

## Project Brief Transboundary Water Management in Southern Africa

# Groundwater monitoring in the Tuli Karoo Transboundary Aquifer Area

Groundwater monitoring is the foundation for sustainable management of shared aquifers. Monitoring of aquifers is indeed fundamental to gain a full understanding of a groundwater system, assess the long-term and annual changes in aquifer storage due to the impacts of climate change and water withdrawals, and to foster sustainable management of groundwater resources. The Tuli Karoo Transboundary Aquifer (12,294 km<sup>2</sup>) – shared by Botswana, South Africa and Zimbabwe – is not monitored in an integrated way at present. The lack of spatial, temporal and integrated data on this aquifer makes it difficult to sustainably manage groundwater resources and fully harness key benefits such as food security and climate resilience.



Borehole BH10638 situated 7 km downstream of borehole BH10635 (one of the four boreholes selected for monitoring in this study) along the Shashe River in Botswana (*photo:* G. Y. Ebrahim).













At present, Botswana and South Africa undertake some monitoring within the Tuli Karoo Transboundary Aquifer Area for their own purposes; Zimbabwe (covering about 57% of the area) does not actively monitor the aquifer (Figure 1). Therefore, an aim of the *Conjunctive Water Resources Management across Borders in the Southern African Development Community* (SADC) Region: Generating Principles through Fit-for-purpose Practice project was to design an integrated groundwater monitoring network for the Tuli Karoo Transboundary Aquifer Area, and pilot the installation of a real-time monitoring system in the three countries sharing the aquifer. Advantages of using a real-time system include the ability to rapidly share data, having access to more reliable and regular data, and a reduction in costs and time lags associated with site visits. It also institutionalizes the process of sharing data, which helps to build trust and cooperation among the three countries.



Figure 1. Tuli Karoo Transboundary Aquifer Area and existing monitoring networks.

#### Key messages

- Transboundary groundwater monitoring is at its initial stages in Africa and elsewhere. The lack of integrated monitoring in Tuli Karoo is consistent with experiences in other shared aquifers. Exchange of data on, and integrated monitoring of, transboundary aquifers is rare. This reality undermines efforts to jointly manage and optimally utilize this increasingly important resource. As such, practical benefits such as climate resilience and food security are not fully realized.
- Tuli Karoo represented a first effort to co-design and pilot a transboundary groundwater monitoring system in a shared aquifer in Africa. Collaboration with three country governments, Southern African Development Community - Groundwater Management Institute (SADC-GMI) and the Limpopo Watercourse Commission (LIMCOM) led to the co-design of a groundwater monitoring system for the aquifer. Locations of 58 observation boreholes for optimal monitoring were identified to understand the aquifer.

Four of these were selected for installing a real-time monitoring system.

- **Groundwater monitoring should be treated as part** of the broader system. Going forward, it is critical to consider surface water and groundwater together, monitoring them conjunctively to gain an integrated understanding of the system. An aquifer system requires a distributed network of monitoring boreholes within an aquifer area, while surface water flows can be monitored at strategic points.
- Process is also a product. Achieving practical outcomes is clearly the primary aim of water resources monitoring. Nonetheless, the process of collaboration in data collection in a transboundary context is also an outcome that should not be underestimated. Joint monitoring can defuse potential cross-country accusations before they manifest, and enhance trust across boundaries at a fundamental level.

### Methods: Designing and piloting a joint groundwater monitoring system

#### Combining approaches for robust

results. A hydrogeological approach was used to produce a spatial priority monitoring index map based on Geographic Information System-based Multi-Criteria Decision Analysis (GIS-MCDA). Seven criteria including geology, lineament density, land use/land cover, soil, slope, rainfall, and drainage density were selected for the GIS-MCDA. Weighted linear combination was used to combine the seven thematic maps to produce a spatial priority monitoring index map. The priority monitoring index map provides (i) a baseline for prioritizing monitoring borehole locations, and (ii) guidance on additional strategic monitoring borehole locations. A geostatistical approach was implemented to identify the optimal number and location of monitoring boreholes. A central concept in the geo-statistical approach is the semivariogram, which describes the variance between the points in a spatial field as a function of their separation distance.

# Ongoing engagement to ensure collaborative design and ownership.

A field meeting was held in Botswana in February 2020 with representatives from the three countries sharing the Tuli Karoo aquifer, SADC-GMI, Umweltund Ingenieurtechnik GmbH Dresden (UIT), Germany, and the International Water Management Institute (IWMI). At this meeting, the approach to be used to design the monitoring network was discussed and agreed. Following the field meeting (February 20-24, 2020), the team collaboratively installed the first data logger in Botswana. A draft version of the report on monitoring network design was then produced and shared with stakeholders in May 2020. Online meetings were held between June and August 2020 to get feedback on the report and refine the approach to be used for the monitoring network design. In the last quarter of 2020, a report incorporating stakeholder feedback was presented to a wider group, including LIMCOM, SADC-GMI, Climate Resilient Infrastructure Development Facility (CRIDF), and representatives and focal persons from the three countries.

**Instrumentation.** The real-time monitoring system developed by UIT was used for this activity (Figure 2). The framework consists of a data logger and telemetry system. The Conductivity, Temperature and Water level - General Packet Radio Service (CTD-GPRS) system was used for measuring and storing electrical conductivity, water level and temperature data. CTD-GPRS is a vented system, so automatically compensates for barometric pressure. To conserve battery life, the real-time system was programmed to collect data every 15 minutes and transmit data to the online system once a day. The online data is transmitted to the server administered by UIT during the project period, but will be transmitted to a SADC-GMI platform in the future.



#### **Key findings**

**Results: 58 boreholes for optimal monitoring.** A geostatistical approach was implemented to identify the optimal number and location of monitoring boreholes. The priority monitoring index was overlaid with a hexagonal sampling grid and 58 optimal monitoring boreholes (Figure 3). This translates to one observation borehole per 211 km<sup>2</sup>. About 63% of the study area has a priority index in the range of 0.57-0.7 and 1.9% of the area has a priority index higher than 0.7. Very high priority zones are concentrated in Botswana and at the edge of the aquifer area in Zimbabwe. It is evident from this map (Figure 3) that high priority monitoring areas are concentrated along the lineaments.

*Four boreholes for installation.* From the 58 optimal monitoring borehole locations, four existing boreholes in close proximity to optimal borehole location or located at strategic locations were selected for installing real-time monitoring. The initial plan was to install one real-time monitoring borehole for each country and one at a strategic location to monitor the response of groundwater to surface water flow. However, the plan was revised with the advent of the Covid-19 pandemic, and it was decided to install three real-time monitoring boreholes in Botswana (BH10504, BH10509 and BH10635) and one in South Africa (A6N0591). This decision was based on the ease of operating the boreholes in these two countries, both of which already possess observation boreholes that can be utilized. Selection of the four existing boreholes for instrumentation was based on the following criteria:

- Ability of the borehole to tap into the productive sandstone aquifer.
- Borehole is strategically located close to a river to provide information on groundwater-surface water interactions.
- Borehole has a suitable casing which can be used to install the data logger.
- Borehole is situated in a location where there is a strong network signal to enable data transmission, and an observation borehole with proper documentation including a borehole log and water level data required to determine cable length of the system.



Figure 3. Priority monitoring index, optimal monitoring borehole locations and selected observation boreholes for instrumentation.

*Lessons.* Design of the pilot monitoring system for the Tuli Karoo aquifer has highlighted numerous insights, which may be relevant elsewhere. A first insight relates to designing a monitoring system for a transboundary aquifer, in which one aquifer-sharing state is 'starting from zero', i.e., currently undertakes no groundwater monitoring in their portion of the aquifer. In the case of the Tuli Karoo aquifer, Zimbabwe does not undertake any monitoring, but has many abandoned pumping boreholes due to closure of mining activities. While these boreholes could be used as potential monitoring sites, it should be noted that there are often reasons for abandoning production boreholes, e.g., damaged borehole, low yield and water quality issues. These dynamics may no doubt present challenges to groundwater monitoring.

A second insight relates to practical challenges of implementation. Notably, while key progress has been made in the roll out of monitoring network design (Box 1), emerging or foreseen challenges associated with the use of existing observation or production boreholes include the following:

- Existing boreholes seldom fulfil all technical or logistical criteria set by the monitoring network design (e.g., suitable casing, borehole depth, network signal).
- Existing boreholes are not always easily accessible.

- Existing boreholes may lack proper documentation, including a borehole log and/or other construction data that adequately describe the physical setting and construction of the borehole. Production boreholes could be converted to groundwater monitoring boreholes, if the boreholes enter important aquifer units and information on the geological strata encountered by the borehole and borehole completion details (e.g., depth, diameter, casing) are available. These details may be obtained from a driller's logs, but these are often not available.
- Few monitoring boreholes tap the productive sandstone aquifer. Therefore, it may be necessary to drill additional boreholes to characterize the aquifer system. In other words, existing boreholes may not achieve a sufficient spectrum of aquifer layers.
- There is a lack of streamflow gauging stations in areas selected as a strategic location to assess groundwater-surface water interactions.
- Vandalism and theft are among critical problems emphasized. Since the real-time monitoring sites are located in remote areas, the risk of vandalism can be a serious issue.



Configuration and installation of a data logger at borehole A6No591 by focal persons in South Africa, November 6, 2020 (photo: Ramusiya Fhedzisani).

#### Box 1. Practical installation of the pilot real-time groundwater monitoring system.

Installation of the real-time monitoring telemetry system was completed in the four selected boreholes (Figure 3). Based on historical water level fluctuation data, cable lengths of 120 m, 60 m, 25 m and 30 m were used for boreholes BH10504, BH10509, BH10635 and A6N0591, respectively.

Installation of the first real-time monitoring system was carried out in Botswana on February 20, 2020, with representatives from the Department of Water and Sanitation (DWS), South Africa, DWS, Botswana, Zimbabwe National Water Authority (ZINWA), SADC-GMI, IWMI and UIT (Figure 4). The plan was to install more systems afterwards. However, these plans could not be realized due to the Covid-19 lockdown and international travel restrictions. To move things forward in the context of a 'new normal', a new plan had to be devised and implemented. Instead of IWMI staff directly installing data loggers, partners in the three countries were capacitated to carry out installations. Online training consisting of data logger configuration, sensor calibration and instrumentation, and online assistance during instrumentation were provided to country focal persons by UIT and IWMI staff. Focal persons were provided with one-on-one training on the instrument on September 22-23, 2020. Training for a larger group consisting of 15 people from the three countries was provided on October 6, 2020. Support was then provided to enable focal persons to travel and install data loggers. Two additional systems were installed in Botswana on October 26 and 28, 2020, and one in South Africa on November 5, 2020.

Institutions from the three countries such as DWS, South Africa, DWS, Botswana, ZINWA and SADC-GMI are actively engaged in the design and installation of the monitoring system, and are responsible for managing the system. LIMCOM is the other main institution that is actively engaged in overseeing the design and installation of the monitoring system, and is responsible for creating this process and ensuring continued implementation in the Tuli Karoo Aquifer Area.



Figure 4. Installation of the pilot real-time groundwater monitoring system in Botswana (photo: G. Y. Ebrahim).



Configuration and installation of a data logger at borehole BH10635 by focal persons in Botswana, October 28, 2020 (photo: Benjamin Ngoni).

#### Conclusion

Existing groundwater monitoring in the Tuli Karoo Aquifer Area was somewhat inadequate. More importantly, some monitoring was undertaken independently by Botswana and South Africa. This level of monitoring is insufficient to enable proper groundwater resource characterization, establish water level trends, and facilitate joint management. As such, there was little knowledge about the status of groundwater quantity, availability and trends in this transboundary aquifer area. Therefore, one of the objectives of this project was to co-design and collaboratively pilot an integrated groundwater monitoring network for this transboundary aquifer area. The design of the monitoring network should be viewed as a dynamic system which is responsive to changing information needs. It is important to review the design periodically and provide recommendations for improving the efficiency and accuracy of the network. It is also important to identify hot spot regions and establish secondary monitoring networks where necessary. Further, since groundwater and surface water are part of the same hydrological system, groundwater cannot be managed in isolation. Ultimately, it is important to contextualize groundwater monitoring with efforts to monitor surface water in a way that is responsive to the needs of users.

#### Source

This brief is largely adapted from the following publication:

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#### Project

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For more information, visit http://conjunctivecooperation.iwmi.org

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