British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

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TECHNICAL REPORT IR/00/61
Overseas Geology Series

Visit to RUWASA Project Area, Mbale, S E Uganda, September 2000

J Davies

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Executive Summary

During 10-15th September 2000 a visit was made to the DANIDA funded RUWASA Project in S E Uganda by a BGS Senior Hydrogeologist, Mr J Davies, to assess the possible application of horizontal borehole drilling to spring development . Within the project area, east of Mbale, Gravity Fed water distribution Systems (GFS), fed by high altitude springs, are being developed as a cost effective, low maintenance method of supplying moderately large villages. Three typical GFS were visited on the lower slopes of Mount Elgon.

Meetings were held at the GFS section of the Directorate of Water Development in Kampala on 11th and 15th September and at the RUWASA project offices in Mbale on 14th September where topics discussed included:

- Application of horizontal drilling to GFS.
- Development of groundwater development potential maps.
- Application of collector well systems in weathered granite and sand river environments.
- Community self monitoring of groundwater resources.
- Groundwater from low permeability rocks in sub-Saharan Africa.

The conclusions of the field visits and meetings included:

(1) Horizontal drilling cannot be undertaken to enhance the yields of GFS as presently designed due to access problems. However, there is a need to assess the potential for drilling horizontal drains into the lower slopes at accessible locations for provision of more sustainable supplies at higher discharge rates away from present spring systems. Such systems should not be greatly affected by seasonal rainfall/water level fluctuations and the effects of prolonged drought. BGS could assist RUWASA in the development of such schemes using procedures developed in St Helena, and within collector well systems constructed in Zimbabwe, Sri Lanka and Botswana.

(2) RUWASA have compiled a comprehensive hydrogeological database that needs to be analysed and used to produce hydrogeological maps designed to meet the needs of district users as a pilot project. The systems and map production method developed could then be applied to other districts in Uganda and ultimately to the production of a series of national hydrogeological maps. BGS could advise RUWASA on the production of hydrogeological and groundwater development potential maps using technologies developed in the UK and Nigeria.

(3) Hydrogeological survey data collection and storage systems in Uganda need to be upgraded along the lines of those developed for the KaR project in Tanzania and Ghana. These methods need to be applied with the full participation of communities who in turn should be encouraged to undertake self-monitoring of their own water supply systems in the long term. The short and long term data produced by these activities should be integrated into an on-going GIS database that would allow production of updated maps on a regular basis. Such maps can be used for short and long term planning. BGS would be able to assist the Directorate of Water Development with the collection of appropriate hydrogeological data, required for the production of hydrogeological maps, using methods used initially in Nigeria, and those being developed in Tanzania and Ghana.

List of Abbreviations

BGS	British Geological Survey
DANIDA	Danish International Development Agency
DFID	Department for International Development
DWD	Directorate of Water Development
ECWSP	Eastern Centres Water Supply Project
GIS	Geographical Information System
GFS	Gravity Flow Scheme
KAR	Knowledge and Research
NGO	Non-Governmental Organisation
RUWASA	Rural Water Supply and Sanitation Project
TM	Thematic Mapper
UNICEF	United Nations Childrens Emergency Fund

1. INTRODUCTION

At the invitation of the DANIDA funded RUWASA Project a BGS Senior Hydrogeologist, Mr J Davies, visited the project area east of Mbale in S E Uganda to discuss with project staff the possible application of horizontal borehole drilling to spring development (Figure 1). Mr Davies was accompanied during this visit by My J Farr, hydrogeologist and drilling advisor to the RUWASA Project (Annex A). Within the project area Gravity Fed water distribution Systems (GFS), fed by high altitude springs, are being developed as a cost effective, low maintenance method of supplying moderately large villages (Annex B). During 10-15th September 2000 this method of village water supply was discussed at meetings held in Kampala and Mbale. Three typical GFS were visited in the project area, on the lower slopes of Mount Elgon (Annex C).

Meetings were help at the GFS section of the Directorate of Water Development in Kampala on 11th and 15th September and at the RUWASA project offices in Mbale on 14th September. Topics discussed at these meetings included:

(i) Application of horizontal drilling to GFS – what potential for use in the south-east, south-west and north-western parts of the country.

(ii) Development of regional groundwater development potential maps.

(iii) Application of collector well systems in weathered granite (Eastern Centres Water Supply Project) and sand rivers (within the semi-arid north of the country).

(iv) Community self monitoring of groundwater resources – development of a future KAR project proposal.

(v) Low permeability rock aquifers – experience gained during work on a current KAR project in Tanzania and potential application of methodologies under development in Uganda.

2. TOPICS DISCUSSED AT MEETINGS

2.1 Gravity Flow Schemes

Mt Elgon, located on the Kenya-Ugandan border to the north east of Lake Victoria, is a former volcanic massif that rises to about 4320 masl. The Mbale area is mainly underlain by Pre-Cambrian gneissic rocks intruded by the odd Cretaceous-Tertiary age carbonatite ring complex. East of Mbale, spring zones occur at 1500-1600 masl on the lower western slopes of Mt Elgon. There, high cliff sections, formed of Tertiary age lavas, tuffs and agglomerates with interbedded thin limestones and sandstones (mid Tertiary Bugishu Series), occur above hummocky steeply sloping deposits of accumulated landslide detritus (Plate 1).

Plate 1 **View looking south east from Bumbo spring site showing cliffs composed of lavas, tuffs and agglomerates. Spring zones occur within hummocky ground formed of landslide detritus, below the break of slope at the base of the cliff face.**

These detritus are composed of large blocks of agglomerate (Plate 2) within a groundmass of dark brown sandy soil. They were deposited as a series of arcuate slip zones piled one above another to form a sub-parallel ridge and trough topography, with springs issuing from the slippage zones within the troughs.

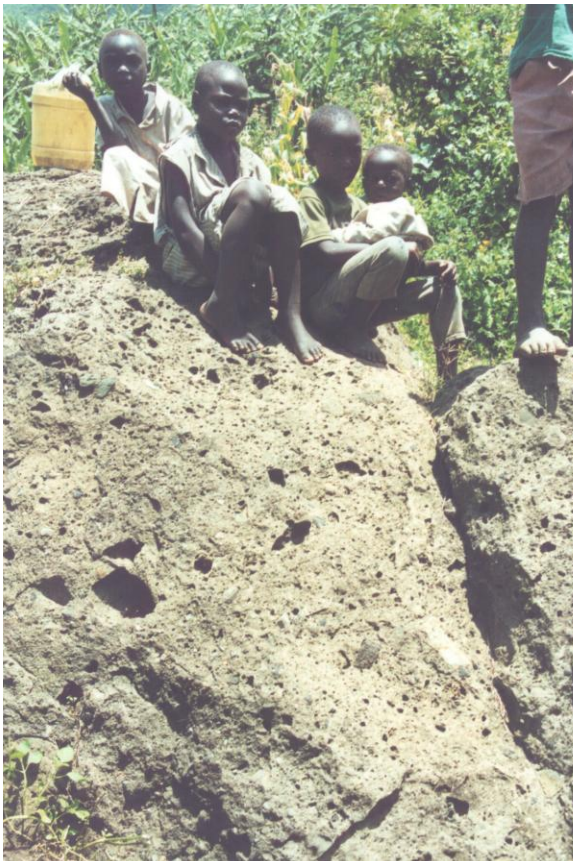

Plate 2 **Boulders of agglomerate at Bumbo spring site.**

These topographic features are readily discernible upon aerial photographs and 1:50,000 topographic maps of the area. The most up-to-date geological map of the area was produced in the 1960's. Digitised Landsat TM imagery and topographic maps of the area, derived from the National Biomass Study project of the Department of Forest, form the base of the ArcView GIS database of the RUWASA project at Mbale. Annual rainfall of about 1300mm occurs mainly during the April-May rainy season with further lighter rains during November-December. Spring discharge rates of 1-2 l/sec are commonly obtained. Unfortunately, the April-May 2000 rains failed causing a decline in spring discharges used by the project GFS' to below the designed village water supply rate, a cause of concern to RUWASA (Annex B). To date seven GFS have been installed within the western Mt Elgon area, east of Mbale, with various degrees of success. Visits were made to several of these sites to assess the potential for augmentation of spring flows through use of horizontal drilling and/or the installation of large diameter wells. Assessment was also made of the potential for development of groundwater sources at lower elevations through installation of horizontal boreholes as drains. At present only the uppermost spring zones are developed as these are perceived to be free of faecal contamination from human sources. Much of the water flows from slippage zone springs at lower altitudes but these are not used for public water supply as they are located below areas of below human habitation and are therefore considered to be liable to faecal contamination. If such sources of water are tapped from within the weathered rock mantle before they issue to the surface via horizontal drains then they should be free of contamination and so could be used for domestic supply without treatment. Similar areas of rugged terrain underlain by volcanic rocks occur in the south western part of Uganda where spring zones have been developed as gravity fed schemes of village water supply. The three gravity schemes visited are located at Bumbo, Buhugu and Busoba. The results of these visits are detailed in Annex C.

2.2 Groundwater Resource Development Maps

The production of groundwater resource potential maps was demonstrated using laminated A4 maps and tabulated data produced for the Oju/Obi area in S E Nigeria, the south Tigray area in Ethiopia and the Siavonga area in Zambia. Such maps could be produced for the RUWASA area using hydrogeological data obtained from nearly 2000 boreholes drilled by the project in 10 or 11 districts. Digital base map and remotely sensed satellite data compiled for the production of national forestry maps with some of the hydrogeological database have already been stored within an ArcView GIS at Mbale. Proposals for the compilation of the remaining data within this system have been presented to RUWASA (Annex C). An example of a project borehole data file is presented in Annex E. Discussions were held with the Principal Hydrogeologist DWD who has submitted a proposal to DFID (Kampala) requesting funding for the preparation of hydrogeological maps of Uganda (Annex F). At the second meeting in Kampala he raised the possibility of using the RUWASA data base to produce a set of Groundwater Development Potential maps for the south eastern part of Uganda covered by the RUWASA project as a pilot scheme before the National mapping was embarked upon. BGS assistance with the pilot project would be sought to use experience gained in Nigeria.

Figure 1 Map showing the location of the RUWASA Project area.

2.3 Collector Well Systems

The application of collector well systems to weathered Precambrian Crystalline Basement aquifers in Zimbabwe and Sri Lanka and to sand rivers in Botswana was described at the DWD Kampala meeting. Much interest was expressed by participants who felt that the former could potentially be installed within the area of Eastern Centres Water Supply Project (ECWSP), and the latter applied to sand rivers in the semi-arid Karamoja area of northern Uganda. Within the ECWS Project extensive use is made of larger diameter boreholes to supply water at rate of about 5 l/sec to peri-urban and larger village settlements via piped water schemes in areas with moderately high rainfall and near surface saturated conditions. The improved storage and seepage area attributes of collector wells may prove to be cheaper to install and have higher yields than these boreholes. Information was requested on the application of collector well systems in both environments.

2.4 Community Monitoring and Data Gathering

The long term monitoring of aspects of groundwater systems in rural Uganda is as difficult and as expensive as elsewhere in Africa. Much interest was shown in the concept of encouraging community self-monitoring of groundwater resources, especially in areas of marginal groundwater resources. A new KAR project proposal, initially proposed for Tanzania, involving community participation in developing patterns of groundwater availability, dependence and resource potential was discussed. This would involve self monitoring of borehole yields and seasonal/long term trends in yield characteristics and discussion of community coping strategies. The DWD expressed interest in participating in such a project.

2.5 Low Permeability Rock Aquifers

The progress of an existing KAR project designed to study the groundwater resources of low permeability rocks in sub-Saharan Africa was outlined, with particular reference to detailed studies recently undertaken within the Tabora region of Tanzania. That area is underlain by similar crystalline basement rocks to those found in much of Uganda. The meeting at the DWD in Kampala felt that the methodologies and technologies developed and used in integrated way would be applicable for use in Uganda.

3. DISCUSSION

3.1 Application of Horizontal Drilling to Weathered Volcanic Rocks

In the upland areas of Uganda, hill side protected springs are favoured as water sources for gravity flow schemes. Such schemes are of low cost to construct and maintain. Ideally, gravity schemes require a good reliable water source that does not require treatment to supply dense settlement patterns in areas of high relief as observed in the Mbale and Kapchorwa areas (Annex B). In 1991, 753 springs were noted in Mbale district of which 535 were protected, while Kapchorwa district had 222 springs of which 38 were protected. Rural water supply requires provision of 25 l/day per capita with max of 1.5km walking radius. UNICEF assumes that each borehole source can supply up to 300 persons at 30 l/day (5 l spillage). For areas with a dispersed population a minimum of 100 persons per borehole and 50 persons per spring should be served. However concerns have been expressed by RUWASA over possible biological contamination of spring sources and their susceptibility to seasonal discharge changes (see Annex B).

To meet these requirements RUWASA and other project GFS' located in eastern, north-western and south-western Uganda developed high altitude springs that are susceptible to seasonal water level and discharge rate fluctuations. Three sites were visited and examined in the western Mt Elgon area (Annex C). These sites were difficult to access with the raw materials required for construction of spring boxes, protected areas and distribution systems. Enhancement of such spring sources by the drilling of horizontal drains is hampered by difficult access in steep terrain and boulder rich, landslide debris piles from which the springs issue. Alternatively horizontal boreholes could be drilled into the lower slopes at end of main roads to create drainage systems and thereby artificial springs (Part 4, Annex C). The waters produced by such systems should meet quality criteria, tapping deep weathered zones. Such drains would be used to supply shallow hand dug wells forming sumps from which water would be fed into GFS systems. Drains of this type have been constructed with the assistance of BGS in St Helena on the slopes of volcanic hills (Lawrence and George, 1987). Suitable drill sites could be identified from analysis of aerial photography and landsat images. These sites would be located in the field using a global positioning system (GPS).

Wechert amd Freeman (1973) describe the application of horizontal drilling methods to water supply development in hilly areas. The feasibility of using horizontal drilling in weathered volcanic terrains, where laterite soils and friable agglomerate blocks should be easily be drilled, needs to be assessed. Within successive layers of landslide debris the most intense weathering should be towards the base of the sequence. There, beneath the lower slopes, groundwater occurrence should be greater, the water table higher, discharge rates should be less susceptible to seasonal fluctuations and therefore supplies should be more sustainable. With the long drainage paths, natural filtration should ensure that the waters produced should be free of pathogens if tapped from within the lower sequence. The modern horizontal/directional drilling systems now available can offer greater flexibility especially if track mounted.

The potential for a catchment study type project looking at soil development and groundwater occurrence within discrete catchments developed on volcanic rocks/soils needs to be investigated. Such a catchment should be typical of the Mt Elgon region with a high population density and irrigation of market garden type crops. Noting the activities of a Yugoslavian road construction company upgrading the main Kapchorwa access road there must be potential for a study of the hydraulic characteristics of the soils and weathered rock, as well as the clay types formed. These can be related to porosity/permeability distributions and the potential for landslide occurrence. Such studies were undertaken by Bronders (1994) on similar soil and rock types in Fiji.

As an extension of the use of horizontal well drilling into other parts of Uganda the application of collector well technology to weathered basement and sand river aquifers was discussed. Attention was drawn to work undertaken by BGS in parts of Zimbabwe where collector wells installed within weathered basement aquifers produced sufficient water for the small scale irrigation of garden plots even in semi arid areas (Lovell et al 1996). The application of collector wells to abstraction of groundwater flow through sand rivers in N E Botswana was also described (Davies, J, Rastall, P and Herbert, R, 1998 and Herbert, R, Barker, J A, Davies, J and Katai, O T, 1997). Comparative costs of installation are given in Lovell et al (1996) and the cost of the drilling unit from Davies, J, Rastall, P and Herbert, R, (1998) is given in Annex G. Copies of the relevant reports and papers are being sent to RUWASA and DWD.

3.2 Hydrogeological Maps

The RUWASA project area encompasses at least seven districts of south-eastern Uganda (Kamuli, Jinja, Mukono, Lganga, Torono and Pallisa, Mbale and Kapchorwa). As outlined in Annex D, much hydrogeological data have been collected during the ten years of the RUWASA Project. This digital hydrogeological database is probably the most comprehensive for any part of Uganda. An example of a typical RUWASA borehole data file is presented in Annex E. Such data files will exist for each of nearly 2000 boreholes drilled by the project. Their spatial distribution, located using a GPS in the field, will be displayed on a series of maps, based upon a digital map base produced by a national forestry mapping project.

National hydrogeological and hydrological maps of Uganda have been prepared by the UNDP (1989a and 1989b) but these were of limited availability and usefulness. They do however demonstrate the state of hydrogeological and hydrological knowledge at that time. The need to provide updateable summary descriptions of the hydrogeological development potential of each of the main lithological units in Uganda and national, regional and site specific hydrogeological maps is recognised both by the RUWASA Project (Annex D) and the DWD at national level (Annex F). The production of various thematic hydrogeological maps of the RUWASA area using that project's comprehensive database has been proposed as a pilot project. As a pre-requisite compilation of the RUWASA data base into the project's ArcView GIS needs to be completed, the national Geology map of Uganda needs to be digitised and the themes and scales of the different types of maps to be produced need to be decided upon. Using this data base maps could be designed to show themes such as:

- Depth of weathering.
- Peizometric water levels.
- Water quality variation.
- Yield variation.
- Structural maps the landsat and aerial photo lineations.
- Rainfall/evapotranspiration data.
- Recommended abstraction type distribution map with potential yields etc.

Struckmeier and Margat (1995) describe the processes and data required for the production of hydrogeological maps. They list the types of hydrogeological maps that could be prepared for specific purposes according to levels of data available.

1. Low data levels:
    - general hydrogeological (aquifer) maps for reconnaissance and exploration.
    - groundwater resource potential maps for planning and development.
    - groundwater vulnerability maps for management and protection.

2. Advanced data levels (systematic investigation programmes with more reliable data):
    - hydrogeological parameter maps for exploration and development.
    - specialized hydrogeological maps for planning and management.

3. High data levels (hydrogeological systems and groundwater models):
    - regional groundwater systems maps (conceptual models) for exploration and development.
    - graphic representation derived from geographic information systems for planning and management.

At the present time only those maps requiring low to fairly advanced levels of data for preparation may be produced in Uganda. The production of hydrogeological maps showing hydrogeological features and types of aquifers for the use of specialist hydrogeologists may be beyond the scope of the available databases, except within the RUWASA area. Elsewhere, the production of more general groundwater development potential maps, that present information on the availability and suitability of groundwater, for the use of non-specialists may be more applicable.

Suitable data held within a GIS system may then be interrogated and manipulated to produce the required hydrogeological analyses and maps for planning purposes to order. Such systems are dependent upon the nature and accuracy of their data. Therefore, much thought needs to be devoted to data acquisition. These include the digitising of data derived from pre-existing maps; data collection during borehole siting, drilling and test pumping exercises; and collection of long term monitoring data. Davies and MacDonald (1999) describe suitable low-cost methods of data collection within groundwater studies in a typical African context. Such data packages need to be collected systematically in a standardised format and entered into an Excel or equivalent format spreadsheet. The types of maps to be produced and their scales need to be defined so that the specific types of data to be collected can be identified. Short comings such as the patchy availability of base topographic maps, their scales and projections need to be understood prior to map production. Problem areas include the geo-referencing of landsat images, topographic maps and geology maps.

Considering the amount of data available from the RUWASA project, preparation of hydrogeological maps of that area would require two main forms of input:

- integration of data into various kinds of specific information layers of hydrogeological information and their manipulation by an ArcView.
- recognition by an experienced regional hydrogeologist of the types of maps that need to be produced from the data collected.

Similar procedures have been followed in Oju/Obi in Nigeria for the production of groundwater resource development maps (MacDonald and Davies, 1998), and are currently being applied at a pilot level in Tanzania and Ghana as part of the DFID funded "Groundwater from low permeability rocks in Africa" KAR project. Copies of relevant papers and project literature are being sent to RUWASA and DWD.

At the meetings held at the DWD in Entebbe methods being developed by the current KaR project of conducting hydrogeological resource surveys in Africa were outlined. These methods include:

- Use of remotely sensed data and geophysics for better siting of boreholes.
- Enhanced data collection during drilling.
- Simple systems of test pumping.
- More applicable analysis and use of geophysics.
- Better appreciation of how groundwater exists in different lithologies and the resources available for development.

The RUWASA project is a good example of what can be achieved. There is also a need to relate long term monitoring of water levels to discharge rates and rainfall patterns, but these will require community inputs if they are to be achieved in a rural setting. The primary aim is to produce groundwater development maps to better inform communities and planners of how groundwater exists, the limited resources available (especially seasonal and long term changes due to climatic events/change) and risks and associated costs involved.

4. SUMMARY

Two main areas of hydrogeological study have been recognised:

- The application of horizontal/collector well drilling/installation.
- The creation and organisation of hydrogeological databases for production of hydrogeological maps.

Gravity fed systems (GFS) piping spring water to villages have been successfully installed at several points within the RUWASA area on the lower slopes of Mt Elgon. However, such spring systems, located as they are at the base of cliffs at the highest level on debris piles to avoid contamination from human effluent, are susceptible to seasonal variations in water levels and thus discharge rates, especially during protracted periods of drought. The application of horizontal drilling to enhance the springs currently being developed for GFS schemes supply is not feasible given the lack of access and nature of the water producing formations. The feasibility of using horizontal drilling to produce more sustainable water sources with constant yields to supply GFSs in more accessible localities at lower altitude should be investigation through trial drilling and testing at suitable sites. The BGS horizontal drilling rig currently located in Botswana, or a new purpose built drilling rig could be procured for such work.

Much interest was shown in the application of collector well technology to weathered basement strata and sand rivers for village water supply schemes. Examples of the application of such technology to rural areas in Zimbabwe and Botswana were described and their sustainability during periods of protracted drought explained. The feasibility of the use of such technology within Uganda would need to be assessed. Trial studies could be undertaken using the horizontal rig procured for the above within suitable areas.

The RUWASA project has amassed much good quality hydrogeological data in a planned way from nearly 2000 boreholes fairly evenly distributed throughout he project area. These data are being reworked into an ArcView GIS to permit their interrogation for production of various hydrogeological analyses and production of appropriate hydrogeological maps. The services of a senior hydrogeologist and an ArcView specialist are needed to identify map themes and manipulate the data for production of analyses and pilot maps with training of local personnel.

DWD recognise the need for hydrogeological mapping for long and short term planning purposes. They have proposed the creation of a national hydrogeological mapping project. The procedures and systems produced at district level using the RUWASA database/maps as a pilot project would then be used by DWD for production of regional hydrogeological development potential maps. However, protocols for the production of hydrogeological data from the drilling and testing of boreholes and study of groundwater systems in general need to be standardised. This should ensure the establishment of a sustainable long term database development system from which up-to-date analyses and hydrogeological maps could obtained on request. The feasibility and costs of establishing such an interactive GIS based database would need to be investigated.

Production of much of the data required would need the establishment of suitable monitoring systems. To ensure a viable coverage need to introduce a sustainable system of community self-monitoring of aspects of water supply system needs to be introduced that can produce data for inclusion within a central database. Thereby areas of risk can be identified and appropriate timely actions can be developed and undertaken. Results of the present study in Tanzania will be supplied to DWD. Also need to apply simple methodologies and techniques developed by the KaR project to ensure maximum data return from regional borehole siting and drilling programs. This will ensure realistic determination of groundwater resources and sustainable usage/abstraction.

5. RECOMMENDATIONS

The feasibility of using horizontal drilling for the development of water sources from the lower slopes of sub-cliff-face landsip zones in the Mt Elgon and similar environments in Uganda should be investigated. Consideration should be given to the transportation of the BGS horizontal drilling rig and ancillary equipment presently in store in North-eastern Botswana to Uganda for this purpose. This equipment could be used for the drilling of laterals within large diameter hand dug wells to form collector well systems and to drill laterals for the development of artificial spring zones for GFS supply. There would also be potential for the use of the collector well system to be applied to sand rivers in the northern parts of Uganda.

There is a need for the production of hydrogeological maps for planning purposes. Such maps would be an output of the dynamic process of collection and compilation of large quantities of good quality data being collected from a large number of well distributed points. Such a data set exists for the RUWASA project area but not yet for the rest of the country. DWD have proposed that this data set be used to produce hydrogeological development potential maps within an ArcView GIS as a pilot project covering the south-east region. Such a project could then be extended to cover other parts of the country. The database would need to be organised in such a way to permit its interrogation to provide analyses to resolve various hydrogeological situations in the required formats.

The techniques and methods developed for the Low Permeability Aquifers project as developed in Nigeria and used in Tanzania should be developed for use in Uganda to provide the data necessary for the production of hydrogeological databases in other regions in a cost effective yet sufficiently detailed manner. These data would be channelled into the national groundwater database. Elements of the self-monitoring of water supply systems should also be introduced to encourage community participation in this mapping exercise. Such monitoring data would enter the database matrix via NGO groups who would pass the data onto district and regional level departments.

The RUWASA project, which aims to produce 2000 boreholes for village water supplies, could provide a useful vehicle for the demonstration of these recommended activities at pilot stage. These activities could form the basis of training exercises which could result in the development of skills and procedures for replication in other parts of Uganda.

6. REFERENCES

Bronders, J, 1994. Technical Note: Hydraulic conductivity of a tropical residual soil prone to landslides. The Quarterly Journal of Engineering Geology, vol 27, part 4, pp 375-382.

Davies, J, Rastall, P and Herbert, R, 1998. Final report on the application of collector well systems to sand rivers pilot project. British Geological Survey Technical Report WD/98/2C.

Davies, J and MacDonald, A, 1999. The groundwater potential of the Oju/Obi Area, Eastern Nigeria. Final Report. British Geological Survey Technical Report WC/99/32.

Herbert, R, Barker, J A, Davies, J and Katai, O T, 1997. Exploiting groundwater from sand rivers in Botswana using collector wells. In: Fei Jin and N C Kothe (Eds). Proceedings of the 30th International Geological Congress, Bejing, Vol 22, pp 235-257.

Lawrence A R and George C, 1987. A review of the groundwater investigation programme on St Helena. British Geological Survey Technical Report WD/OS/87/13.

Lovell, C J, Batchelor, C H, Waughray, D K, Semple, A J, Mazhangara, E, Mtetwa, G, Murata, M, Brown, M W, Dube, T, Thompson, D M, Chilton, P J, Macdonald, D M J, Conyers, D and Mugweni, O, 1996. Small scale irrigation using collector wells pilot project – Zimbabwe. Final Report, October 1992 – January 1996. Institute of Hydrology Report ODA 95/14.

MacDonald, A M and Davies, J, 1998. Groundwater development maps of Oju and Obi Local Government Areas, Eastern Nigeria. BGS Technical Report WC/98/53.

Struckmeier, W F and Margat, J, 1995. Hydrogeological Maps: A guide and standard legend. International Association of Hydrogeologists, volume 17.

UNDP, 1989. Hydrogeological Map of Uganda, Scale 1:1,500,000, World Bank – UNDP Project RAF/87/030.

UNDP, 1989. Hydrological Map of Uganda, Scale 1:1,500,000, World Bank – UNDP Project RAF/87/030.

Welchert, W T and Freeman B N, 1973. 'Horizontal' wells. Journal of Range Management, vol 26, pt 4, pp253-256.

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ANNEX A ITINERARY AND PERSONS MET

Itinerary

10th Sept. Flew from Dar es Salaam to Entebbe on Air Tanzania flight TC772. Arrived at Entebbe at 13:30. Driven from Entebbe airport to Kampala where met John Farr and discussed visit programme.

11th Sept. To the Directorate of Water Development/ Gravity Fed Schemes section where met Mr Gilbert Kimanzi and the department advisor Mr Rudolf Glotz. At meeting with them and staff from ECWSP, GFS and RUWASA discussed problems that DWD are experiencing with GFSs in eastern, south western and north western parts of the country. In general, there has been a countrywide drought for the past year and yields have declined. The experience of BGS with application of horizontal drilling to collector wells in weathered basement in Zimbabwe and Sri Lanka, sand rivers in Botswana and the drilling of inclined adits on St Helena was outlined. Also described recent BGS studies undertaken in Nigeria (small scale rural water supplies from low permeability sediments), Ethiopia (springs developed on basalt/sandstone contact zones) and Tanzania (limited groundwater resources of low permeability rocks in sub-Saharan Africa). DWD requested a further meeting on Friday to discuss the topics raised. Drove from Kampala to Mbale where met RUWASA Project Co-ordinator Mr Dison Ssozi and members of his team. Discussed the possible application of horizontal drilling methods to improve spring yields. A programme of visits to typical sites in the Mt Elgon region was proposed.

12th Sept. Studied maps of sites to be visited at the project office. With John Farr and members of the RUWASA team drove south of Mbale, past a carbonatite ring complex, to Bumbo village. There met the district chairman with whom visited the protected spring zone at the base of the cliff face. The spring was developed on a rotational slip within agglomerate, with large boulders within fine-grained dark brown sandy soil. Determined discharge of spring as 1.1 l/sec of which 0.4-0.5 l/sec was lost to the overflow. Only design of the distribution system was available, as produced by Manzi, an offshoot of WaterAid. Followed the course of the distribution system down-hill inspecting various parts of the system. Inspected a borehole that had been rehabilitated using hydrofracing. Held discussions with the district chairman before returning to Mbale.

13th Sept. Drove to the north-east of Mbale into the hills towards Kapchorwa but road blocked by extensive road works. Drove into the hills east of Mbale to Buhugu village. There visited a protected spring with three eyes that produces 2 l/sec of water. This spring is not yet connected to a distribution system. Drove via Mbale to Busoba village where visited a partly developed spring with a partially completed protection box. The yield of this spring is low, therefore visited adjacent spring zones that could be used to improve the capacity of the system. Returned to Mbale.

14th Sept. With John Farr wrote a short report on visits made to the three spring sites. At 14:30 had a wrap-up meeting with Jacinta, Patrick (Deputy PC), Simon Otoi, Angela, Miriam and John Farr. Discussed the use of horizontal drilling to improve flow of spring zones, poor at high elevations presently developed but potential for development of sources at lower levels. Described findings at each of the three sites in turn, discussing hydrogeological and distribution problems. Noted that the RUWASA project as a whole has produced large quantities of data which are stored within a GIS. There is a need to submit a proposal for some one to manipulate the data according to a series of hydrogeological development themes to produce maps suitable for planning purposes. Obtained copies of maps of project area and examples of data sheets. Drove from Mbale to Kampala. Discussed content of meeting to be held at DWD.

15th Sept. To the DWD office where gave seminar on a variety of themes. Discussed spring fed gravity flow systems in three parts of Uganda and the use of horizontal drilling to enhance flow from these or to produce sources at lower elevations. Using a set of sides to illustrate them, discussed collector well systems within weathered basement (for the Eastern Centres Water Supply project) and as applied to sand-rivers as in Botswana (for application in the Koramoja area). Showed a series of slides to illustrate health and supply accessibility problems. Lastly discussed aspects of current work in Tanzania with reference to the storage and manipulation of data within ArcView GIS for the production of groundwater development potential maps. Illustrated this part of the seminar with maps produced at intermediate level in Ethiopia and Zambia and the types of maps produced for planning purposes in Nigeria. Proposed that the RUWASA database could be used to provide the basis of a regional groundwater development potential map/s to be extended nationally. Completed discussion at 13:00. Provided a copy of the Oju final report and Zambian maps to the DWD principal hydrogeologist and organised the photocopying of a paper describing the application of collector well systems to sand rivers. Contacted Philip Barlow the DFID engineering advisor in Kampala with who discussed the proposed hydrogeological mapping of Uganda. Received a copy of a project concept note from the DWD principal hydrogeologist. Drove from Kampala to Entebbe by taxi. Departed from Entebbe at 22:30 on flight BA2066 to London Gatwick.

16th Sept. Arrived London Gatwick at 05:00.

Institutions Visited and Persons Met

RUWASA (Rural Water and Sanitation East Uganda Project)
Disan Ssozi, Project Co-ordinator, Project Office, Directorate of Water Development, P O Box 987, Mbale, Uganda. Tel (256) 045 34564/34571/ 34573, FAX (256) 045 34592, e-mail: ruwproj@imul.com
Directorate of Water Development, P O Box 20026, Kampala. Tel (256) 041 220376/220560, FAX (256) 041 220775
Simon Otoi, Head, Technical Services Section.
Jacinta Barrins
Angella Bwiza, Hydrogeologist, RUWASA
John – geologist/hydrogeologist
Miriam Kutesa, Assistant Water Engineer. Mobile tel 077 484983
Patrick , Deputy Project Co-ordinator
John Farr, Hydrogeologist and Drilling Advisor

Gravity Fed Schemes, Directorate of Water Development, P O Box 20026, Kampala, Uganda. Tel: 256 41 220376, Fax: 256 41 220375, e-mail: kimanzi-wes@dwd.co.ug
Gilbert Kimanzi, Project Co-ordinator,
Dickson Berabose, Engineer Trainee, GFS/DWD
Rudolf Glotzbach, Technical Advisor, GFS/DWD
James Ssegwya, Engineer Trainee, GFS/DWD
Rudolf Glotzbach, Programme Manager WES, SNV, Netherlands Development Organisation, Plot 36, Luthuli Rise, Bugolobi, P O Box 8339 Kampala, Uganda. Tel 256 41 220582/220584/223995, mobile tel 077 200778, FAX: 256 41 220780, E-mail:rudolf@snvuganda.com

Ministry of Water, Lands and Environment, Directorate of Water Development, Office address - P O Box 19, Entebbe, Uganda. Tel 256 41 321342, FAX 256 41 321368. E-mail: wrap@imul.com
Callist Tindimugaya, Principal Hydrogeologist / Head of the Hydrogeology Section

Eastern Centres Water Supply Project
S Kagaba, Hydrogeologist, ECWSP
Stanley Matenga, Water Engineer, ECWSP

DFID EA Uganda, Rwenzori Courts, 3 Floor, Plot 2, Makaseru Road, P O Box 7306, Kampala. Tel 256 41 348727-31, FAX 256 41 348732
Philip Barlow, Country Engineering Advisor, e-mail: p-barlow@dfid.gov.uk

ANNEX B

PROPOSAL FOR THE RESOLUTION OF THE PROBLEM OF DRYING SPRINGS FOR GRAVITY FLOW SCHEMES

A Paper prepared by the Technical Services Section for presentation to Management over drying source springs for GFS, By Simon P Otoi, Head, Technical Services Section.

Background

The implementation of gravity flow schemes in the RUWASA Project Area is a relatively new experience. It started in 1999 with a pilot scheme for gravity flow schemes at Bumbo and Buwalasi in Mbale. The program then extended to Kapkoros in Kapchorwa district.

Gravity flow schemes as implemented by RUWASA and in the country in general, are based on natural spring sources at a higher ground than the target consumer group. This implies that the schemes can only be located near hilly populated slopes. It also means that the geological conditions for the existence of the spring must be present: a **catchment area** underlain by an impervious **clay** or **rock layer** and sufficient **recharge** from rain. The implication of the above is that the existence of the GFS is determined by the natural occurrences alone, which are inherently unreliable.

Experience with the spring sources for the GFS that have been or are being constructed by the PO is quite disappointing as can be seen from the table below.

The design and actual flows of the springs that make up seven GFS that have been measured are as follows [1]:

	Gravity flow scheme	Estimated flow (l/s)	Design flow (l/s)	Actual flow - May–June 2000 (l/s)
1	Kapkoros	1.00	0.70	0.20
2	Bumbo	2.20	1.63	0.95
3	Buwalasi	1.70	1.18	Not measured
4	Busoba	0.47	0.33	0.30
5	Bududa	3.30	2.30	0.37
6	Buhugu	2.90	2.00	
7	Chepsegei	2.60	1.80	0.48

In Bumbo and Bududa, the reduction in the flows is too large (more than 50%, also see footnote) to warrant the construction of the whole scheme. It is clear that the design flow measurements were done during the rainy season. Now with the prolonged dry season, the catchments are drying up and exposing the fallacy of the design measurements.

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1 Note that the Design flows in the table already include a factor of safety of about 30%, i.e., the design flows are some 70% of the actual flows. When the same ratio is applied to the measured flows in the table, the picture is therefore a lot more depressing.

The large fluctuations indicate, as will be seen below, to small and/or rocky catchment areas. ***The fluctuations indicate that even when complete, the schemes will be quite unreliable, and will therefore be prone to poor O&M, especially vandalism by the frustrated consumer community***.

The construction of GFS is in the Component Description, so it would be foolhardy at this stage to stop implementation of GFS. It would also be costly and wasteful of resources. TSS would therefore like to propose a sustainable, completely feasible solution to this problem for approval by Management.

To have the problem understood in the proper context, we wish to analyze each of the factors contributing to the success of the spring separately.

a. Catchment Area

This is the area above the spring that catches rainwater and collects it so that it will flow downhill to a narrow exit point. The spring usually appears at the exit point. To be satisfactory, the catchment area should be large and the soil type should be that which could retain water for a long time. The slope of the catchment should also not be too steep lest the moisture drains away too quickly. Larger and deeper catchments contain more soil that can capture and retain water in its pores and therefore take longer to dry up.

It therefore follows that large catchments cannot exist too high up the mountains, the favorite location of the source springs. These are likely to be only sub-catchments of larger catchments. The lower the catchment is, the larger it can possibly be. But the requirement of the supply head needs to be put into consideration. So, again, the catchment should not be too low.

The soil type of the catchment is very important. Rocky soils do not retain a lot of moisture in them as the water runs off rapidly. Loamy soils retain moisture, but easily lose it through evaporation and exfiltration. Clayey soils do not have much retention capacity, but do not lose the moisture rapidly, but the water quality might be affected by the colloids in the clay. The depth of the soil (to the impervious layer) is also crucial as it helps to increase the storage volume of the catchment area.

Determination of the catchment area characteristics should therefore be done carefully since they have a direct bearing on the quantity and quality of the water output. Unfortunately, there is no evidence that this exercise was done scientifically for the current set of source springs.

b. Recharge of the Catchment

This is the amount of rain that the catchment receives in any one year. During the dry season, little or no rains fall, so water is lost through evapotranspiration and exfiltration from the catchment. While smaller catchment areas quickly run dry, the larger and deeper catchments will take much longer to dry up. As water tables lower, some water usually remains at deeper levels so that the lowest springs are more reliable than those higher up the catchment.

A study of the rainfall patterns and amounts and the age of the water may therefore help to determine the likelihood of the catchment running dry.

However, these studies may not be within the reach of the community or the funding agency in terms of the resources and the time required for them to be completed. The shortcut is therefore to rely on historical or oral records of the performance of the springs, and heavily rely on the instantaneous measurements taken once in a while. A **factor of safety** is then applied to the flow measurements. But the determination of the factor of safety is not easy and requires a lot of experience.

This approach is still unreliable, since investigators rarely consult the persons who normally fetch water from the springs – the women and the children. The men do not usually pay attention to the behavior of springs, let alone those that are located high up the mountains to where they rarely go.

A detailed study to determine the viability of the spring for development into a GFS should consequently take anything up to 5 years, and should involve meteorological records stretching many years. This is desirable but hardly feasible for a Project like RUWASA with a short life span. **The results will however still be heavily influenced by the capricious weather.**

A Proposal for use of Existing Technologies to Solve the Problem

Not all catchments discharge their water through a visible outfall like a spring or river. Much of the water from the catchment dissipates into the aquifer through fractures that can be detected by normal hydrogeological and geological investigations. ***Tapping into the groundwater and the fractures using large diameter dug well technology or its improvements is therefore a feasible option for improving the reliability and yield of the GFS source.*** We could utilize the siting capacity that is available in the Project Office to carry out the investigations at little cost to PO.

Since it can reduce the chance of the source drying up, the large diameter dug well option will be much more reliable. The problem of searching for reliable natural springs would therefore not arise**.** ***The source would be chosen so as to be more accessible for construction, monitoring, maintenance and repairs, and the flows could be scientifically determined and controlled.*** More importantly, the selection of the source for the GFS will be reduced from guesswork with the clear risks involved, to a scientific process.

The outfall from the modified shallow well must be located at such a level as to allow for free flow even at the lowest foreseeable groundwater level.

Such a design can still be improved by drilling or cutting other horizontal arrays of collection chambers to identified fractures.

This kind of technology has been applied successfully on a large scale in the Federal Republic of Germany. The author visited such a GFS serving the City of Munich with a population of more than 5 million people.

Drawbacks to Large Diameter Dug Well Technology

The main drawback to large diameter dug well technology is the well-known water quality problem of the RUWASA Phase I experience, which must be acknowledged. It however is not an insurmountable obstacle.

Care in siting of the well (away from the population or sources of contamination and agricultural activities) and care in construction and drainage will certainly achieve a good result. Even the cost of the source may arguably be lower than that of the conventional spring source [2].

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2 A detailed financial analysis will be done as soon as preliminary hydrogeological investigations have been completed.

Recommendations

Further development and refinement of the proposals are necessary to make them practical. We have therefore sent a copy of the proposal to HR for comment.

We strongly recommend that this proposal be accepted by RUWASA for refinement so that the Directorate can possibly adopt it for national implementation.

For the complete GFS of Bumbo, a siting team should be sent to the place to carry out the necessary hydrogeological investigations. They should determine the new source at a convenient location.

For the new GFS of Busoba, Bududa, Buhugu and Chepsegei, the team must ***urgently*** visit the sites to determine the potential that exists, to form the basis of further work on the GFS. This should then be used for the redesign of the GFS to allow for the new location of the source. We believe the new large diameter dug well source can be located near the current source, lower or even higher. The effect of the changes should be to make the GFS more reliable and possible to get more water.

The survey of the other GFS sources (five in Mbale and two in Kapchorwa) should therefore start with the catchment (local) and regional studies for rainfall and soil characteristics, followed by the construction of the source. The design of the GFS should then follow. Activities can be precisely integrated in TSS.

Consequences of this Proposal

This proposal, if accepted by Management, will have significant consequences for the GFS program. The following are the most important:

The construction of all the four recently awarded contracts must be suspended to allow for siting and testing of the large diameter dug wells. This will cost some money in claims from the Contractors for demobilizing and standing time. The designs may also significantly change the scope of works leading to large variations with the current works. This may also cost the PO.

The instructions to Mbale and Kapchorwa districts to protect the source springs for the seven planned GFS has to be cancelled, or stayed.

On the positive note, the overall program will move faster once it restarts, and PO will be confident of a lasting GFS.

The proposals could have a wider application and could be adopted for national application.

Shown below is a sketch for the proposed design.

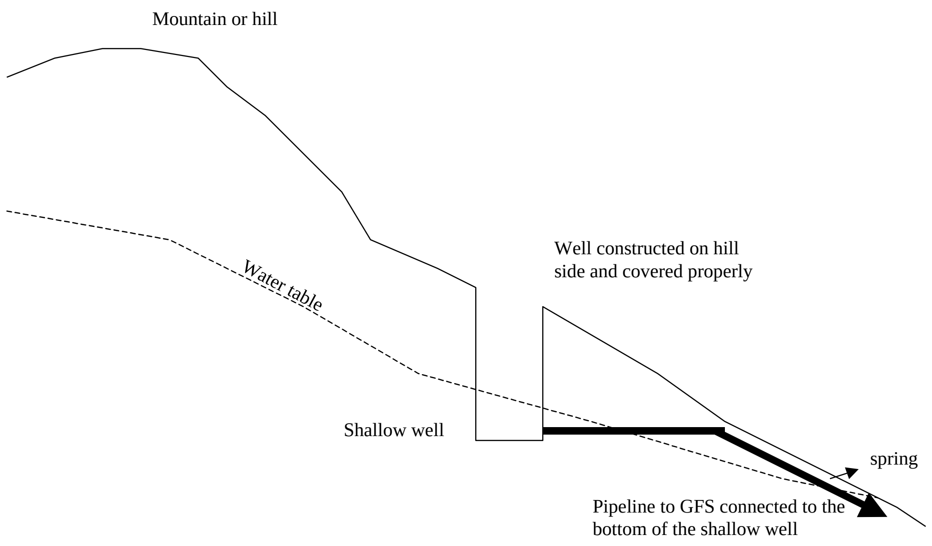

Figure 2 Sketch of proposed shallow hand dug well/GFS design.

ANNEX C

VISIT TO EXISTING GFS SCHEMES

1. Bumbo (12/9/2000) (Plates 3,4,5 and 6)

Problem: Scheme already completed. Not delivering water to the lower portion of the distribution network. Source not producing the design yield (original estimated discharge 2.2 l/sec; design yield 1.63 l/sec; actual yield at visit >1.1 l/sec).

Observations: Spring source at very high elevation, large head on the system. Source from Late Tertiary agglomerates, boulders beds at the base of the cliff, developed as successive slumps. Typical ridge and trough slump topography, with seepages along the trough margins. Design is to produce a source from as high as possible to minimise potential pollution. Highly variable sequence of weathered volcanic soils (dark clayey silts) and volcanic boulders – intrinsic permeability of soils is low. Soil thickness limited by distribution of boulders, but unlikely to be greater than 2 metres. A section is shown through the spring protection system (Figure 3) as is a map of the protection zone (Figure 4).

SECTION THROUGH THE BUMBO PROTECTED SPRING SYSTEM

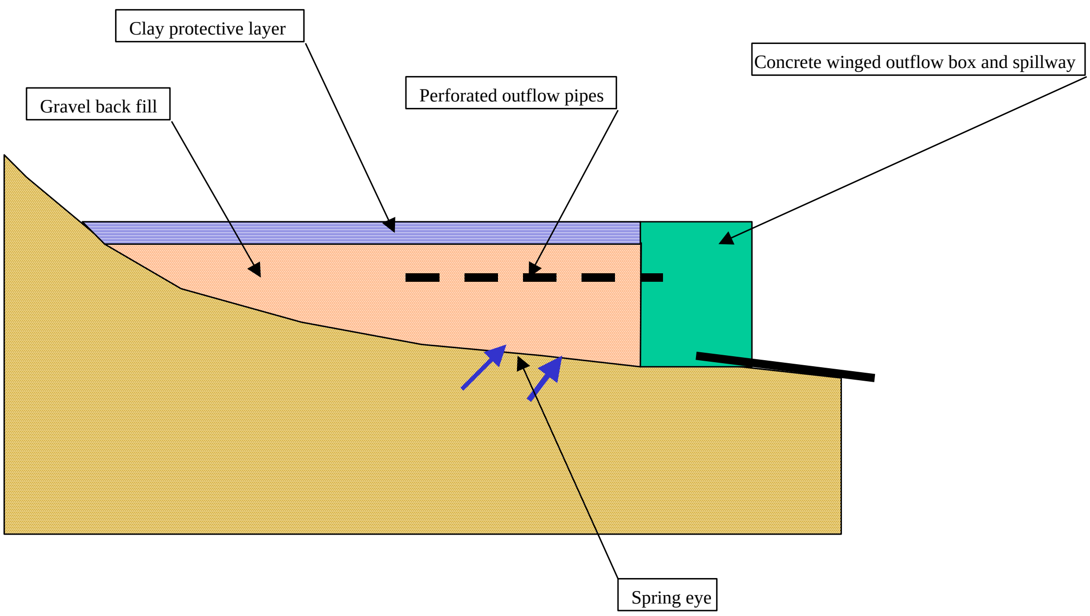

Figure 3 A section through the Bumbo protected spring section.

MAP OF THE BUMBO PROTECTED SPRING

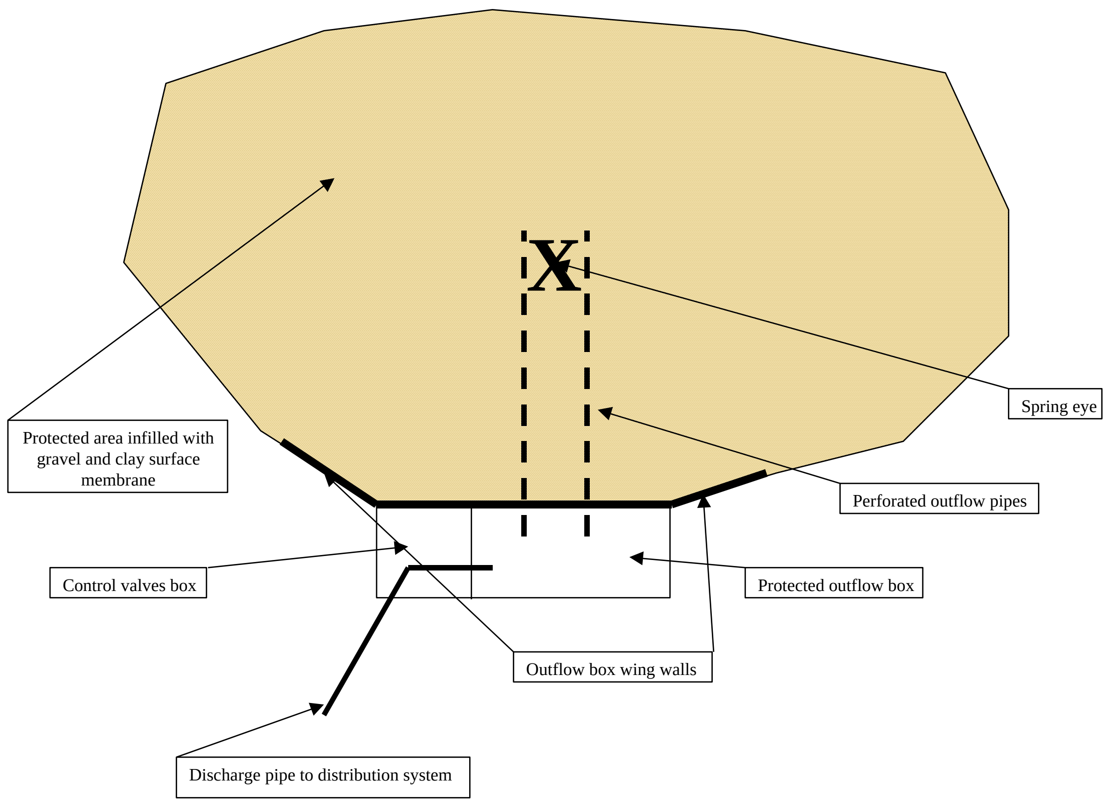

Figure 4 **A map of the Bumbo protected spring.**

Plate 3 **Protected area and outflow box with restricted wing walls at Bumbo Spring.**

Plate 4 **Spring outflow pipes within outlfow box at Bumbo Spring. Discharge from pipes is about 1.1 l/sec. Discharge down the overflow pipe (bottom left) is about 0.5 l/sec.**

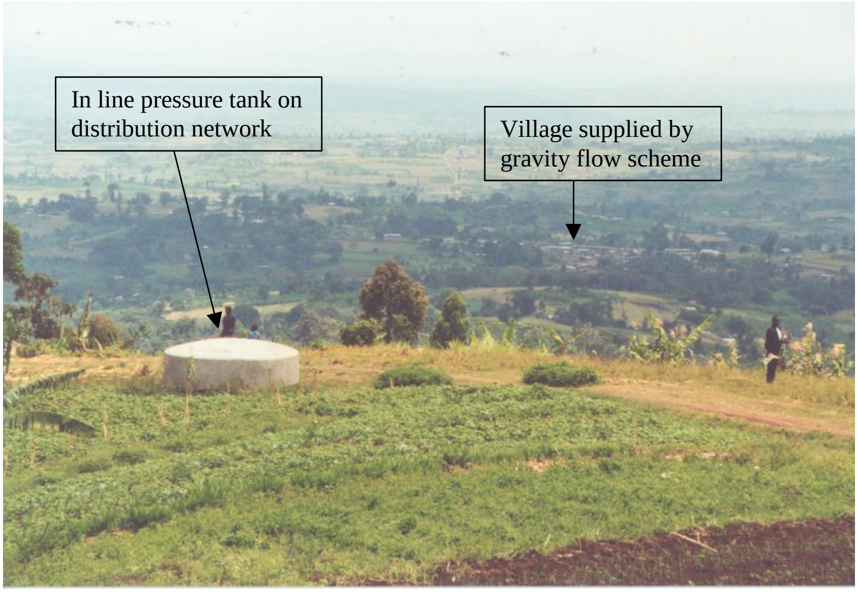

Plate 5 **Pressure tank on distribution pipeline from spring located on hillside overlooking Bumbo village, end of the main gravity flow scheme pipeline.**

Examination of the constructed source protection (Grid Ref E 657145 N 098721) suggested the following:

- The perforated inflow pipework set into the excavated collector pool (filled with rocks and covered with a clay seal) appears to be too high, well above the presumed level of the spring eye. There will be a damming of water in the pool up to this level, with a likelihood that this will induce flow around or beneath the wing walls.

- No construction details available, but it seems likely that the thickness of rock fill above the level of the inflow pipes is thin.

- No PVC membrane had been used between the rock fill and the clay seal (reported to be puddle clay imported from lower elevation). The clay may have migrated downwards into the rock fill, thus possibly reducing the flow.

- The wing walls do not appear to extend sufficiently wide to intercept and collect the maximum potential throughflow. Several short collector drains are reported to have been constructed, but these may not be either deep enough or long enough to be effective.

- The yield determined at site proved to be less than 50% of the original discharge. This could be due to several factors, including seasonal variation, movement of water around the structure as suggested above, exacerbated by blockage of the collector pool.

Plate 6 **Alternate spring zone west of protected site at Bumbo, showing the two spring eyes available for development.**

Examination of a possible alternative or supplementary source (Grid Ref E 657043 N 098566) to meet the design criteria located nearby suggested the following:

- This source is a smaller spring in a broader seepage area, with 2 apparent spring eyes (Plate 6). Yield is apparently less than the protected site.

- Development of the 2 spring eyes is possible, but does not lend itself to collection drains. However, the broader seepage area adjacent to these eyes could potentially be developed using a series of shallow drains to enhance the total yield from these spring sources.

- Construction of collector drains will be problematical, due to the near surface boulders. Drains should ideally be > 0.5 m, at an appropriate gradient and filled with suitable gravel to allow water flow to a sump at the 'neck' of the seepage area.

Recommendations

- There is apparently a serious problem with the distribution system, as it does not even deliver the available water. The engineering design should thus be carefully re-evaluated before any other action is taken. If the design proves adequate, then the system needs to be examined for leakages and/or airlocks.

- At the constructed source consideration should be given to dismantling the collection structure with the aim of examining why the discharge has reduced, and whether this is a function of design or poor construction, or both. It is important to determine whether the collector pool has been dug to bedrock, and well sealed. The current flow of the main spring eye should also be measured, to establish whether in fact the natural flow has diminished seasonally.

- The inflow pipework should be set lower, a good thickness of rock fill should be present between the inflow pipe level and the clay seal, and a PVC membrane should be installed to prevent any movement of the clay into the rock fill.

- If possible, the wing walls should be extended, with a good seal beneath the walls.

- The adjacent spring sources should be measured carefully and several pilot collector drains excavated to estimate the possible water contribution. Then a decision needs to be made whether this flow can be utilised by a re-designed distribution system.

2. Buhugu (Nambulenzi) (13/9/2000) (Plates 7 and 8)

Problem: None. Source protection already completed. Source producing the design yield (original estimated discharge 2.9 l/sec; design yield 2.0 l/sec; actual yield at visit 2.0 l/sec). Distribution system yet to be installed, trenches for pipework have been excavated.

Observations: Spring source at very high elevation. Source from Late Tertiary agglomerates, boulders beds at the base of the cliff, developed as successive slumps. Design is to produce a source from as high as possible to minimise potential pollution. Highly variable sequence of weathered volcanic soils (dark clayey silts) and volcanic boulders – intrinsic permeability of soils is low. Soil thickness limited by distribution of boulders, but unlikely to be greater than 2 metres.

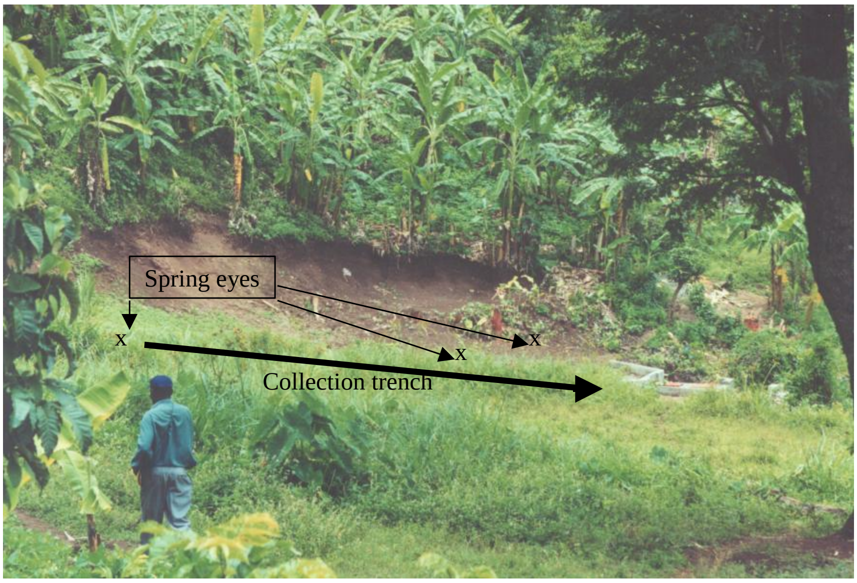

Plate 7 **Buhugu Spring protected area. Spring system includes three eyes flow from one is channelled along a gravel lined trench toward the outflow box while flow from the other two occurs from within the gravel infill.**

Plate 8 **Outflow from the Buhugu Spring into the outflow box at the rate of 2.0 l/sec.**

Examination of the constructed source protection (Grid Ref E 649635 N 132851) suggested the following:

- The protected area was moderately large, encompassing 3 spring eyes. Two were behind the wing walls and the third located some 30m away at the end of a collector drain (Plate 7).
- Inflow pipework was apparently at a lower level in the flow chamber, and thus closer to the level of the original spring eyes.
- The Contractors representative was on site to explain the construction. The collector pool had been excavated to bedrock, 12" of rock fill added, the inflow pipes installed, another 12" of rock fill added and then approximately 12" of clay seal. No PVC membrane was used.
- The overflow pipes in the flow chamber were set at a higher level, allowing greater storage on the chamber (Plate 8).
- There has been a decline in discharge rate from 2.9 to 2.0 l/sec, which may be seasonal or design related.

Recommendations

- The source needs to be connected to a completed supply network with sufficient capacity to ensure full use of the design yield.

3. Busoba (13/9/2000) (Plates 9 and 10)

Problem: Scheme partially completed, protection construction still to be finished. Trenches for distribution network dug. Source not producing the design yield (original estimated discharge 0.47 l/sec; design yield 0.33 l/sec; actual yield at visit 0.3 l/sec).

Observations: Spring source at very high elevation, potentially large head on the system. Source emerging from very large boulders of Late Tertiary agglomerates, boulders beds at the base of the cliff, developed as successive slumps. Design is to produce a source from as high as possible to minimise potential pollution. Highly variable sequence of weathered volcanic soils (dark clayey silts) and volcanic boulders – intrinsic permeability of soils is low. Soil thickness limited by distribution of boulders, but unlikely to be greater than 2 metres.

Examination of the constructed source protection (Grid Ref E 639338 N 111738) suggested the following:

- Low potential discharge, no scope for enhancing the existing source by either collector drains or other methods because of rock.
- Two spring eyes had apparently been excavated to bedrock and rock fill emplaced, but inflow pipes had not been positioned within the rock fill (Plate 9). A PVC membrane had been used, but clay seal appeared to be minimal.

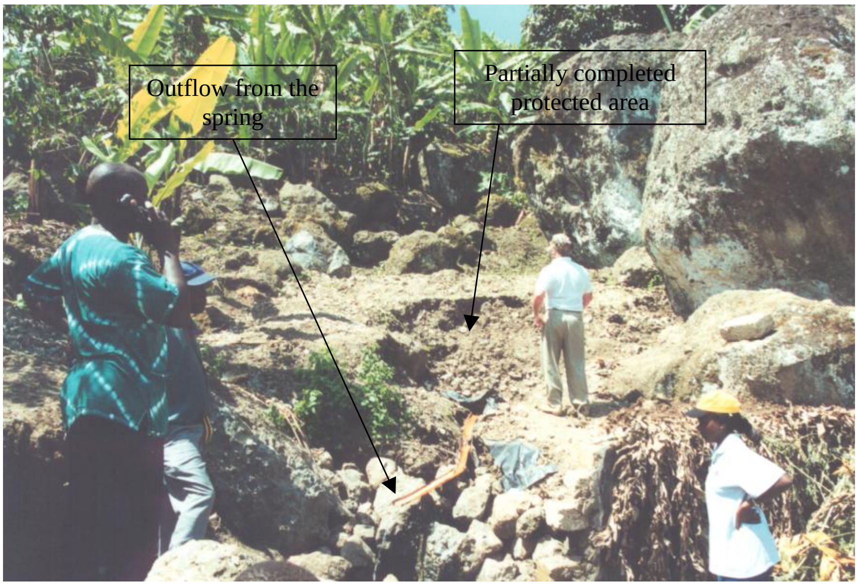

Plate 9 **The partially constructed protection area at the Busoba Spring. This low discharge (0.3 l/sec) spring issues from beneath several large agglomerate boulders.**

Plate 10 **Second possible alternate site visited at Busoba. This has a large potential seepage area.**

Examination of a possible alternative or supplementary sources (Grid Ref E 638631 N 111775) to meet the design criteria located at Mbwikwe, some 500m away, suggested the following:

- Small spring at the base of the slippage zone produced a low flow, but the area indicated potential for flow enhancement by the installation of a series of collector drains.

- A second possible site was located several hundred metres downslope, in an area of slippage with a number of seepage points (Plate 10). There appeared to be considerable scope for the development of collector drains and a sump to provide supplementary water to the distribution system from the existing source.

- The downslope site had an increased soil thickness, although boulders were apparent. Excavation of drains would be possible, but both depth and extent would be dictated by boulders.

- The 'neck' of the slippage zone appears to be an infiltration area for the seepages originating upslope. A lined collector sump would be required at this point to inhibit movement of water back into the soil system.

- The second possible site is downslope of some habitation, but the likelihood of pollution from latrines is considered to be minimal.

Recommendations

- Considering the very limited yield of the existing site, additional sources must be developed to supplement the system if an adequate number of people are to be served.

- The possible supplementary sources examined should be further investigated by excavation of the spring eyes, measurement of flow, and digging of pilot drains to assess contribution of broader seepage zones. This should be undertaken prior to the completion of the current distribution network, as re-design may be necessary.

4. General Comments

It is apparent that in the geological environment of the existing (and probably projected) GFS schemes, the access and the presence of boulder beds will preclude the application of actual collector well systems and technology (ie drilling of lateral holes from the base of large diameter hand dug wells). However, some of the sites visited may lend themselves to the installation of shallow collector drains to enhance the yield of the system.

Collector well technology could be applied within areas of significant weathering along lower slopes adjacent to good access, so developing 'artificial' springs in areas apparently lacking natural seepages. However, here both biological quality and elevation of the site may be the limiting factors.

It is very apparent that little record exists of the seasonal variation in discharge of springs to be used for relatively expensive GFS systems. In future much greater attention must be given to monitoring to prospective sites for at least one complete year, preferably longer. Possibly a spring monitoring network should be designed and implemented, in which a number of specific springs are monitored on a regular basis to identify longer term variations with respect to drought periods etc. The range of natural discharge variations needs to be understood if long term planning for sustainable supplies is to be achieved.

ANNEX D

DRAFT: OUTLINE PROPOSAL FOR ANALYSIS AND PRESENTATION OF GROUNDWATER RESOURCES DATA GATHERED BY THE RUWASA PROJECT.

John L Farr.Hydrogeology/Drilling Advisor

1. Background

The RUWASA Project has the most comprehensive database of hydrogeological information in the country, gathered over a period of almost 10 years as a part of the substantial groundwater development activities undertaken. This data has been largely collected in a controlled and consistent manner and has been archived in digital form, but has not been systematically analysed or presented in a form that will contribute to District or National usage for future planning purposes.

As part of Project on-going activities in this latter stage of the programme, a basic information presentation exercise has been instituted. As a first step this consists of preparation of 'Borehole Data Catalogues' for each District, with the catalogue comprising individual Data Books of essential data for each borehole drilled during the Project. These Data Books are being compiled form data already contained in the Project Database, as well as information that exists in the Project archives in non-digital form. Each Data Book comprises a Borehole Location Map (prepared by GIS), a graphical borehole log, and standardised forms containing geophysical siting information, borehole testing and water quality data, and a summary Borehole Completion Certificate. This work is approximately 25% complete. ***It should be noted that there is no analytical component to this current exercise, although it should be noted that considerable effort has to be put into correcting and upgrading the main Project database.***

It is planned that the current 'Borehole Data Catalogue' exercise should be followed by several other steps relating to information presentation and analysis, which will manipulate the RUWASA data and make it useable and useful to the Districts. The next step will be the preparation of a Borehole Data Report on a District by District basis. Such a Report will essentially provide a summary of and statistics from the Borehole Data Catalogues. ***It should be noted that only statistical and not spatial analysis of groundwater data is envisaged.***

The final step in the manipulation of RUWASA groundwater data is envisaged to be the crucial analytical process, involving the spatial evaluation of information using GIS techniques and the production of a comprehensive 'Groundwater Resources Report' and accompanying resources maps for each District, as well as for the RUWASA region as a whole. ***This step will require a high level of analytical skill and experience if it is to produce reliable and meaningful results.***

The above process has been agreed with Project Management and is designed to utilise the large amount of information for the benefit of future water supply planning. It is, however, the minimum technical/scientific output that should be expected from a project of this magnitude, and will only be achieved with some difficulty with the current professional inputs that are available.

2. Points to Consider

- The Project has to provide reliable and useable products derived from the accumulated data to the RUWASA Districts for future water supply planning. Provision of a voluminous database will not in itself meet these planning requirements since technical expertise in the Districts to utilise this data will be limited.

- Recent discussions with DWD Principal Hydrogeologist have indicated a desire to produce a series of hydrogeology/water resources maps on a national basis. Any similar work undertaken by RUWASA should thus conform to any analyses, standard formats or presentation ideas that this may involve.

- As noted above, RUWASA has a substantial archive of groundwater data and has committed to produce a set of technical outputs. However, it is apparent that there is inadequate Project Office expertise to achieve all these outputs.

- The recent visit by J Davies from British Geological Survey has revealed that BGS has substantial expertise and considerable experience in other African countries in the analysis, evaluation and graphical presentation of groundwater information, and may be in a position to provide short-term technical assistance to RUWASA.

- The analysis and graphic presentation of RUWASA data can provide a basis for, and will stimulate the further development of, a national evaluation of groundwater resources for long term planning purposes.

- Although not specified in the Project Document, it is incumbent upon RUWASA to utilise the accumulated data in a scientific manner for the future benefit of Uganda, and its rural population in particular.

3. Recommendations

- The production of Borehole Data Catalogues continues as at present, as this is basic to the presentation of useable information, and ensures that all data is in standardised digital form for any subsequent analysis. However, this process is proving to be substantially slower than had been anticipated [only 443 out of 1644 (25%) of the Project boreholes have been processed (Sept 2000), at an average rate of 80-100 boreholes per month], and consideration must be given to mechanisms for speeding up the activity if the next stages of data manipulation are to be achieved during the final year of the Project.

It is thus proposed that additional personnel be dedicated to this task – if suitable personnel are not available from within the PO, these should be sourced externally on short-term contract.

[This may involve taking on an additional suitably qualified person or persons from a recognised consultancy company to assist Jane with the work, such that the processing rate can be increased to at least 200 boreholes per month ie +/- 6 months to completion].

- To undertake the next, analytical, stages of the data evaluation and presentation activity, it will definitely be necessary to involve personnel with greater expertise than is currently available in the Project Office.

It is thus proposed that in order to provide immediate impetus and continuity both RG and JLF schedule additional inputs against Consultant time allocations, to be partially executed externally due to constraints on making residential visits.

[This could involve QA control, individual Data Book and District Catalogue completion, production of copies, collating and binding etc externally in Botswana].

- The complete analysis of data and preparation of reliable graphic outputs and the interaction with possible DWD national initiatives may also require other additional technical expertise at the PO.

It is thus proposed that RUWASA formulate a request for short-term technical assistance from British Geological Survey, to be either engaged directly as external Consultants, or via DWD and DFID as part of ongoing bilateral research-orientated assistance to the water sector in Africa.

[This should preferably involve interaction and collaboration with DWD to ensure consistency of approach, the production of a proposal and/or ToR, and, if agreed by BGS/DFID, the subsequent input by BGS of a qualified highly computer-literate hydrogeologist on short-term assignment to RUWASA Mbale. The most appropriate time for this to happen would be end 1st Quarter 2001, after the initial processing of data should have been substantially completed].

4. Concluding Comments

RUWASA has generally been considered by both Donor and DWD to be a 'production-orientated project, with little or no requirement or inbuilt capacity to produce any substantial technical output that may be applicable or useful in the future broader national context. However, with the proposed metamorphosis of the PO into one of a number of national support units resultant upon the decentralisation policy in the water sector, more lateral thinking in the approach to the wind-down period, the activities that it should encompass and the results it should produce is required. The production of technical outputs that have benefits to both the RUWASA area and nationally, along the lines discussed above, is one such approach that is very definitely worthy of adoption.

ANNEX E

Example of RUWASA data file

ANNEX F

PROPOSAL
UGANDA: MAPPING OF GROUNDWATER RESOURCES IN UGANDA

Prepared by Callist Tindimugaya, Principal Hydrogeologist
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Issue

Uganda requires hydrogeological maps depicting the quantity and quality of groundwater resources at the district and national levels in order to target the poorly served areas using cost-effective technologies. These maps are currently unavailable. As a result, groundwater development activities continue to occur in a haphazard manner. Hydrogeological mapping of the country is, therefore, critical to the guidance of rational and sustainable groundwater use throughout Uganda.

Background

Groundwater plays a significant role in domestic water supply in Uganda with construction of boreholes commencing in the early part of the century. The current national rural water supply coverage is estimated at 47% while the urban water supply coverage is estimated at 56%. Under the newly formulated rural water supply investment plans it is intended to significantly improve the water supply coverage in the whole country to at least 95% by the year 2015. The focus is on groundwater development using low-cost, simple water-supply technologies to achieve this objective.

Current groundwater development plans at the national level have been made with very little information on the hydrogeological conditions and groundwater potential of different areas of the country. Uganda does not have a hydrogeological map with which to plan the development of groundwater resources for agriculture, industry and public water supplies. Similarly, at the district level, very little is known about (i) the nature and extent of aquifers; (ii) their potential for both large and small-scale groundwater development; (iii) the quality of available water resources; and (iv) the feasible water supply technologies in different parts of the district.

Hydrogeological mapping has not been conducted because data collected during the development of groundwater resources has not been synthesised to depict groundwater resources both spatially and vertically. A large body of hydrogeological data exists in the National Groundwater Database but has not, to date, been incorporated in groundwater resources planning and development because it is not synthesised and interpreted.

District administrations often seek financial support for water supply without due consideration of the most appropriate and cost effective technologies, regularly opting for technologies which may work but are expensive to construct, operate and maintain. Under the current Sector Wide Approach (SWAP), both the Directorate of Water Development and District Administrations require maps to guide them in planning water development activities thereby targeting poorly served areas using the most cost-effective technologies. Maps are currently unavailable and planning has been haphazard. Hydrogeological mapping of the country is thus a necessity and the generated mps will be very useful in rational and sustainable groundwater supply to the rural and urban population of Uganda. The current GIS mapping project and the National Groundwater Database will provide very useful inputs to this activity.

Argument

A project is proposed with the overall objective to assess and map groundwater resources at the district and national level in order to guide efficient and cost-effective water resources planning and development. Developed hydrogeological maps will represent the assessed groundwater resources in terms of their quantity and quality and summarise this information spatially. Recommendations of feasible water-supply technologies that can be used to improve water supply coverage in different areas of the country, will also be provided.

Mapping of groundwater resources will take advantage of the existing but scattered data on quality and quantity of water resources throughout the country. This includes not only the results of previous groundwater investigations but also data stored in the National Groundwater Database. Such information includes borehole drilling logs, pumping-test and geophysical data, water quality data, water source co-ordinates, aerial photos, topographic and geological maps, precipitation, water levels and discharge etc. These data are available from both in government departments and non-governmental organisations.

Data will be analysed with the aim of delineating the distribution of aquifers and water resource potential in different areas for use in water supply planning. The results will be presented as hydrogeological maps at appropriate scales as found necessary. Activities will start in a few selected districts resulting in district hydrogeological maps. Once maps have been prepared for al the districts, they will be combined to produce a hydrogeological map of the country. This will be made possible by use of geographical information system (GIS) and mapping facilities.

Participants in this project include the Water Resources Management Department of the Directorate of Water Development, Department of Lands and Surveys, Geology Department of Makerere University and the Hydrogeology Group of the University College, London. All the participants with come with different professional experiences and inputs for purposes of achieving the objectives of the project. The overall co-ordination of the project will be done by DWD which is responsible for storage and analysis of all water resources data. The Lands and Surveys Department will provide mapping capabilities and will guide on proper map production. Geology Department will assist in geological mapping and characterisation of the different formations whereas the Hydrogeology Group of the University of London will act as technical advisors to the project.

ANNEX G

Quotation for the supply of a Hydroquest drilling rig with vehicles and ancilliary equipment (compressor not included) for drilling horizontal boreholes with collector well systems. NB prices quoted at 1997 rates.