First Technical Report Geophysical experiments near Kajiado town

Synthesis Report of First case study within the ISGEAG VIA Water project

By:

Michel Groen *), Harry Rolf **), and Ammon Muiti ***)

*) Acacia Water, presently working at Wiertsema & Partners, Netherlands

**) SamSamWater Foundation, Netherlands

***) KenGen Ltd, Kenya

The Final 1st Technical Report (to be released August 2018) contains over 100 pages and will become available on the SamSamWater website (http://www.samsamwater.com/projectdata.php?projectid=81). In this Synthesis Report the technical chapters are left out

Executive summary

The geophysical experiments described in this synthesis report were carried out for the project: 'Improving Sustainable Groundwater Exploration with Amended Geophysics' (ISGEAG) a partnership between Amref Health Africa, KenGen Ltd., Acacia Water and SamSamWater Foundation, relevant local stakeholders, (Earth Water Consultants) and students from Nairobi University (UoN) and Kenya Water Institute (KEWI). The project is funded by the Dutch innovation program VIA Water.

Main objective is to investigate the added value of new geophysical techniques in Kenyan groundwater exploration in comparison to the common practices in using conventional methods like VES soundings and HEP profiling as well as to address the limitations and commonly encountered pitfalls in Kenyan 'borehole siting' practices. This report gives the outcomes of a field campaign in the basement geology near Kajiado Town. Two more ISGEAG pilots are foreseen in the Coastal area of Kwale and in the Volcanic rock area of Naivasha. The final report will be issued after these 2 pilots (spring 2019).



Abstract

ISGEAG (Improving Sustainable Groundwater Exploration with Amended Geophysics) is a research project which main objective is to combine relatively new geophysical techniques and the correct application of known, conventional geophysical methods for a better conception of the groundwater aquifer systems in Kenya. This is essential for a sustainable groundwater exploration.

The project is a partnership between Amref Health Africa, KenGen Ltd. Earth Water Consultants, Acacia Water, SamSamWater Foundation and other relevant Kenyan stakeholders. Students from Nairobi University (UoN) and Kenya Water Institute (KEWI) are actively involved in the project. The project is funded by the Dutch innovation program VIA Water.

The ISGEAG research will be implemented at three different locations. This report gives the results of the first pilot application in typical basement geology near Kajiado Town. Two more ISGEAG pilots (2018) are foreseen in the Coastal area (sedimentary rocks) in Kwale County and in an area with volcanic rocks.

The first study research in Kajiado Town, Kajiado County was performed over three periods of fieldwork. During the first period (February 2017) conventional geophysical methods were applied by Earth Water Consultants Ltd, partly to support another VIA Water project (Sponge City Kajiado). In the second period (April 2017) the more advanced methods (ERT, AMT, TDEM) were successfully executed by KenGen on two selected profiles northwest of Kajiado town, one crossing the Kajiado River and one across one of the main storm water runoff gullies ('Gulley C'). Additional VES and HEP measurements were executed by AMREF. In March 2018 ISGEAG project staff shortly returned to Kajiado to conduct 4 additional TDEM soundings with the new ABEM WalkTem equipment.

General Conclusion and Recommendation

This Kajiado experiment shows how skilled applications and integrated interpretation of multiple soundings and methods can help to a better insight in the groundwater system, leading to an increased borehole drilling success rate. Lack of documented information from existing boreholes and previous surveys and the quality of survey reports is a main hinderance to fully understand the system. This is why we urgently advise to pay more attention to the quality and availability of consultant survey and borehole completion reports. These technical documents should be easy to acquire, while the information of the reports should be complete, correct and reproducible in a way that the data can be of use in future programs and help to get more insight in the hydrogeology of a certain area. This ongoing process of gaining and increasing knowledge is fundamental for the way forward to a sustainable groundwater exploration.

Summarized results of the Kajiado geophysical campaign

The main results of the Kajiado geophysical fieldwork campaign can be summarized as follows:

- The ERT method (2D electrical resistivity tomography) gave the best results especially in lateral resolution;
- When working with ERT it should be kept in mind that the exploration depth of ERT, its lateral extend of the exploration depth and its vertical and horizontal resolution is always depending the electrode distance and measuring protocol (Wenner, Schlumberger, Dipole-Dipole etc.);
- The applicability of one dimensional method as VES soundings and HEP profiling is limited, because of inherent limitation of the long electrode distance, compared to its exploration depth (1/6 of total AB length as 'rule of thumb'). Many Consultants' reports wrongly assume a much deeper exploration depth;
- HEP profiling results can be misleading because anomalies are mostly the effect of superficial (top 25m) layers and are therefore not an indication for deeper structures. Many Consultants' survey reports wrongly assume that a HEP profile measures the resistivity changes at a specific

'probing depth' of AB/2. This is not the case: each HEP measurement gives the apparent resistivity of a subsurface 'block' of roughly 1/6 of the AB in use

- Single and isolated VES measurements will not give the required insight for prospecting drilling locations, especially where the geophysics is not compared to borehole logs and not guided by wider hydro-geological insights from existing information;
- Survey 'borehole siting' reports encountered in Kenya often lack essential information and proper argumentation of the advised drilling location and drilling depth;
- The exploration depth of TDEM is potentially much deeper than ERT. The exploration depth and the resolution of TDEM is however limited in areas like Kajiado where the resistivity increases with depth.
- Standard TDEM instrumentation and AMT methodology lack information of the first tenth of meters and are poor in resolution compared to ERT. However new developments in instrumentation (ABEM WalkTem) can achieve a much higher vertical resolution even than ERT. This was confirmed by the four (4) additional TDEM soundings with the new WalkTem equipment executed insidethe fracture zone at the Kajado River, which confirmed the low resistivity up too 200 meters below ground level. The results are consistent with ERT results. See also Figure 1 on the next page. The most evident advantages of the WalkTem instrument over Zonge are:
    - The positive effect of the smaller WalkTem loop size on the influence of lateral change;
    - Increased resolution, because more datapoints are available for inversion with WalkTEM:less points need to be skipped and more 'time windows' are measured);
    - A better estimation of the depth to the basement (based on uncontrained 'smooth' inversions);
    - A better location of anomalies and its lateral extend, and a better indication of the anomaly depth (e.g. fractures).
- To derive proper resistivity information from AMT measurements, AMT has to be combined with TDEM soundings;
- Single TDEM and AMT require less labor than VES soundings and (under favorable conditions) also ERT. On the other hand, TDEM and AMT are is less straightforward, while instrumentation and interpretation are more complex. Due to the recent development of instruments like WalkTem and software like SPIA this is changing rapidly and becoming more user-friendly;
- Interpretation based on individual soundings (VES, TDEM, and AMT) assumes horizontal layering. This assumption is not valid when the geology changes within the 'spread' of the measurement. Therefore, detailed information on the location and geometry of faults cannot be obtained in complex geology with small scale lateral change (when lateral change is within the size of the (transmitter) spread. With VES, due to its relatively large electrode spread, this effect is most severe;

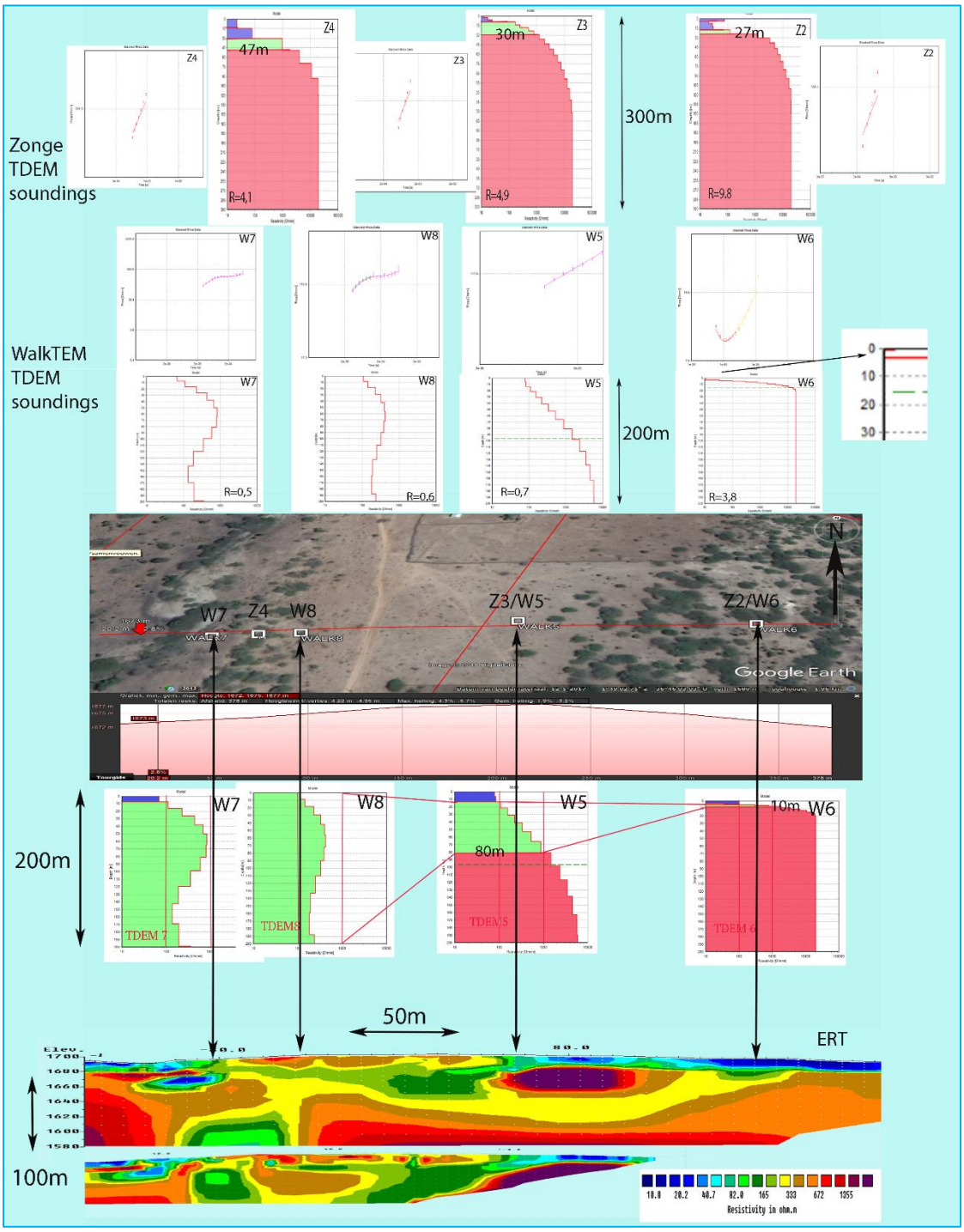


Figure 1. Kajiado River profile. Results of 4 additional ABEM WalkTem inversions (above) compared with ERT results (below). The fracture zone (deep green zones in the ERT) is confirmed by low resistivity (green) WalkTem soundings and the buried river valley (yellow in ERT) is confirmed by the 80 m basement depth in WalkTem W5.

Lessons Learned

Some of the lessons that were learned during these three periods of fieldwork include:

- It is important to get the Kenya Water Resources Authority (WRA) more involved into the project, being 'game changers' in groundwater exploration and exploitation; the project plan should have incorporated WRA involvement from the beginning. It has been difficult to contact WRA officials and get the right persons involved;
- The same goes for University of Nairobi, they could play an important role in the dissemination of the newly gained knowledge;
- Memorandums of Understanding (MOUs) with project and involved partners should be signed well in advance of starting the fieldwork mission;
- The project plan does unfortunately not allow the required time for mutual interpretation and reporting, in particular between KenGen and Dutch experts. Mission time is mainly spent on measuring in the field, logistics, data quality analysis and building a database. Afterwards email communication proves not to be effective. While in Kenya, there should be ample time for mutual interpretation, comparison, discussion. This will improve the results and the reporting and it will enforce the role and knowledge of the local partners;
- File names, stations names and numbers should be unambiguous;
- GPS coordinates should be from the start according to international standards and reciprocal with Google-Earth;
- Before the start of the fieldwork, the field location should be visited for reconnaissance and social grounding by a field hydrologist and local community leaders;
- It should be noted that in the next location the geology is completely different and a different approach will be needed;
- The ABEM WalkTem system proved to be very successful, especially in Kwale but also in Kajiado, it is an easy to use sounding system with a very high resolution combined with a relatively small transmitter loop (spread). This system should also be available in the final Naivasha exercise.

Hydrogeological interpretation

A hydro-geological concept for the Kajiado river area has been developed. See also Figure 2. The combination of a major fracture zone and an old buried river valley aquifer may have excellent potential for sustainable groundwater exploitation. Due to the lack of specific geological drilling information the concept is still hypothetical. Verification by test wells is required to decide on the area's exploitation to a sustainable water supply.

Groundwater recharge can be enhanced if vegetation cover is well-developed and kept in equilibrium. Excess rainwater from hard surfaces in the urban areas in Kajiado Town may also contribute if it is channelled towards and artificially infiltrated in the buried river valley aquifer.

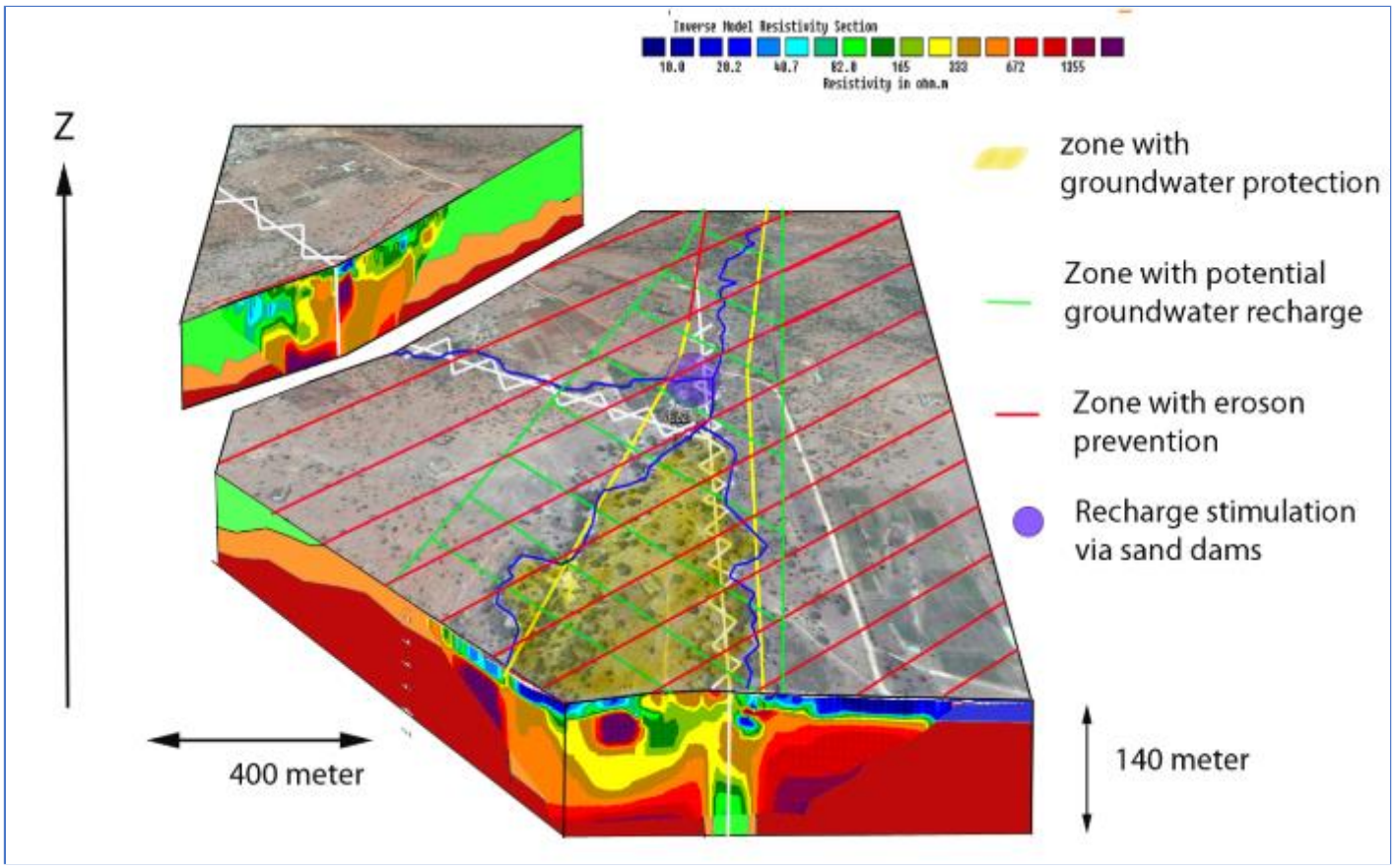


Figure 2. Hydrogeological concept based on Kajiado River results, including prospective areas for groundwater exploration shown as the buried river valley (yellow zone) next to a deep fracture zone (light green).