



**Unlocking the
Potential of
Groundwater
for the Poor**



**Groundwater
risk management
for growth and
development**

Can groundwater promote growth and reduce poverty?

Groundwater is essential for economic growth and can contribute to human development if used sustainably. The aim of this collaborative research project with government, research institutions and the private sector is to develop a **Groundwater Risk Management Tool** to improve decision-making to balance **economic growth**, **resource sustainability** and promote **poverty reduction**.

This newsletter has been created by the Gro for Good partners to provide an update on project progress and present preliminary results of monitoring and modelling work covering surface-water analysis, groundwater usage and welfare mapping in Kwale County.



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1. MESSAGE FROM KENYAN LEAD INVESTIGATOR

**Professor John Gathenya,
Jomo Kenyatta University of
Agriculture and Technology**

Droughts often lead to enormous pressure on finite groundwater resources, both from domestic and commercial users. Indeed, the Kenyan government has declared the current drought a national disaster, with 2.7 million people in need of food aid in arid and semi-arid parts of the country. The impacts of the drought have been felt here in Kwale, where water sources have dried up in Lunga Lunga and Kinango causing 200,000 people to suffer famine. The large economic investments like mining and agriculture have felt the impact through the diminishing surface water resource and groundwater level. The most vulnerable to drought include poorer populations, schools and health centres. Working together with all stakeholders, the Gro for Good project is advancing the development of a groundwater risk management tool that will help address such risks to groundwater security and livelihoods. The groundwater risk tool will help decision-makers to improve groundwater governance, balancing economic growth and groundwater sustainability for domestic and commercial users in pursuit of the wider goal of poverty reduction.



We would like to thank the local communities of Kwale County, Water Resource User Associations (WRUA), Kwale County Government, Water Resources Management Authority (WRMA), Base Titanium Ltd., Kwale International Sugar Company Ltd. (KISCOL), the Kenya Meteorological Department (KMD), Rural Focus Ltd. (RFL), the University of Oxford, the *Grupo de Hidrología Subterránea* of the Polytechnic University of Catalonia (UPC), the Jomo Kenyatta University of Agriculture and Technology (JKUAT), the University of Nairobi (UoN), the National Drought Management Authority (NDMA), and the World Wildlife Fund (WWF) for their continued support towards the development of the groundwater risk management tool.

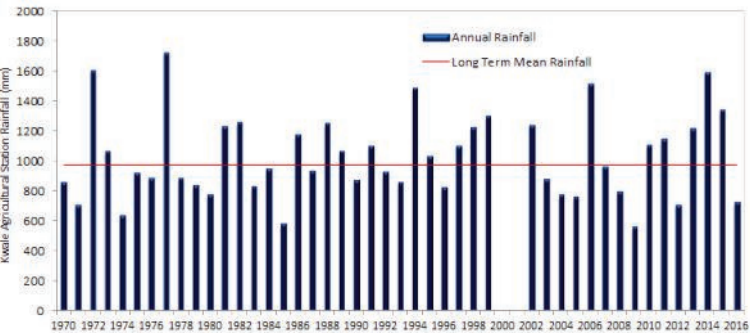
Photo of John Gathenya by V. Atakos
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2. RAIN - KWALE’S KEY RESOURCE

Everyone knows rainfall varies from season to season and year to year. Improved understanding of changes in rainfall patterns will help us evaluate the availability of water in rivers and dams, and calculate the amount of water entering into groundwater reserves (aquifers). The project has been working with local partners to combine multiple sources of historical and existing data records to give us more confidence in our understanding of rainfall patterns and variation in Kwale County. We are grateful for the generous support of the Kenya Meteorological Department, Base Titanium and KISCOL for sharing daily rainfall data from recent decades.

Preliminary analysis of this data suggests that:

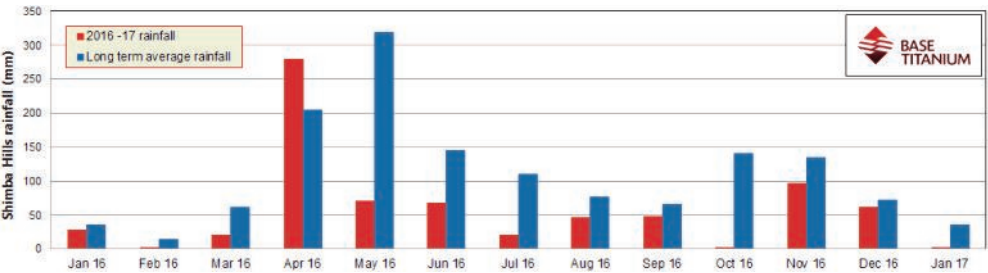
- Annual rainfall varied between 500 - 1700mm with a mean annual total of 977mm
- On average there are 60 days of rain per year - though there have been years with as few as 35 days of rain and as many as 100 days



Long term rainfall data from the KMD rain gauge at Kwale Agricultural Station (no data from 2000-2001)

- From 1970 to now, we see no pattern of increase or decrease in annual rainfall or number of rainy days per year
- Further analysis is being conducted on other stations to build on these findings.

Base Titanium's environmental network records show that rainfall at Shimba Hills Centre was significantly below average in 2016. The long term mean annual rainfall at this site is 1,380mm; 2016 rainfall at this gauge was 739mm, which is 54% of the mean. 2016 was the second driest calendar year on record, the driest year being 1974 (with 693mm, 50% of the long term mean).



Drought data: Actual and average monthly rainfall at Shimba Hills (1-Jan-16 to 31-Jan-17)

3. IMPROVED DATA FOR BETTER DECISIONS TO BENEFIT ALL

Environmental Monitoring Collaboration

Gro for Good project has designed and installed an environmental monitoring network to complement existing data gathering by Base Titanium, KMD, WRMA and KISCOL. The environmental monitoring network collects data on surface and groundwater quantity and quality, handpump abstraction and climate monitoring. There are 21 manual rain gauges, 4 Automatic Weather Stations (AWS), 3 automatic in-stream water level monitors (data loggers) and 5 groundwater level loggers. This network builds on the existing network of over 70 monitoring sites operated by Base Titanium Ltd., over 30 monitoring sites operated by KISCOL, and more than 10 sites operated by KMD. Additional flow measurements using Current-Velocity Meter has also been undertaken by the project. The WRMA has been responsible for installation and operation of all the main river gauging stations on Ramisi and Mukurumudzi rivers and has been actively collecting data generated by different stakeholders. A message from the WRMA can be found on the facing page.



Flow Measurement on Ramisi River at Eshu Bridge during short rains in November 2017 using Current Velocity Meter



Gilbert of TAHMO undertaking regular maintenance of the AWS at Kidongo Gate in Shimba Hills



A MESSAGE FROM WRMA: OUR SUPPORT FOR THE GRO FOR GOOD PROJECT

The Water Resource Management Authority (WRMA) is a State Corporation under the Ministry of Water and Irrigation. WRMA was established in the year 2003 pursuant to the enactment of Water Act number eight of 2002. WRMA is the lead agency in the regulation and management of water resources nationally.

One of WRMA's core functions is to ensure that there is fair, transparent and participatory allocation and apportionment of water resources to all users, so that everyone who needs water can access it now and for generations to come. Communities are directly affected by the state of water resources. Livelihoods depend not only on water availability but also on the quality of available water, which may be affected by organic pollution from sewage, animal and human waste as well as inorganic pollution from transport, agriculture or industry. The quality of groundwater resources may also be affected by seawater intrusion.



WRMA staff Susan Mwangi and David Shokut undertake borehole monitoring at Tiwi BH 6

Kwale's groundwater resources have attracted several major abstractors in recent years. Recognising the importance of balancing competing demands for domestic, agricultural and industrial uses of groundwater, the Water Resources Management Authority (WRMA) has been collaborating closely with the Gro for GooD project since its inception. We have been involved directly in a number of activities, including provision of the ABEM SAS1000 Terrameter and participation in the geophysical survey and installation of water level recorders and other monitoring equipment. Data generated from these activities will provide critical inputs to the hydrogeological flow model for Kwale County that is under development by the project and will form the basis of the Groundwater Risk Management Tool. The tool, once developed, will prove most useful in decision-making by WRMA as we allocate the groundwater resources in Kwale County.

WRMA is ISO 9001: 2008 Certified

Monitoring people's welfare

Gro for GooD collected data from over 3,000 households each year in 2014, 2015 and 2016 with the support of over 20 local staff trained by Oxford University. These data provide insights into who is poor, where people suffering poverty live and what is changing people's welfare over time. The sampling strategy spans across Matuga, Msambweni and Lunga Lunga constituencies.

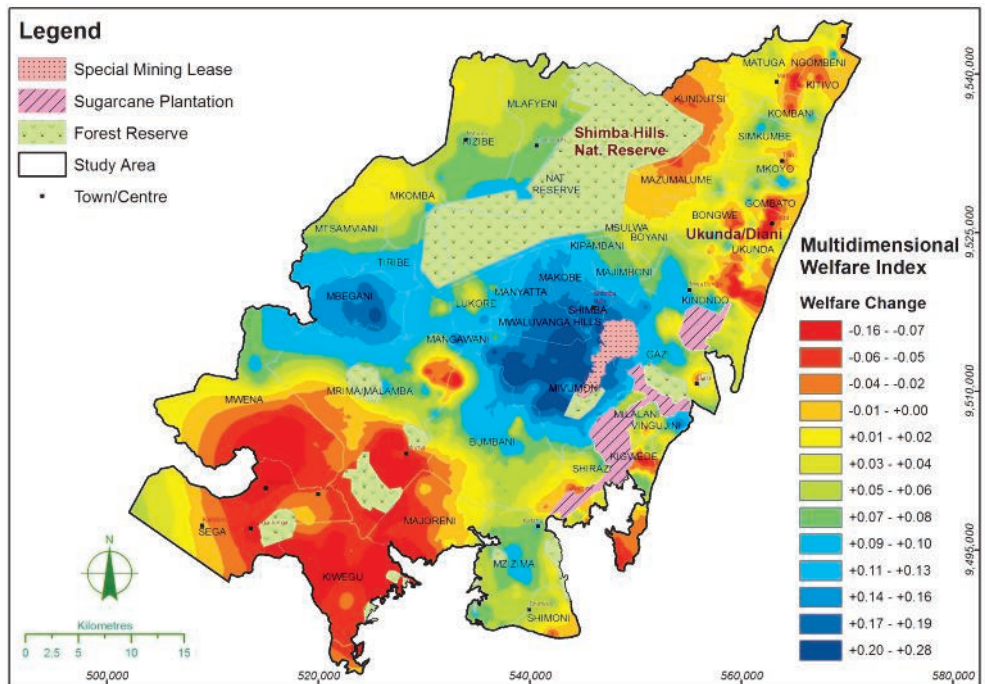
The latest round of the household survey took place in September to November 2016. The survey captures information on demographic and socio-economic, health, water sources, waterpoint management, water payments, water resources management as well as governance issues. In addition to the face-to-face interviews Gro for GooD has successfully piloted a mobile-based socio-economic survey instrument on 2000 households. This has been designed to be used for rapid updating of the social component of

the Groundwater Risk Management Tool.



Where are the poor?

Welfare change 2014-2015



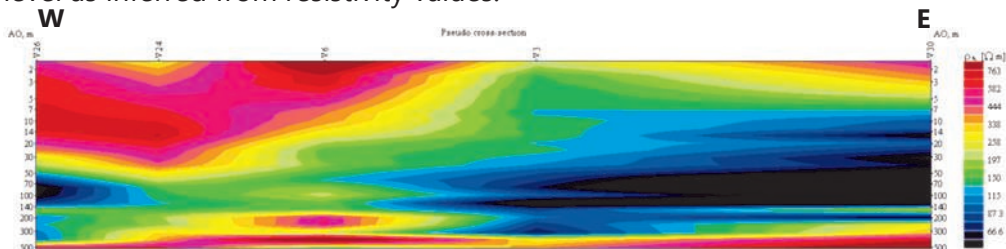
Kwale County Government is responding to the need to improve the lives of 7 out of 10 Kwale County residents who live below the poverty line of USD\$1.25 a day. To achieve this, the County needs to know who the poor are, where they are and the likely impacts of different poverty interventions. In an effort to answer some of these questions, data from the three household surveys were used to evaluate and map welfare between 2014 and 2015.

Households experiencing declining welfare in this period were observed to be in regions largely influenced by the tourism (Ukunda/Diani) and fishing (coastal strip) industries. However, some pockets within the coastal strip (Kinondo and Vingungiri) were observed to have a positive change in welfare. Households that experienced a large positive change in welfare were observed to be around Lukore, Shimba Hills, Mivumoni, Mbegani, Majimboni, Mangawani, Mzizima, Kinondo and Mwaluvanga, among others. The majority of households in Lunga Lunga experienced a decline in welfare. The welfare impacts of the current drought could be monitored using a similar approach.

4. UNDERSTANDING KWALE'S HYDROLOGY

The research team have developed a detailed surface water hydrological model using the Soil Water Assessment Tool (SWAT). This tool allows simulation of the quality and quantity of surface and groundwater, prediction of environmental impacts of land use, land management practices and climate change. The hydrological model covers Mukurumudzi, Ramisi, Mtawa and Mwachema River catchments. The input data included; land-use and land cover data (from Food and Agriculture Organization), Soil data (from Kenya Soil and Terrain Database) and 90m digital elevation model (from NASA Shuttle Radar Topographic Mission). Outputs from the model are being used to support the development, advancing and recalibrating of the groundwater model. Results from these models will be shared in the next newsletter issue.

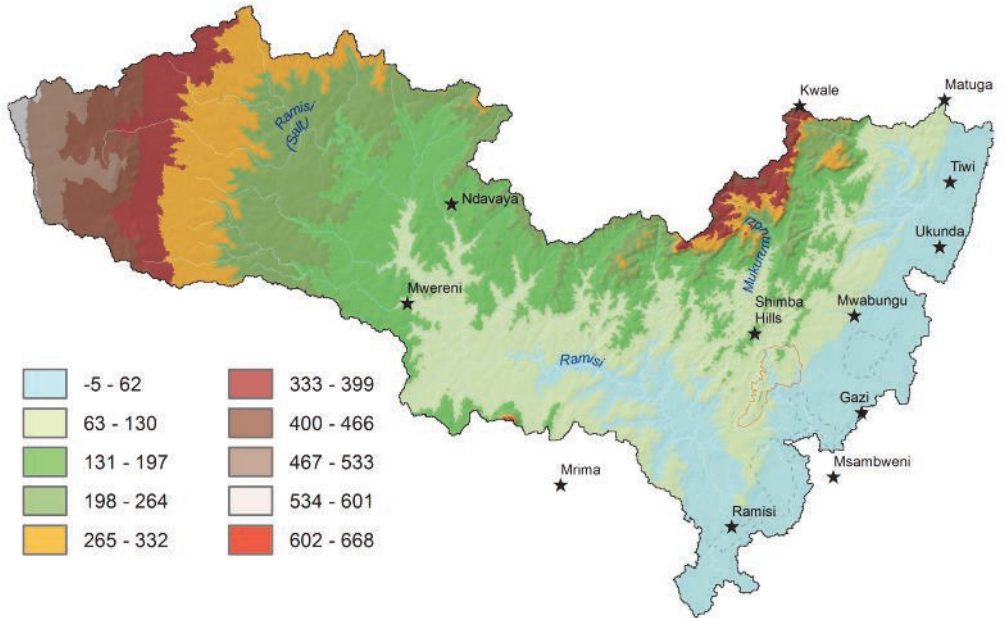
As we read from WRMA, geophysical surveys conducted by the University of Nairobi, WRMA and Rural Focus Ltd. are also feeding into our understanding of the groundwater system beneath Kwale county. One of the methods used - Vertical Electrical Sounding - involves putting an electric current of known intensity through the ground and measuring electric potential difference between two points along a transect. This indicates the resistivity of subsurface structures which can be used to identify the presence of water or different geological formations. The results below shows that saline/ brackish water (dark blue) extends inland to about 6km around Diani, whilst lenses of saline water are observed beyond 8km from the coastline. These are fossil water and may be associated with the Maji ya Chumvi (Saline Water) Beds. However, fresh water (light blue to light green) can be obtained at depth greater than 200m below ground level as inferred from resistivity values.



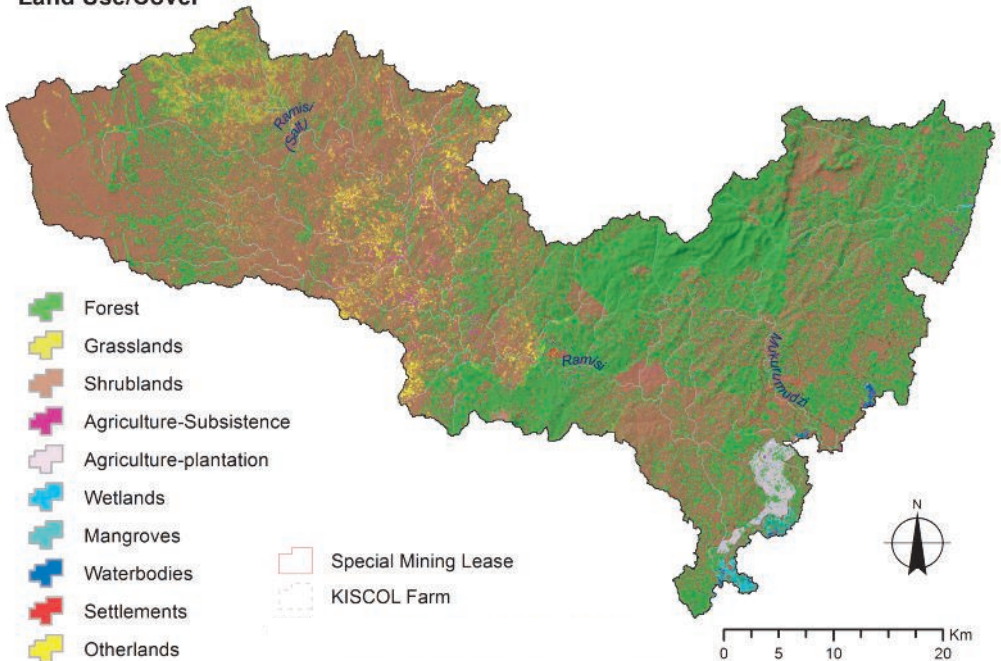
Tomograph resulting from Vertical Electrical Sounding running inland from the coast through Kinondo to Kubo

The Ramisi-Mukurumudzi-Mwachema Basin

Elevation (m.a.s.l)

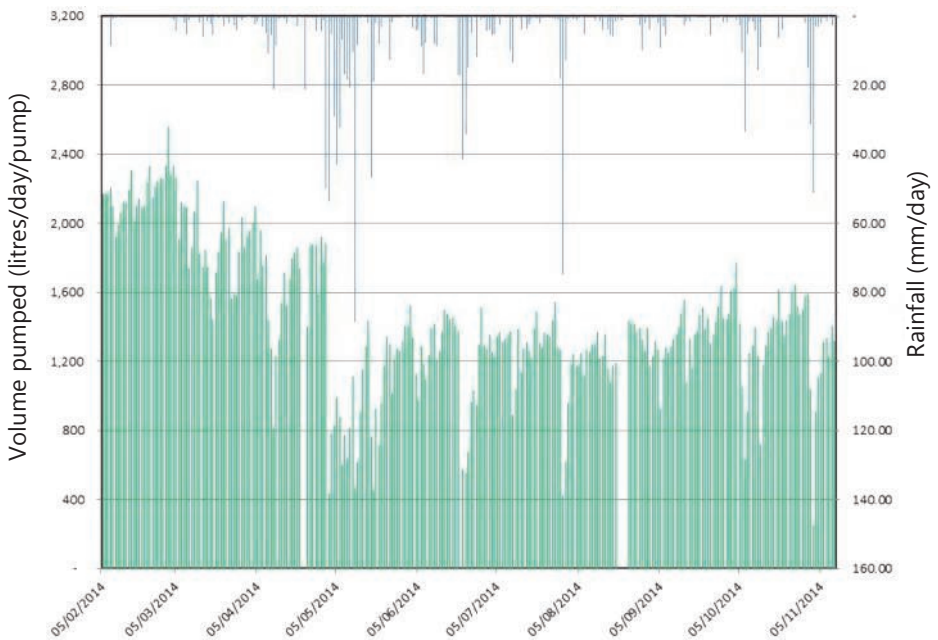


Land Use/Cover



5. CAN HANDPUMPS TALK?

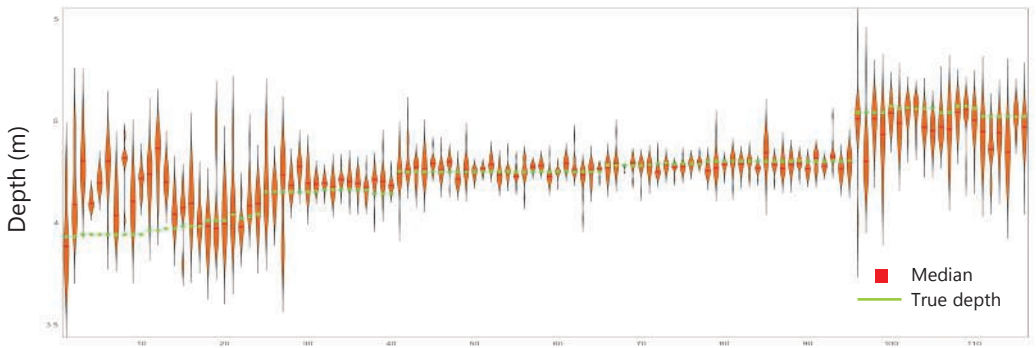
Kwale handpumps have had an 'upgrade' with a transmitter installed to send mobile data on daily usage. These 'smart handpumps' provide lots of useful data on how and when people use handpumps to help keep the water flowing. Some of the early data has shown that with certain rainfall patterns people stop using the handpumps. Through our analysis we hope to better understand how these rainfall-water use patterns will vary in the future with implications for public health and the financial sustainability of maintaining community water supplies.



Above: Rainfall and handpump use in 2014; Below: Unprotected surface water sources are at higher risk of microbial contamination in comparison to groundwater.



In addition, we have been testing a new technique to estimate groundwater depth from the smart handpump data. Using machine learning methods we are making progress in using handpumps to tell us how the groundwater level is changing. This will provide an early warning of risks to communities and allow appropriate responses before people and livelihoods are affected by significant changes in groundwater levels.



Above: This graph shows the spread and median of groundwater depth estimations (in red) from handpumps where the true groundwater level is also being measured (shown in green), Machine learning techniques using data transmitted from handpumps have reduced the median absolute error in our depth estimates to just 2.5cm. Below: Heloise Greeff and Farah Colchester, DPhil students in the Department of Engineering, University of Oxford collecting data from handpumps.



6. IS GROUNDWATER SAFE TO DRINK?

In June 2016, a study of waterpoints was conducted to better understand groundwater contamination. These were handpumps and open wells located in Munje Madukani, Milalani-Nimbodze kwa Mwabiti, Vingujini (2 points), the Fihoni Salha Centre, Fihoni Primary School, Magaoni -Mskitini and Gazi. Samples were taken every day for a month using three different testing methods. The tests showed that microbial water quality can be very variable from one day to the next, or only minutes apart. This variability is partly explained by the test methods and also by the inherent variability in 'microbial organisms' and the groundwater system.

To test the water, thermotolerant coliforms (TTCs), a group of bacteria that indicate contamination from faecal matter, were cultured using filtration and incubation in petri dishes. *Escherichia coli* (*E. coli*) bacteria, an even more specific indicator of faecal contamination, were measured using specially designed bags and a reagent that makes the sample water change from yellow to blue if *E. coli* are present. Finally, using a portable fluorimeter, tryptophan-like fluorescence (TLF) was measured, which is a property of the proteinaceous material that bacteria excrete when they consume and break down organic matter. The analysis is ongoing and results will be shared in the next newsletter.



Left: Bacteria cultured in a petri dish to investigate groundwater contamination; Right: Test kit bag showing colour change on presence of E. Coli (Photo: Aquagenx)

In addition to the detailed microbial water quality study that focused on eight specific water points, a wide range of water quality measurements have been taken for more than eighty points throughout the study area. This large-scale sampling campaign was conducted three times (in September 2015, March 2016 and June 2016). A flow-cell was used to measure pH, electrical conductivity, temperature, dissolved oxygen and redox potential (ORP) at each water point. Alkalinity, ammonia and *E. coli* were also measured in the field. Other parameters including major ions, trace metals, water isotopes (deuterium and oxygen 18) and total organic carbon were analysed in laboratories in Barcelona, Spain. As well as providing information on risks to people depending on Kwale's groundwater for drinking water supplies, the results from these sampling campaigns also inform the hydrogeological model which will inform the Groundwater Risk Management Tool.

During the June sampling campaign, two sites where groundwater was rising up through the sand were discovered on beaches in Diani and Msambweni. One might expect that this was sea water that was pushed inland during high tide and was flowing back to sea during low tide. However, after sampling the upwelling water we discovered that it had lower electrical conductivity than the sea water, which seems to suggest that it is a mixture of sea water and groundwater. The upwelling water also had high concentrations of some trace elements and some microbial contamination, which was further evidence that this was not seawater.



Upwelling water on Diani beach

7. REGIONAL AND INTERNATIONAL PUBLICITY AND COLLABORATION

- Since 2015, the programme has convened two public stakeholder workshops in Kwale County, both of which were officiated by His Excellency Governor Salim Mvurya. The third of these annual workshops will be held on 3rd March 2017 at Leopard Beach Hotel in Diani



- Project partners are benefitting from international links through the UPGro consortium project to which Gro for Good belongs: In February 2017, Faith Ngei (Base Titanium) and Willy Sasaka (RFL) participated in a Capacity-strengthening & Knowledge Co-production workshop on the management and analysis of long-term groundwater records organised by UPGro, AfriWatSan and The Chronicles Consortium at Sokoine University of Agriculture, Morogoro, Tanzania

The project has also shared insights from research in Kwale at major international events:

- A key note presentation from the Kwale work was presented at 10th anniversary conference of the ESRC-DFID Joint Fund for Poverty Alleviation Research titled "Lessons from a Decade's Research on Poverty: Innovation, Engagement and Impact" in Pretoria, South Africa in March 2016
- Gro for Good findings were presented at 7th Rural Water Sustainability Network global forum titled "Water for Everyone" held in Abidjan, Cote d'Ivoire between 29th Nov 2016 and 1st Dec 2016

8. OPPORTUNITIES TO PARTICIPATE

1. Schools project

Gro for GooD is looking to pilot a small-scale education project giving secondary school students in Kwale County the opportunity to investigate groundwater issues for themselves. If you would be interested in taking part in this project as an expert to whom students can address questions, whether in writing or during a classroom session, please get in touch with the Gro for GooD office.

2. Mobile phone panel surveys

The project will continue to collect socio-economic data through mobile phone interviews and greatly appreciates the support of our respondents – thank you!

9. SUCCESS THROUGH PARTNERSHIP

All monitoring activities will continue in collaboration with our partners. Once again we would like to thank the local communities of Kwale County, Water Resource User Associations (WRUA), the respective Ministry in the County Government of Kwale, the Water Resources Management Authority (WRMA), Base Titanium Ltd., Kwale International Sugar Company Ltd. (KISCOL), the Kenya Meteorological Department (KMD), the National Drought Management Authority (NDMA), and the World Wildlife Fund (WWF) for their continued support.



Left: Groundwater is more interesting than football; Right: Ramisi WRUA members with RFL staff installing river staff gauges at Eshu Bridge on Ramisi River



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For feedback or follow up on any items in this newsletter, please contact:

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Project partners



Kwale
County
Government



Oxford University



Jomo Kenyatta
University



University of
Nairobi



Rural Focus Ltd.



WRMA



Grupo de
Hidrología
Subterránea



BASE
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