

**36th WEDC International Conference, Egerton University, Kenya, 2013**

**DELIVERING WATER, SANITATION AND HYGIENE SERVICES  
IN AN UNCERTAIN ENVIRONMENT**

**Towards sustainable groundwater management for  
refugee camps in Dadaab, Kenya**

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**BRIEFING PAPER 1731**

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*Close to half a million refugees live in Dadaab, Kenya and rely on groundwater from the Merti Aquifer. Preliminary hydrogeological mapping indicates over exploitation of the fresh water aquifer could result in salt water intrusion, which would put the security of water supply for the refugee camps and host population at risk. UNHCR together with University of Neuchâtel has embarked on a comprehensive study of the Merti Aquifer including remote monitoring, and numerical modelling of the aquifer in order to develop a sustainable groundwater management plan for the aquifer which supplies water to all the refugee camps in Dadaab, Kenya.*

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**Introduction**

Past experience from Darfur (Bromwich, 2007) has shown that sustained extraction of large volumes of groundwater for Refugee and Internally Displaced Persons (IDP) camps can have a significant impact on the environment, and on the host communities surrounding the camp. Since this time there has been a greater awareness that it is important to follow proven engineering and environmental management principles for sustainable aquifer monitoring and management during a humanitarian crisis and especially in a protracted refugee or IDP camp situation where large populations rely solely on groundwater sources.

The refugee camps in Dadaab, Kenya now have a population close to half a million and water for the camps is provided solely through groundwater extraction. In order to minimise impacts of the groundwater extraction and to sustainably manage the ground water resource, UNHCR together with University of Neuchâtel have embarked on a programme to gather data to comprehensively map the underlying Merti Aquifer, monitor the impact of the groundwater extraction for the Dadaab Refugee camps and numerically model long term scenarios, in order to develop a sustainable management plan for the groundwater resource.

**Context**

Dadaab is located approximately 100 kilometers from the Kenya-Somalia border. It is situated in the Garissa District, in the semi-arid North Eastern Province of Kenya. Dadaab town serves the refugee camps around the town. The camps cover a total area of 40 square kilometres and are within a 20 km radius of Dadaab town. The refugee camps host people that have fled various conflicts in the larger Eastern Africa region, most have come as a consequence of the civil war in southern Somalia. The first Dadaab camps (Ifo, Dagahaley, Hagadera) were established in the early 1990s, and have steadily grown since this time. In 2011, the East Africa drought caused a massive influx of refugees, bringing the total population to 474,000 (UNHCR, 2013), and two new camps were established Ifo 2 and Kambioos.

Water for the refugees is provided through groundwater extraction from the underlying Merti Aquifer. After the refugee influx in 2011, extraction volumes doubled from 1.8 million m<sup>3</sup>/year pumped from 18 boreholes (Lantagne, 2009), up to 3.8 million m<sup>3</sup>/year pumped from 28 boreholes within the camps (UNHCR, 2013). A further 60 boreholes across the region, draw and estimated additional 2.25 million m<sup>3</sup>/year from the aquifer (Enghoff, 2010). Security is becoming an increasing concern in the area, which means that access to the camps and the borehole locations is becoming increasingly difficult for humanitarian workers.

### Hydrogeology

Existing hydrogeological reports, Gibb (2004) and Swarensky (1977), suggest that the Merti aquifer consists of a large inland freshwater lens (200km long and 50km wide) ‘floating’ on brackish water, increasing in salinity with depth (refer Figures 1 and 2). Water quality measurements in the boreholes indicate a lateral increase in salinity from Dagahaley camp towards Hagadera camp, which is located at the edge of the freshwater lens. Over exploitation of the fresh water aquifer could result in upconing, or in lateral mobilisation of saline groundwater into the fresh water lens.

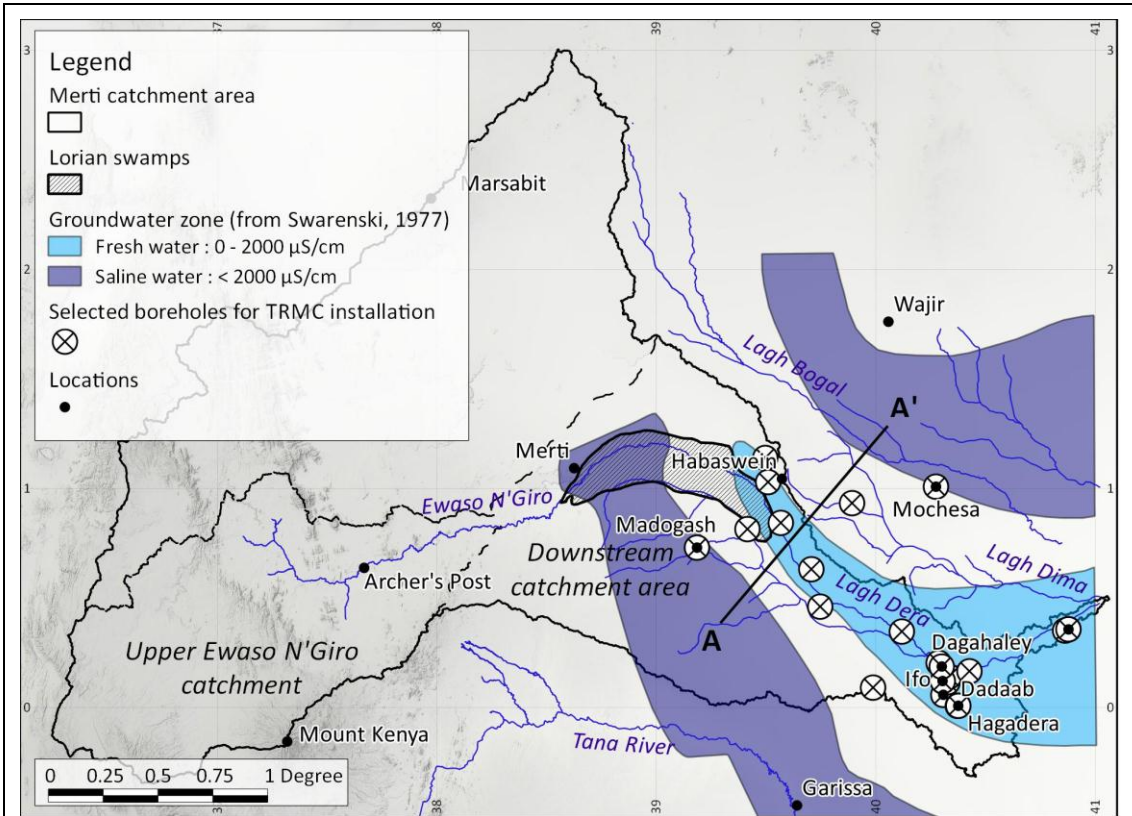


Figure 1. Plan of Merti Aquifer

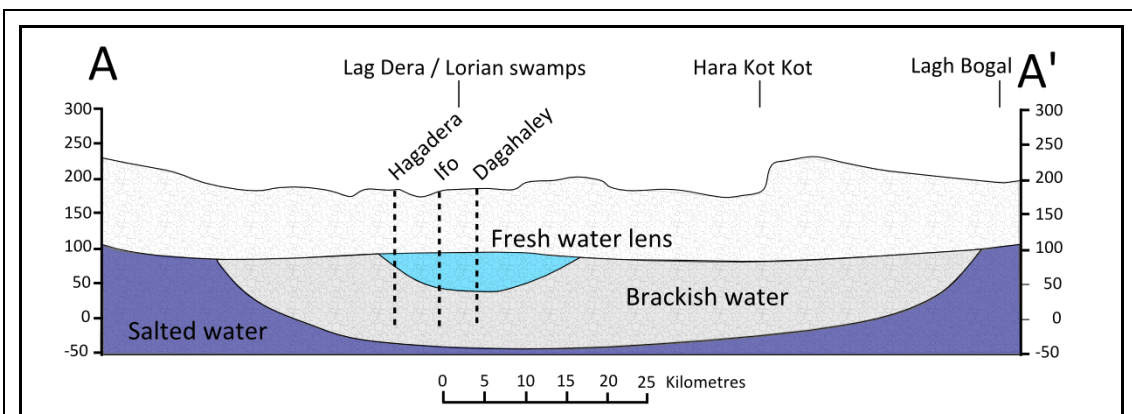


Figure 2. Cross Section of Merti Aquifer

The Merti Aquifer is located in the downstream area of the vast Ewaso N’Giro catchment (80,500km<sup>2</sup>), where infiltration of river water most probably contributes to groundwater recharge in the area of the Lorian swamps. However, major agricultural developments with irrigation systems in upstream Ewaso N’Giro catchment in recent years have led to drastically reduced river runoff, thereby possibly reducing groundwater recharge to the Merti Aquifer. The majority of the catchment area is in the semi-arid zone

which is primarily used for pastoralist activities. The refugee camps are situated at the downstream end of the catchment area. Enghoff (2010) reports that total aquifer recharge is estimated to be on average 4.5 million m<sup>3</sup>/year with an unknown lag-time between rainfall events and aquifer recharge that is likely to take centuries. So with combined refugee and host community extraction now in excess of 6 million m<sup>3</sup>/year, it is likely that the rate of extraction now exceeds the rate of fresh water recharge, and may be causing groundwater salinization of the fresh water lens. Given that the Merti Aquifer groundwater source is the only water source for the refugees and host community in the Dadaab region, the issue of fresh water scarcity has significant implications.

## Methodology

In order to understand the dynamics of the freshwater lens and potential groundwater salinization, UNHCR together with University of Neuchâtel has embarked on a comprehensive aquifer study combining remote sensing techniques, field data collection, remote monitoring technologies and numerical modelling. This includes quantifying two critical groundwater recharge mechanisms: (a) areal recharge through infiltration of rainfall and (b) infiltration through sporadic but intense flooding events in riverbeds.

## Remote sensing techniques

- For measurement of recharge by areal infiltration of rainfall, remote sensing imagery, reflecting the spatial and temporal distribution of rainfall (FEWSNET) and real evapotranspiration (MOD16) are used to quantify the efficient areal groundwater recharge in time and space.
- For measurement of groundwater recharge by infiltrating surface waters, remote sensing techniques are used to correlate rainfall and flooding events in order to spatially and temporally quantify recharge of the groundwater by ponding of surface waters.

Remote sensing data is cross-validated and calibrated with field data.

## Remote monitoring technique (TRMC)

In order to quantify groundwater recharge and dynamics (e.g. decreasing groundwater levels caused by over exploitation), direct measurements of the groundwater table and of the water quality (salinity) are necessary. Twenty boreholes across the Merti Aquifer were identified, and Tetraedre Remote Monitoring Control (TRMC) devices are being installed to transmit data from probes within the the boreholes on a daily basis via the mobile phone network to a server platform (Figure 3). Given the isolated location of the boreholes and the significant security risks associated with travel in the area, the TRMC system is a much more effective alternative to manual data retrieval.

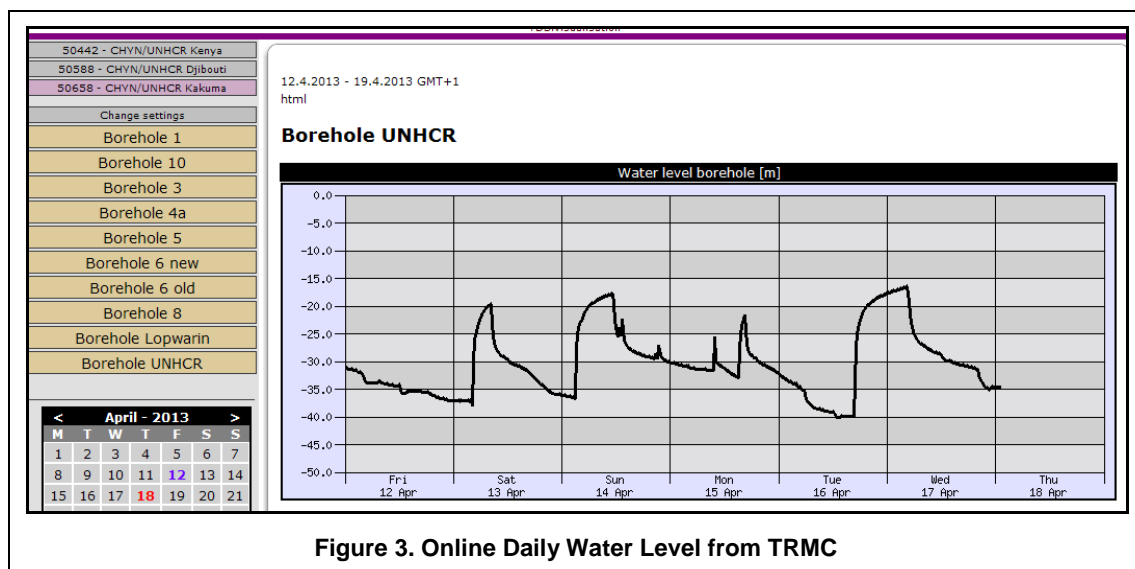


Figure 3. Online Daily Water Level from TRMC

## Numerical modelling

A conceptual hydrogeological model has been developed based on historical data reproducing the main features of the observed reality. From the conceptual model of the freshwater lens, i.e. a large inland freshwater lens 'floating' on brackish water (200km long and 50km wide), and with the compiled knowledge of aquifer geometry and parameterisation (from pumping tests) a numerical model was

constructed. Input for the model on infiltration by rainfall and along the riverbeds will be obtained from the remote sensing analysis. Model calibration will then be carried out, using the continuous and spatially distributed data from the TRMC devices in order to validate the results. In a last step, simulation of different extraction and recharge scenarios will be carried out in order to evaluate the future impact on groundwater quality and quantity. The model will test various scenarios in order to design the best exploitation strategy and assess the vulnerability of the groundwater resource. The numerical modelling aims to determine extraction limits and long term impacts.

### Main findings to date and next steps

The mapping and data collection and compilation resulted in comprehensive knowledge of the aquifer characteristics including storativity, transmissivity, water quality characteristics; leading to a good knowledge of the main groundwater conditions of the Merti Aquifer. This allowed elaboration of a first conceptual model of the area which was used to identify data gaps and sites where continuous data is essential for a numerical modelling approach. Seventy borehole locations across the Merti aquifer have been assessed with respect to the feasibility to install TRMC devices. Twenty of these locations were then identified and chosen for installation, which is now on-going. Figure 1 shows the distribution of the monitoring boreholes distributed over the entire Merti aquifer, showing that groundwater investigations aiming at sustainable water management within a spatially limited area such as Dadaab still requires data from an entire groundwater system. TRMC installation should be finalised by mid-2013, while the remote sensing analysis is on-going. Numerical modelling will then follow as soon as monitoring data is available and will be updated during a whole hydrological year, before scenarios can be simulated.

### Conclusion

Merti Aquifer studies have so far established that there is a risk of groundwater salinization into the Dadaab refugee camp water sources if the fresh water aquifer is over exploited. Within the framework of this study, the large scale remote borehole monitoring system (TRMC) is a new innovation in such a context, where groundwater salinity is monitored continuously. This data is essential for numerical modelling, but is also extremely useful for a day-to-day groundwater management in the area. The on-going numerical modelling will allow design of a sustainable water resource management plan for the Merti Aquifer, to ensure sustained access to potable water for the refugee population and host community.

Once this study is completed it will be possible to establish best practice protocols for analysis, remote monitoring and sustainable management of an aquifer in a humanitarian crisis situation, especially applicable in areas with limited access due to security or other reasons.

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