

# Groundwater and surface water interaction: FROM THEORY TO PRACTICE



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***Historically, groundwater (GW) and surface water (SW) have been viewed, and managed, as two separate entities. Most water resource management plans focus on the latter, but the constant development of land and water resources has made it clear these systems affect each other both in resource quantity and quality. Article by Petro Kotzé.***

Recent research has shown that development is not the only reason why it is important to understand how surface water and groundwater interact. Climate change is likely to affect the availability and distribution of both, so increasingly this interaction

is playing a bigger role for water resource management.

In the simplest terms, if we don't know if, and how much water infiltrates from a river into an aquifer, we don't know how much water to allocate from the river to a particular user. In a water-scarce country like South Africa, explains Prof Gideon Steyl, research fellow at the Institute for Groundwater Studies (IGS) at the University of the Free State, we might increasingly have to look towards groundwater as a sustainable source of water. If this is the case, knowledge of the interplay between these systems is imperative.

In order to understand the mechanisms of this interaction, observational data is integral but,

lacking in South Africa. Even more so, the available data is mostly segmented into purely atmospheric, surface hydrology or geohydrological data for specific areas. Mostly, no significant overlap exists between the surface and sub-surface hydrological data in order to ascertain a relationship between these two systems. Up until now, there has also not been a local test-site to rectify the situation.

Fortunately, this state of affairs is changing. Researchers from the IGS are tackling a multi-disciplinary project, investigating the multiple processes involved in surface water and groundwater interactions. These include surface hydrology, evapotranspiration, geohydrology and vadose zone hydrology (also known

as the unsaturated zone, it is the portion of Earth between the land surface and the zone of saturation). The three-year study, which started earlier this year, is focusing on gathering all available data necessary to enable the group to identify important processes and field measurement methods. This knowledge can later be applied to more test sites.

## A UNIQUE APPROACH

The study area is situated close to the Krugersdrif Dam in the Southern Free State, between the R64, S264 and the S328 roadways. Underlain by Beaufort Group formations with dolerite dykes intruding in certain areas, it is intersected by the Modder River from an easterly to a westerly direction. Flow in the river is controlled from the Krugersdrif Dam sluice gates, either at regular intervals or if water levels drop significantly downstream.

This is the ideal site for a number of reasons, explains Prof Steyl, who is leading the study. Among others, water seeps freely from the surrounding formations into the river at some places, which indicates that there is movement of groundwater into the river system. The area has escaped relatively unscathed from pollution and over-development and also features a shallow water table.

The study covers the river, the riparian and background zones, and brings together specialists in the areas of surface hydrology, evapotranspiration, geohydrology and vadose zone hydrology. Prof Steyl adds that he also aims to involve a geophysicist (who, through the use of magnetic measurements of the area, can establish a well defined concept of the interaction of the dykes on the subsurface movement of water in the study area). Funded by the WRC, with support from the IGS, Department of Water Affairs (DWA) and local farmers and property owners, it is the first study of its kind to merge this variety of

**“In the long term, it is hoped that the data will be developed into a set of ‘checkpoints’ that can be used by water resource managers to determine the amount of water that is available for use in a system.”**

disciplines. In essence, the data will sketch a complete picture of all the elements involved in the interaction between water in the atmosphere, groundwater and surface water.

In order to obtain this data, the project involves a number of tests and observation locations. Firstly, boreholes are drilled in triangles, enabling participants to determine the local gradient in the riparian zone and the general area on both sides of the river. To date, researchers have constructed 40 holes, in two areas of about 4 km x 2 km and 1 km x 2 km. The holes are also of different depths so that both the surface and deep aquifer system can

be characterised to determine if the river system is connected directly with the riparian zone or general area.

Prof Steyl explains that the next step is chemical analysis of water from the boreholes and river. Tests include macro- and micro-chemical analysis and, in a novel approach, isotopes, “something that’s a bit unusual for us,” he admits. The adage of this method enables them to pick up if a substantial volume of water from certain boreholes ends up in the river.

Researchers will furthermore apply geophysics (down-hole investigations and profiling) to establish local geological features and borehole characteristics, as well as pump tests to determine both local and regional hydraulic properties. An added advantage is that knowledge of the Free State’s rock formations and isotopic composition will be gained, as not many of these types of studies have been done in that specific area. Further research includes the monitoring of the water levels in both the river and boreholes over a

*The study area is situated close to the Krugersdrif Dam in the southern Free State.*







**Above:** (From left) Prof Gideon Steyl of the Institute for Groundwater Studies at the University of the Free State on site with PhD student Modreck Gomo and MSc students Khakliso Leketa and Shakhani Teboho.

**Right:** Dr Eddy van Wyk of the Department of Water Affairs inspecting a dolerite dyke showing the fractured zones in the rock face at the western site.



few years (to determine fluctuations due to seasonal changes and river flow volumes).

Then, the unsaturated zone will be studied. This entails a soil profile analysis and determining the infiltration rates at the specified sites. Prof Steyl adds that there are many ways in which water can move through this zone. The techniques to be applied include physical measurements of how water moves through this zone, and through to the aquifer when it rains. Porous cups will be used not only to evaluate the flow of water in the subsurface, but also the chemical composition as it drains to lower levels. A second method will include geophysical methods. These rely on, among others, capacitance and resistivity of the subsurface environment. The project team has already had some success during the heavy rainfall that the area experienced in June. "If we can get this aspect of the project right," notes Prof Steyl, "we will definitely have world-class data available."

Once the geophysical data are added, the team would theoretically have a 'picture' of all the elements at play in the aquifer. This is then combined with evaporation and climatic (analysis of the rainfall and temperature fluctuations at the river and background area) data.

In addition, the site is used as a training ground for post-graduate students at the IGS. Two students have already completed their MSc theses on the project, while it is expected that at least 60 geohydrologists (training and active in the field) will visit the site over the duration of the project. It is also expected that personnel from the DWA will visit in order to assist with the development of regional management plans during the course of the investigation.

## **RIISING TO THE CHALLENGE**

**A** study of this nature is not without its challenges. Indeed, one of its biggest strengths counts among



them. “Analysing and interpreting the results in way that all the different parties agree on is easier said than done,” admits Prof Steyl. In addition, correctly determining the recharge potential in the unsaturated zone, and obtaining sensible hydrological data (Prof Steyl’s background is in chemistry and geology) is not easy.

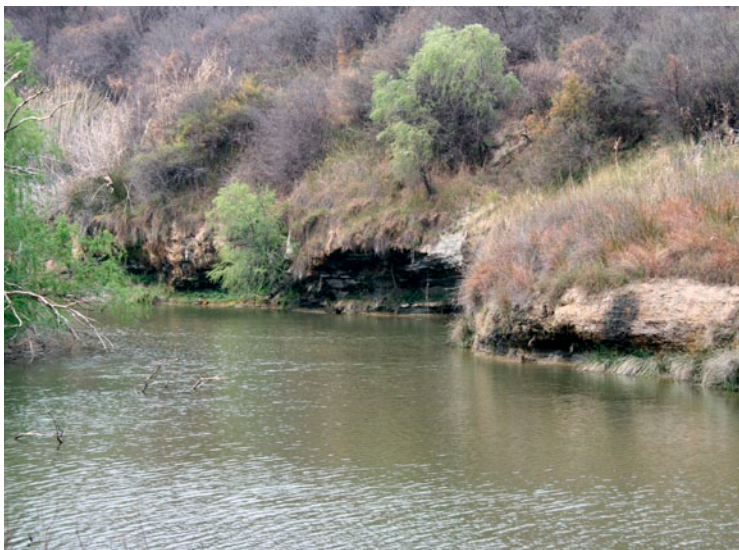
He also admits that the research area is small, and that the data are very site specific. The evapotranspiration data, for example, are dependent on the types and distribution of flora on the site. It is thus hoped that the study might be continued for a further three years, in order to apply the mechanisms defined in the current study areas to other areas. Eventually, Prof Steyls and his team want to apply the results to areas representative of every groundwater and surface system. In the long term, it is hoped that the data will be developed into a set of ‘checkpoints’ that can be used by water resource managers to determine the amount of water that is available for use in a system.

The project has already yielded interesting results in the geohydrology arena, which might have remarkable consequences for water resource management. Among these, notes Prof Steyl, are that the two sides of the Modder River are completely different worlds, not only geologically and chemically, but also isotopically. For example, while the one side of the river consists of basic sand formations, the other is made up mostly of chalk. Furthermore, it looks as if the river comes down much slower on the one side than the other.

Without a doubt, a study of this unique nature will continue to generate exciting results, not only for the researchers involved, but for those involved in water resource management who will eventually apply the results. Possibly more important is that it is the first step in the right direction, and that the generated data will go a long way towards filling a worrying gap that currently exists in the area of groundwater and surface water interaction. □



**Top left:** The study site is intersected by the Modder River from an easterly to a westerly direction. Flow in the river is controlled from the Krugersdrift Dam sluice gates.



**Middle left:** Water seeps from the surrounding mudstone formations into the river, which indicates that there is a movement of groundwater into the river system.



**Bottom left:** MSc student Khakliko Leketa collects borehole samples for further lab analysis at the University of the Free State Soil Analysis Laboratory.