ORANGE - SENQU RIVER COMMISSION
BOTSWANA LESOTHO
ORASECOM
NAMIBIA SOUTH AFRICA
Established 2000

IMPROVING GROUNDWATER KNOWLEDGE IN SELECTED TRANSBOUNDARY AQUIFERS

Joint Survey Process Report

May 2018

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The *Support to* ***the Improving Groundwater Knowledge in Selected Transboundary Aquifers*** Study was commissioned by the Secretariat of the Orange-Senqu River Commission (ORASECOM) with technical and financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ), in delegated cooperation with the UK Department for International Development (DFID), implemented through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

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ORASECOM SECRETARIAT

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Joint Basin Survey Process Report

Approved by the Consultant:

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IMPROVING GROUNDWATER KNOWLEDGE IN SELECTED TRANSBOUNDARY AQUIFERS

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DOCUMENT INDEX

Index Number	ORASECOM Report Number	Report Title
1		**Inception report**
2		Draft final report with updated groundwater recharge estimates in the main recharge areas in the Karroo Sedimentary and the Khakhea/Bray Dolomite Aquifers
3		An agreed list of priority transboundary aquifer features & characteristics, and groundwater quantity & quality parameters and variables of concern, and a list of those areas within the Orange-Senqu River Basin where aquifer characteristics, and groundwater quantity and quality issues are of particular concern
4		A web-based robust framework/programme/system for monitoring and management of important transboundary aquifer

Index Number	ORASECOM Report Number	Report Title
		features/characteristics, and groundwater quantity & quality of all transboundary aquifers in the Ba-sin
5		Report indicating inputs made at the stakeholder's workshop
6		Final Recharge report
7		User manual of the established groundwater information system.
8		Report on the joint survey

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1 INTRODUCTION

1.1 BACKGROUND

The four southern African countries, Botswana, Lesotho, Namibia and South Africa, each have a contribution to the Orange-Senqu River Basin both in terms of surface water and groundwater. To address the issue of transboundary groundwater, the SADC framework comes into play. The ***SADC Protocol on Shared Watercourses (adopted 1995, revised 2000)*** was framed to set the rules for the joint management of regional water resources. The overall objective of this Protocol is to foster closer cooperation for judicious, sustainable and co-ordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration.

The Protocol is the SADC legal instrument that promotes the concept of Integrated Water Resources Management. The ***Regional Strategic Action Plan on Integrated Water Resources Development and Management (RSAP, 1998***) includes seven areas of intervention identified as key issues for the Region: Legal and regulatory framework; Institutional strengthening; Linkages with sustainable development policies; Data collection, management and dissemination; Awareness building, education and training; Stakeholder participation; and Infrastructure Development.

One of the objectives of the 'Improving Groundwater Knowledge in Selected Transboundary Aquifers' Project is the undertaking of a ***joint basin survey*** (JBS), by the members of the GWHC in order to foster closer cooperation by specialists in member states and increase awareness of transboundary issues. ORASECOM intends the joint survey to provide hands-on field observation of key transboundary aquifers, and the issues of concern to members of the GWHC.

This Process Report is to include a checklist of parameters and features for observation by a joint team of officials responsible for groundwater from the four State Parties. A subsequent report is to be based on the findings and provide justification of features to observe and recommendations on further and similar joint surveys.

Experiences from the survey will enable the GWHC members to give technical advice to the Member States regarding the relevance of transboundary issues. Moreover, the JBS provided the opportunity for experts from the Member States to exchange ideas. This interaction helps to facilitate a mandate of ORASECOM to establish dialogue and assist with the exchange of information.

1.2 Checklist of Processes to be Observed

- Alluvial wellfields that may impact on baseflow (Maputsoe wellfield)
- Highland wetlands and their role in Interflow and baseflow to transboundary rivers (Wetlands in the Lesotho Highlands)
- Gauging Station that monitors transboundary flow (Oranjedraai)
- Abstraction that affects transboundary aquifers (Tosca-Verlegee)
- Discharge from dolomitic compartments (Kuruman eye)
- Discharge from a transboundary aquifer sustaining an ecosystem (Rooiputs water hole)
- Recharge area of a transboundary aquifer (Stampriet

2 COORDINATION AND LOGISTICS

2.1 Background

Planning for the JBS was initiated during the Visit to the State Parties and their relevant national departments, where the relevant staff in each member state were asked to identify areas they would like to visit, and which areas in their country they thought would be of interest to delegations from other countries.

The survey is to be undertaken by a core team made up of two staff from each of the Member States and a member of the ORASECOM Secretariat. The Joint Basin Survey was made possible by the funds from GIZ. The Survey will be supported by the respective line departments of the governments of the ORASECOM member States.

One of the key objectives of the JBS was to promote interaction among the specialists from each of the ORASECOM Member States. To encourage this, transboundary aquifers were process could impact on neighbouring countries were identified and sites for visitation were selected. For the site visits a brief background of eac is given in Chapter 3 to provide the delegates with some background, and an example list questions for the survey team to discuss are presented to facilitate awareness of the issues of concern.

An estimated distance of 3000 km will be covered by the team within a time frame of 7days.

2.2 Local Contribution

It is expected that the delegates from each host country will facilitate site visits and provide additional background information on the sites.

2.3 Itinerary

The planned itinerary is provided in table 2-1.

Table 2-1 Travel Itinerary

Description	Day	Date	Distance (km)	Hours, Minutes
Arrival in Maseru	Sunday	9 September 2018		
(i) 2 x Batswana people x air ticket – Maun tp Maseru 1 x Batswana People x air-ticket :- Gaborone to Maseru	Sunday	9 September 2018		1hr
(ii) 2 x Namibian People x air-ticket :- Windhoek to Maseru	Sunday	9 September 2018		1hr40min
(iii) 4 x South African People x air-ticket :- Johannesburg to Maseru	Sunday	9 September 2018		0.55min
Travelling to Maputsoe Wellfield	Monday	10 September 2018	20	30min
Visiting Maputsoe Wellfield	Monday	10 September 2018		1 hr
Travelling from Maputsoe to Lesotho Highlands and Wetlands	Monday	10 September 2018	214	3hrs

Lunchbreak	Monday	10 September 2018		1hr
Travelling back from Lesotho Highlands to Maseru		10 September 2018	214	3hrs
Overnight in Maseru	Monday	10 September 2018		overnight
		Total Monday	**448**	**10 hrs**
Travelling from Maseru to Oranjedraai	Tuesday	11 September 2018	164	2hrs
Oranjedraai visit	Tuesday	11 September 2018		2hrs
Travelling to Gariep dam	Tuesday	11 September 2018	228	3hrs
Lunch at Gariepdam	Tuesday	11 September 2018		1hr
Gariepdam	Tuesday	11 September 2018		2hrs
Travelling to Guesthouse	Tuesday	11 September 2018	10	20min
		Total Tuesday	**238**	**8hrs20min**
Travel from Gariepdam - Vergelee/Molopo	Wednesday	12 September 2018	712	8hrs
Lunch	Wednesday	12 September 2018		1hr
Vergelee/Molopo irrigation		12 September 2018		1hr
Travel from Vergelee to Guesthouse at Tosca	Wednesday	12 September 2018	31	40min
			743	**10 hrs, 40 min**
Travelling from Tosca to Kuruman	Thursday	13 September 2018	294	3 hrs
Lunch	Thursday	13 September 2018		1hrs
Kuruman Eye	Thursday	13 September 2018		2 hrs
Travelling from Kuruman Guesthouse to Upington	Thursday	13 September 2018	266	2hrs36min
Overnight in Upington	Thursday	13 September 2018		
		Total Thursday	**560**	**9 hrs**
Travelling from Upington to Rooiputs water hole	Friday	14 September 2018	276	3 hrs
Rooiputs 1 hr	Friday	14 September 2018		1hr
Rooiputs to Upington	Friday	14 September 2018	276	3 hrs
Overnight in Upington	Friday	14 September 2018		Overnight
		Total Friday	**525 km**	**7 hrs**
Travelling from Upington to Johannesburg	Saturday	15September 2018	850	10 hours
Johannesburg Guesthouse	Saturday	15September 2018		Overnight
		Total Saturday	**380**	**10hrs**
Travel to OR Tambo airport	Sunday	16 September 2018	60	1 hr
(i) 3 x Batswana People x air-ticket :- to Maun and Gaborone	Sunday	16 September 2018		

(ii) 2 x Basotho people x air-ticket :- to Maseru	Sunday	16 September 2018		
(iii) 2 x Namibia people x air-ticket :- to Windhoek	Sunday	16 September 2018		
			60	**37 min**

2.4 Inputs and costing

The costs of, and inputs for, the overall planning and ensuring the logistical arrangements for the JBS are provided in table 2-2.

Table 2-2 Budget for Joint Basin Survey

Description	PAX	Unit	Amount per Person	Amount in Euro	Total Amount in Rands
2. Travel costs					
2.1 Joint Survey					
2.1.1 Flights and Bus Hire	11	Persons		6997	R108 460
2.2.1 Flights (Summary)					
2.2.2.0. Maun to Maseru	2	officials	R6 500	839	R13 000
2.2.2.1 Gaborone to Maseru (Lesotho)	1	officials	R 4 800	310	R4 800
2.2.2.2 Windhoek (Namibia) to Maseru (Lesotho)	2	officials	R 4 880	630	R9 760
2.2.2.3 Johannesburg to Maseru (Lesotho)	4	officials	R 3 200	826	R12 800
RETURN					
2.2.2.5 Johannesburg to Maseru	2	officials	R2 500	323	R5 000
2.2.2.6 Johannesburg to Windhoek	2	officials	R2 700	348	R5 400
2,2.2.7 Johannesburg to Gabarone	1	officials	R2 900	187	R2 900
2.2.2.8 Johannesburg to Maun	2	officials	R3 700	477	R7 400
2.2.2.6 Hiring of Bus (13 Seater)				2897	R44 900
2.1.2 Subsistence[1]	10	Officials	R 2 790	13 860	R 195 300
Contingencies @10%				1960	R30 376
Grand Total				*21 557*	**R 334 136**

1. Subsistence is based on 10 people for 7 days at R2790 per day

3 BACKGROUND OF SITES TO BE VISITED

3.1 Maputsoe Wellifled

The Water and Sewage Authority (WASA) in Lesotho is responsible for water supply and sanitation in the 13 urban areas within Lesotho, all of which are part of the Orange-Senqu River basin. The water supply scheme at Maputsoe northeast of Maseru comprises three sources andassociated infrastructure. The Mohokare/Caledon River, two well-point systems and a borehole supplying 300 m³/day.

The well-fields are installed in the sandy river bed. The Quaternary and Recent alluvial aquifers have good hydraulic characteristics although their size is limited. The hydraulic characteristics are variable and often site specific, making borehole siting difficult. Some of the largest alluvial aquifers in Lesotho are located at Maputsoe (figure 3-1).

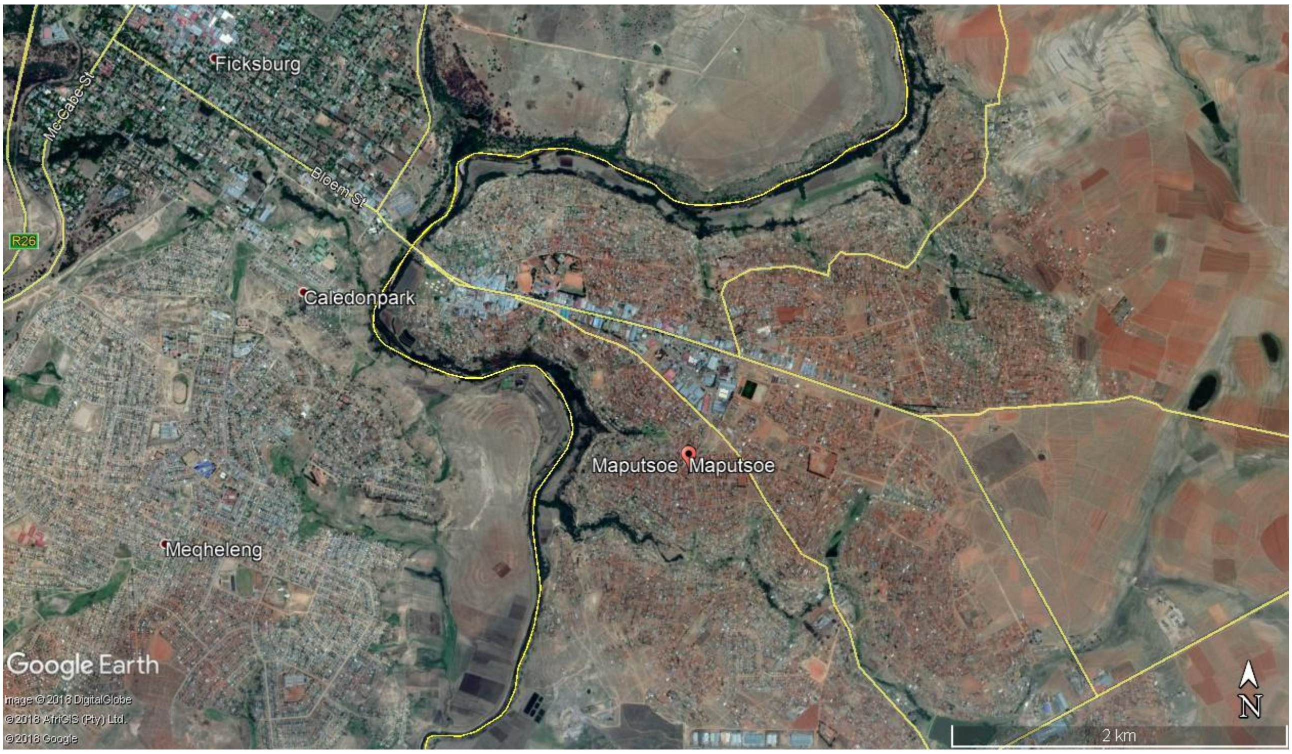


Figure 3-1 Location of Maputsoe

This wellfield provides a good basis for understanding surface-groundwater interactions. The following process can be observed:

BASEFLOW

- Groundwater baseflow discharged from the regional aquifer to surface water as baseflow to river channels, either to perennial effluent or intermittent streams.

RIVER LOSSES

- Transmission losses of surface water when river stage is above the groundwater table in phreatic aquifers with a water table in contact with the river.
- Groundwater baseflow reduction and induced recharge caused by pumping of aquifer systems in the vicinity of rivers causing a flow reversal.

Under natural conditions, the aquifer discharges baseflow to the aquifer (figure 3-2). When such aquifers are subject to abstraction, the nature of interactions may change (figure 3-3).

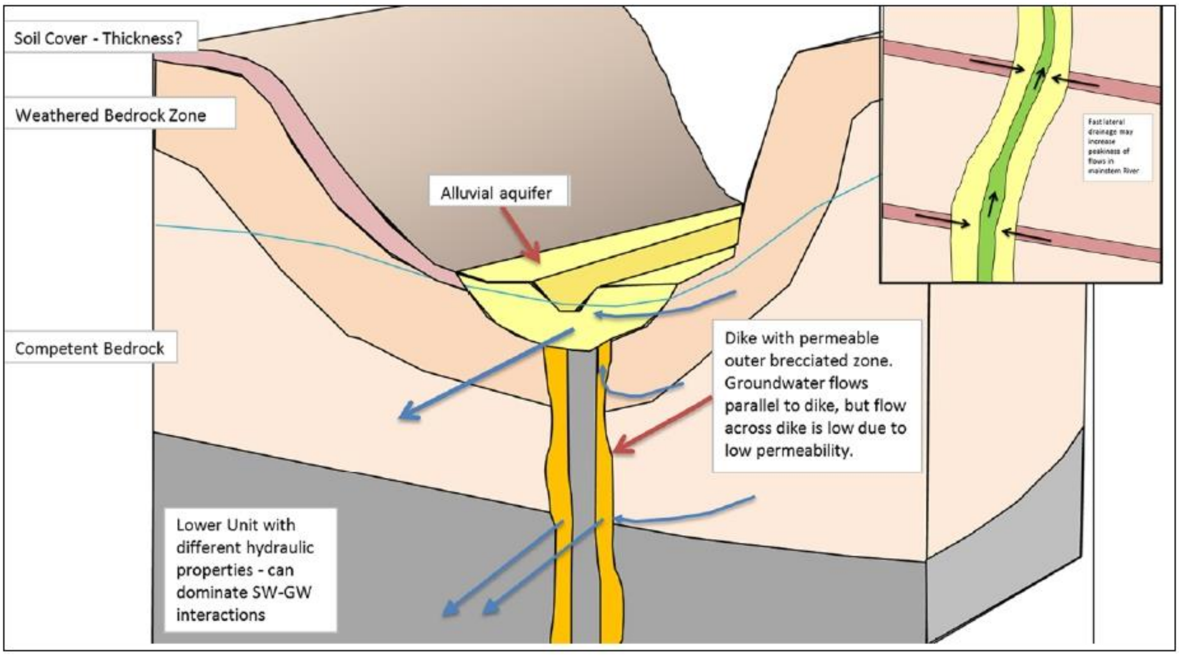


Figure 6
Conceptual flow model – local stream system with subsurface controls (dykes, layered units, weathered bedrock zones)

Figure 3-2 Surface subsurface interaction under natural conditions

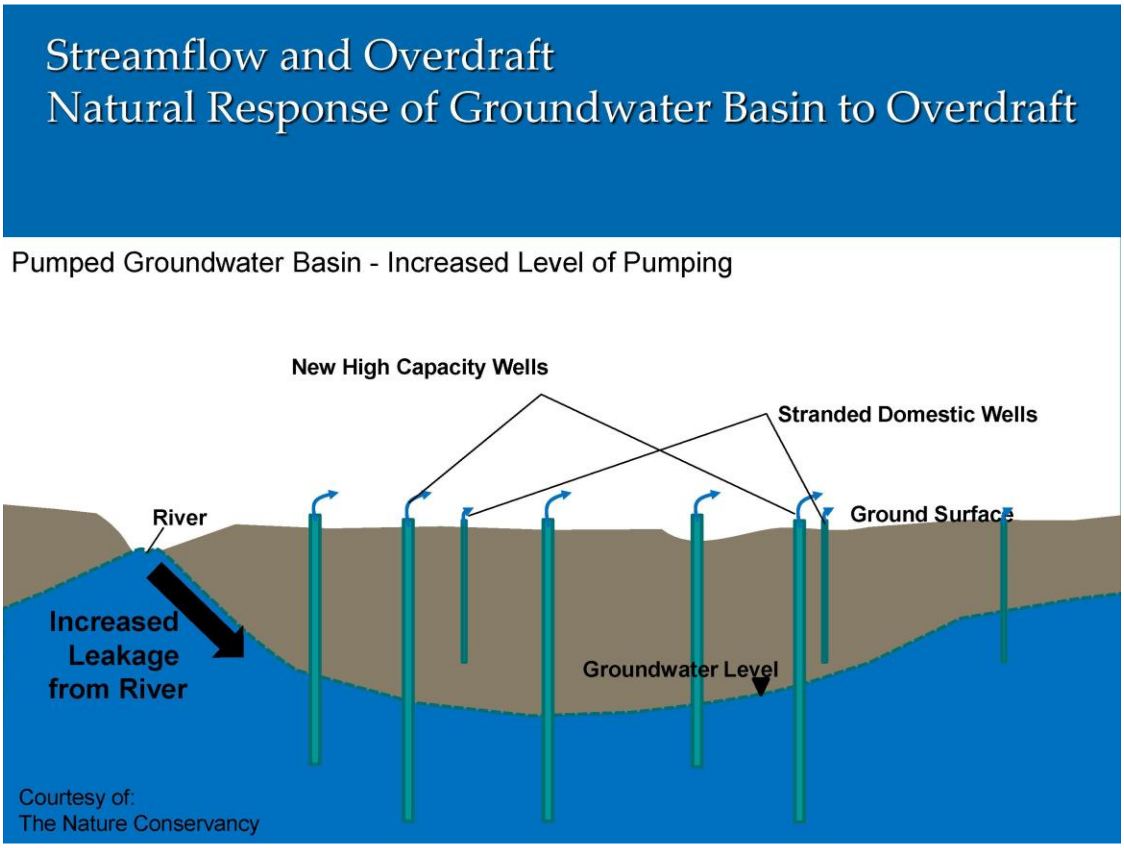


Figure 3-3 Impacts of abstraction from abstraction in the vicinity of rivers

Questions to be discussed:

- What is impact of abstraction of the wellfield on each component of the hydrological cycle and how can impacts be minimised by operational procedures?
- What is the origin of water being abstracted, and how can the origin be determined using laboratory or in situ monitoring?
- What is the impact of abstraction on downstream users?
- How can the impacts of abstraction be monitored?
- Is the existing monitoring system adequate to monitor impacts and how can it be improved?
- How could abstraction affect South Africa?

3.2 Lesotho Highland Sponges

The river systems in Lesotho contribute approx. 45% of the Orange-Senqu runoff. Most of the water sources originate in the rugged mountainous terrain in the Highlands of Lesotho above 2,000 metres above sea level where the terrain, geology, rainwater and run-off form a myriad of wetlands. High-lying wetlands on slops above the regional valley bottom aquifer are sustained by interflow from perched water tables, which is baseflow occurring before recharge reaches the regional aquifer, hence not available to boreholes. Interflow is the reason why in areas with high recharge, little true groundwater exists for access by boreholes.

These wetlands are valued for their hydrological functions such as their support to river flow as interflow and groundwater baseflow, through the storage and subsequent slow release of rain-water through springs and into streams and rivers. Despite the importance of these wetlands to the people and the economy, the systems continue to be degraded, mainly because of infrastructure development, uncontrolled livestock grazing and trampling.

Deep gullies indicate elevated erosion rates. As some of these wetlands are on steeper slopes, the apparent loss of vegetative cover has rendered them vulnerable to wind and water erosion. The degradation of the wetlands vegetative cover may reduce the ability of the wetlands soil to dissipate the erosive water forces. As such, rills and channels have formed resulting in gullies with extended soil scouring.

These wetlands can be observed along the A1, between Buthe-Buthe and Mohotleng. One such degraded wetland can be observed at Liphulaneng (figure 3-4). These are side slope interflow sustained wetlands and valley bottom groundwater fed wetlands.

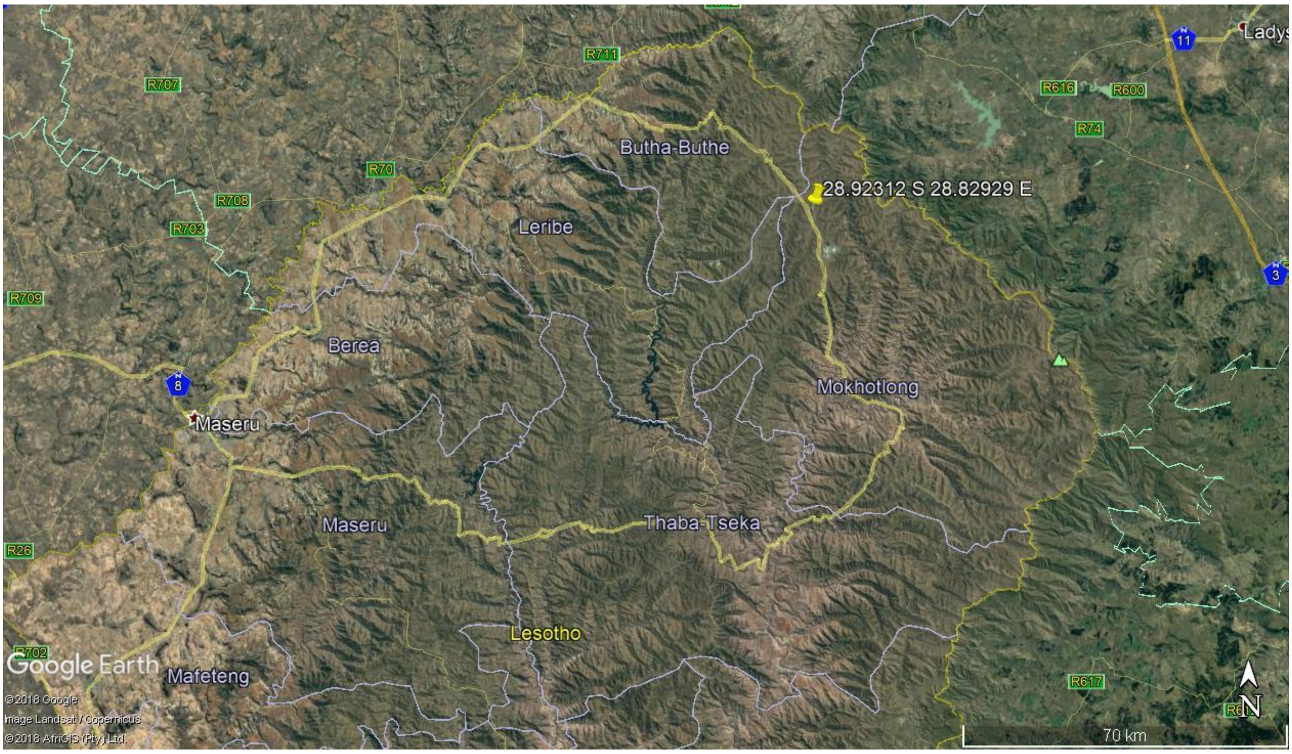


Figure 3-4 Degraded wetland in Lesotho (pin)

Questions to be discussed:

- How does degradation of wetlands impact on the water balance and hydrology in terms of flow peaks and base flow?
- What role does groundwater play in sustaining these wetlands?
- How does the basalt geology favour the formation of wetlands?
- What are the downstream impacts of wetland degradation and how can they have transboundary effects?
- What can be done to prevent wetland degradation, while still allowing the current land use?

3.3 Oranjedraai Weir

The farm Oranjedraai 383 is located on the north bank of the Orange River near Zastron. It is the site for gauging flow from Lesotho (30.33611 S, 27.35944 E). The farm is reached from the turn-off on the R26 between Wepener and Zastron onto the R726 to Sterkspruit. The S368 secondary gravel road is then followed past Bergkloof until the sign board to Oranjedraai is reached (figure 3-5).

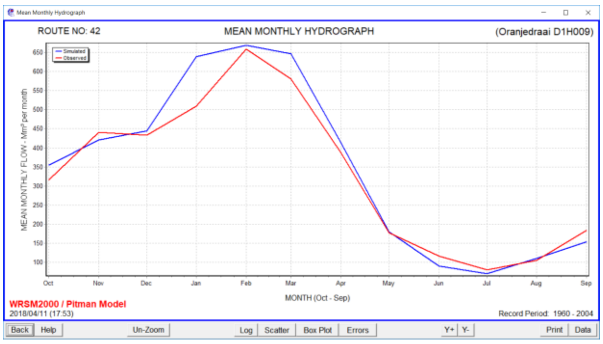
Figure 3-5 Oranjedraai weir

Oranjedraai is the first flow gauging station and monitoring site within South Africa's border. This site is about 550 km downstream from the origin of the river in the Drakensberg (Lesotho) and represents a fairly un-impacted site with natural characteristics.

The site is downstream of the confluence of the Senqu and Makhaleng Rivers with a catchment area of 24 550 km_2, of which 96.8 % is within Lesotho's national territory. The river width at Oranjedraai is approximately 170 m. The stream flow (monthly averages) at Oranjedraai are highly variable and ranged between 1.68 and 934.2 m_3/s (mean, 126.6 m_3/s, i.e. about 3 990 million m_3/a).

Thus, about 60 % of the water resources generally associated with the Upper Orange originate from the Senqu River in Lesotho. The average flow-rates shown a slight decrease ascribed to the inter-basin transfer of 770 Mm_3/a (~24 m_3/s) to the Vaal River system.

The stream flow clearly follows a seasonal pattern with high flows during summer months (November – March) and low flows during winter (May – July). The stream flow usually peaks during February and the lowest flow is usually observed during July. Recorded and simulated low flows are shown in figure 3-6.



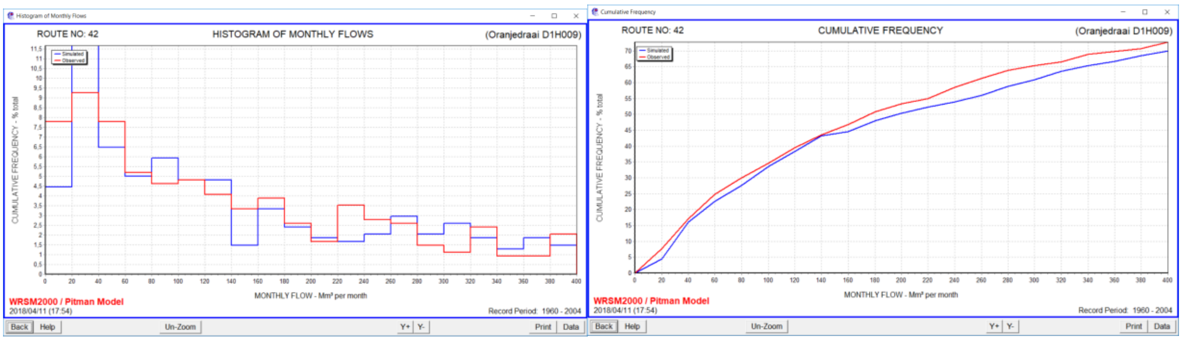


Figure 3-6 Histogram of low flows, mean monthly flows and cumulative frequency of flows at Oranjedraai weir.

<u>Questions to be discussed:</u>

- How will land use and wetland degradation observed in Lesotho impact on the low flow curves?
- How will impacts on flows affect the environment and downstream dam yields?
- What is the significance of groundwater recharge and baseflow in the hydrology at Oranjedraai?
- What methods could you use to monitor baseflow and quantify baseflow volumes?

3.4 Tosca/Khakea-Bray dolomitic aquifer

In the Khakea/Bray area, two main aquifer types can be identified: porous sedimentary and karstic. The porous aquifer, that stores and transmits water via the interstitial pore space in the sedimentary formations is represented by alluvial and Kalahari Bed aquifers. The karstic fractured aquifer is of carbonate rocks where solution weathering along joints, fractures, and bedding has enhanced the water-bearing capabilities of the rock. The fractured aquifer is transboundary in nature and of significant yield.

The Molopo river is ephemeral and used to flow after heavy rainfall events, however the building of dams (Disaneng dam and recently the Modimola dam) upstream has impeded river flow. There is no groundwater baseflow to rivers in this area. Instead the Molopo river acts as a ‘water loss’ river, recharging groundwater during runoff events.

The dolomitic compartment extends from Pomfret In south Africa, north east to Tosca and Vergelee, and to the Boshoek police station in South Africa along the Molopo river. The compartment then extends across the river into Botswana (figure 3-7).

The compartment is heavily utilised for irrigation, which can be observed by taking the 3R77 to the Molopo River (Boshoek police station) then driving northwest along the river (figure 3-8). Irrigation also occurs across the river in Botswana. Water level drops were recorded of over 60 m before intervention limited abstraction (figure 3-9).

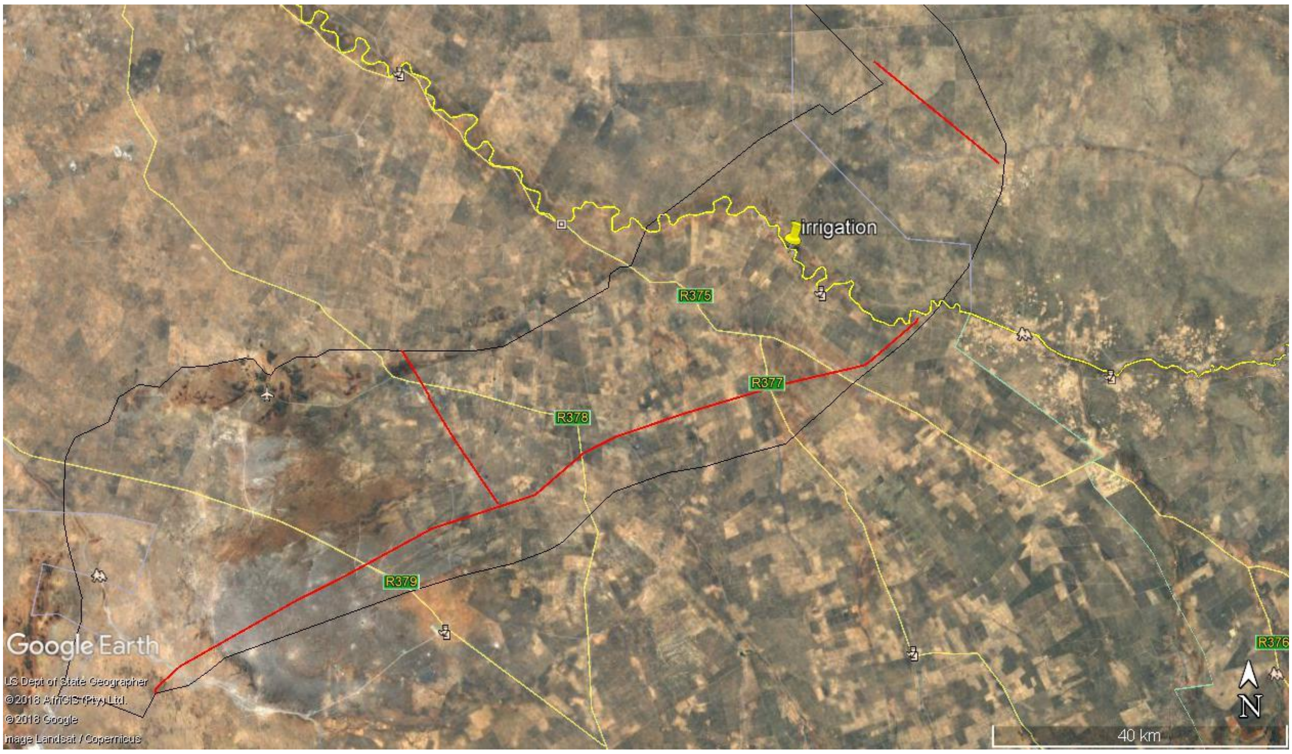


Figure 3-7 Khakea-Bray dolomitic compartment and sub-compartments.

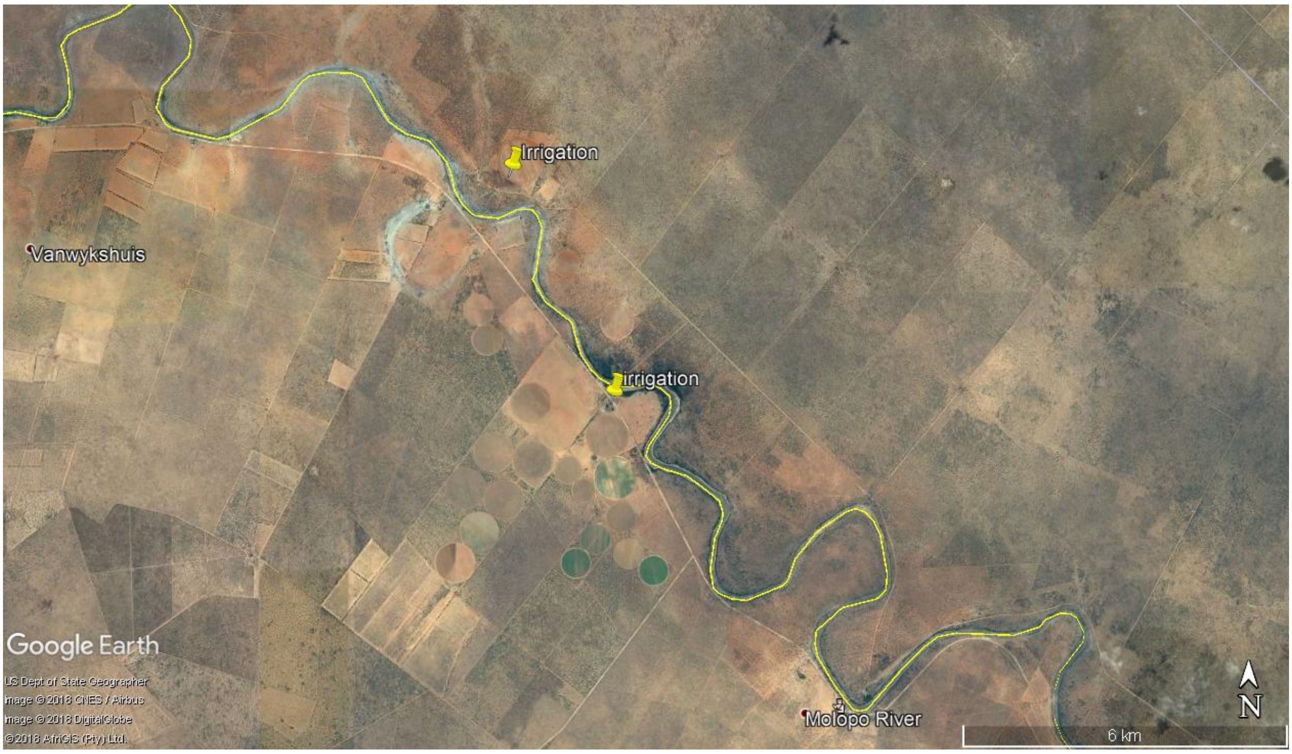


Figure 3-8 Irrigation from the Khakea Bray dolomitic compartment

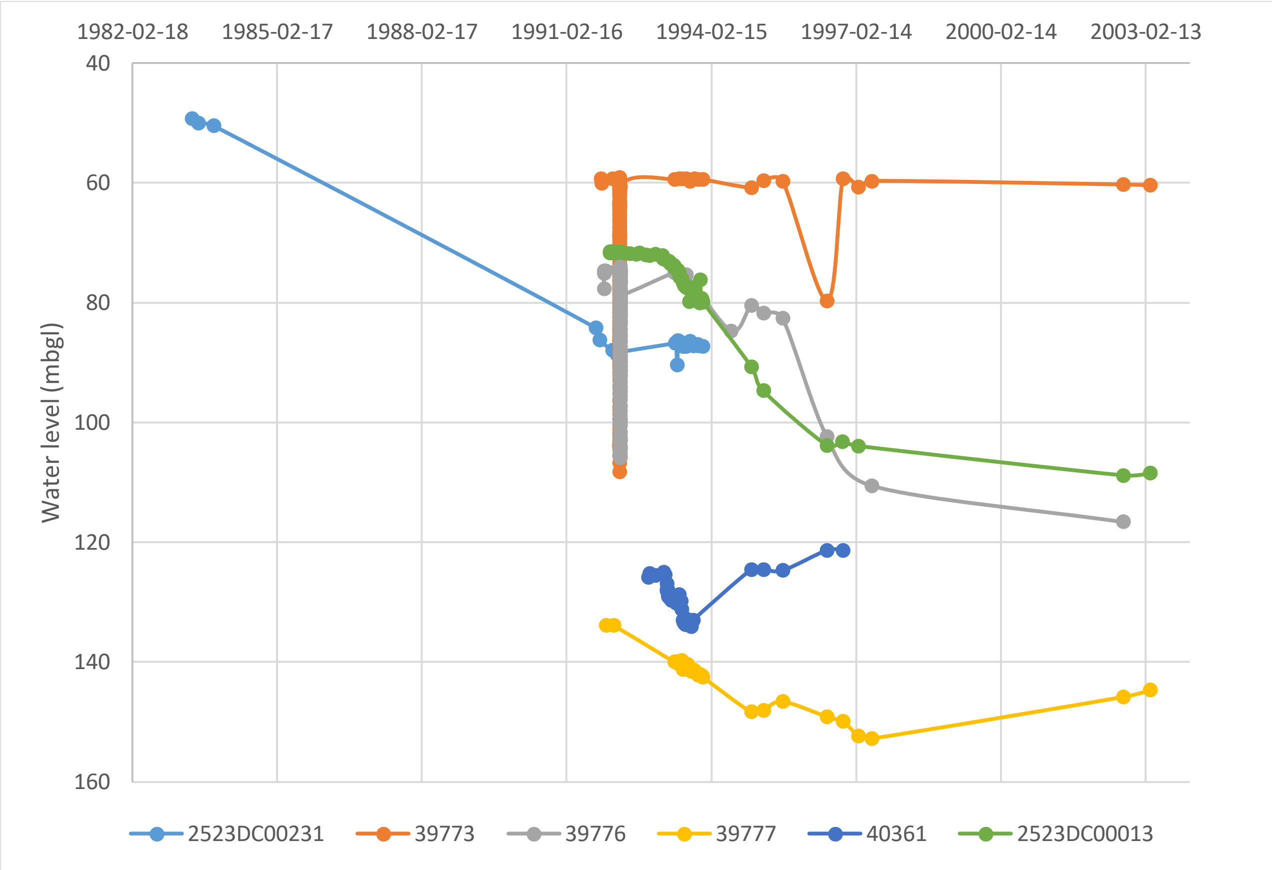


Figure 3-9 Water levels in the Khakea Bray aquifer near Pomfret

Questions to be discussed:

- What is the impact of uncontrolled abstraction on international water resources?
- How would the development of dams upstream on the Molopo River affect ground water resources downstream in this aquifer?
- How does the lack of monitoring data affect the management of groundwater and international protocols?
- How could the international impacts of abstraction be monitored and what data is required?

3.5 Kuruman Eye

The site lies in Quaternary catchment D41L, which is part of the Auob-Nossob and Molopo drainage system. The Kuruman River originates south east of Kuruman, where it is fed by various dolomitic springs, most notably the Great Koning Eye, Little Koning Eye and the Kuruman Eye. The river flows in a north-westerly direction over a distance of approximately 140 km; it then turns west and flows parallel to the Molopo River, until it has its confluence with the Molopo River at Andriesvale, in close proximity to the Nossob/Molopo confluence. The natural Mean Annual Runoff of the catchment is 10.78 million m^3/a. This discharge is largely attributed to baseflow from the Kuruman springs. This flow no longer contributes to sustaining the perennial flow in the Kuruman River.

The area lies within the Upper Kuruman Groundwater Management Area (GMA), which is 1795 km^2 in size. This GMA is compartmentalised by intrusive dolerite and diabase dykes of low to impervious hydraulic conductivity into several compartments labelled Groundwater Management Units (GMU).

The compartment drained by the eye is compartmentalised by the ENE trending Kuruman dyke to the north, the N-S trending Cubbic dyke to the east, and in the west by banded ironstone of the Kuruman Formation, which form the Kuruman Hills, and to the south by a topographic divide. The compartments are believed to be interconnected, with leakage across sub compartments. The Kuruman dyke is believed to be a relatively impermeable barrier as a water level step of 5 or more metres occurs across the dyke.

The Kuruman eye is a major spring draining the compartment and its flow has been maintained throughout droughts. Discharge from the compartment also occurs at the Kuruman B eye when water levels are high, and the Klein Koning and Groot Koning springs.

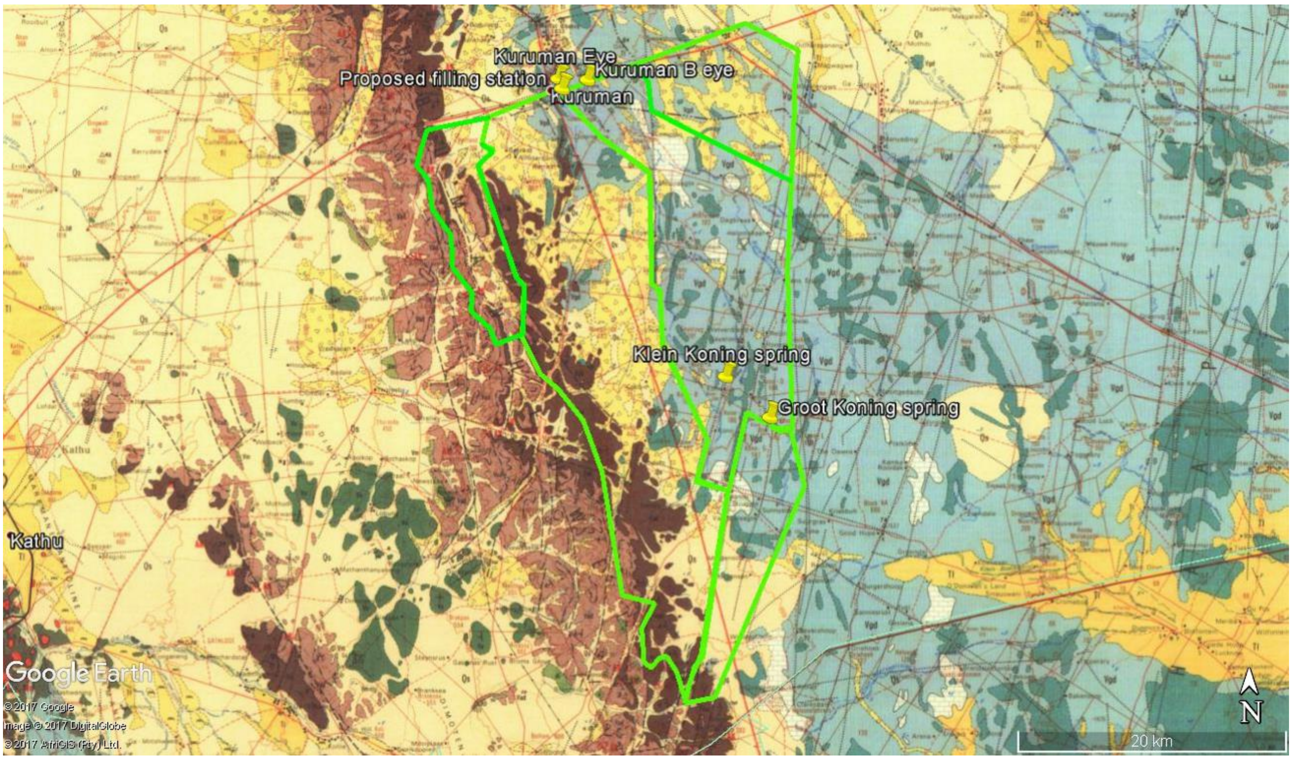


Figure 3-10 Map of compartments at Kuruman

Although not a transboundary aquifer, the processes occurring are similar to those occurring at Khakea-Bray and Stampriet. The eye functions as a discharge point and supports an ecosystem vulnerable to processes occurring far upgradient.

Questions to be discussed:

- How would large scale abstraction far upgradient affect the eye?
- How has use of water at the eye affected downgradient ecosystems?
- Would you consider use of discharge from the eye as a surface or groundwater use in terms of licensing? What are the implications for resource assessment from such a decision?
- If a governmental boundary existed across the compartment, what monitoring would be necessary to ensure equitable water use?

3.6 Stampriet aquifer

3.6.1 Overview

The Stampriet Transboundary Aquifer System (STAS, figure 3-11) stretches from Central Namibia into Western Botswana and South Africa's Northern Cape Province and lies within the Orange River basin. It covers a total area of 86 647km2, of which 73% is in Namibia, 19% in Botswana, and 8% in South Africa.

The STAS is delineated based on the occurrence of geological formations belonging to the Ecca Group within the Auob and Nossob River basins. The Auob and Nossob Rivers are the only major streams within the study area and these originate in Namibia and flow in a south-easterly direction towards the Molopo River between South Africa and Botswana. The Auob and Nossob Rivers are ephemeral and only flow for short periods during heavy rainfall events.

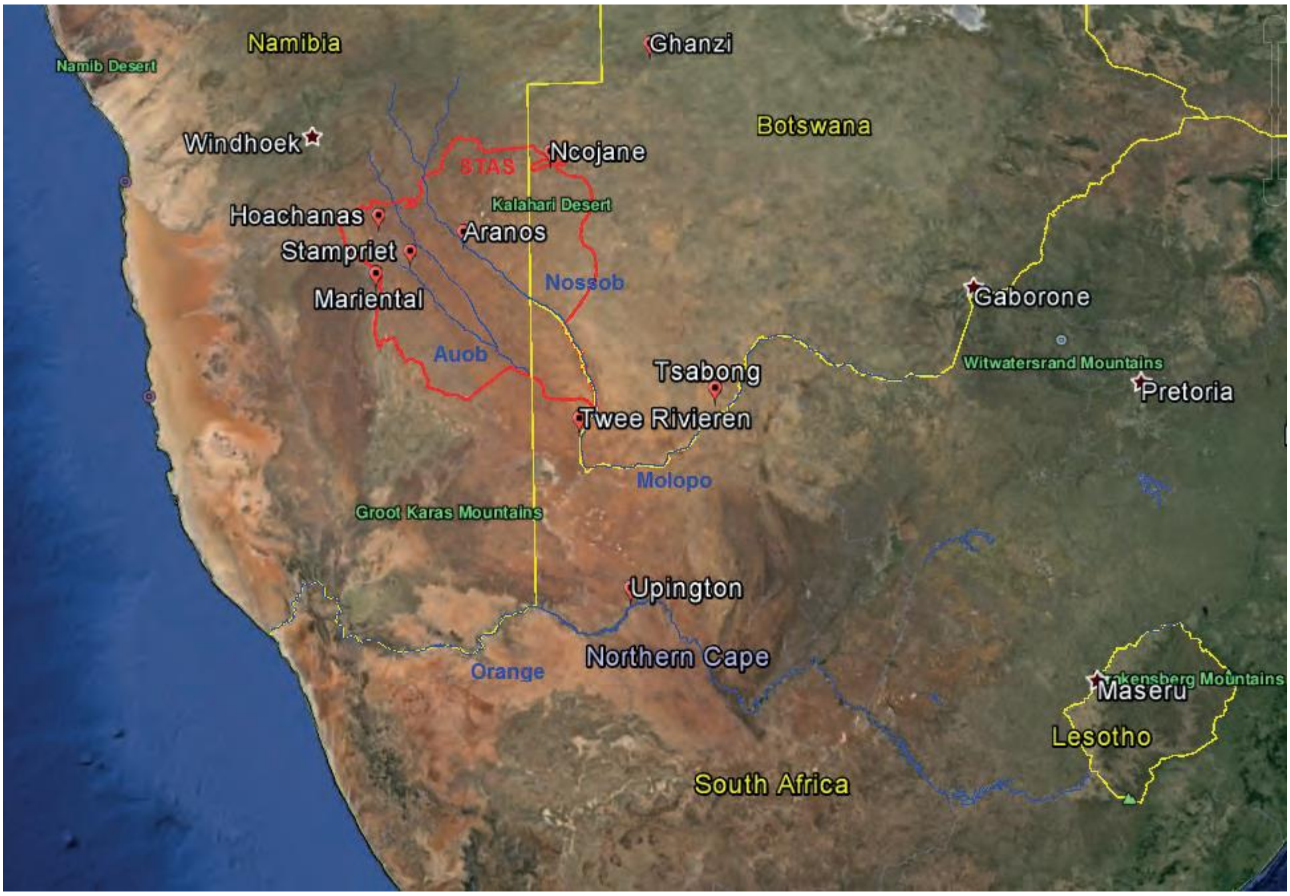


Figure 3-11 Stampriet aquifer

The aquifer is a huge sedimentary basin of mainly sandstones, shales, mudstones, siltstones and limestone. They are covered by a blanket of sediments of the Kalahari Group, of Tertiary-Quaternary age.

The STAS is formed by the confined artesian Auob and Nossob aquifers, and the overlying phreatic Kalahari aquifers (figure 3-12).

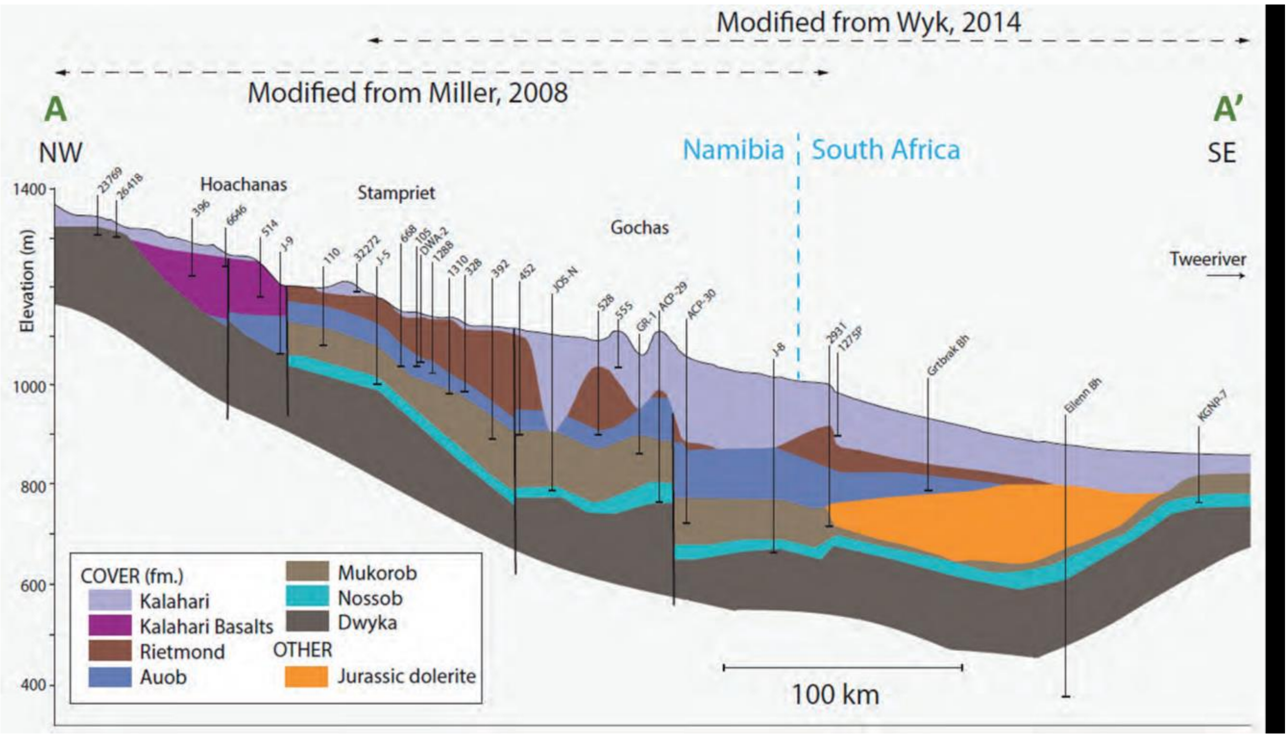


Figure 3-12 Cross section of the STAS

Average rainfall in the STAS area is of 150 to 310 mm/yr. Recharge to the Kalahari aquifer during years with average rainfall is estimated at 0.5% of rainfall. Recharge to the Auob and Nossob aquifers in normal rainfall years is negligible but considerable recharge occurs during extreme rainfall events. The general groundwater flow in the STAS is from northwest to southeast. Groundwater quality generally decreases towards south-western Botswana and the north-western Cape in South Africa for all the three aquifers.

3.6.2 *Discharge area*

In the South-Eastern quadrant of the area, groundwater massively seeps upward from the confined aquifers and discharges into the Kalahari Formations, from where it evaporates from pans and water holes. Groundwater salinity in this zone – known under the name Salt Block – therefore is rather high. It is estimated that it takes more than approximately 30 000 years for groundwater to travel from the Auob and Nossob recharge zones to the discharge zones.

Over 20 million m³/year are abstracted rom the Stampriet aquifer, most of which occurs in Namibia (over 95%). The largest consumer of water is irrigation (~46%) followed by stock watering (~38%) and domestic use (~16%).

In South Africa, the aquifer has only limited potential for further development because, apart from the poor water quality (figure 3-13), the permeability and storativity are low.

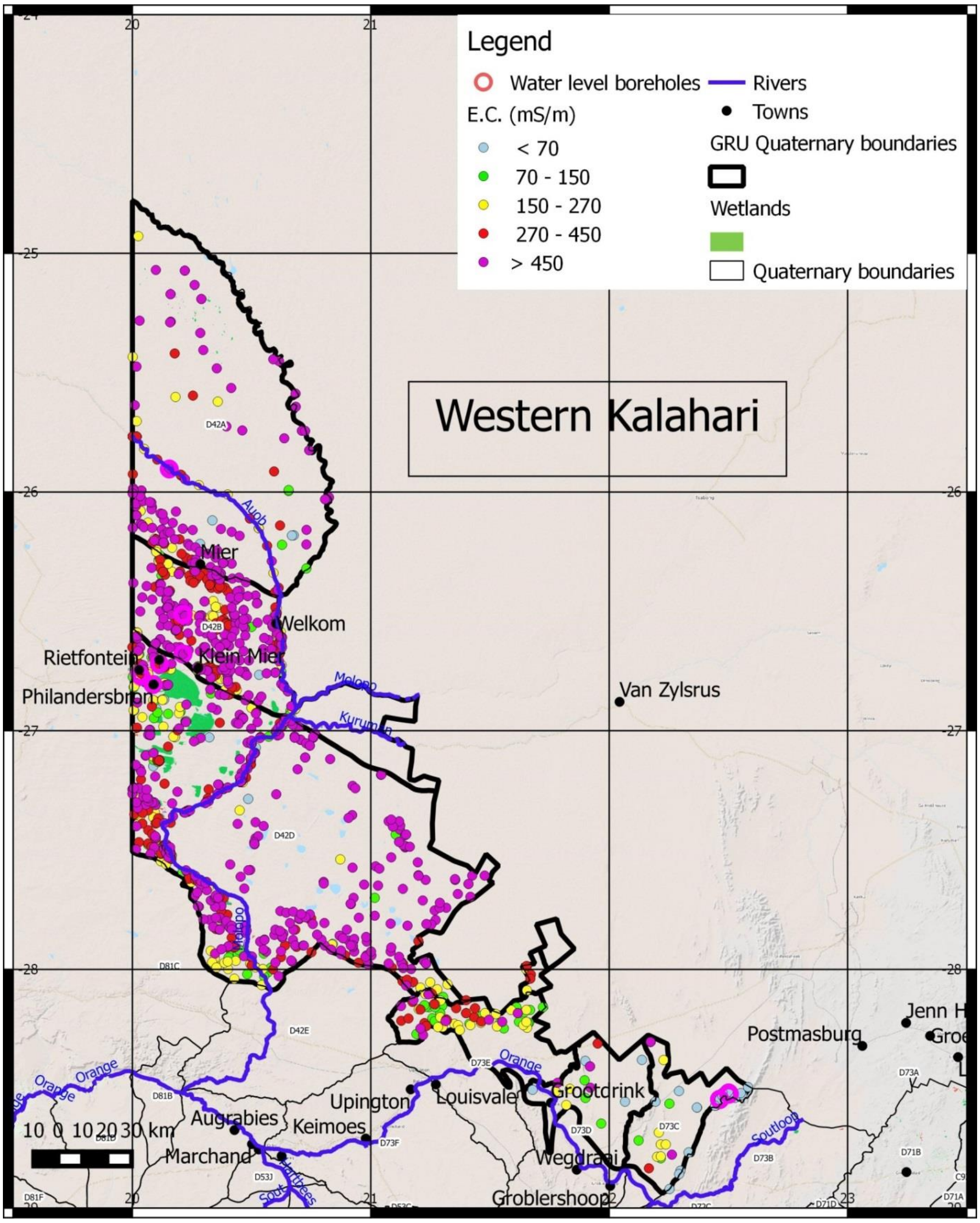


Figure 3-13 Water quality in the STAS

Groundwater levels show little variation in the discharge zone of south Africa (figure 3-14).

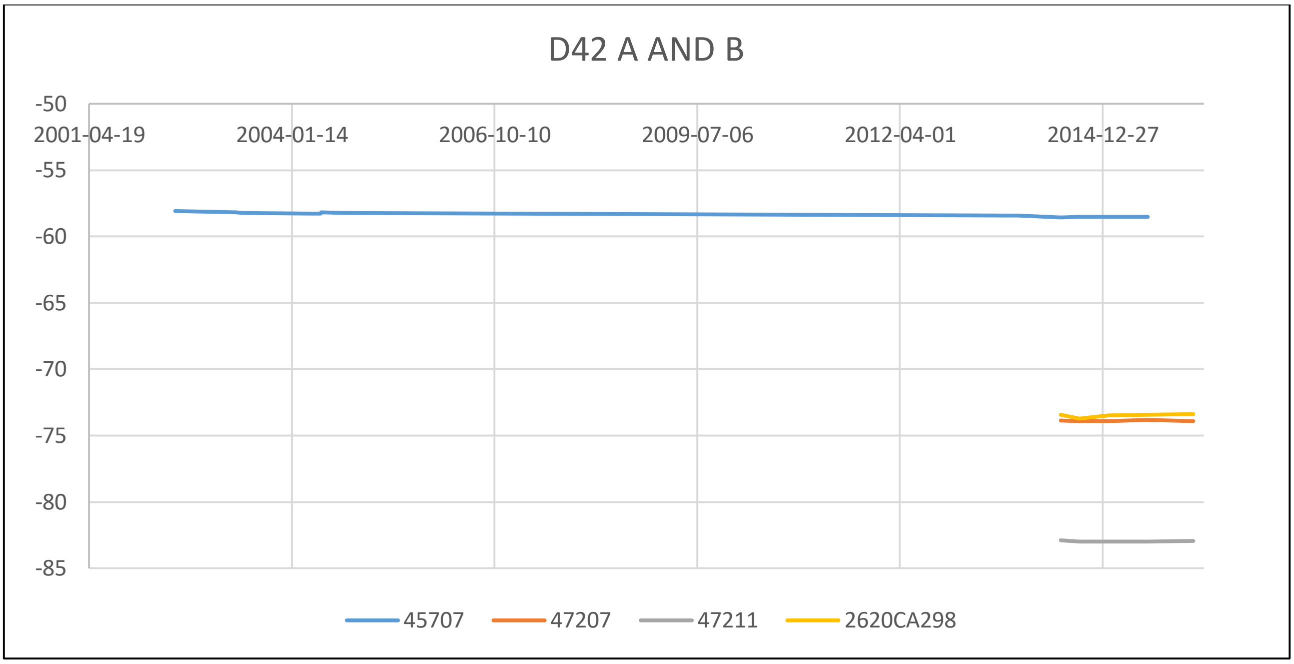


Figure 3-14 Water levels in the Stampriet in South Africa

A water hole and numerous pans which serve as the discharge of groundwater originating in Namibia can be seen driving north along the R360 towards the Rooiputs waterhole (figure 3-15).

Figure 3-15 Rooiputs water hole

<u>Questions to be discussed:</u>

- How would abstraction in Namibia affect the water holes in South Africa?
- Why are the water levels in boreholes (figure 3-14) flat without showing annual fluctuations?
- Why do salinities vary greatly in boreholes?

- While driving on the R31 towards the Ritefontein border post to Namibia, what geological conditions distinguishes the pans and water holes (figure 3-16) from those seen near Rooiputs?

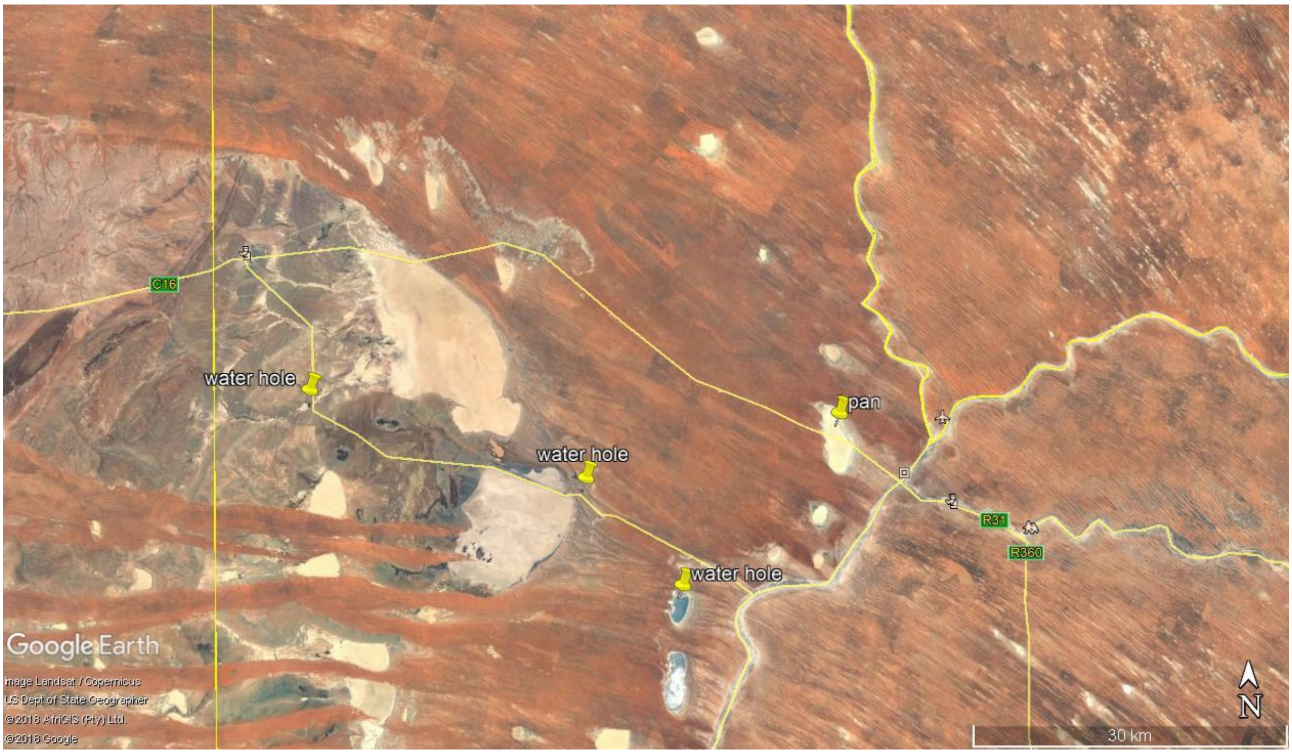


Figure 3-16 Pans and water holes near Rietfontein

3.6.3 Recharge area

The C20 between Mariental and Stampriet is representative of the recharge area of the aquifer (figure 3-15).

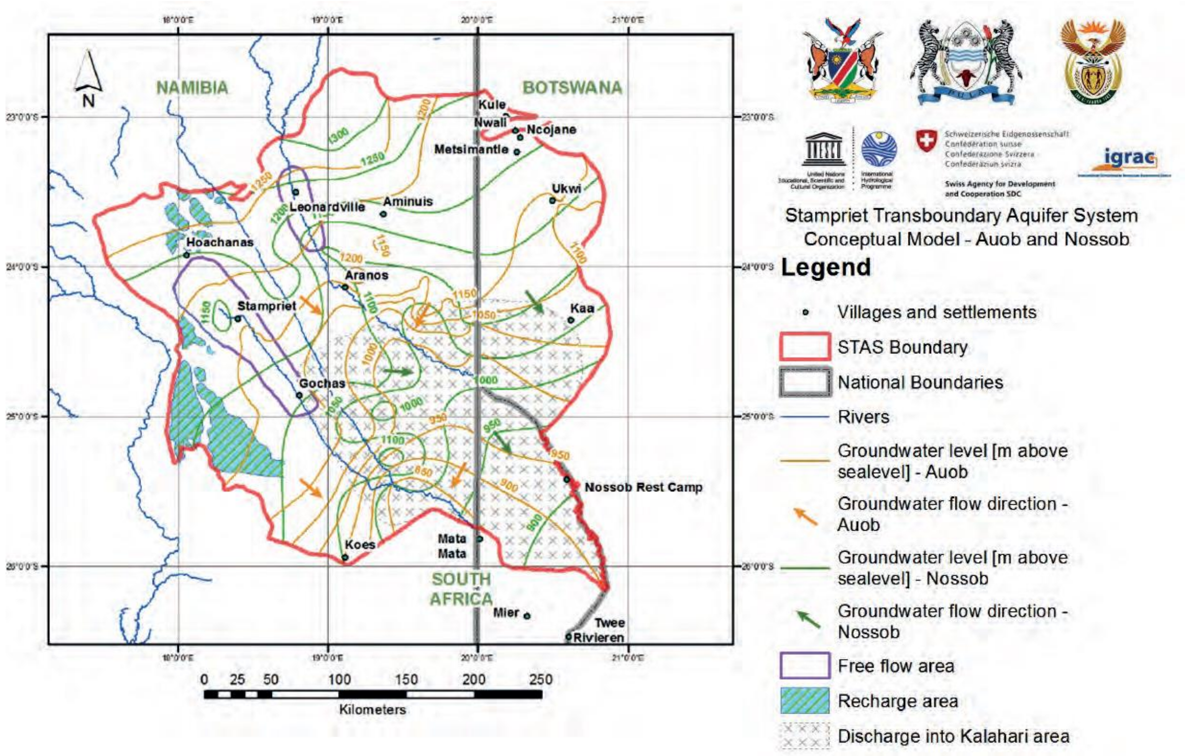


Figure 3-17 Recharge and discharge to the STAS

<u>Questions to be discussed:</u>

- How does the geology differ between the recharge and the discharge zone and why is the recharge zone restricted to only certain areas?
- Where and how should a monitoring programme to be implemented?
- Since the aquifer is multi-layered, would the heads vary between the Auob and Nossob aquifers? Which would be higher in the discharge zone and would how would it affect a monitoring programme?
- Since recharge is primarily in Namibia, whose water is it and what principles for apportionment apply?