Review of the Report: Advanced Survey of Groundwater Resources of Northern and Central Turkana County, Kenya (RTI, August 2013)

In this document IGRAC provides brief review of the Final Technical Report *Advanced Survey of Groundwater Resources of Northern and Central Turkana County, Kenya* conducted as a part of the GRIDMAP Project and co-commissioned by UNESCO. IGRAC is interested in the GRIDMAP project because it deals with regional groundwater resources assessment - one of IGRAC's main activities.

Abstract

The methodology used in the GRID project is referred to as WATEX, short for "water exploration" which has been developed and executed by RTI. It combines data from different sources (remote sensing, geophysical data, geological maps, borehole data, rainfall data, etc.) to make a first assessment of groundwater development potential for relatively large areas. In general this is a proven approach to hydrogeological reconnaissance surveys, and therefore the method should be suitable for groundwater mapping for emergency situations, crisis areas and as a preliminary groundwater resources assessment. The report however claims several innovative features and very high success rates for drilling boreholes. These claims have raised attention not only to the groundwater resources which have been mapped, but also to the method itself.

Reviewing the Final Technical Report raised a number of issues which should be resolved to enable verification of the applied procedures and to avoid potentially unrealistically high expectations of the potential for groundwater development in the Turkana region and of the capabilities of the WATEX method itself. Most importantly: the report contains no clear description of the methodology, procedures and data used; nor does it describe limitations of the method. This means it is not possible to verify or reproduce the method. It will also limit further development of the method and its application in other parts of the world. The method used to estimate groundwater recharge is extremely basic and seems unrealistically high in comparison to recharge rates reported in relevant literature.

The over-all impression on the report is that the results presented are very optimistic and that the potential for sustainable groundwater development in the region may prove to be significantly less. Before any structural development of the resource is undertaken, improved estimates should be made of the available groundwater resources (better estimates of groundwater volume, recharge rates and groundwater quality distribution) and of the sustainable development potential (taking into account negative effects of groundwater development e.g. on ecosystems or existing users).

General Comments

Since the WATEX methodology is promoted as a powerful and innovative tool for quickly finding groundwater in emergency situations and crisis areas, a clear accounting of the methodology implementation in the project should be made publically available and supported by a sound documentation of the methodology. A clearer description of the applied methodology, its limitations, datasets used and the data processing should be presented to the reader. The report should make clear that the WATEX method combines multispectral imagery (LANDSAT data), satellite radar data (L-band), ground penetrating radar (GPR) data, a digital elevation model (DEM) and ground-truthing to locate regions with a high potential for containing groundwater reserves. Also an insight should be given as to what data are used when referring to the 'proprietary RTI database with data from around the world'. As it stands now, the methodology section could mislead the reader about the project's use of satellite radar data and its potential applications more broadly. The report also needs to carefully differentiate between the use of satellite radar data and GPR measurements carried out in the field. Additionally, information about the processing and integration of remote sensing data is insufficient to allow replication. Further specific concerns about the methodology and some results presented in the report are summarized below.

Soil Moisture Detection using Radar Data

In its current presentation, the methodology leads the reader to believe that satellite radar data (L-band) in combination with a 'proprietary RTI image processing tool' can detect soil moisture up to depths of 20m (pp.18 & 28) or 40 meters (p.16). A brief literature review indicates that this is unlikely to be possible. The following should be included and clarified in the report to avoid possible misconceptions:

1) Radar data are primarily used to map fractures, uplifts and subsidence (Gachet 2008).
2) The maximum ground penetration depth of L-band radar is 3m when applied on dry sands. For detecting soil moisture at depth of 20 to 40 m one must either use modelling to link surface soil moisture to deeper soil moistures or use ground penetrating radar (GPR) in the field (Meijerink et al. 2007, p.75).
3) According to Gachet (2008), the detection of moisture using satellite radar data is only of secondary importance and restricted to wadis, since the penetration of radar signals is restricted to the near-surface.

Justifiably, the survey focuses upon the assessment of the water potential of alluvial aquifers located along existing wadis and nearby fractures and faults. However, clarification of the methodological issues (listed above) in the report is necessary. Otherwise a reader might believe that WATEX detects and maps (deep) groundwater bodies directly using satellite radar data in combination with its undocumented image processing tool.

Recharge Rates

Review of the report also raises concerns about the reliability of the estimates of precipitation-based recharge rates. Admittedly, assessing groundwater recharge and storage in such a large study area is not an easy task. Groundwater recharge cannot be directly measured on a regional scale and is difficult to estimate, especially in semi-arid regions such as Turkana County. Groundwater recharge is not just determined precipitation, but is also highly dependent on other factors like evapo-transpiration and local hydrogeology. Basing recharge calculations on only precipitation data can only give very rough estimates. Consequently, groundwater resource management decisions should not be based solely on such data.

One would also expect conservative estimates of recharge or at least indications of minimum and maximum estimates, also based on findings of other scientific studies. The reported recharge rates seem unrealistically high, compared to what is discussed in available literature. The regional recharge rate of the study area is estimated to be 16.3% of annual precipitation. Studies by Bouwer (1989) and Andersen (2008) show that average regional recharge may be as low as 1% of the annual precipitation since evapotranspiration captures most of the water entering the soil and recharge occurs only during extreme rainfall events (Pilgrim et al., 1988). Green et al. (2012), for example, estimated recharge rates for seven different regions with semi-arid climates within the US ranging from 2% to 7% only. Most convincingly, Scanlon et al. (2006), in their global synthesis of 140 recharge study sites in semiarid and arid regions, conclude that average recharge rates in these regions range from 0.1 to 5% of long-term average precipitation.

Given the large discrepancy between the recharge rate presented in the study and those found in literature, the report's conclusions on renewable groundwater resources for the area should be treated with extreme care.

Estimates of Annual Precipitation and Recharge

The report does not clearly explain how precipitation estimates were calculated and it appears that the area used to calculate the total rainfall is most likely not correct (it seems to be too large). The methodology implies that annual precipitation volume of the study area was calculated based on river basins (p. 38 and 55). The problem is that these basins extend well beyond the study area's boundaries into regions with possibly much larger annual precipitation. If this is truly the case, annual rainfall from an area of 43,442 km² is infiltrating and recharging shallow aquifers in the much smaller study area of 36,000 km². In addition, some of the drier parts of the study area were not considered in this calculation (Figure 2.15 on page 35), which would make the discrepancy even larger. Consequently, the reader might infer that the actual volumes of rainfall and recharge within the study area are higher than they are in reality.

The Turkwell watershed for example receives most of its rainfall upstream in the Kenyan highlands (p. 34), outside of the survey area. This portion of rainfall should however not be included when calculating precipitation and shallow aquifer recharge within the study area. Accurately calculating the total annual rainfall of the study area requires using a spatially distributed rainfall map (as included in p. 15 of the report) to find the rainfall occurring within the study area boundaries. To compare and possibly validate precipitation and recharge estimates, the study might have used available remote sensing products for parameters such as regional precipitation, temperature and evapotranspiration. However, these data sources are not mentioned in the report.

Total Recharge Volumes

Review of the methodology indicates that annual recharge volumes for deep aquifers may have been calculated without properly accounting for recharge already received by shallow aquifers – resulting in double counting. Data presented in the study supported this indication: the estimated total annual recharge of the study area of 3.45 Bm³ (p. 59) is 0.68 Bm³ larger than the total available recharge of 2.77 Bm³ (p.55). For the Lotikipi basin, annual groundwater recharge for the deep Lotikipi aquifer was estimated almost two times larger than the recharge volume actually available for this area (compare tables 3.1 and 2.7). Consequently, these estimates should be carefully reviewed.

Selection of Aquifers with Potential for Development

The justification and potential impacts of identifying aquifers as having development potential should be discussed in more detail. The study qualifies shallow Wadi aquifers with an overall productivity of ~100,000 m³/yr and a recharge area supplying at least 1Mm³/yr (p.40) as having development potential for communities of 20,000 people. References and scientific justifications for these values should be provided in the report. Prior to deciding the potential development of an aquifer, additional impact assessments - such as eco-system dependency and current groundwater usage volumes - should be carried out.

The report should also explain in greater detail how exactly annual recharge volumes of Wadi aquifers were calculated as this procedure appears to be different than the one for the overall study area. The methodology for estimating Wadi aquifer recharge volumes seemingly accounts for evapotranspiration, erratic runoff and other water losses. However, this section does not provide further details. If the methodologies applied to the regional and local contexts are different, then the report should justify the appropriateness of each approach.

Usage of Borehole Data

According to the report, the used groundwater model is based mainly on "an indirect scientific approach" and some existing borehole data (see p. 50). Since the validation process of the groundwater model was carried out using the borehole data it should be clarified which data was used as model input and which for validation (this should be two separate data sets).

Conclusions

It seems that the WATEX methodology may be suitable to execute as a first groundwater mapping in the regions with a high likelihood of containing renewable groundwater reserves. However, claims about the innovative nature of the method cannot be verified as the report does not give clear descriptions of the applied method, leaving the reader with unanswered questions about methodology, limitations and replicability elsewhere.

Estimates of renewable groundwater resources are based on very rough and seemingly unlikely high estimates of recharge rates. In terms of development potential of the groundwater resources in the Turkana region this means the report may prove to be too optimistic. Future development or planning of the groundwater resource should not be based solely on these optimistic estimates.

Recommendations to improve the report:

1. A clear description of the applied methodology and its limitations should be made available.
2. The report needs to carefully differentiate between the use of satellite, ground penetrating radar data and other data sources to avoid misleading the reader about the potential application of satellite radar data, especially concerning the detection of soil moisture in depths of 20m or more.
3. The chosen recharge rates seem unrealistically high and based on broad assumptions. This needs to be made explicit in the report.
4. Precipitation and recharge calculations seem to be based on a much larger area than the study area which might result in unrealistic estimations of renewable groundwater volumes.
5. Recharge for deep aquifers may have been calculated without properly accounting for recharge already received by shallow aquifers – resulting in double counting.
6. The methodology for calculating annual recharge volumes of Wadi aquifers needs to be explained in more detail as this procedure appears to be different than the one for the overall study area.
7. The selection process of aquifers with potential for development needs to be explained in more detail and should include impact assessment.
8. It should be clarified which borehole data was used as model input and which for validation.

Literature

- Andersen, F.H. (2008): Hydrological modelling in a semi-arid area using remote sensing data, Doctoral Thesis, Department of Geography and Geology, University of Copenhagen, Copenhagen.
- Bouwer, H. (1989): Estimating and enhancing groundwater recharge, in: Sharma, M. & L., Balkema (eds): Groundwater Recharge, Rotterdam, The Netherlands.
- Gachet, A. (2008): WATEX: A new Approach to preventing Water Based Conflicts. In: Ricci, A. (ed.) (2008): From early warning to early action? The debate on the enhancement of the EU's crisis response capability continues. Office for Official Publications of the European Communities.
- Green, R.T., F.P. Bertetti, & M. Hernandez (2012): Recharge Variability in Semi-Arid Climates. Nature Education Knowlede 3 (10): p. 34.
- Meijerink, A.M.J., Bannert, D., Batelaan, O., Lubczynski, M.W. & pointet, T. (2007): Remote Sensing Applications to Groundwater. UNESCO: Paris.
- Pilgrim, D. H., T.G. Chapman & D.G. Doran (1988): Problems of rainfall runoff modelling in arid and semiarid regions/Problemes de la mise au point de modeles pluié ecoulement dans les regions arides et semi-arides, Hydrolog. Sci. J. 33: p. 379–400.
- Scanlon, B.R., K.E. Keese, A.L. Flint, L.E. Flint, C.B. Gaye, W.M. Edmunds & I. Simmers (2006): Global synthesis of groundwater recharge in semiarid and arid regions. Hydrological Processes 20: p. 3335-3370