land as well as the proximity of the project to the Kogelberg state forest – an important protected

⁵⁸ C.P.R. Roberts & J.J. Erasmus, Environmental considerations of the Drakensberg pumped storage scheme, *The Civil Engineer in South Africa*, 24(8), August 1982, p. 362.

⁵⁹ DWA, *Management of the water resources of the Republic of South Africa*, p. 6.43.

⁶⁰ VVPA, OA1, N. van Wyk, DWA: Chief Engineer, 2012-06-16.

⁶¹ L. van Vuuren, Palmiet – An environmentally sound example, *The Water Wheel*, 12(1), January-February 2012, p. 23.

⁶² C.P.R. Roberts, Environmental implications of the proposed Palmiet River water and power development projects, *Veld & Flora*, 68(1), March 1982, p. 5

⁶³ G.M. Branch & J.A. Day, Ecology of Southern African estuaries: Part XIII. The Palmiet river estuary in the south-western Cape, *South African Journal of Zoology*, 19(2), April 1984, p. 63.

⁶⁴ C.P.R. Roberts, Environmental implications of the proposed Palmiet River water and power development projects, *Veld & Flora*, 68(1), March 1982, p. 4.

⁶⁵ G.M. Branch & J.A. Day, Ecology of Southern African estuaries: Part XIII. The Palmiet river estuary in the south-western Cape, *South African Journal of Zoology*, 19(2), April 1984, pp. 63-77.

area for Cape fynbos.⁶⁶ The latter is particularly important from a conservation point of view, as many as 1600 floral species can be found in the state forest – 150 of which are considered endemic.⁶⁷ Hangklip Dam was eventually discarded due to the impact it would have on the Palmiet estuary. Instead the DWA and Eskom selected a configuration that included the Kogelberg and Rockview dams located higher up in the catchment.⁶⁸ The project itself included a detailed environmental management plan in what became known as the “Blue Book”.⁶⁹ Under the environmental management plan measures were put in place to, among others, reduce to a minimum the areas cleared for construction, avoid outcrops of sensitive plants, create demarcated refuse areas, inspect construction material to prevent the introduction of invasive alien plants, designate eating areas to prevent the spread of exotic Argentinean ants, rehabilitate borrow pits and provide toilet facilities for construction staff – the latter being unusual for the time.⁷⁰ In addition, contrary to normal practice staff housing was not provided on site, but rather located at the nearby urban conurbations of Grabouw and the Strand.⁷¹ Following the Palmiet project, these approaches became standard on DWA construction sites.⁷² While none of these projects influenced the manner in which bulk water infrastructure impacted on ecological flows, it did serve the purpose of creating a general awareness of the environment among government departments such as DWA that would eventually translate in the need to reserve the right of water for the environment in state legislation. Completed in 1989 the Wolwedans Dam, outside Mossel Bay, was one of the first dams in South Africa where the design was influenced by environmental considerations. During the planning stages of the dam in the mid-1980s DWA called on the CSIR to lead an environment committee in determining the potential impacts of the dam on the Great Brak estuary on the south coast and to work out an environmental management plan and monitoring programme to

⁶⁶ C.P.R. Roberts, Environmental implications of the proposed Palmiet River water and power development projects, *Veld & Flora*, 68(1), March 1982, p. 4.

⁶⁷ B.R. Davies *et al.*, A synthesis of the ecological functioning, conservation and management of South African river ecosystems, p. 184.

⁶⁸ L. van Vuuren, Palmiet – An environmentally sound example, *The Water Wheel*, 12(1), January-February 2012, p. 24.

⁶⁹ VVPA, OA1, N. van Wyk, DWA: Chief Engineer, 2012-06-16.

⁷⁰ L. van Vuuren, Palmiet – An environmentally sound example, *The Water Wheel*, 12(1), January-February 2012, p. 24.

⁷¹ VVPA, OA1, N. van Wyk, DWA: Chief Engineer, 2012-06-16.

⁷² VVPA, OA1, N. van Wyk, DWA: Chief Engineer, 2012-06-16.

mitigate some of these impacts.⁷³ Based on the determined minimum flow, it was agreed that 1 million m³ of the dam's capacity be reserved for the estuary, and that the estuary would be entitled to any flood overspill from the dam.⁷⁴ The capacity of the sluice gates of the Wolwedans Dam were specially adapted to release the water entitlement of the estuary from the storage dam.⁷⁵ South African authorities were now not only realising the importance of the environment, but also the role of flow in sustaining environmental processes.

The 1980s drought, along with collaborative research programme such as the Pongolo floodplain research programme (described in Chapter 4), propelled ecological science forward in South Africa.⁷⁶ By this time South African authorities were well aware of the impact of water resource developments both on the quantity and quality of water in river systems, specifically as they started to struggle with water quality impacts, such as eutrophication and the invasion of water weeds on local dam waters.⁷⁷ Interestingly, the first South African to address the question of how much water should be made available in South Africa rivers for the environment was not a scientist but an engineer. At the 1983 convention of SAICE former DWA Deputy Director-General, Paul Roberts, presented a paper on the water needs of estuaries.⁷⁸ In his paper he proposed that 11% of total exploitable water resources be set aside for environmental requirements.⁷⁹ Roberts admitted that this was a simplistic calculation and challenged the aquatic science community to provide a more accurate picture of ecological flow needs in South Africa. The figure of 11% provided an important baseline for aquatic scientists to work from. In

⁷³ P. Huizinga, River basin management and estuarine needs: The Great Brak case study, *Water Science Technology*, 32 (5-6), December 1995, p. 87.

⁷⁴ P. Huizinga, River basin management and estuarine needs: The Great Brak case study, *Water Science Technology*, 32 (5-6), December 1995, p. 89.

⁷⁵ L. van Vuuren, *In the footsteps of giants – Exploring the history of South Africa's large dams*, p. 233.

⁷⁶ J. Heeg and C.M. Breen. Man and the Pongolo floodplain (South African National Scientific Programmes Report No. 56, CSIR: Pretoria, 1982).

⁷⁷ W.H.J. Hattingh, *Water year +10 and then*, p. 3.

⁷⁸ C.P.R. Roberts, Environmental constraints on water resources development. Unpublished paper delivered at the Seventh Quinquennial Convention of the South African Institution of Civil Engineering, 1983.

⁷⁹ C.P.R. Roberts, Environmental constraints on water resources development. Unpublished paper delivered at the Seventh Quinquennial Convention of the South African Institution of Civil Engineering, 1983, p. 22.

1986 there were again calls from the engineering fraternity for aquatic scientists to assist them in supplying them with information for sustainable water resource development.⁸⁰

Still, ecological flow science remained a generally unexplored discipline by South African scientists, until 1987 when the Skukuza workshop was held between engineers and aquatic scientists to discuss the ecological needs of the rivers of the Kruger National Park.⁸¹ The resultant Skukuza method, described in Chapter 5, while not accepted by the aquatic science community, did provide important elements to the South African ecological flow methods which were consequently developed.⁸² The Skukuza workshop was followed in the same year by another workshop (known as the Cape Town workshop) organised by the Foundation for Research and Development. As South African ecological scientist, Jackie King, puts it, this meeting of the country's leading aquatic scientists on the way forward with regards to ecological flow science was essentially determined by scientists' desire "to do something" to halt the increasing destruction of river systems by anthropogenic actions.⁸³ Together, these two events provided tremendous momentum to ecological flow science in South Africa. King points out that

*[These meetings] gave [ecological flow scientists] the insights of others across the country, and gave [them] courage and support to launch into new thinking, questions and approach.*⁸⁴

A significant outcome of these two workshops was that they highlighted just how little South Africa knew about its water ecosystems. Knowledge still lacked in terms of the impact of ecological flows on the general geomorphology, sediment transport, water quality, habitat structure, biotic structure, and riparian zone of South African river systems.⁸⁵ While collaborative research programmes such as the NPES had propelled aquatic science forward, knowledge was still contained to a small number of river systems, and practically nothing was known about how changing ecological flows

⁸⁰ W.A. Jezewski & C.P.R. Roberts, Estuarine and lake freshwater requirements, p. 1.

⁸¹ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

⁸² J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology, and initial development of alternative instream flow methodologies for South Africa, p. 5.

⁸³ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

⁸⁴ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

⁸⁵ A.A. Ferrar (ed.), Ecological flow requirements for South African rivers, p. 20.

impacted South African river systems in general.⁸⁶ There was a clear call for aquatic scientists of all disciplines to pool their knowledge and so come up with ways to improve the holistic management of South Africa's scarce water resources both from within the scientific fraternity and from water authorities.⁸⁷ South African scientists were now under pressure to find ways of determining the ecological flows of local rivers. The first comprehensive study into ecological flow studies in South Africa was undertaken by King and Tharme, between 1990 and 1993, in a project funded by the WRC as part of phase 1 the KNP rivers research project.⁸⁸

In 1986 DWA recognised the environment as a legitimate water user albeit one that would have to compete with other water users in a catchment.⁸⁹ This had significant consequences, because it meant that the environment now also had to be considered when new water resource developments were planned. When the DWA launched a series of studies to determine the water demand and possibility for bulk water infrastructure it simultaneously launched a series of so-called instream flow requirement (IFR) workshops where aquatic scientists were invited to make contributions towards determining the water needs of river systems where dams were being planned. The ultimate objective of these workshops was to determine the water needs of the environment, which was then added along with the water demand of other water users in the catchment and reconciled with what the catchment could potentially supply.⁹⁰ The IFR workshops thus cemented the position of the environment as part of a move towards integrated water resource management in South Africa. The first of these workshops was the Lephalale River workshop, held in 1992.⁹¹ Experts representing various aquatic science disciplines, from hydraulic modelling, sedimentology and fluvial geomorphology, to water chemistry, riverine vegetation, and aquatic invertebrates, and anthropology were called together to

⁸⁶ A.A. Ferrar (ed), *Ecological flow requirements for South African rivers*, p.1; B. Davies & J. Day, *Vanishing waters*, p. 64.

⁸⁷ J.H. O' Keeffe, *Conservation of South African rivers*, p. 88; W.J.R. Alexander, *Conservation of the water environment – is it attainable?*, p.6; R.D. Walmsley & B.R. Davies, *An overview of water for environmental management*, *Water SA*, 17(1), January 1991, p. 73.

⁸⁸ J.M. King & R.E. Tharme, *Assessment of the instream flow incremental methodology, and initial development of alternative instream flow methodologies for South Africa*. (WRC Report No. 295/1/94, December 1993).

⁸⁹ DWA, *Management of the water resources of the Republic of South Africa*, p.2.25.

⁹⁰ N. van Wyk [vanwykn@dws.co.za], IFR workshops, private email message to L. van Vuuren [laniv@wrc.org.za], 2016-11-02.

⁹¹ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

determine the ecological flow needs of rivers where new dams were being planned.⁹² Following the Lephalale workshop, further workshops were held for the rivers of the Berg, Olifants (Western Cape), Lomati, Koekedouw, Senqu (Lesotho), Mooi, Thukela, Mogalakwena, Mvoti systems as well as for the Kruger National Park (Olifants, Letaba, Luvuvhu, Sabie-Sand) between 1992 and 1996.⁹³ By 2000, the IFRs of an estimated 30 South African rivers had been determined.⁹⁴ The workshops provided the necessary practical application and refinement for South African ecological flow methods to develop and mature within a short period. The South African ecological flow method developed out of these workshops became known as the Building Block Methodology (BBM). Specifically developed to overcome the challenges of lack of data, time and budget, the BBM considers the hydrological, ecological and geomorphological characteristics of a river as it is known at the time of assessment.⁹⁵ The method works on a premise of “best knowledge at the time” therefore allowing for adjustments as more information about the ecological workings of the river becomes known.⁹⁶ Stakeholders have to negotiate what kind of river they want (e.g. near natural, slightly modified, or largely modified). A modified flow regime is then calculated according to that predetermined status using several “building blocks” such as base (or low) flows, wet season floods and freshets (i.e. small floods).⁹⁷ For each of these types of flows the suitable volume of water is then described.⁹⁸

While South African scientists were honing locally-developed ecological flow methods, the country was introducing large-scale legislative reform. The process leading up to the promulgation of the National Water Act in 1998 has been reported on in various publications.⁹⁹ Minister of Water Affairs and Forestry, Kader Asmal, announced the

⁹² J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology, and initial development of alternative instream flow methodologies for South Africa, p. 6.

⁹³ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 18.

⁹⁴ D. Louw *et al.*, The IFR process: Beyond the specialist workshop, *African Journal of Aquatic Science*, 25(1), 2000, p. 183.

⁹⁵ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 362.

⁹⁶ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 17.

⁹⁷ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 362.

⁹⁸ Anon, New methodology determine river instream flow requirements, *SA Waterbulletin*, 25(3), May/June 1999, p. 20.

⁹⁹ See C.G. Palmer, Application of ecological research to the development of a new South African water law, *Journal of the North American Benthological Society*, 18(1), March 1999, pp. 132-142; J.S

government's intent to review the country's water laws on 19 May 1994, barely a month after the country's first democratic elections.¹⁰⁰ This was followed in November 1994 by the appointment of a National Water Advisory Council. The country's new water law has at its foundation the South African Constitution, and more particularly, the Bill of Rights, which declares that all citizens have the right to equality, dignity and life, as well as clean water and an environment that is not harmful to them.¹⁰¹ Contradictory to previous water legislation reforms, where discussions took place behind closed doors, the post-1994 water law review was an inclusive process where stakeholders were consulted widely. The consultation process started with the distribution of the publication, *You and your water rights*, in March 1995.¹⁰² The document sets out the basis for review, provides a short overview of the historic development of water legislation in South Africa as well as the 1956 Water Act and touches on the water legislation of other countries. Following the distribution of the booklet, workshops were held in each province to allow water users to express their views and make their contributions towards the new water legislation. Large water users, such as industry, agriculture, mines and forestry also arranged their own meetings in this regard.¹⁰³ In the water law review the water resources management function was separated from the water services function and the process to develop a new water act occurred in parallel with the process to develop South Africa's first water services legislation, namely the Water Services Act (Act no. 108 of 1997).¹⁰⁴

Minister of Water Affairs and Forestry, Kader Asmal, appointed a water law review panel to drive the reform process in April 1995.¹⁰⁵ The review panel comprised various experts, including Carolyn Palmer (appointed as vice chair), an aquatic scientist and member of

Wallace *et al.*, The sharing of water between society and ecosystems: From conflict to catchment-based co-management, *Philosophical transactions: Biological Sciences*, 358 (1440), December 2003, pp. 2011-2026; H.C. Biggs *et al.*, Engaging a window of opportunity: Synchronicity between a regional river conservation initiative and broader water law reform in South Africa, *International Journal of Water Resources Development*, 24(3), September 2008, pp. 329-343; C. de Coning & T. Sherwill, An assessment of the water policy process in South Africa (1994-2003). (WRC Report No. TT 232/04, WRC: Gezina, 2004); M. Bourblanc, The South African 'ecological reserve', a travelling concept, *Politikon*, 42(2), July 2015, pp. 275-292.

¹⁰⁰ C. de Coning & T. Sherwill, An assessment of the water policy process in South Africa (1994-2003), p. 15.

¹⁰¹ RSA, Constitution of the Republic of South Africa No 108 of 1996.

¹⁰² T. Palmer *et al.*, Some, for all, for ever. Water ecosystems and people, p. 7.

¹⁰³ DWAF, White paper on a national water policy for South Africa, p. 8.

¹⁰⁴ RSA, Water Services Act No 108 of 1997.

¹⁰⁵ C. de Coning & T. Sherwill, An assessment of the water policy process in South Africa (1994-2003), p. 17.

SASAqS. Palmer had been a participating researcher in the KNP rivers research programme at the time.¹⁰⁶ Palmer mobilised members of SASAqS who, after a series of internal workshops, made a strong submission to the water law review process, calling for the aquatic environment not be seen as a competing water user, but as the foundation on which other water uses depend.¹⁰⁷ While the lawmakers conceded that water quality and quantity hinged on general ecosystem health, there was uncertainty over whether South Africa's ecological science methods were robust enough to be able to determine the water needs of the environment.¹⁰⁸ By the time the Sabie-Sand IFR workshop was held in August 1996 the BBM was well-refined. This workshop is significant as it was the first workshop that officially brought together ecological flow researchers with researchers of the Kruger National Park rivers research programme.¹⁰⁹ The workshop was further attended by Francois Junod, a member of the water law review panel. The Sabie-Sand IFR workshop finally demonstrated that South Africa did have the necessary expertise and methods in place to successfully determine ecological flow.¹¹⁰

The result of this confidence in South Africa's ecological flow methods was such that when the final fundamental principles and objectives for a new water law was approved by Cabinet in November 1996, the environmental reserve became one of the 28 principles on which the NWA was eventually based.¹¹¹ Five months later these principles were reiterated when parliament approved the White Paper on a National Water Policy in South Africa. The National Water Act was passed a year later. South Africa's new water legislation introduces several new principles that differ widely from the previous legislation. Fundamentally, the new water act replaces the ownership of water with a right or authorisation to use water.¹¹² This means that the right to water is no longer linked to land ownership. The entire water cycle is now considered a common resource under

¹⁰⁶ See C.G. Palmer *et al.*, Developing of a recirculating artificial stream system to investigate the use of macro-invertebrates as water quality indicators. (WRC Report No. 475/1/96, WRC: Gezina, 1996)

¹⁰⁷ C.G. Palmer, Application of ecological research to the development of a new South African water law, *Journal of the North American Benthological Society*, 18(1), March 1999, pp. 133.

¹⁰⁸ VVPA, OA1, J. King, ecological flow scientist, 2016-10-31.

¹⁰⁹ J.M. King & R.E. Tharme, Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa, p. 362.

¹¹⁰ N. van Wyk [vanwykn@dws.co.za], IFR workshops, private email message to L. van Vuuren [laniv@wrc.org.za], 2016-11-02.

¹¹¹ DWAF, Fundamental principles and objectives for a new water law for South Africa, Appendix A of National Water Resource Strategy First Edition.

¹¹² RSA. National Water Act 36 of 1998.

national control in contrast to the former water act which distinguished between private water (rain falling on the property, groundwater, streams that have their origin on a property) and public water (rivers that flow across multiple properties).¹¹³ National government – through the Minister of Water Affairs – is responsible for the management and allocation of water resources, including ensuring that water is used equitably, sustainably and efficiently (for both present and future generations), and that reserve requirements are met.¹¹⁴ While national government is the custodian of the nation's water resources, the day-to-day management of the resource is to be undertaken at a catchment level by catchment management agencies and water user associations representing all of the users in a river catchment. Along with the human right to water, the environmental right to water is the only "right" acknowledged in the NWA. These water rights are given priority over all other water uses in a catchment, which have to be authorised by the DWA. The "reserve" is defined as the quantity and quality of water required to supply basic human needs, and to protect aquatic ecosystems.¹¹⁵ Where the resources of a river have historically been over-allocated so that the provision of the reserve is not possible, the NWA calls for "active intervention" on the side of the state to rectify the situation. This could mean withdrawing historical water use allocations and redirecting it towards restoring the reserve. The NWA does, however, recognise the need for South Africa to develop as a people and a country, and that water is required for socio-economic growth. It thus allows for river systems to be managed in different management "classes".¹¹⁶ The management class is used to describe the ecological state of the river, which is determined by the health of various aspects of the river ecosystems, including water quality, integrity of the habitat, and invertebrate health, among others. The management class varies from "A" (the highest grade) or a completely unmodified system, to "F" (the lowest grade) or a highly degraded river system. The management class determines the kind of reserve that is set for the river system, as well as the range of activities that are permitted in the catchment. The allowances for water use activities is led by a set of resource quality objectives, which are developed once the river's management class is set.¹¹⁷ Once the RQOs have been set for a river they are "binding

¹¹³ DWAF, *You and your water rights. South African law review. A call for public response*, pp. 13-14.

¹¹⁴ RSA, National Water Act 36 of 1998.

¹¹⁵ RSA, National Water Act 36 of 1998.

¹¹⁶ DWA, Procedures to develop and implement resource quality objectives, p. 1.

¹¹⁷ DWA, Procedures to develop and implement resource quality objectives, p. 1.

on all authorities and institutions when exercising any power or performing any duty under this Act.”¹¹⁸

In the early 2000s the BBM was replaced by the more refined DRIFT (Downstream response to imposed flow transformations) methodology. Also a holistic methodology, this ecological flow assessment method features a stronger socio-economic component and is scenario based rather than prescriptive such as the BBM method.¹¹⁹ Basically, the scenarios presented by the DRIFT method provide

*[a] number of future options on how the rivers could change with flow changes, and how this would impact overall environmental condition and subsistence users.*¹²⁰

The DRIFT method was first tested on the Palmiet and Breede rivers in South Africa as well as the Senqu River system in Lesotho in preparation as part of phase 1b of the Lesotho Highlands Water Scheme.¹²¹ The method essentially comprises four modules. The biophysical module is used to describe the predicted changes to the ecosystem should the flow be modified while the sociological module identifies communities dependent on the river system and how their livelihood will be impacted by modified flows.¹²² The third module provides a series of scenarios that balances the results of the first two modules, while the fourth module considers how communities should be compensated and what the potential costs will be.¹²³ The method promotes transparent decision-making, and allows for negotiations and trade-offs between different stakeholders. Since its development, DRIFT has become the preferred ecological flow determination method in South Africa and has found various national and international applications.¹²⁴

¹¹⁸ DWA, Procedures to develop and implement resource quality objectives, p. 1.

¹¹⁹ J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 1.

¹²⁰ J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 27.

¹²¹ J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 8.

¹²² J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 10.

¹²³ J.M. King *et al.*, Development of DRIFT; a scenario based methodology for environmental flow assessments, p. 10.

¹²⁴ J. King & H. Pienaar (eds), Sustainable use of South Africa's inland waters, pp. 162-163.

6.4 Conclusion

Ecological flow science did not originate in South Africa. Rather this scientific discipline developed out of the concern of the natural environment as water resource development led to increased disruptions of natural ecological flows. As the concern for the impact of flow disruption increased, this led to the methodologies to determine the quantitative and qualitative water needs of the environment. Ecological flow methods have their origins in the well-watered rivers of the northern hemisphere where early approaches, such as the Tennant method, focused on the protection of single target species. When these methods were tested in South Africa they were found to be inappropriate for the country's variable river systems. Australia, whose dryland rivers have similar characteristics to that of South Africa, experienced the same challenge. Scientists from the two countries began working together to develop more holistic methods which would focus on the allocation of high and low flows (as opposed to minimum flows) to protect the integrity of the entire aquatic ecosystem (rather than only target species), although each country ended up with its own holistic flow determination methodology.

The evolution of ecological flow methodologies required a shift in thinking, from viewing the aquatic environment as a competing water user to allocating water for the environment first, and then allocating water to other water users. The philosophy of considering the water quantity and quality needs of the entire aquatic ecosystem was subsequently taken up in the legislation and policies of both Australia and South Africa. Water resource planning by the DWA, which called on aquatic scientists to provide information on how much water was required to keep aquatic ecosystems functioning stimulated ecological flow science in South Africa and the resultant BBM method was refined during a series of IFR workshops in the early 1990s. Once decision-makers were convinced that scientific methods existed – and indeed were workable – to determine the ecological flow needs of rivers in South Africa they felt comfortable enough to include the ecological reserve in South Africa's new water law, enacted in 1998. The next chapter considers the role of the country's largest collaborative aquatic science programme, The KNP rivers research programme, in building the required scientific capacity and influencing policy and decision-making around the environmental management of rivers in South Africa.

Chapter 7 Environmental reserve and the role of the Kruger National Park rivers research programme

7.1 *Introduction*

The rivers transecting the Kruger National Park had been considered important from a water-supply perspective from the time of the park's establishment. However, by the 1980s Sanparks realised that the park's aquatic ecosystems warranted protection in their own right. Not only were these rivers the main source of water supply to game and tourists within the park; they also contained a rich biodiversity which, in some cases, was endemic to South Africa.¹ There was a strong realisation that without these rivers, the Kruger National Park would cease to function as South Africa's primary protected area.² Following years of correspondence, officials of the DWA and Sanparks came together with aquatic scientists in Skukuza in March 1987 to discuss the flow requirements of the Kruger National Park's rivers. The workshop was prompted by a series of catchment studies which the DWA had initiated in the Eastern Transvaal as part of a water reconnaissance exercise. Up until the time the so-called Skukuza workshop took place, there was no comprehensive information available on the ecological functioning of the Kruger National Park rivers or how the aquatic ecology reacted to variable flow conditions.³ This prompted the establishment in 1988 of the Kruger National Park (KNP) rivers research programme.

7.2 *The KNP rivers research programme first phase (1988-1992)*

The first phase of the KNP rivers research programme ran between 1988 and 1992, and was largely based on a concept document drawn up by a working group tasked with this purpose.⁴ The working group comprised senior representatives of Sanparks, the DWA and the Foundation for Research and Development (FRD), as well as scientists from the CSIR and the universities of the Witwatersrand, Rhodes and Cape Town.⁵ Funding

¹ Bruwer, C. (ed), Flow requirements of Kruger National Park rivers, p. 10.

² Bruwer, C. (ed), Flow requirements of Kruger National Park rivers, p. 10.

³ Bruwer, C. (ed), Flow requirements of Kruger National Park rivers, p. 1.

⁴ Sanparks, B/8 [8-1], Minutes of a planning meeting for the KNP rivers research programme, 9 and 10 May 1988.

⁵ Sanparks, B/8 [8-1], Minutes of a planning meeting for the KNP rivers research programme, 9 and 10 May 1988.

agencies, the WRC and FRD, as well as the Departments of Water Affairs and Environmental Affairs, agreed to fund the programme. The FRD also provided secretarial services to the programme while Sanparks provided research facilities and manpower to the programme. An important aspect of the latter was providing accommodation for the steady stream of researchers who arrived at the Kruger National Park to study its rivers once the research programme had begun. Prior to the KNP rivers research programme almost all the scientific activities within the Kruger National Park had been undertaken exclusively by Sanparks staff.⁶ To accommodate visiting researchers, the DWA donated a series of temporary structures to the programme, which became known as the “river park homes”.⁷ The structures became an important neutral meeting space, both for formal and informal discussions between participants in the programme.⁸

The KNP rivers research programme had a two-tiered management system – the first tier comprised a policy committee, which included high-level representatives from Sanparks (who also acted as chair), the DWA, FRD, WRC, and the DEA. The main goal of this committee was to set the objectives of the programme and manage its funding.⁹ The second, management committee (initially known as the coordinating committee), comprised a wider group of specialists (mainly mid-level managers from participating organisations and co-opted stakeholders) and was concerned with implementing the actions of the policy committee and coordinating research activities.¹⁰ Among others, this committee identified research projects and made proposals for funding, while ensuring research outputs were properly documented and disseminated.¹¹ The concept document motivated for a multidisciplinary research programme with the main objective of building an understanding of the ecological water requirements of the rivers of the Kruger National Park with the aspiration that the knowledge and methods emanating from the programme would lead to improved management of South African rivers and their environmental

⁶ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

⁷ L. van Vuuren, ‘End of an era’ as old KNP river research accommodation demolished, *The Water Wheel*, 11(4), July/August 2012, p. 41.

⁸ L. van Vuuren, ‘End of an era’ as old KNP river research accommodation demolished, *The Water Wheel*, 11(4), July/August 2012, p. 41.

⁹ Sanparks, B/8 [8-1], Minutes of the second meeting of the policy committee for the KNP rivers research programme, 5 June 1989.

¹⁰ Anon, Research opportunities in the Kruger National Park, *SA Waterbulletin*, 15(4), June-July 1987, p. 28.

¹¹ SAWHAR, Waterlit Collection, Anon, Kruger National Park rivers research programme. Programme description phase 1, p. 2.

water requirements in general.¹² The first phase of the programme set the following objectives, namely to:

- define and evaluate scientific information pertinent to the allocation of water to the Kruger National Park;
- develop the appropriate expertise for managing water allocation for ecological purposes;
- develop and maintain the necessary inter-institutional cooperation and communication;
- define and initiate research in priority areas; and
- secure and make recommendations on funding requirements.¹³



Figure 7-1: The so-called “river park homes” erected at Skukuza at the start of the KNP rivers research programme. The temporary accommodation served the researchers and members of the programme who undertook research inside the Kruger National Park. The structures were demolished in 2012¹⁴

¹² Sanparks, B/8 [8-1], Motivation for a cooperative multidisciplinary research programme on the Kruger National Park river systems, document drawn up by the Working Group on behalf of the National Parks Board, 1988-07-19.

¹³ SAWHAR, Waterlit Collection, Anon, Kruger National Park rivers research programme. Programme description phase 1, p. 2.

¹⁴ Photograph, VVPA, Water Research Commission Photographic archive (WRCPA), River park homes.

The park was thus seen as a living laboratory for unravelling the complexity of South Africa's river systems and testing ecological flow determination methods and management scenarios that could ultimately be applied on a broader, national scale. Any research output stemming from the programme would therefore have to have real-world application and be able to be plugged directly into the management policies not only of Sanparks but also those of the DWA.¹⁵ It is uncertain whether the programme initially set out to determine the minimum flow requirements of the Kruger National Park rivers (as was the norm with global ecological flow determination at the time) or whether the concept of ecological flows had been embedded in the programme from the take off. Certainly by 1991 there already was an understanding amongst DWA engineers that the objective of the programme was not only to determine the minimum volume of water by which the ecology of the Kruger National Park rivers could be sustained, but to ensure flow of different volumes at different times of the year to mimic natural conditions (i.e. ecological flow).¹⁶ A further important driver of the programme was preventing flows in the perennial rivers of the Kruger National Park to cease completely, as they had already done from time to time in rivers such as the Letaba and the Luvuvhu.¹⁷ From the start of the programme the emphasis was on effective knowledge exchange between researchers and water managers so as to ensure that the project would eventually make a definitive impact on the way water for the environment was managed in South Africa.¹⁸

The first research project proposals were received in 1989 and researchers submitted their proposals under five priority topics, namely water availability, characteristics of the river systems, water quantity requirements, water quality requirements, and impact on the environment.¹⁹ Despite the programme's ambitious objectives, it was difficult to garner

¹⁵ Sanparks, B/8 [8-1], Motivation for a cooperative multidisciplinary research programme on the Kruger National Park river systems, document drawn up by the Working Group on behalf of the National Parks Board, 1988-07-19.

¹⁶ SAWHAR, Waterlit Collection, F. van Zyl, Making it happen – The Sabie experience (In Pigram J.J. & Hooper, B.P., eds. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991. pp. 247-258.)

¹⁷ SAWHAR, Waterlit Collection, F. van Zyl, Making it happen – The Sabie experience (In Pigram J.J. & Hooper, B.P., eds. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991. pp. 247-258.)

¹⁸ SAWHAR, Waterlit Collection, Anon, Kruger National Park rivers research programme. Programme description phase 1, p. 2.

¹⁹ Sanparks, B/8 [8-1], Minutes of the second meeting of the policy committee of the Kruger National Park rivers research programme, 1989-06-02.

immediate management decisions from the information emanating from the programme as so little was known about the Kruger National Park rivers to begin with. Initial projects comprised mostly basic research focused on obtaining a first order understanding of how these rivers and their ecosystems functioned, population dynamics, the impact of these rivers on the movement of terrestrial faunal populations, how their riparian zones functioned, and their geomorphological dynamics – the latter of which had hardly ever been studied in South African rivers before.²⁰ Other projects investigated the impact of water quality on the health of river biota, control of invasive alien plants (both aquatic and riparian), and the study of hippopotami populations.²¹ By 1991, there were 41 projects registered under the programme, the majority of the funding being shared by the WRC and the FRD.²²

There were, however, two projects undertaken under the first phase of the KNP rivers research programme that applied to the broader management of water in South Africa in a direct way. The first project focused on the historical origins of South African water law as a contribution towards amending the Water Act of 1956 to recognise the environment's right to water.²³ The study argued that such an amendment was necessary to

*(e) establish a fair allocation system for water utilisation by all organisms [including the environment], and at preserving the resource.*²⁴

As such the study determined that the allocation of water to the environment could no longer be seen as a voluntary function, but was in fact crucial in order to safeguard the sustainability of the resource and its ongoing use by all water users.²⁵ The study recommended, therefore, that environmental rights be accommodated in South African

²⁰ SAWHAR, Waterlit Collection, Anon, Current research projects. Annexure to Kruger National Park rivers research programme. Programme description phase 1.

²¹ SAWHAR, Waterlit Collection, Anon, Current research projects. Annexure to Kruger National Park rivers research programme. Programme description phase 1.

²² Sanparks, B/8 [8-1], Minutes of the eleventh meeting of the coordinating committee for the KNP rivers research programme, 1991-11-01.

²³ M. Uys, A structural analysis of the water allocation mechanism of the Water Act 54 of 1956 Vol 1, p. 5.

²⁴ M. Uys, Statutory protection for the water requirements of natural ecosystems, *Koedoe*, 35(1), September 1992, p. 105.

²⁵ M. Uys, Statutory protection for the water requirements of natural ecosystems, *Koedoe*, 35(1), September 1992, p. 105.

water law.²⁶ A case study of water allocation in the Letaba river system, undertaken as part of this project, also pointed to the conundrum of providing water to the environment in a scenario where water had already been over-allocated to other water users.²⁷ The only solution, according to the final report, was a comprehensive redistribution process – something which the post-1994 government has been grappling with since the introduction of the ecological reserve in 1998.²⁸ Despite being made publicly available the results of the study were not widely shared, but author, Maritza Uys, in addition to several project steering committee members, would later contribute to the NWA where many of these early sentiments were eventually captured as the ecological reserve.²⁹

The second project, undertaken by Jackie King of UCT, was aimed at assessing the instream flow requirements of rivers in South Africa. As described in chapter six, this study first examined the application of international ecological flow methods (particularly IFIM) in South Africa. When these methods, of North American origin, were found not to be compatible with South African river characteristics, it led to further studies outside of the KNP rivers research programme and the development of the holistic ecological flow methodology BBM, with an initial work being undertaken in collaboration with Australian scientists. This methodology was later applied to the first IFR workshops in South Africa and eventually influenced the inclusion of the environmental reserve in the NWA. While King's initial investigations never focused specifically on the Kruger National Park's rivers, it was considered part of the suite of projects funded by the WRC under phase 1 of the programme.³⁰ In this way the KNP rivers research programme laid a firm, albeit subtle, foundation for the evolution of ecological flow science in South Africa.

²⁶ M. Uys, A structural analysis of the water allocation mechanism of the Water Act 54 of 1956 Vol II, p. 752.

²⁷ M. Uys, A structural analysis of the water allocation mechanism of the Water Act 54 of 1956 Vol I, p. 107.

²⁸ M. Uys, A structural analysis of the water allocation mechanism of the Water Act 54 of 1956 Vol I, p. 107.

²⁹ VVPA, OA1, M. Uys, Advocate and water law expert, 2015-06-04.

³⁰ SAWHAR, Waterlit Collection, Anon, Current research projects. Annexure to Kruger National Park rivers research programme. Programme description phase 1.



Figure 7-2: Angela Arthington, an ecological scientist from Australia (on the right), during a visit to the Kruger National Park in 1991. Accompanying her is Andrew Deacon (formerly of Sanparks) on the far left and Peter Reid (formerly of the Water Research Commission). Researchers of the two countries had several information exchange visits and together developed the first holistic ecological flow methods³¹

Another important project undertaken as part of the first phase of the programme, which directly influenced policy decision, investigated the potential impacts of proposed new dams on the Sabie River on aquatic life in the river in the downstream Kruger National Park. This project was undertaken over two years and funded by the WRC. The DWA considered seven dam sites at the time of the investigation, the largest being the 62m-high Madras dam, to be located on the main stem of the Sabie River just outside the

³¹ Photograph, VVPA, WRCPA, Angela Arthington.

Kruger National Park.³² While aquatic researchers initially objected to the construction of a large dam in the Sabie River system at all given the near natural state of the river, no evidence could be found that these objections were ever considered by the DWA.³³ Of all the dams under consideration the Inyaka Dam (earlier spelt Injaka), located on the Marite River (a tributary of the Sabie River), was found to have the least impact on the flow of the Sabie River into the Kruger National Park. This dam was thus put forward in parliament in 1994 by way of a White Paper.³⁴ The dam was to have multiple purposes, namely to boost domestic water supply in previously unserved rural and semi-rural areas, to augment irrigation water supply and, importantly, to improve river flows to the Kruger National Park and the adjacent Sabie-Sand Game Reserve.³⁵ Plans were put in place to release water from the dam to the Kruger National Park on a regular basis, especially during dry periods so as to ensure that river flow never fell below 0.6m³/s as it entered the park. This figure was adjusted as more information about the ecological flow requirements of the Sabie River became known.³⁶ The KNP rivers research programme therefore played a significant role in driving the underlying research that determined the location and operating rules of the Inyaka Dam. The park has come to rely on the water of the Inyaka Dam, and releases from the dam have played a definitive role in keeping the Sabie River flowing through the Kruger National Park during the *El Niño*-induced drought of 2015-16.³⁷

Despite many achievements, the programme threatened to unravel by the end of 1991. Trust issues began to surface between the managers of the programme and researchers, while different organisations jostling for position pushed the agenda of the programme in

³² J.H. O'Keeffe & B.R Davies, Conservation and management of the rivers of the Kruger National Park: Suggested methods for calculating instream flow needs, *Aquatic conservation: Marine and freshwater ecosystems*, 1(1), September 1991, p. 62.

³³ Sanparks, B/8 [6-1], Correspondence between F. de Moore & C. Palmer and S.C.J. Joubert on conservation of the Sabie river, Skukuza-Grahamstown, 1989-11-07 to 1990-01-09.

³⁴ RSA, WP D-94, Report on the proposed Sabie river government water scheme. First phase: Injaka Dam and Bosbokrand transfer pipeline. (Government Printer: Pretoria, 1994).

³⁵ RSA, WP D-94, Report on the proposed Sabie river government water scheme. First phase: Injaka Dam and Bosbokrand transfer pipeline. (WP D-94, Government Printer: Pretoria, 1994).

³⁶ SAWHAR, Waterlit Collection, F. van Zyl, Making it happen – The Sabie experience (In Pigram J.J. & Hooper, B.P., eds. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991. pp. 247-258.)

³⁷ L. van Vuuren, Drought – Nature's lessons in overdrive in Kruger National Park, *The Water Wheel*, 15(5), September/October 2016, p. 36.

different directions.³⁸ The conflict between managers and scientists occurred despite the inclusion of interaction and communication as key objectives of the programme. Water managers felt that researchers were not committed to providing the information they required in a timely manner, while researchers were of the view that they were not being given enough autonomy to conduct research and were bound by a lack of formal processes by which information could be transferred between the two parties.³⁹ The disjuncture between researchers and water managers is not unique to the KNP rivers research programme. Several authors have pointed to the fundamental differences between researchers – who are focused on learning and garnering new knowledge – and water managers (traditionally engineers) – who require information which can be applied in a practical sense – and how difficult it is to transcend these cultures in a multidisciplinary space.⁴⁰ Cullen sums up the fundamental difference between how researchers and water managers operate as:

*(e)ngineers don't care why it works as long as they think it does. Scientists don't care if it works or not as long as they understand why.*⁴¹

Ongoing concerns led to a review process of the entire programme, and in March 1992 a team of external consultants, led by André Görgens, were appointed to assess the programme and provide a new management plan for its continued existence.⁴² While the review pointed to several significant achievements, such as laying the foundation for ecological water research in South Africa and stimulating meaningful interaction between ecological scientists and water managers on the environment's rights to water, it also

³⁸ Sanparks, B/8 [8-1], Minutes of the fourth meeting of the policy committee for the KNP rivers research programme, 1992-06-03.

³⁹ SAWHAR, Waterlit Collection, F. van Zyl, Making it happen – The Sabie experience (In Pigram J.J. & Hooper, B.P., eds. Proceedings of Water allocation for the environment. An international seminar and workshop organised by Centre for Water Policy Research, University of New England, Armidale. November 1991. pp. 247-258.); Sanparks, B/8 [8-1], K.H. Rogers *et al.*, An integrated programme for research on the Kruger National Park rivers, p.3.

⁴⁰ R. Grayson *et al.*, On the adoption of research and development outcomes in integrated catchment management, *Australian Journal of Environmental Management*, 7(3), (no month) 2000, p. 152; D.J. Roux *et al.*, Framework for participative reflection on the accomplishment of transdisciplinary research programmes, *Environmental Science & Policy*, 13(8), December 2010, p. 735; C.M. Pringle *et al.*, The role of aquatic science in freshwater conservation: cooperation between the North American Benthological Society and organisations for conservation and resource management, *Journal of the North American Benthological Society*, 12(2), June 1993, p. 179; M. Acreman, Linking science and decision-making: features and experience from environmental river flow setting, *Environmental Modelling & Software*, 20(2), February 2005, p. 100.

⁴¹ P. Cullen, The turbulent boundary between water science and water management, *Freshwater Biology*, 24(1), August 1990, p. 202.

⁴² VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

pointed to several deficiencies in the programme.⁴³ The initial goals of the programme were found to be too ambitious and there appeared to be a lack of coordination and communication between participating members. While 23 research projects had been completed by the time of the review, the complexities of the Kruger National Park river systems were such that there were still many unanswered questions with regards to the ecological flow requirements of these rivers.⁴⁴ The challenge was that management decisions could not be postponed while scientists were still seeking answers around the functioning of the aquatic environment.⁴⁵

The consultants made several recommendations with regards to the restructuring of the KNP rivers research programme, pointing to a refocusing of the goals and objectives and that these should be ranked in order of priority. The review recommended that research projects, not directly linked with the programme's goals be terminated or redirected, and pushed for stronger emphasis on the water quantity aspects of the information needs of the programme.⁴⁶ The review also called for the appointment of a dedicated programme manager to actively manage the programme and provide the interface between the policy and the management committee.⁴⁷ An important outcome of the review was the realisation that the KNP rivers research programme had to evolve from a programme focused solely on gathering as much data as possible in the shortest possible time towards a programme that optimised communication and information sharing between science and management.⁴⁸ Scientists had to accept that they had to share information even though they did not yet have all the answers. In turn, water resource managers had to accept that whatever answer they received might not be the ultimate one and that the answers might change in future. Thus, the review introduced the first principles of

⁴³ A. Görgens, & J. Lee, Kruger National Park rivers research programme: Situation statement and management assessment, p. 70.

⁴⁴ A. Görgens, & J. Lee, Kruger National Park rivers research programme: Situation statement and management assessment, p. 7.

⁴⁵ A. Görgens, & J. Lee, Kruger National Park rivers research programme: Situation statement and management assessment, p. 34.

⁴⁶ A. Görgens, & J. Lee, Kruger National Park rivers research programme: Situation statement and management assessment, p. 34.

⁴⁷ Sanparks, B/8 [8-1], Minutes of an extraordinary meeting of the policy committee of the KNP rivers research programme, 1992-02-24.

⁴⁸ K.H. Rogers, The real river management challenge: Integrating scientists, stakeholders and service agencies, *River Research and Applications*, 22(2), February 2006, p. 271.

strategic adaptive management – or learning by doing – that would later become entrenched in the management policies of the Kruger National Park.

In November 1992, a formal decision was made by the policy committee of the KNP rivers research programme to restructure the programme, starting with the development of a decision support system to guide the programme into the next phase.⁴⁹ An interim management committee was appointed to oversee this process. It was also agreed to appoint a programme manager, Charles Breen, who had earlier led research on the ecological flow requirements of the Pongolo floodplain, was appointed to the position.⁵⁰ While the KNP rivers research programme was being restructured the park entered one of its worst drought periods on record, amplified by an *El Niño* event.⁵¹ The year 1991-92 was marred by low rainfall and high temperatures, with a record high temperature of 45.6°C being measured at Skukuza on 26 February 1992.⁵² On average, the Kruger National Park received only 44% of its normal annual rainfall.⁵³ The Letaba and Luvuvhu rivers stopped flowing for extended periods, while low flows in rivers such as the Olifants and Crocodile were only maintained thanks to periodic releases from dams upstream from the Kruger National Park.⁵⁴ The lack of water, in addition to the lack of fodder, led to large-scale deaths among several species in the park, including baboons, buffalo, impala, crocodile, and hippopotami.⁵⁵ The Sabie River measured its lowest flow ever – a meagre flow of 0.33m³/s was recorded at Lower Sabie in September 1992.⁵⁶ In 1992, Sanparks initiated the Sabie River Working Group – a catchment-based forum comprising the major water users of the Sabie River system following discussions with the Sabie River Irrigation Board.⁵⁷ The group was chaired by Japie Lubbe, an irrigation farmer from

⁴⁹ Sanparks, B/8 [8-1]. Letter from the policy committee chair to members of the KNP rivers research programme on the reconstitution of the programme, 1992-12-03.

⁵⁰ Sanparks, B/8 [8-1]. Letter from the policy committee chair to members of the KNP rivers research programme on the reconstitution of the programme, 1992-12-03.

⁵¹ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

⁵² Sanparks, Annual Report 1991/92, p. 5.

⁵³ N. Zambatis & H.C. Biggs, Rainfall and temperatures during the 1991/92 drought in the Kruger National Park, *Koedoe*, 38(1), August 1995, p. 16.

⁵⁴ Sanparks, Annual Report 1992/93, p. 10.

⁵⁵ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

⁵⁶ Anon, Researchers determine ecological status of the Sabie River, *SA Waterbulletin*, 23(2), March/April 1997, p. 13.

⁵⁷ Sanparks, Annual Report 1992/93, p. 20.

Hazyview, who had just retired as chairperson of the irrigation board.⁵⁸ Through various interactions between Sanparks personnel and the forum on the importance of the flow of the Sabie River for ecological processes in the Kruger National Park, water users (mainly irrigators) initially voluntarily restricted their water use up to 60% during the drought period, while the forestry sector started an alien invasive plant clearing programme in the catchment.⁵⁹ When the drought persisted and upstream water users became less inclined to voluntarily restrict their water use and the DWA applied Article 9A of Water Act to ensure continued water supply to the Kruger National Park.⁶⁰ Towards the end of 1992 the drought was broken by a series of good rain events.⁶¹

While the interaction between the Kruger National Park and its upstream neighbours were not a direct result of the KNP rivers research programme, it was the knowledge generated about the importance of ecological ecosystems that prompted Sanparks to finally cross its borders and build working relationships with its neighbours.⁶² At the commencement of the KNP rivers research programme, Sanparks had established an active monitoring system for its perennial rivers, including the use of fixed-point photographs, monitoring of aquatic invertebrates and larger species such as fish and hippopotami, as well as taking regular water quality samples.⁶³ By sharing this information with upstream water users, a general awareness of the environmental impact of anthropogenic activities was created.⁶⁴ In addition to the Sabie River Working Group other points of contact were established with upstream water users, such as the Phalaborwa Pollution Control Coordination Committee, Phalaborwa Barrage Silt Working Group and the Olifants River Working Group, all aimed at finding sustainable solutions to water quality issues in the Olifants River outside the Kruger National Park.⁶⁵ Sanparks personnel also started attending the meeting of irrigation boards on a regular basis.⁶⁶ These relationships have persisted, especially following the establishment of the Inkomati-Usuthu catchment management

⁵⁸ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

⁵⁹ P. Kotze, Kruger getting house in order for severe drought, *The Water Wheel*, 14(5), September/October 2015, p. 17.

⁶⁰ S. Joubert, Kruger National Park water resources, p. 51.

⁶¹ Sanparks, Annual Report 1992/93, p. 20.

⁶² VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

⁶³ VVPA, OA1, A. Deacon, Former Sanparks senior scientist, 2016-11-22.

⁶⁴ VVPA, OA1, A. Deacon, Former Sanparks senior scientist, 2016-11-22.

⁶⁵ Anon, Management of Kruger's rivers, *Custos*, March 1994, p. 38.

⁶⁶ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

agency, and the Kruger National Park has now been accepted as a major stakeholder in all decision-making processes around the water resource management in its river catchments.⁶⁷ While forums such as the Sabie River Working Group ceased to exist following the establishment of the catchment management agency, others such as the Olifants River Working Group (renamed the Olifants River Forum) have persisted, and continue to play an important role in addressing water quality and quantity issues in the Lowveld river catchments.⁶⁸



Figure 7-3: The original members of the Sabie River Working Group, circa 1992⁶⁹

7.3. Phase 2 (1994-1996)

In the second phase of the KNP rivers research programme the goals of the programme were reaffirmed as determining and sharing the water quality and quantity requirements

⁶⁷ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

⁶⁸ See, for example, J.M. Dabrowski (ed), Risk assessment of pollution in surface waters of the Upper Olifants river system: Implications for aquatic ecosystem health and the health of human users of the water. Summary report 2009 to 2013. (CSIR: Pretoria, 2013).

⁶⁹ Photograph, VVPA, SPA, Sabie River Working Group.

of the Kruger National Park rivers on a local scale and “developing, testing and refining” ecological flow methods for South African rivers on a national scale.⁷⁰ A set of subsidiary goals emphasised the development of decision-support systems to stimulate the information exchange between managers, stakeholders and researchers to allow for more informed decision-making around the management of the river environment; on building the necessary capability (both in terms of human capacity and systems) to deal with the complexity of managing aquatic ecosystems amidst anthropogenic influence both in the Kruger National Park and nationally; and focused and integrated research projects that would assist the programme in achieving its desired outputs.⁷¹ These elements – introduced in the second phase as a more “holistic approach” towards management of the rivers of the Kruger National Park, and how they integrate with each other is illustrated in Figure 7-4. In the second phase research activities were divided into four sub-programmes, each with its own (sub)programme manager to ensure the integration of the individual projects.⁷² These four subprogrammes were:

- information systems development and management – aimed at the development and management of a central management system to capture all the output emanating from the research projects of the KNP rivers research programme;
- decision-support system and management – aimed at developing a decision-support system to more accurately link the information needs of managers and stakeholders with information emanating out of the research programme;
- research, development and management – aimed at providing, through research, the information required to improve management of the rivers of the Kruger National Park; and
- training, information and technology transfer – aimed at ensuring that the information and methods developed through the research programme was transferred effectively to stakeholders and managers.⁷³

⁷⁰ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 20.

⁷¹ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 20.

⁷² SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 29.

⁷³ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 29.



Figure 7-4: Four main elements of a holistic approach to river research and management, introduced during the second phase of the KNP rivers research programme⁷⁴

The Sabie River – as the most environmentally intact of all the perennial rivers of the Kruger National Park – was selected as the focus area for phase 2, and most of the research projects initiated in this phase centred on this river system. The introduction of Breen – who brought with him his experience in dealing with diverse stakeholders at Pongola – made a significant difference in the perceived success of the programme.⁷⁵ In addition to acting as a neutral go between between the policy and management committee Breen introduced a programme research committee.⁷⁶ This committee, which included the managers of the sub-programmes met a day before the management committee to discuss the status of research projects and iron out any differences of

⁷⁴ SAWHAR Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 21.

⁷⁵ VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

⁷⁶ VVPA, OA1, C. Breen, Former programme manager: KNP rivers research programme, 2015-07-07.

opinion. In this way a single message was passed on to the management committee.⁷⁷ This action brought greater coherence to the management of the programme. The second phase of the KNP river research programme built on the strong scientific foundation of the first phase. A particular focus was to take the knowledge that had been gathered of the individual components of the aquatic ecosystems of the Kruger National Park and gear it towards a greater understanding of the health of the river systems, with the ultimate aim of predicting the outcome of upstream anthropogenic impacts.⁷⁸ The Kruger National Park now had intimate knowledge and inventories of all the major components of the river systems, from the fish and riparian vegetation to the invertebrates, hydrology and channel hydraulic characteristics of the rivers.⁷⁹ By the end of phase 2 it was confirmed that the Kruger National Park rivers research programme had made “an important contribution to understanding the dynamics of [South Africa’s] river systems”.⁸⁰

The programme made contributions in all fields of ecological science, but made a particular impact in the field of fluvial geomorphology, a discipline that had hitherto been largely unexplored in South Africa.⁸¹ The programme firmly established fluvial geomorphology as a discipline in South Africa, not only increasing knowledge about the fluvial geomorphological processes in South African rivers (and the Kruger National Park rivers in particular), but also developing capabilities to predict geomorphological change.⁸² Studies further discovered the rich biological characteristics not only of the Kruger National Park’s rivers but also of its riparian areas and revealed the strong link between the integrity of riparian vegetation and flow.⁸³

Phase 2 of the KNP rivers research programme placed significant emphasis on the development of a decision-support system (DSS) – a protocol underlined by a suite of models, methodologies and tools to assist resource managers to make more informed

⁷⁷ VVPA, OA1, C. Breen, Former programme manager: KNP rivers research programme, 2015-07-07.

⁷⁸ J. O’Keeffe & Y. Coetzee, Status report of the Kruger National Park rivers research programme: A synthesis of results and assessment of progress to January 1996, p. 27.

⁷⁹ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 3, p. 20.

⁸⁰ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 3, p. 20.

⁸¹ VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

⁸² VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

⁸³ J. O’Keeffe & Y. Coetzee, Status report on the Kruger National Park rivers research programme: A synthesis of results and assessment of progress to January 1996, p. 16.

decisions around the management of the Kruger National Park's rivers (see Figure 7-5).⁸⁴ The DSS became the framework on which research outcomes were tagged. Therefore this system played a strong role in the selection of the right kind of research projects to align with the information required for ecosystem management.⁸⁵ The DSS was based on three legs, namely an "operational framework" that set targets and goals for the environmental state of the rivers; a "predictive modelling framework" that would be able to foresee how the system would react as a result of both human and natural influences; and a "system response framework" that would set up an extensive monitoring programme for the Kruger National Park's rivers.⁸⁶ A review of phase 2, published in 1996, highlighted just how important this jump was, from understanding the various individual components of the Kruger National Park's rivers (the focus of phase 1) towards collating all the research outputs into a cohesive river management framework.⁸⁷ The authors of the review wrote that:

*(f)rom such links the programme will be able to provide managers with predictions of the effects of changing flow regimes (as a result of water resource development) on the structure and biota of the rivers.*⁸⁸

⁸⁴ H. MacKay, A prototype decision support system for the Kruger National Park rivers research programme, pp. 2-3.

⁸⁵ H. MacKay, A prototype decision support system for the Kruger National Park rivers research programme, p. 4.

⁸⁶ K. Rogers & R. Bestbier, Development of a protocol for the definition of the desired state of riverine systems in South Africa, p. 15.

⁸⁷ J. O'Keeffe & Y. Coetzee, Status report on the Kruger National Park rivers research programme: A synthesis of results and assessment of progress to January 1996, p. 27.

⁸⁸ J. O'Keeffe & Y. Coetzee, Status report on the Kruger National Park rivers research programme: A synthesis of results and assessment of progress to January 1996, p. 27.

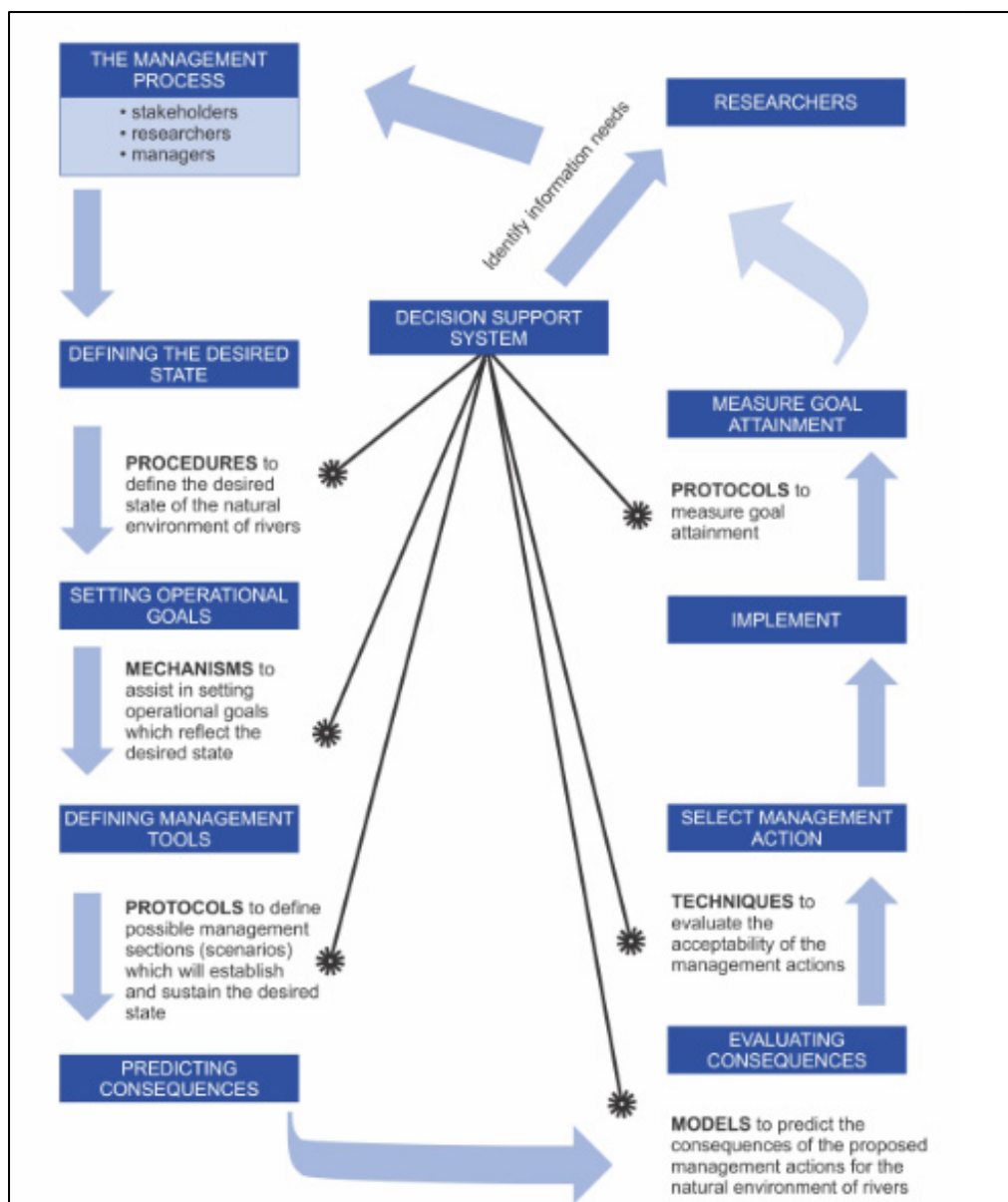


Figure 7-5: The main elements of the decision support system and how it feeds into management processes⁸⁹

Despite this increased knowledge of the functioning of the aquatic ecosystems, the question of how to manage the Kruger National Park aquatic ecosystems was vexing. The more researchers and managers learnt about how these river systems functioned and how they reacted – both to natural external forces and anthropogenic impacts – the more they realised how complex, variable and heterogeneous these systems were. In a

⁸⁹ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 2, p. 25.

changing social environment, the park could also no longer shut out the other stakeholders located upstream of its water systems, but rather had to work with these stakeholders towards a common goal. It became clear that the Kruger National Park's rivers could not be adequately managed under the traditional "command and control" management style which sought to stabilise the natural variability in the system within the Kruger National Park fences.⁹⁰

Sanparks did loosen its rigid management over the Kruger National Park's water resources once the KNP rivers research programme started, changing from trying to taming the natural variability of the system to adopting a more casual approach that allowed nature to "take its course".⁹¹ However, as a result of this management style, management decisions became too reactive to situations such as drought and pollution.⁹² What was required then was a management strategy that was flexible enough to support and sustain the inherent variability in these systems while allowing management to take proactive decisions to prevent the long-term degradation of the system. Rogers and Bestbier describe this type of management style, known as strategic adaptive management, as one that focuses on establishing a "balance in nature".⁹³ Instead of establishing management rules that diminish natural variability and reacts to extreme events strategic adaptive management recognises the "flux in nature", and rather aims to be proactive towards extreme events.⁹⁴

Sanparks introduced strategic adaptive management in the Kruger National Park towards the end of the second phase of the KNP rivers research programme in 1995.⁹⁵ Once successfully applied to the management of the rivers in the Kruger National Park, strategic adaptive management was expanded to the entire park. It remains the framework around which all ecosystems in the park are managed.⁹⁶ This management process has also seen wider application. When the Inkomati Catchment Management

⁹⁰ VVPA, OA1, H. Biggs, former Sanparks senior scientist, 2015-06-06.

⁹¹ VVPA, OA1, H. Biggs, former Sanparks senior scientist, 2015-06-06.

⁹² VVPA, OA1, H. Biggs, former Sanparks senior scientist, 2015-06-06.

⁹³ K. Rogers & R. Bestbier, Development of a protocol for the definition of the desired state of riverine systems in South Africa, p. 29.

⁹⁴ K. Rogers & R. Bestbier, Development of a protocol for the definition of the desired state of riverine systems in South Africa, p. 29.

⁹⁵ D.J. Roux & L.C. Foxcroft, The development and application of strategic adaptive management within South African National Parks, *Koedoe*, 53(2), May 2011, p. 1.

⁹⁶ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

Agency (now the Inkomati-Usuthu Catchment Management Agency or IUCMA) was established in 2006 it also adopted strategic adaptive management as its approach to overseeing integrated water resources management of the Inkomati and Usuthu river catchments.⁹⁷ The strategic adaptive management approach works off the premise that nature is heterogeneous and variable and that it can be, at times, unpredictable.⁹⁸ The management process starts by selecting a mutually-accepted “desired state” or common vision in consultation with stakeholders, which is then translated into a set of operational goals aimed at achieving this vision.⁹⁹ The third step is to set up the necessary action plans for implementation. Scientific learning is integrated into the system in the form of continuous monitoring. Knowledge about the system and how it reacts to management decisions is continually fed back to the planning stages.¹⁰⁰ As more knowledge becomes available management processes are altered and improved, therefore making strategic adaptive management a “learning by doing” approach.¹⁰¹ In this way, management of the system is continually improved. An important part of the monitoring process is to set thresholds against the variability of the system that, if exceeded, indicate that the system has reached beyond the limits of acceptable change and is being compromised. These indicators are known as “thresholds of potential concern”.¹⁰²

One of the first steps under the Kruger National Park’s new management regime was to review its water policy, which it did in 1997.¹⁰³ Investigations showed that, while the provision of dams and boreholes in the park had good intentions, it had some unexpected side-effects. The provision of water, where previously there had been none, opened bigger areas for grazing. However, this led to overgrazing and changed the composition of foliage in some areas, with other, good grazing areas being replaced by unpalatable

⁹⁷ K.R. Rogers & R. Luton, Building an adaptive and stakeholder-centred catchment management agency in the Inkomati/Usuthu river catchment, p. 2.

⁹⁸ D.J. Roux & L.C. Foxcroft, The development and application of strategic adaptive management within South African National Parks, *Koedoe*, 53(2), May 2011, p. 1.

⁹⁹ K. Rogers & R. Bestbier, Development of a protocol for the definition of the desired state of riverine systems in South Africa, p. 15.

¹⁰⁰ D.J. Roux & L.C. Foxcroft, The development and application of strategic adaptive management within South African National Parks, *Koedoe*, 53(2), May 2011, p. 3.

¹⁰¹ R.T. Kingsword & H.C. Biggs, Strategic adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world, p. 7.

¹⁰² R.T. Kingsword & H.C. Biggs, Strategic adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world, p. 24.

¹⁰³ I.P.J. Smit, Systems approach towards surface water distribution in Kruger National Park, South Africa, *Pachyderm*, 53(1), January-June 2013, p. 92.

grasses.¹⁰⁴ During the 1980s the lack of fodder led to massive starvation as grazers could now easily reach previously difficult accessible areas.¹⁰⁵ Sanparks began to systematically close the artificial water points in a programme that has persisted up to present times. Of the 325 boreholes that once existed in the Kruger National Park 185 had been closed by 2016.¹⁰⁶ Dams and weirs that have become silted up or breached by floodwaters are targeted for removal.¹⁰⁷ The Kruger National Park's current water management policy was severely tested during the El Niño induced drought of 2015-16. The closure of artificial waterholes created pockets of good grazing away from water.¹⁰⁸ While the park did suffer animal casualties, especially among the hippopotamus and buffalo populations, it was mostly old and sick animals which perished, as stronger animals were able to reach these forage areas.¹⁰⁹

A particular challenge of the KNP rivers research programme was what to do with the reams of data emanating from its projects so as to ensure they would remain accessible to all the parties participating in the programme. This became the goal of the information systems development and management sub-programme. All of the data emanating from the programme, including documents, models, flow records and multimedia were taken up in the Computing Centre for Water Research (CCWR), a computer-based information system established at the University of KwaZulu-Natal in collaboration with the WRC and IBM, in 1986, to provide a central database for water researchers.¹¹⁰ The data was grouped into a number of categories, namely hydrology and catchment studies, geomorphology and hydraulics, geographic information systems, water quality, instream flow, biota, conservation status and importance, legal/decision support systems, and a hard copy catalogue created which listed each item.¹¹¹ While this arrangement made the

¹⁰⁴ I.P.J. Smit *et al.*, Do artificial waterholes influence the way herbivores use the landscape? Herbivore distribution patterns around rivers and artificial surface water sources in a large Africa savannah park, *Biological Conservation*, 136 (1), April 2007, p. 86.

¹⁰⁵ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹⁰⁶ A. Watson, Kruger Park closes five man-made watering points to restore ecosystem, *The Citizen*, 2016-12-08, <http://citizen.co.za/news/news-national/136929/kruger-park-closes-man-made-watering-points-to-restore-ecosystem/>.

¹⁰⁷ VVPA, OA1, F. Venter, Sanparks Head: Conservation, 2016-06-22.

¹⁰⁸ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹⁰⁹ VVPA, OA1, D. Pienaar, Sanparks Head: Scientific Services, 2016-06-23.

¹¹⁰ G. Jewitt & J. Smithers, The computing centre for water research: Lessons learned (a user perspective), slide 4.

¹¹¹ H. Biggs *et al.*, KNPRRP Information systems and data management subprogramme data catalogue Vol I-IV. (WRC Report no. 655.883/1-4/00, WRC: Gezina, 1998).

data emanating from the KNP rivers research programme available to a wider audience – both within and outside the programme – little attention was given to the sustainability of the arrangement over the long term. In 2002, the CCWR lost its funder and its host and a process was started to phase out the centre.¹¹² Despite enquiries, it could not be established whether the database of the KNP rivers research programme is still intact although its web address is no longer functional.

7.4 Phase 3 (1997-1999)

By the time the KNP rivers research programme entered its third phase in 1997, the milieu in which the programme was operating was vastly different to the one in which it had started in 1988. South Africa's water law review process was now in full swing (a process that was taking place outside of the programme), and the needs of the environment were not only accepted but were being actively catered for in South Africa's new water legislation. The emphasis of phase 3 was therefore not so much on gathering further scientific information, but on consolidating existing information and processes and packaging it in such a way that it could be applied for decision-making and monitoring and therefore contribute maximally to the new water resources management paradigm that was being established in South Africa.¹¹³ Various scientific modelling tools – aimed to improve the predictive capability of integrated river managements, were developed and improved during this phase of the programme.¹¹⁴ The philosophy underlying the change was that the rivers flowing through the Kruger National Park were “common property resources” and thus management of these water resources could not take place in isolation from the needs of water users in the catchment.¹¹⁵

Recognising the need to include all stakeholders in the catchment management process (particularly those that had been previously marginalised) phase 3 also focused on raising emphasis of the importance of aquatic ecosystems among all water users and, in particular, strengthening the river forums which had been established during phase 2 of

¹¹² G. Jewitt & J. Smithers, The computing centre for water research: Lessons learned (a user perspective), slide 11.

¹¹³ VVPA, OA1, C. Breen, Former programme manager: KNP rivers research programme, 2015-07-07.

¹¹⁴ C. Breen *et al.*, The Kruger National Park river research programme. Final report, pp. 28-39.

¹¹⁵ SAWHAR, Waterlit Collection, C. Breen, Change: A strategic leadership issue for river management. Paper presented at a conference on Integrated Management of River Ecosystems, organised by the Kruger National Park rivers research programme, 10-11 August 1999.

the programme.¹¹⁶ For this purpose a new sub-programme, the integrated river sub-programme, was established alongside the other existing sub-programmes.¹¹⁷ Freek Venter of Sanparks was appointed the manager of this sub-programme. A useful outflow from the KNP rivers research programme has been the Shared Rivers Initiative. A programme driven mainly by the non-governmental research organisation (NGRO), the Association for Water and Rural Development (AWARD), the initiative is aimed at driving and tracking implementation of the catchment management goals of the NWA.¹¹⁸ However, as the Shared Rivers Initiative has also illustrated, while the South African water laws have evolved, institutional change has occurred more slowly, and thus stakeholders such as the DWA were still undergoing transformational change when the KNP rivers research programme ended in 1999.¹¹⁹ This has meant that many of the tools put in place by the programme has remained under-utilised and a feeling by some participants that the programme was perhaps terminated prematurely.¹²⁰

The authors of the final report wrote in 2000 that they

*underestimated the complexity of transformation. It will be some time before the institutions being set up and those which already have responsibilities for contributing to river management have made the conceptual and organisational transformations which are required to effectively engage strategic adaptive management of river systems.*¹²¹

The Kruger National Park itself proved the most receptive to the tools and processes introduced by the programme, as illustrated by the continued use of the strategic adaptive management framework.

¹¹⁶ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 3, p. 31.

¹¹⁷ SAWHAR, Waterlit Collection, C. Breen *et al.*, A description of the Kruger National Park rivers research programme: Phase 3, p. 42.

¹¹⁸ Anon, Shared Rivers Initiative: Supporting the wise use of southern Africa's waters, *The Water Wheel*, 12(3), March/April 2013, p. 15.

¹¹⁹ VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

¹²⁰ VVPA, OA1, K. Rogers, Former researcher, 2015-05-05.

¹²¹ C. Breen *et al.*, The Kruger National Park river research programme. Final report, p. 49.

7.5 Conclusion

The KNP rivers research programme was the most ambitious collaborative ecological research programme ever to be undertaken in South Africa.¹²² The programme had three distinct phases, evolving from a narrow, research focused first phase to a third phase focused on the implementation of knowledge-based decision-making. A crucial aspect in the success of the programme was the direct involvement of top decision-makers in the management committee, which allowed research outcomes to be shared in a direct line and thus improved chances of the uptake of research information. No direct line can be drawn between the KNP research programme and the environmental reserve, but at a time when the South African government was re-evaluating its policies around the aquatic environment the programme built critical mass in the ecological science space. The programme also provided an enabling environment for scientists and decision-makers to reach across their individual disciplines and collaborate towards the common goal of the conservation of the Kruger National Park's rivers. Thus, the influence of the programme was rather more subtle in practically illustrating the important links between maintaining natural flow and keeping ecological processes intact. In this way the KNP rivers research programme has left a lasting legacy, particularly in the Kruger National Park itself where the strategic adaptive management framework developed during the programme is still being used today. The programme also allowed park managers to reach across the borders to other water users in the catchment and today the Kruger National Park is considered a strategic player in the Lowveld river catchments.

¹²² J. King & D. Louw, Instream flow assessments for regulated rivers using the Building Block Methodology, *Aquatic Ecosystem and Health Management*, 1(2), January 1998, p. 110.

Chapter 8 Conclusion

When the National Water Act [Act No 36 of 1998] was passed it marked the first time in South African history when the right of the environment to water (the environmental reserve) became enshrined in the country's laws. The role of aquatic sciences, particularly the sub-discipline of ecological flow science, is acknowledged as playing an important role in the passing of the Act. Yet there has been little by way of historiography on how aquatic science and the aquatic science community have evolved in South Africa and how this influence played itself out in South Africa's water legislation. The influence of collaborative, multidisciplinary aquatic science programmes in driving policy changes during the 1980s and 1990s had not been subject to detailed historical investigation. This study aimed to, by way of a historical discourse, determine a part of the history of aquatic science that led to the passing of the environmental reserve in the South African water legislation. The study specifically focused on the Kruger National Park and the KNP rivers research programme, a multidisciplinary, collaborative, aquatic research programme, which ran from 1988 to 2000.

The study first defined the characteristics of freshwater ecosystems, more specifically, rivers as a way of underlining the importance of river system in the historical development of humankind. Rivers are indivisible from their catchments, making them difficult to conserve. Counted among the richest habitats on earth, these freshwater ecosystems contain almost a third of vertebrate species on Earth. Arguably the most important characteristic of a river is its flow, which shapes it geomorphologically and determines the extent of biotic and abiotic life along its reaches. Anthropogenic disruptions to flow, such as the construction of dams and the abstraction of water, therefore, have a marked impact on the ecological functioning of a river. South Africa's river systems are naturally influenced by the country's semi-arid climate, high evaporation rates and general topography. Because of the country's generally low, erratic rainfall, the country's rivers are highly variable, with only a quarter of South Africa's rivers flowing throughout the year. While South African rivers are generally species poor compared to the international average, the country's rivers generally host a high number of endemic species, which have adapted to naturally erratic flow conditions.

It is clear from the research that man's influence over freshwater ecosystems stretches over thousands of years back to at least the first agricultural societies, and is thus not limited to South Africa. Evidence of this influence is found in the remnants of ancient civilisations along the Nile, Euphrates, Tigris, Indus and Yangtze rivers as the review of literature on this subject has showed. Even these early disruptions of natural flow impacted on the natural ability of river systems to deliver ecological services and may have had an impact on the longevity of these civilisations. As man's scientific and technological abilities grew so did his proficiency to alter water courses to suit his needs. The industrial era – along with technological innovations such as the water wheel – spurred on the acceleration of dam-building in particularly Europe and the USA where advances in engineering and construction also saw the rise of the first large dams to supply water and hydropower to cities and industries. A visual impact of these disruptions was the diminishing of fisheries. The technological advances made during the Second World War again saw the amplification of water resource development, particularly in First World countries, but also in developing countries such as India, Brazil and South Africa. Today, there are more than 45 000 large dams registered with ICOLD.

South Africa is considered a leading dam-building nation, although the country's water resource development history is relatively young, with dams only having been constructed over the last 300 years. Rather than manipulating freshwater ecosystems, indigenous pre-colonial cultural communities were well adapted to the semi-arid environment. As a result of their nomadic lifestyles, their impact on the water environment is thought to have been minimal. Bantu-speaking farming communities practiced forms of irrigation and rainwater harvesting although the nature of water resource development among these communities remain largely unexplored. It was the first European settlers who brought dam- and canal- building expertise from their well-watered homelands to the South African environment. The first modernist water storage structures were constructed in the 17th century at the Cape to serve the European community as well as passing ships. The discovery of gold and diamonds in the 1800s provided important impetus to water resource development in South Africa. The sudden influx of people into hitherto small towns and the establishment of new urban centres resulted in a sharp rise in demand for water supply and technical expertise. Growing populations also proved favourable for the agricultural sector, which started building more dams to irrigate larger fields of crops to be sold at market. At the time of unification in 1910, the irrigation sector was responsible

for 96% of all water used in South Africa. The Irrigation Department (established in 1912) provided engineering expertise for the construction of the country's first large dams – all aimed at irrigation. During the economic slump in the 1930s, the Union government launched a series of infrastructure projects to relieve unemployment, particularly among the white population. Some of the country's largest dams were constructed during this period (built mostly through manual methods) including Loskop, Clanwilliam and Vaal dams. In line with international trends, dam building reached a peak in South Africa in the post-war period up to 1980, by which time the country had constructed dams and water transfer schemes on all its major river systems. Today, South Africa's large dams store about 70% of the country's mean annual runoff and the country remains among the top ten countries in the world in terms of its number of large dam structures.

The study then turned to the Lowveld and the historical development of the river catchments that feed into the Kruger National Park, which is in the north-eastern corner of South Africa. The park's main water supply comes from five historically perennial rivers, including the Sabie River, which is considered the most biologically diverse river in South Africa. The Lowveld rivers are subject to ten-year climate cycles that oscillate between wet and dry years, showing great flux in flow regimes. These rivers receive little water inside the Kruger National Park, making the park particularly vulnerable to human activities outside its borders. In turn, the lack of downstream rainfall influences river flow across the park boundary into neighbouring countries. South Africa's water resource development history is mirrored in the Lowveld. This part of the country has been inhabited by people for thousands of years. Evidence suggests that these ancient communities made use of the ecological services offered by rivers, particularly for food, shelter, and water supply although their water footprint was small. Metalworking communities exploited copper, and iron ore resources, particularly in the Olifants River catchment and would have used water as part of the metalworking process. The main human activities that have influenced the rivers in the Lowveld have been agriculture, mining, and forestry. Artisanal mining became superseded by commercial activities when gold was discovered in the Lowveld in the 19th century. The ensuing gold rush prompted an influx of people and a proliferation of economic activities, including the establishment of towns such as Barberton and Phalaborwa, and the building of railways. Agriculture initially remained limited to areas relatively free of tse tse fly and mosquitoes but later expanded to large, commercial settlements around agricultural centres, including

Hazyview, Malelane and Tzaneen. Increasingly, large bulk water infrastructure was developed to overcome the natural variability of flow in the Lowveld rivers, the latest dam, De Hoop, being completed in the Steelpoort river as recent as 2014. Stands of exotic trees, planted in the upper catchments, have reduced the mean annual runoff of the rivers. These anthropogenic activities have affected the integrity of the aquatic ecosystems in the Kruger National Park, particularly in winter and drought years when flow is drastically reduced causing some of the rivers to cease flowing.

The Kruger National Park's rivers benefited from the evolution of aquatic science in South Africa, particularly ecological flow science. South Africa's aquatic science knowledge grew out of concern for the country's deteriorating freshwater environment and a curiosity about how these systems operated. However, it was not until the modification of river flow and concomitant pollution started having significant impacts on human health that science evolved from the mere counting and naming of species to higher level ecosystem studies. European travellers provided the first recorded scientific observations of the South African waterscape, garnering information about climatic conditions, topography, water resources, geography and the way in which local communities harnessed ecosystem services. These early recordings were influenced by the way that South Africa waterscapes were so fundamentally different from the European waterscapes these travellers were akin to. The early European scientists were aware of South Africa's aridity and the general variability of the country's rivers systems. Early studies were mostly focused on zoological and biological finds. The first hydraulic engineers who arrived at the Cape in the 19th century also studied the hydrological behaviour of South African rivers. The aquatic science sphere continued to be dominated by taxonomic studies following the establishment of the Union of South Africa, and various freshwater plants and animals were named and described by scientists stationed at universities and museums. From these taxonomic studies evolved disciplines such as medical entomology, and it was medical entomologists who first voiced their concern over the potential impacts of flow disruptions to the freshwater aquatic environment. While these scientists focused on water-related diseases such as malaria and schistosomiasis, they did note the fact that aquatic communities change when flow regimes are altered through, for example, the construction of a dam.

The intensification of the industrial sector prompted fears of pollution and spurred the development of the first water pollution studies in South Africa, with a focus on the eutrophication of water courses. A significant highlight in the history of South African aquatic science was the establishment of the CSIR and its water research unit, the NIWR, which was responsible for leading significant advances in the aquatic science sector. The unit not only made meaningful strides in wastewater and industrial effluent treatment, but also launched large-scale hydrobiological studies in rivers in the country. The CSIR studies made some startling revelations in terms of how human actions had influenced aquatic ecosystems in South Africa. The studies also contributed to building a small, but productive community of practice in South Africa. Among the most in-depth river studies were those undertaken in partnership with the Natal Provincial Town and Regional Planning Commission and the University of Natal on KwaZulu-Natal's major river systems. The studies must be considered an important milestone in the evolution of aquatic science in South Africa, as they started to draw a clear line between land use practices in a catchment and the impact on the receiving river system.

The CSIR was at the forefront in South Africa in launching one of the first collaborative science programme in the 1960s. South Africa's participation in the international IBP programme led to the launch of a national initiative, the NPES in 1972. While the research projects undertaken under this programme had a strong bias towards standing waters (i.e. artificial reservoirs) as opposed to flowing water, they did much to build capacity in the aquatic sciences field in South Africa, particularly in limnology. Several water research groups were established at universities as a result of the programme. The KNP rivers research programme would later be mirrored on these early collaborative programmes, and include many of the same roleplayers. The participation of decision-makers in these programmes started influencing government thinking around development and the aquatic environment and in 1980 environmental impact assessments became part of DWA policy. Environmental management plans were launched at some water infrastructure projects to reduce their impact on the surrounding landscape. In 1986, while not yet reflected in law, the DWA officially recognised the environment as a legitimate water user. The most influential of the NPES projects with regards to water was the Pongolo floodplain research programme undertaken between 1967 and 1987. This was the first comprehensive study in South Africa focusing on water releases for human and environmental benefit and the resulted in the first attempt by government to coordinate

releases from a dam for ecological purposes. The programme also illustrated the dependence of communities on intact ecological processes. South Africa was not subjected to the environmental activism experienced in the USA in the 1960s and 1970s. Rather it was the above-mentioned collaborative science programmes – which brought deliberate interaction between aquatic scientists and government decision-makers – that led to an increased environmental awareness in the South African government. Despite the country's political isolation South African decision makers at the DWA (mostly engineers by discipline) were well aware of the changes on the international arena, thanks to South Africa's membership of organisations such as ICOLD. This would have influenced local initiatives, such as the establishment of EPPIC, aimed at incorporating environmental awareness into infrastructure development initiatives.

The Kruger National Park played an important role in the development of aquatic science and water resource management in South Africa. While the park was not originally established with freshwater ecosystems in mind, the dependence of this premier nature reserve on the perennial rivers flowing through its borders turned the park into a living laboratory for the testing of new scientific theories and management approaches. The iconic status of the park – both in the eyes of conservationists and in the eyes of policy makers – undoubtedly played a crucial role in ensuring collaboration to ensure the park's sustainability. The location of the park at the downstream end of the river catchments means that it has had to cope with reducing flows of deteriorating quality because of upstream anthropogenic activities. These impacts, along with the fact that before 1998 the environment had no legal right to water, drove the park to seek alternative ways to ensure water for its tourists and animals. In the decades preceding the KNP rivers research programme Sanparks tested various approaches to water management – all within its own borders (which was the only part of the catchments under its control). Sanparks started with a *laissez faire* approach up to 1946 where nature could establish its own equilibrium. Dams and boreholes constructed during the early years of the park's history were mainly aimed at discouraging animals from migrating out of the then unfenced park towards better watered areas and providing water for tourists and personnel. Human intervention became intensified once the park became fully fenced in 1963. This was done through the park's water-for-game programme, which augmented natural water supply with an exponentially increasing number of artificial waterholes and dams. It is perhaps ironic that this management approach relied strongly on the

engineering expertise of the park, rather than on conservation approaches. It therefore mirrored the command-and-control approach of the national government aimed at reducing the troughs and the peaks of natural water flow that persisted in South African natural water resource management until the nineties.

It was only once the KNP rivers research programme highlighted the negative impact of these alternative water resources, not only for the freshwater ecosystems but also for the wildlife of the Kruger National Park that the rollout of dams and boreholes slowed. In 1997 the KNP rivers research programme introduced a new management regime. Strategic adaptive management recognises nature's inherent variability, and instead of reducing this variance aims to optimise management around it. A "learning-by-doing" approach this management method aimed to govern the ecosystem towards a "desired state" by continually increasing scientific knowledge and getting to know the ecosystem – and its processes – better. It is clear from this research project that an important factor in the Kruger National Park's approach to water management has been its interaction with upstream water users and government decision-makers. As long as park management remained inwardly focused it could not manage to successfully curb the impact of upstream anthropogenic activities on the rivers entering the Kruger National Park. It was only once Sanparks started engaging with other water users – particularly irrigation boards and the DWA – that it could effect change in the way water was being managed in the catchments that feed into the perennial rivers.

At the same time Sanparks made increased calls to the DWA to acknowledge the Kruger National Park as a legitimate water user in the Lowveld. In 1970 the park, along with St Lucia, became the first conservation areas for which water was set aside following the commission of enquiry into water matters in South Africa. The commission recommended that 1% of South Africa's water resources be allocated to the environment (namely St Lucia and the Kruger National Park). The commission's recommendation did not, however, guarantee water to the Kruger National Park. While Sanparks increasingly recognised the value of its rivers – not only as sources of water for tourists and game but also as rich ecological entities in their own right – its calls to government to conserve the Lowveld rivers was made difficult by the fact that so little was known about their ecological functioning. As the 1980s drought caused some of the KNP perennial rivers to run dry, the DWA along with Sanparks hosted the 1987 Skukuza workshop – a meeting of aquatic

scientists and policy makers that became the first attempt at determining the ecological flow needs of South Africa's rivers.

It is clear from the research that the legal right South Africa now bestows on its aquatic environment did not evolve in a linear fashion and is not the result of a single individual, entity or programme, but is rather the culmination of various developments in various spheres that converged at the right time. The Skukuza workshop is an important marker in aquatic science history in that it not only launched the KNP rivers research programme, but also initiated the first dedicated research into locally-developed ecological flow methodologies in the country. Prior to this workshop there had been no concerted efforts to develop ecological flow methods for South African rivers apart from tentative attempts by South African engineers. Various ecological flow methods existed prior to the South African effort. However, these early methods, developed for well-watered Northern Hemisphere rivers, mostly focused on determining minimum flows rather than the quantity and quality of flows required by the river ecosystem throughout the year. After attempted application of these methodologies on South African rivers showed how inadequate they were for local requirements South African aquatic scientists sought to develop their own, more holistic methods, in collaboration with Australia, who was grappling with the same challenge. Together the two countries developed the first holistic ecological flow tools aimed at not only protecting key river species, but rather the entire aquatic ecosystem through predicting the quality and quantity of flow required throughout the year.

While the inadequacy of South Africa's water laws for the protection of its aquatic environment had been debated for some time before 1994 the democratisation of the country and concomitant law review process provided the opportunity to finally legally protect the country's rivers. The dependence of communities on ecological services allowed for the right of the environment to water to be combined with the human right to water. The DWA IFR workshops were organised outside the sphere of the water law review process that occurred after 1994 and was rather an attempt at improved water resource management on the side of the department. However, because of this process – and the research that preceded it – lawmakers became confident in the South African aquatic science fraternity's ability to determine ecological flows and hence, included it in the NWA.

While the KNP rivers research programme was specifically focused on the functioning and management of the Lowveld's river ecosystems it was certainly timely. It is unlikely that the programme would have received as much attention (or funding) had South Africa not at the time of its launch entered a period of reflection with regards to environmental policies, particularly around water. The fact that the DWA had by that time accepted the environment as a legitimate water user resulted in fertile ground for the research outcomes of the programme. The Lowveld rivers became the testing ground for new scientific methods, which helped convince authorities that ecological science was mature enough in South Africa for the reserve to be written into law. Thus, the KNP rivers research programme became a conduit which allowed for scientific outputs to be fed directly into new policy. The aquatic science community used the opportunity of South Africa's post-1994 law review to ensure that the right of the environment was written into the country's new water laws.

The programme also made important contributions to the building of critical mass in the aquatic science sector in South Africa. As the largest collaborative aquatic science programme ever undertaken in South Africa, the programme launched the careers of many young aquatic scientists, many of whom would later go on to head research units at universities and private organisations. The programme also made important contributions to the various sub-disciplines that fall under the greater umbrella of aquatic science, such as fluvial geomorphology. In addition, the KNP rivers research programme provided an important platform for collaboration between scientists and decision makers, driven by the fact that knowledge transfer was an important objective of the programme from the start. In the course of discussion and debate members of both parties were forced to reach outside their respective disciplines to find solutions towards a common goal. The high-level management of the programme ensured that information was constantly fed into the decision-making structures of the organisations involved. The involvement of funding organisations such as the WRC resulted in much of the findings of the research undertaken under the programme reaching the public domain in the form of research reports. Further the KNP rivers research programme opened the doors of the Kruger National Park to external researchers. As many as 300 research projects – across various disciplines – are now conducted in the park on a yearly basis, and a permanent research camp has been set up at Skukuza for this purpose.

The KNP rivers research programme firmly established the Kruger National Park as a key stakeholder in the management of water in the Lowveld river catchments. The park undertakes frequent river monitoring activities and corresponds with external water users on a regular basis. The longevity of Sanparks' engagement with other water users has had long-lasting repercussions such as the fact that during the 2015/16 El Niño induced drought, none of the perennial rivers entering the park stopped flowing. While not a focus of this research project the fact that the first catchment management agency in South Africa, the Inkomati-Usuthu Catchment Management Agency, was established around the Lowveld rivers is significant and bears further investigation.

A significant concern emanating from this research is the apparent demise of the KNP rivers research programme database following the phasing out of the CCWR. This points to a larger challenge in the South African water sector. Information previously captured in electronic databases and hard copy collections, which today have substantial historical value, are at risk of being lost. The establishment of SAWHAR by NWU is a positive response to this challenge and should be expanded to capture what remains of these, now dormant, databases.

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