Short-Term Consultancy

Capacity Building Actions in Groundwater Management Issues as an Aspect of IWRM for the Nile Region

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EXECUTIVE SUMMARY

This short term consultancy is supported by the Cap-Net/UNDP programme for capacity building in integrated water resources management and the Federal Institute for Geosciences and Natural Resources (BGR). The main objective is to analyse the integration of groundwater aspects in national water management in East Africa with a focus on, and recommendations for, possible capacity development actions aiming at strengthening this integration.

The current study involved a guided survey through resource person in six countries, namely: Burundi, D R Congo, Ethiopia, Rwanda, Sudan and Uganda. The main objective is to propose a relevant set of capacity building actions in groundwater management issues as an aspect of IWRM for the Nile Region.

In this Summary major constraints to a deeper integration of groundwater into national water (resources) management are formulated following Annex I of the term of reference. A summary of these constraints is provided hereafter under relevant headings.

Key capacity building actions are then recommended and approaches/modalities for implementation are suggested.

Summary of Capacity Development Needs

A relevant set of priority capacity building needed for groundwater management issues as an aspect of IWRM for the Nile basin countries are listed in this section.

Proposed capacity building activities address the findings of the countries review above, which highlighted groundwater management constraint under an IWRM framework.

Actions are classified under three themes, namely: groundwater governance, operational management and analytical tools to support operational management.

1. Groundwater Governance: Polices, institutional and legal frameworks

Recommended actions to develop an enabling environment for sustainable groundwater management involve:

- Capacity building support is needed in developing appropriate institutional frameworks for groundwater management in view of decentralisation of groundwater development to districts and decentralisation of water resources management to basin boundaries or water management zone.
- Training on policy instruments for integrated groundwater management (use, protection and conservation)
- Applied research on issues of legislative framework for groundwater management with regards to emerging challenges of MDGs, climate change and environment sustainability;
- Training on legal requirements for groundwater allocation, evaluation and assessment of groundwater permits applications, groundwater resources assessment for use in permitting (recharge assessment, determination of exploitable groundwater etc), enforcement of groundwater permit conditions, effective groundwater monitoring as part of compliance monitoring
- Certify basic skills by developing a core curriculum and create a certification law
- Value capacity in career development to retaining skilled man power,

2. Development, Operation and Maintenance

Here recommendations that affect groundwater basins directly are considered. To enhance operational management of groundwater it is recommended to work directly with different sectors (drilling, maintenance and operation) to provide skills building for their members. Moreover, a community of local experts should be developed to sustainably build the skills of the members of various sectors in operational management instruments, namely: concrete activities, regulation, economic instruments, communication & awareness raising, and capacity building.
Key recommendations for capacity building action in operational management include:

- Training for managerial and administrative staff in integrated groundwater basin plans to improve and support operational management.
- Capacity building to water authorities, private operators, pump mechanics, and some community members on methodological operation and maintenance of both rural and urban water supply installations.
- Continuous follow up training and technical and financial support for the VLOM structures where the communities' capacities have been overstretched.
- Build capacity of drilling firms through short refresher courses to enable them improve their performance
- Refresher trainings in optimum pump selection, pump installation and maintenance, determination of optimum pump setting depths and pump servicing.
- Capacity building at both national and local levels to identify and monitor potential threat to groundwater due to poor sanitation and waste discharge. Specifically, capacity for regulation of both point and non point source pollution needs to be built.
- Capacity building in policing of water legislation by increasing and raising awareness among the population on need for groundwater protection.
- In-depth post graduate education in hydrogeology to give adequate insight in the discipline and upgrade limited skills in hydrogeology and groundwater management obtained at the civil engineering and geology departments. Subjects, which can also be delivered as regular short courses targeting working professionals, cover areas related to groundwater exploration, regulation, development, monitoring, assessment, groundwater hydraulics & computational methods.
- Training in areas of groundwater and IWRM tools, groundwater use efficiency, demand management, groundwater resources use planning, economic instruments recognizing water as an economic good that should be priced in regards with Equity and Efficiency principles

3. Analytical Tools: Resources exploration, Assessment, prediction

Analytical support and development of tools is found to be essential to carry out integrated groundwater management in an effective and efficient way and to help managers making the right decisions.
Supporting analytical tools is identified to address different challenges and different subjects in operational decisions and strategic decisions, etc.

Analytical tools can be used to assess and present the current situation and explore developments in the future. Key capacity needs in the region are:

- More training of trainers and practitioners is required in areas of groundwater resources assessment emphasising geophysical exploration methods, monitoring network design, data management (data collection from ground or remote-sensed sources, data analysis and interpretation and groundwater data presentation using GIS tools.
- Enter into cooperation agreement for database regular maintenance and update.

- Regular refresher trainings in groundwater development, well site selection and well testing. This can be provided as short courses and also included in the curriculum of the universities.
- There is limited understanding of groundwater occurrence and movement and this has big implications on the development and protection of the resource. Organisations in-charge therefore need to establish specialised groundwater education centres to build skilled human resources. Curriculum envisaged for such centre involves groundwater occurrence and hydrodynamics, sustainable groundwater development, groundwater monitoring and protection, groundwater data collection and data management, general IWRM principles, conjunctive use of groundwater/ surface water management, hydrogeological modelling.
- Support competency centres in groundwater in the region to be involved in the setting out regional groundwater database and support capacity building for groundwater management.

Recommended Key Capacity Building Actions

Approaches recommended to implement the capacity building actions are three folds. Capacity building actions recommended involve working with institutions (enabling environment) to enhance sustainable water delivery in the groundwater sector (state governments & national governments). A second category of recommended capacity building actions move beyond individual skill building and call attention to improving the organisational capacity. Most responses emphasised more programmatic actions to engage with a number of interventions with local capacity building institutions, or directly with communities, local governments and groundwater use sectors.

A. Building Individual Skill

Awareness raising to enhance political will and stakeholder commitment

- For decision making level on integrated groundwater basin management concepts, issues and tools and interactions with surface water, with socio-economic and environmental systems, etc.
- For communities on issues and roles for sustainable resource protection and water service delivery
- Among water managers on multidisciplinary nature of groundwater management and managing groundwater within basin natural boundaries

Trainings of trainers and Water Managers

- Training on groundwater policies and strategic planning to achieve development objectives
- Training on legal framework and implementation measures for integrated groundwater management
- Separate trainings on IWRM issues related to groundwater management.
- Training on groundwater operational plans for IWRM including demand management instruments.
- Training in integrated exploration and geophysical methods in various aquifer environments
- Training on network design, well site selection and well field design,
- Information management: databases and data analysis and interpretation and data management including software/ hardware systems involved
- Groundwater quality and pollution hazards
- Economic valuation of groundwater

- Hydrogeologic modelling, Groundwater hydrodynamics, Basin balance and mass transport as part of DSS
- Remote sensing and Geographical Information Systems (GIS) applications to groundwater exploration

Training of community

Training of local community on:

- Water resources issues (quality threats, demand management, etc) and primary health care.
- Promoting and creation of local committee.
- Local community conflict resolutions
- Monitoring of water points and its importance for demand management
- Groundwater protection and policing of water legislation.
- Operation and maintenance of rural water supply installations, such as hand pumps

Technical know-how for Technicians

Need for capacity building to private operators, pump mechanics, water authorities in proper operation and maintenance of both rural and urban water supply installations involves.

- Drilling operations and technologies,
- well construction and pump installation
- installing monitoring wells for discharge, level and quality sampling
- Monitoring for compliance to permit conditions
- Use of information and communication technology for groundwater data handling by regional water bureaus. This involves data collection and use of data databases for processing, quality control and production of useable reporting formats.

B. Enhancing the Organisational Capacity

- Support piloting IWRM organisational models at selected major groundwater basins such as:
  - Hydrogeological model: IRBM in hands of one single groundwater Basin Authority.
  - Administrative model: Water management in the hands of national, provincial and local governments
  - Coordinated model: Water management along administrative boundaries, but River Basin Commissions with a coordinating task.

C. Direct Interventions and Programmes

- Enter into cooperation agreement for database regular maintenance and update
- Support for groundwater maps at operational scales of 1:25 000 & 1:10000 to assist development work.
- Research studies on managing groundwater development at selected basins including assessments/ benchmarking
- Standards, guides on pumps, monitoring networks, etc
- Educational curriculum in hydrogeology, geophysics, computational methods` for resources assessment, resource protection from pollution and over draft,
- Support specialised groundwater education/ training centres by establishing or upgrading regional groundwater oriented research and education body

1. Introduction

1.1 Background

The importance of groundwater for various water use sectors may vary from country to country. Although not well recognised in national water policies, groundwater has proved major resource in development plans of water supply, irrigation as well as industrial sectors. Drinking water supply in all Nile countries rely on groundwater for more than 65% of the total consumption. In some countries groundwater is considered as the only realistic water supply option for meeting dispersed rural demand, as well as supplementing expanding urban centers. Moreover, currently large agricultural investments that are believed to greatly contribute to the food security and national economy are solely dependant on groundwater use.

With the emergence of MDGs and the 2015 targets for drinking water supply, a call for managing groundwater development was triggered by the conflicting irrational abstractions and failure to meet outputs in east Africa. However, this was linked to sustainable WASH, PPP and not directly to the resource management and governance system. The situation deteriorated with the decentralisation of water services to states level and central management of groundwater resources is no longer in control on local development.

Groundwater potential is largely defined by the hosting hydrogeological environment. There are four hydrogeological provinces in the Nile Basin, namely: Precambrian “basement” rocks; volcanic rocks; unconsolidated sediments; and consolidated sedimentary rocks. The geographical distribution of the four hydrogeological environments suggests that thirteen groundwater basins are shared among two to three countries with no corporate management of their resource. While sedimentary basins form the largest hydrogeological province population distribution was exceptionally higher on basement terrain, where the groundwater potentially is lower than sedimentary basins. This has exposed groundwater to pollution risks from human activities on the unprotected basins’ catchment zones.

The safe development of groundwater reserves should consider various scenarios such as variability of natural recharge, transboundary reaches and legal and institutional mechanism. These scenarios add to the challenges for groundwater management, which involves lack of sufficient knowledge on natural recharge due to key methodological gap, lack of corporate management of transboundary aquifers and poor understanding of local institutional roles, legislation and water rights.

It is believed that Hydrogeological capability makes groundwater allocation more effective, but the issues remain to ensure the institutional and regulatory frameworks as well as management instruments for the sustainable management of this precious resource. Integration of groundwater into national water resources management as an aspect of IWRM need to target these issues as will be addressed by this study.

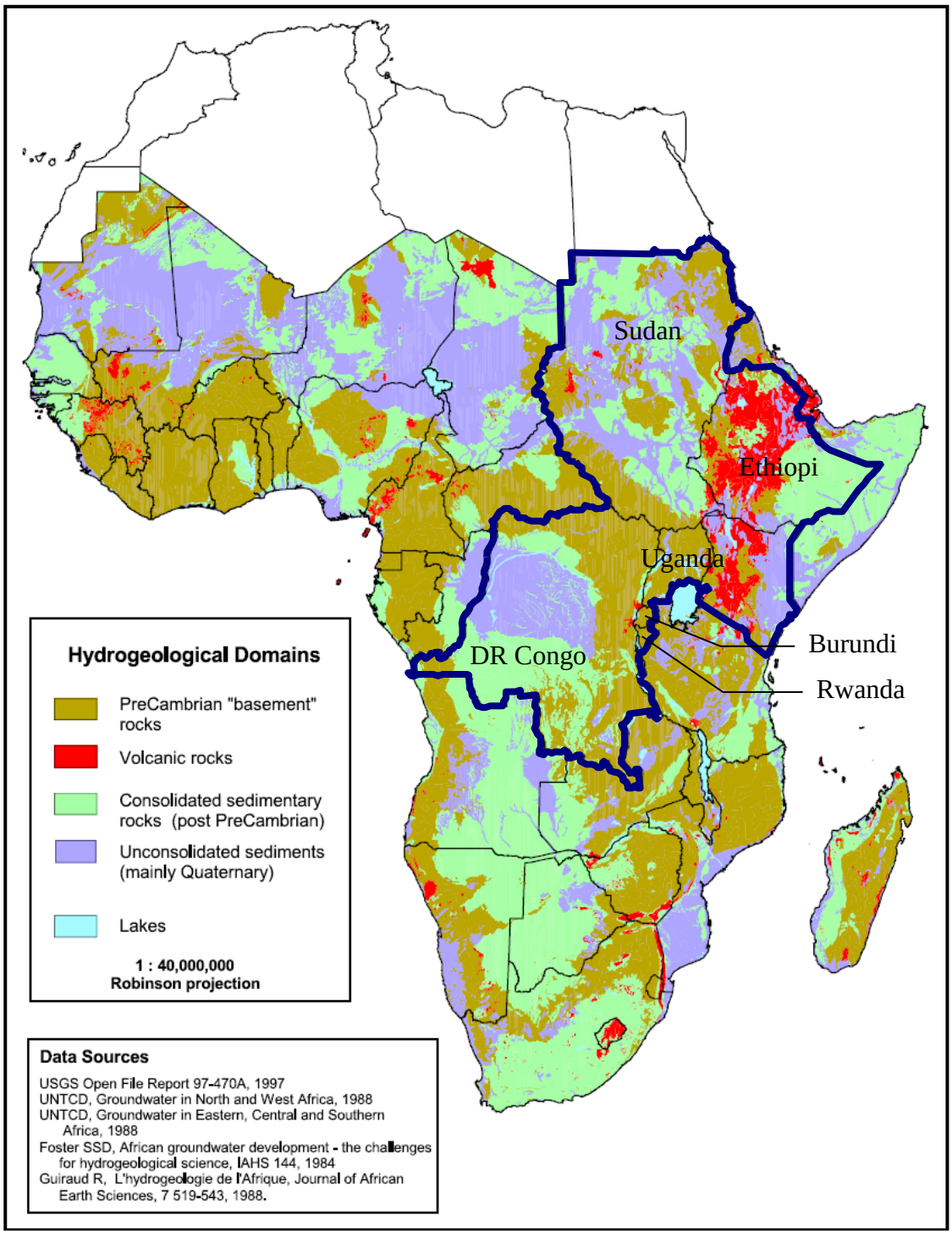

Figure 1: Location of countries covered by the study, *source: DIFID, 2005*

1. 2. Methodology

This study has been conducted by regional team of resources persons from six countries in the Nile Basin. The team involved:

1. **Dr. Muna Mirghani** – Assistant Professor , School of Rural extension, education and Development, Ahfad University for women, Sudan – team leader
2. **Dr. Callist Tindimugaya**, Assistant Commissioner, Water Resources Regulation, Water Resources Management Department, Directorate of Water Development, Ministry of Water and Environment.
3. **Mr. Raphael Tshimanga**, lecturer, Department of soil and water Management, Faculty of Agricultural Sciences, University of Kinshasa.
4. **Dr. Ir. Gaston Hakiza,** a Professor at the University of Burundi, Faculty of Sciences, Department of Earth sciences, Bujumbura, Burundi.
5. **Dr. Tamiru Abiye**, Associate professor at the Department of Earth Sciences of the Addis Ababa university, Ethiopia
6. **Dr. Robert Baligira**, Assistant Professor, Kigali Institute of Science and Technology (KIST) Faculty of Civil Engineering and Environmental Technology Department (CE&ET).
7. **Mr. Mohamed Hassan Doori,** Director, Groundwater and Wadis Directorate, Directorate of Water Resources, Ministry of Irrigation and Water Resources.

The team have conducted local data acquisition and country review guided by a questionnaire based on Annex 1 of the term of reference. Moreover, the study includes a review of the management in relation to IWRM and general water sector reforms.

The study combined desk study and review of literature with field visits of structured rapid appraisal with responsible authorities in each country to collect and confirm various data by the country team member.
Country data were then compiled in spreadsheet format by the various team members. And finally a regional report has been compiled for six countries, namely: Burundi, D R Congo, Ethiopia, Rwanda, Sudan and Uganda.

The specific outputs of the study are:

1. Baseline information compiled in spreadsheet format covering the questions specified in Annex I of the term of reference.
2. Review of groundwater management in relation to IWRM and general water sector reforms.
3. a relevant set of capacity development actions (at least five) in groundwater management for the Nile basin, addressing the findings of the analysis above
4. Regional report

The above outputs were approached conducting separate country level surveys to fill a questionnaire and recommend capacity building actions by national focal points / resource persons.

The study has been accomplished following the plan outlined in table 1 below.

The report is structured in twelve sections. After this introduction collected country information is presented in separate sections reflecting the IWRM dimensions for groundwater management.

Countries capacity building need is given separately under each section; While recommendations addressing the major constraints to a deeper integration of groundwater into national water (resources) management are formulated in Boxes.

Table 1: Work Plan

Output	Activity	Input	Responsibilities
Output 1: Inventory/ Baseline information compiled in spreadsheet format covering the components specified in annexI of the term of reference	• Data review and interpretation of existing information on: 1. Institutional Management 2. Legal Status/ frameworks 3. Resource Assessment 4. Resource use 5. Maintenance 6. IWRM 7. Groundwater development 8. Environmental aspects 9. Economic aspects 10. Groundwater Education and Training • Entering data in spreadsheet format	Annex I of ToR and spread-sheet guiding questionnaire form circulated	national focal points/ resource persons
Output 2: Review of ground-water management in relation to IWRM and general water sector reforms	Analysing the integration of groundwater aspects in national water management strategies in Nile basin countries by: • Assessing the national groundwater activities/projects underway and list good experiences in the countries on groundwater management in the context of an integrated approach, • Finding out to what extent water sector reforms in the country are addressing groundwater issues • Investigating between water use and ground-water management within the context of IWRM and against the against the background of social and economical relevance of groundwater in the region • Making suggestions on how to implement groundwater management issues aiming at an integrated water resources management	ToR Expert	national focal points / resource persons
Output 3: a relevant set of capacity develop-ment actions (at least five) in groundwater management for the Nile basin, addressing the findings of the analysis above	• Proposing Activities for a capacity building action plan in ground water management issues as an aspect of IWRM for the Nile basin countries. • Formulate recommendations addressing the major constraints to a deeper integration of groundwater into national water (resources) management.		national focal points / resource persons
Output 4: Regional report	Compilation of countries outputs into a regional report	ToR and Country Information	Coordinator
Output 5: Final draft shared with Cap-Net & BGR		Expert	Coordinator

2. Institutional Management:

Introduction

The study indicated that four countries Burundi, D. R. Congo, Rwanda and Sudan have not yet developed water policies. While two countries Uganda and Ethiopia have already put in place an IWRM policy which are still under piloting phases with varying attention to groundwater management.

Sectoral practices are deeply entrenched in the governance system, and coordination imposed at ministerial/central level hardly works on the ground. More fragmentation arises from the decentralisation of services to states level, where domestic water supply and in some countries agriculture are solely dependant on relatively cheap groundwater. Moreover, a large number of organisations with varying interest are involved in groundwater development. This has made basin level management a dilemma bringing all possible consequences on the groundwater reserves' quality and quantity. At local level where the work is done, water managers and practitioner apparently not in a position to lead IWRM implementation due to the lack of enabling environment, regulatory framework and more importantly the capacity and knowledge on IWRM management instruments.

A major conclusion from the conducted review that IWRM process have started the inverse way in the Nile counties leading to weak bases for its implementation. The few existing national water policies in the Nile countries treat surface and groundwater resources separately. Surface and groundwater interaction is not considered in water resource management. Only Uganda national water policy recognises the interaction between groundwater and surface water and provides guidance for conjunctive use of groundwater and surface water.

The large number of organisations involved in groundwater at local level, mainly concerned with the resource development, drinking water supply for rural people, displaced communities, communities in urban peripheries and cattle filling the gap of insufficient surface water supply; investments with lucrative objectives, operations during emergency periods, private drilling company and in few cases establishment of community-based operation and maintenance systems.

Institutional capacity building support is recommended to help in coordination of the various players (utilities, industries, NGOs, private sector, local/central government etc) involved in groundwater development within basin hydrological boundaries through:

- Awareness raising on Integrated Basin Management with a specific focus on groundwater.
- Empowerment of groundwater management authorities and its local offices to control and oversee other actors and resource users. This can be achieved through reform revising the general polices, institutional framework and legislative background of groundwater with regards to emerging issues of IWRM.
- Improved policy framework that emphasises:
  - Basin scale management to enable better integration of hydrogeologic, socio-economic and environmental consequences of development options.
  - Stakeholders' participation and sector-wide coordination amongst various water related institutions.
- Appropriate office should be established for groundwater management, licensing and control by the Ministry of Water Resources, which should have good linkage with regional water bureaus and related institutions such as geological survey of the country should provide access to groundwater information to users.

- Use of a range of regulatory, economic (e.g. charges, subsidies) and management instruments
- Enhance financial, legal and human capacities
- Develop accessible and reliable data management system
- Consider appropriate professional recognition scheme with incentives among government offices to fill the gap in qualified staff.
- Trainings on institutional setup for groundwater management with emphasis on separation between service delivery and resource management functions; on framework for involvement of users and stakeholders and coordination within level; and on sustainability of data management systems.

Institutions / authorities tasked by government with the management of groundwater

Institutions tasked by government with the management of groundwater in the six surveyed countries are presented in table 2.

Table 2: Institutions/ Authorities tasked by government with the management of groundwater

Country	Groundwater management Institutions / Authorities
Burundi	• Ministry of Energy and Mines: o Dept of geology; o General Direction of Rural Water and Energy o Public Corporation and energy. • Ministry of Country Planning, Tourism and environment: o Geographical Institute of Burundi
DR Congo	• Ministry of Environment, Nature Conservation, Water and Forest o Directorate of Water Resources • Ministry of Energy o The national company of water supply and sanitation (Régie de Distribution d'Eau – REGIDESO, o National Commission of Energy, • Ministry of Rural Development o The national Service of Rural Hydraulics (Service National d'Hydraulique Rural – SHNR), • Ministry of Planning o Congo National Action Committee for Water Supply and Sanitation – CNAEA • Ministry of Heath o The rural health zone (Zones de santé Rurales – ZSR) • Ministry of public works o The service of drainage (Office de Voirie et Drainage – OVD)
Ethiopia	• Ministry of Water Resources o Regional Water Bureaus (9 Bureaus) • Addis Ababa Water and Sewerage Authority. • Ethiopian Geological Survey.
Rwanda	• Ministry of lands, Environment, water and forestry – MINITERE

Sudan	• Federal Ministry of Irrigation and Water Resources o Groundwater & Wadis Directorate o National water corporation • State Ministries of Agriculture, Irrigation, and Animal Wealth • State Ministries of physical Planning o State water corporations
Uganda	• Ministry of Water and Environment o Directorate of Water Development – Water Resources Management Department

Do these institutions have an IWRM policy?

IWRM policy can be defined as the Water Resources Management Policy that outlines fundamental policy principles based on Dublin-Rio statements (1992). These include the following

- The right for access to sufficient water of acceptable quality to satisfy basic human needs.
- Water is both an economic and social good;
- Water resources development should be based on decentralized management and participatory approaches.
- Management of water resources shall ensure social equity, system reliability and environment sustainability;
- Recognizes the hydrologic boundary or basin as the fundamental planning unit and water resources management domain.

In Uganda, a national Water Policy following IWRM principles exists. Ethiopia, although the Ministry of Water Resources has got Water Resources Management Policy, but has been described in the survey as not inclusive. However, increasingly the groundwater basin is emerging as a unit of management of land, water and other natural resources in an integrated fashion.

With the exception of Uganda and Ethiopia, other Nile countries covered by this survey have not endorsed national water sector policy. Various policy drafts are available as part of external water policy funds. However, such documents and other individual attempts are normally not known to public and were not yet to be recognised by the government (sector Ministries and, parliament).

According to the survey results, Burundi and Rwanda has no IWRM policy. In Sudan and DR Congo, the water resources policy is weakly defined and does not provide a clear direction of the attributions for water resources management. This has in many cases led to conflict of roles between institutions involved in water resources management. It is also important to note that even the process to developing a water policy is not clear for the water professionals or to decision maker.

Levels of operation of institutions: National or catchment level

In general national level institutions with decentralised administrative boundaries according to the hierarchical governmental structure (state/province, district, town/village, locality) are the units of water management in the majority of the surveyed countries.

Again Uganda and Ethiopia are the only countries which started adopting the basin management level. Although the institutions are at national level but they work with local governments (districts) to implement groundwater management activities. Piloting of implementation of these activities at catchment level is being done in Uganda in preparation for rolling out to the rest of the country.

Box 1:

Recommendations: Capacity building support is needed in developing appropriate institutional frameworks for groundwater management in view of decentralisation of groundwater development to districts and decentralisation of water resources management to the catchment or water management zone.

Organizations involved in groundwater development

The fact that groundwater development is predominately linked to the water supply sub-sector, increasing number of NGOs and donor funded programmes/organisations are involved. This has been influenced by the emerging international support to the millennium development goals (MDG) on water supply and sanitation sector.

The survey results have named some major NGOs and donors (table 3) working in the Nile countries in groundwater resources development, however, the list could be a very long one.

Key concerns of the organizations involved with groundwater

Key concerns of the different organisations involved with groundwater are varied, including:

- Development, protection and management of groundwater resources.
- Groundwater exploration, assessment and mapping; issuance and surveillance of policy, strategy and water laws; Groundwater development; water supply
- Drinking purpose for rural, displaced communities, communities in urban peripheries and cattle to fill up the gap of insufficient surface water supply;
- Lucrative objectives looking benefits from investments.
- Operations during the emergence period and
- Private drilling company
- Sustainability: Establishment (in few cases) of community-based operation and maintenance systems.

The survey clearly indicated shortcomings in groundwater data and information leading to:

- Limited knowledge of groundwater potentials in various areas making which a Constraint to sustainable and efficient groundwater development,
- Limited capacity for groundwater development,
- Pollution of groundwater from onsite sanitation,
- Poor catchment protection leading to reduction in yields and pollution of springs and shallow wells.

Box 2

Recommendations: Capacity building and support is recommended to help in coordination of the various players involved in groundwater development such as NGOs, private sector, central government institutions etc needed. In addition, awareness raising on IWRM with a specific focus on groundwater needed.

Table 3: organizations (NGO's, donor organizations, etc.) involved in groundwater development

Country	Organisations	Concern
Burundi	UNICEF, PNUD, FAO, CUD (Belgium)	Development, protection and management of groundwater resources
D R Congo	OXFAM ,MIDRILCO ,FOLECO ,SFA, ADIR, C.D.I.	Apart from OXFAM, SFA and FOLECO which are supporting the government's efforts to fill up the gap of insufficient surface water supply; other organizations are behind lucrative objectives looking benefits from investments.
Ethiopia	Consultants and contractors; Charity organizations; World Vision, UNICEF, Concern, Menschen für Menschen, Water Action, Goal, COOPI, Private companies; Design and control enterprises; Water works enterprises etc.	Groundwater exploration, assessment and mapping; issuance and surveillance of policy, strategy and water laws; Groundwater development; water supply
Rwanda	LWF, Oxfam, ARC, during the emergency period, Electrogaz, Foraky, Drillcon	Drinking purpose for people and cattle, LWF and other organisations operated during the emergence period and Foraky is acting as private drilling company
Sudan	Some UN Agencies (UNICEF, UNDP, FAW, IFAD, WFP,..etc), voluntary international organizations (CARE, Save The Children, MSF, OXFAM, GOAL, USAID, PLAN Sudan, CRS…etc) and a number of National NGOs and societies.	Mainly safe drinking water supply for rural and displaced communities as well as communities in urban peripheries. Sustainability: Establishment (in few cases) of community-based operation and maintenance systems.
Uganda	Over 150 NGOs involved in groundwater development in Uganda, and these are coordinated under the Uganda Water and Sanitation NGO Network (UWASNET). These are however mainly local NGOs with a few international NGOs. Notable international NGOs include World Vision, CARE, Oxfam, Catholic Relief Services (CRS) etc.	The key concerns of organisations involved in groundwater include limited knowledge of groundwater potentials in various areas making which is a constraint to sustainable and efficient groundwater development, limited capacity for groundwater development, pollution of groundwater from onsite sanitation, poor catchment protection leading to reduction in yields and pollution of springs and shallow wells.

Perceived capacity building requirements for these organizations

Many of these organisations are manned by staff with limited or no technical expertise in groundwater development and management. Generally, there is limited understanding of groundwater occurrence and movement and this has big implications on its development and protection of the resource. These organisations therefore need building of human resources, institutional and technical capacities.

Human resources development:
Develop skills of specialized personnel is the main sectoral problem/issues through specific training in groundwater occurrence and movement, sustainable groundwater development, groundwater monitoring and protection, groundwater data collection and data management, general IWRM principles, conjunctive use of groundwater/ surface water management, hydrogeological modelling.

Appropriate professional recognition with incentives among governmental offices should be considered to fill the gap.

The institutional capacity

- empowerment through legislative frame work.
- reform revising the general polices and legislative background of groundwater with regards to emerging issues of IWRM
- basin scale management to enable better integration of hydrogeologic, socio-economic and environmental consequences of development options.
- stakeholders participation
- sector-wide coordination amongst various water related institutions
- all actors in the groundwater development sectors should take responsibilities through sectoral laws. Appropriate office should be established for groundwater management, licensing and control by the Ministry of Water Resources, which should have good linkage with regional water bureaus. Geological survey of the country should provide access to groundwater information to users.
- Use of regulatory and legislative instruments
- financial and administrative capacities/ instruments
- accessible and reliable data management system

Technical capacity

- Groundwater exploration technologies,
- Monitoring network and database management system
- Suitable and locally available groundwater development technology choice.
- System maintenance.

3. Legal Status:

Introduction

Legal limitations are met equally in all countries. With the exception of Uganda, there are no specific laws covering groundwater use and development, however, general water laws apply to groundwater when relevant.

The existing water laws in all Nile countries are not effectively enforced. However, there were good examples of reinforcement in some basins projects, but are no longer working after the end of the projects. Such cases are important to document to share success experiences.

Control of inappropriate private water use is constrained by limited financial resources, limited technical capacity and understanding of the feasibility and potential of installing private water supplies.

Capacity building is needed in legal aspects of groundwater regulation, groundwater permits applications, groundwater resources assessment for use in permitting (recharge assessment, determination of exploitable groundwater etc), enforcement of groundwater permit conditions and effective groundwater monitoring as part of compliance monitoring.

Specific recommendations for capacity enhancement include:

- Revision of existing legislations for consistency.
- Put in place and implement specific laws and regulations for groundwater permitting, pricing, aquifer protection, sanctions, etc. .
- Establish and maintain compliance monitoring and supervisory mechanisms to enable law enforcement.
- Establish coordination linkage and communication at different management levels.
- Develop standards, limits and guidelines to control withdraw and technology choice.
- Awareness raising and training at all levels on regulatory aspects for sustainable groundwater management.

Institutions empowered by law to manage groundwater

All institutions indicated in table 1 are empowered by law for carrying out specific groundwater management roles. In some countries like Sudan, such roles are overlapping, contradicting or lacking the proper status to achieve tasks.

Specific laws covering groundwater use and development

Again, groundwater use is covered within general laws for water resource management, including rights to water use, resource development, protection from pollution, etc..
However, specific regulations have also been issued for groundwater resources in general and in some countries only for managing certain basins. Some countries are more advanced than others in setting regulatory framework for groundwater management. Table 4 list the specific laws covering groundwater.

Table 4: Laws governing groundwater management as identified by the study survey.

Country	Laws
Burundi	• No laws!
DR Congo	• Ordinance law of 1st July 1914 on pollution and contamination of sources, lakes, aquifers and rivers. • Ordinance law No 52/443 of 24 Dec 1952 on measures to protecting sources , aquifers, streams and rivers, wastage of water and control of right to use water and ownership. • Ordinance law No 74/569 0f 3rd Dec 1958 related to irrigation • Ordinance law No 69/041 of 22 August 1969 related to Nature Conservation. • Ordinance law No 77- 019 of 22 February 1977 on the charges of REGIDESO Ordinance law No 81 -013 of 02 April 1981 on general legislation of mining and hydrocarbons. • Ordinance law No 82- 006 of 25 February 1982 on territory, political and administrative organization of the Republic, especially in its article 173. • Ordinance law No 91 – 348 of 27 December 1991 fixing the rate and modalities of taxes and charges for the ministry of Energy. • Ministerial act No E/SG/O/0133 C2/93 0f 7 Mars 1993 fixing conditions for obtaining the ground water and surface water permit, conditions for carrying out a drilling of aquifer and exploiting ground water in DRC.
Ethiopia	• General regulation No. 115/2005. • Proclamation No. 197/2000 of the Ethiopian Water Resources management
Rwanda	• Some laws and decrees aiming at controlling water pollution including groundwater • Water law is under development otherwise the water was governed by many fragmented laws.
Sudan	• Water resources Act (1995). • The Groundwater Law is in draft form pending approval.
Uganda	• Water Act (2000) • Water Resources Regulations (1998)

Laws enforcement

Although describe penalties imposed in case of contravention, the existing water laws in all the Nile countries are not effectively enforced. Efforts are being put into strengthening enforcement in some countries such as *Uganda*. Enforcement mechanisms have been very successful in *Sudan* under certain projects in specific groundwater basins (Gash and Nyala) however, have not lasted long after the termination of the project.

Level at which users/ developers are required to seek permits from the relevant authorities

Three countries (*Burundi, Rwanda* & *Sudan*) out of six countries under this survey do not apply any system of permits at any level because there is no legal base for it.

In *Sudan*, in accordance with The Water Resources Act (1995) all waters are within the public domain and as such any development should have been subject to approval. However, there are no laws or regulations (stemming from the Water Resources Act) that specify how, when, or where such an approval can be obtained. The result is no restriction on groundwater development for public or private use.

Ethiopia although by law requires permit to drill a well, however, such laws are not enforced and are not mandatory. Users do not know about the availability of such laws and institutions are not capable to implement them.
Uganda and *D R Congo* have developed comprehensive regulations restricting groundwater abstraction without permit.
In *DR Congo*, and according to the Ministerial act No E/SG/O/0133 C2/93 of 7 March 1993, the general secretary of the Ministry of Energy provides the permit against extensive information on identity of the organization or individual, a request of investment project justifying the demand, a drawing at a scale of 1/10.000 showing the location and the surface area of the groundwater exploitation, an extract of environmental plan showing the features of the location where the exploitation will be undertaken, the results of preliminary studies including geological profile and chemical and bacteriological analysis, all these counter signed by an official organization in charge, and all necessary documents attached. At local level, the demand is requested from the representative of the Ministry of Energy at local level who later addresses the demand to the general secretary of the Ministry.

In *Uganda*, users and developers are required to apply for permits when they are abstracting groundwater using motorised pumps irrespective of the volume of water being abstracted. These procedures are enforced although the permits coverage is still low. Outreach campaigns have been ongoing for almost 2 years now to ensure that all the water users are aware of these requirements and apply for permits with minimum inconveniences. This expected to increase on water permits coverage and improve enforcement of the laws.

Box 3

Recommendations: Need for capacity building and support in monitoring compliance to the laws and regulations and enforcing their implementation.

- Breakdown to public and Private water: capacity constraints for improving / increasing / conserving the use of private water

DR Congo, *Ethiopia*, *Sudan* and *Uganda* consider water as a public good belongs to the government which holds it in trust on behalf of the people.

However, in *DRCongo* the right to groundwater is subject to the regime of land ownership governed by the law No 73-021 of 20 July 1973, which specifies the permissible volume and period of groundwater pumping for different uses.

Except in *DRC*, other surveyed countries do not exercise any restriction on groundwater development for public or private use. However, in *Uganda*, most of the water supplies are installed by government while privately installed water supplies for domestic, industrial or irrigation use constitute less than 20%.

The capacity constraints for improving private water use include limited financial resources, limited technical capacity and understanding of the feasibility and potential of installing private water supplies.

- The capacity building needs

The survey identified the need for legal water reform by revising the general legislative framework for groundwater management with regards to emerging challenges of MDGs,

climate change and environment sustainability; as well as setting up an empowerment mechanism for the implementation of the required legislations.

Some countries emphasized the need to build capacity to provide bottom line information for developing relevant reforms. There are calls for more qualified personnel in groundwater sectors and equipment for field investigation and for laboratories in *Burundi* and *Rwanda*. The existing water resource laws in *Ethiopia* do not give full coverage in support of groundwater management. Therefore, the need for specific law for groundwater licensing, pricing, aquifer protection, monitors etc. is highlighted. To that end another need for assessment tools to carry out estimation of the quantity, quality and conservation mechanisms is also emphasised.

In *Sudan* recommendations for capacity need included:

- Revision of existing legislations for consistency.
- Put into place and implement specific rules and regulations.
- Establish and maintain monitoring and supervisory mechanisms.
- Establish coordination linkage and communication at different levels.
- Standards, limits and guidelines to control withdraw and technology choice
- Awareness raising at all levels.

Uganda capacity building needs include; legal requirements for groundwater regulation, evaluation and assessment of groundwater permits applications, groundwater resources assessment for use in permitting (recharge assessment, determination of exploitable groundwater etc), enforcement of groundwater permit conditions, effective groundwater monitoring as part of compliance monitoring.

Box 4

Recommendations: Capacity building is needed in legal aspects of groundwater regulation, evaluation and assessment, groundwater permits applications, groundwater resources assessment for use in permitting (recharge assessment, determination of exploitable groundwater etc), enforcement of groundwater permit conditions, effective groundwater monitoring as part of compliance monitoring.

4. Resource Assessment

Introduction

Limited knowledge on groundwater potential in various areas poses a great constraint to sustainable and efficient groundwater development.
Groundwater exploration, assessment and mapping are crucial for issuance and surveillance of policy, strategy and water laws, groundwater development for various purposes and basin protection and conservation efforts.

While databases have been established in some countries within previous projects, the survey clearly indicated poor state of groundwater information and data management system.
Measures to counteract reduction in yields and pollution of groundwater from onsite sanitation, industry, and agricultural practices are hindered with the lack of required data.

Recommendations for resource assessment include:

- Improvement of groundwater database systems to meet the practical needs of groundwater stakeholders.
- Establish national catchment-based monitoring networks with wide coverage for major Basins in particular the shared ones.
- workout a mechanism for collection of data from different sources such as academic and research institutions, some NGOs and consultancies, private companies and donor projects or programmes.
- Coordination among different institutions involved in groundwater development for proper assessment of various aspects of quantity, quality, uses, demands, etc.
- Transfer required groundwater exploration technologies,
- Develop guides for monitoring network design and database management system (soft and hardware) including operation & maintenance.
- Set standards for compliance with quality and quantity
- Provision of regular training/education modules on groundwater assessment as well as data management system.

State of knowledge about groundwater in any country

Generally, knowledge about groundwater is far from complete in the region, although a process with various degrees of advancement has started in some surveyed countries. Usually emphasis is concentrated in certain basins of transboundary nature (e.g. the Nubian Sandstone Basin in Sudan) or where good groundwater potential exists as the only accessible water resource such as the alluvial plains in Burundi.

Looking separately at countries under consideration, some special features are highlighted by country resource persons with varying details.

In *Burundi* knowledge is linked to studies made in some areas. A new competency centre of ground water is established at University of Burundi to collect all information and create database. Based on the geological units in Burundi, two very different hydrogeological substratums are distinguished, namely: Precambrian and Alluvial formation. All basins identified in Burundi exist in the Precambrian formations. Measuring equipments were installed in some Basins by the Geographical Institute of Burundi, but most of them are actually destroyed. While many wells have been installed in the Alluvial plains by Belgians before 1961, descriptions are available for a part of them.

Groundwater resources of *DR Congo* occur in six geological formations.

1. The *Equateur* and *Bandundu* formations, which represent very important aquifers in North West of *DRCongo.*

2. Central Cuvette Sand with average thickness of 120m covering larger proportion than the previous in North West of *DRC*. It extends to the central part of *DRC* sharing the boundaries with heterogeneous and anisotropic materials. The hydrodynamic characteristics related to this type of geological formation include normal yield range from 25-450 m^3/h, static level range from 2m to artesian, dynamic level from 5.7 to 41.6 m with drawdown of 6.2 to 27.5 m. The submersible depth of GMP is about 18 m and the normal yield using GMP ranges from 18 to 250 m^3/h

3. Low potential Sand Aquifer of thickness 80 m occurs in Southwest of *DR Congo* and extends to Southeast in *Kinshasa*, *Kasai Occidental* and *Lubumbashi*. The hydrodynamic characteristics related to this type of geological formation described as Normal yield range from 15 to 40 m^3/h, static level range from 10 to 131.9m, dynamic level from 23.3 to 147 m with drawdown of 0.43 to 15 m. The submersed depth of pumps varies from 30 to 171 m and the normal yield using GMP ranges from 15 to 40 m^3/h.

4. Heterogeneous and anisotropic material with rapid infiltration and presence of salt water in their deepest part are located in central part of *DRC* essentially in *Kasai Occidental* and *Kasai Oriental*, extending to *Bandundu*, but is also found in *Kinshasa*. The hydrodynamic characteristics related to this type of geological formation range from 42.5 to 55 m^3/h Normal yields, the static level approximately 97.6m and the dynamic level 113.68 m with the drawdown of 16.8m. The immersed depth of GMP varies between 30 to 120 m and the Normal yield using GMP ranges from 30 to 50 m^3/h.
The aquifer transmissibility is 2.26 $\times 10^{-3}$ m^2 /s and the coefficient of storage S = 10^{-5}.
The quality analysis of sampled water from this geological formation shows a pH of 6 (in situ) and 6.4 (in laboratory). The CO2 (equilibrium) is 0.17 mg/L, CO2 (free) is 123.12 mg/l with a pH of equilibrium equal to 8.75

5. Very heterogeneous and anisotropic materials with compact cretaceous rocks containing very important water resources essentially found in *Katanga*. This type of geological formations is characterized by a normal yield of 80 to 180 m^3/h, a static level of 14.7 to 21 m and a Normal yield using GMP of 40 m^3/h

6. Fractures conditioning the development of aquifer zones are the major geological formation found in DRC. It extends from Northeast in *Orientale* province to Southeast in *Katanga* including Kivu. It is also located in *Equateur*, *Kasai oriental* and *Bas Congo*.
The Normal yield of this geological formation range from 30 m^3/h in *Bas congo* (*Moanda*) to 60 m^3/h in the *Orientale* Province. The static level is about 2m and the artesian level is about 45 m with a drawdown of 43 m and a normal yield using GMP ranging from 10 to 45 m^3/h.

In *Ethiopia*, the information about groundwater is not widely known all over the country. Fairly enough information is available for some well fields for not more than 29% of the country. It is captured in a map format which is prepared by the Ethiopian Geological Surveys that has mapped 30% of the country at 1:250,000 scale map. The maps are not quite available for end users. There are also numerous studies by higher education centres in a published and unpublished format.

There is little knowledge about groundwater resources in *Rwanda*. A total number of 404 wells were drilled in Eastern province and the western part of the country. The depth is less than 60m.

Apart from few well developed areas, knowledge on groundwater is mostly general in *Sudan*. Some areas are even unexplored. Information is captured on ad hoc basis through demand

driven activities, donor supported projects, and degree research studies at universities. The information is available generally on cost but exemptions are possible. Users of information include public and private sector institutions, NGOs, civil society groups, researchers, and individuals.

In *Uganda* knowledge about groundwater is still limited although efforts initiated in 1996 to improve this situation have started bearing fruits. The information is generated from the national groundwater monitoring network, specific groundwater resources assessment studies and water well construction programs. This information is captured in a National Groundwater Database and is accessible to anybody. It is currently being used by drilling contractors, groundwater consultants, researchers and students, government departments, NGOs, construction companies etc.

Groundwater database

State of groundwater database varies from country to another. Catchment level monitoring of groundwater for the purpose of integrated basin management is completely absent in all Nile countries. National groundwater monitoring network is only available in *Uganda*, while in other countries monitoring is mostly limited to well-fields supplying important centres or related to specific research or development project for limited time. Access to groundwater data as to all data on water is generally restricted to permission of a government body, and in some cases available only in hard copies against fees after the approval.

In some countries the process of defining, constructing and manipulating groundwater databases has started, yet far from been complete due to existing capacity gaps. Defining the groundwater database by specifying the data types, structures and constraints was done within projects framework in *Ethiopia*, *Rwanda* and *Uganda*. Computerised groundwater databases have been constructed and defined data was stored in MS Access database that provides manipulation functions vis-à-vis querying the database to retrieve specific data, updating the database or reflect changes in the quality and generating reports from the data.

No groundwater database currently exists in the country *Burundi*. Limited relevant local training is available to support implementation of a groundwater data management system.

Most of data monitored in *DR Congo* are still kept in hard format, renders the access to the information very difficult. The information stored in hard copy form includes hydrogeological maps, Geographical and climatic maps, reports and publications. A digitalized and computerized database system is lacking but may be accomplished with the help of UNESCO which has just initiated a project for database management in water sector.

Box 5

Burundi

More training of trainers and practitioners is required in the area of groundwater resources assessment as well as specialized training in groundwater data management software.

The competency centre in groundwater, recently installed at University of Burundi need be involved in the setting of groundwater database development.

The adequacy of a database system can be evaluated in accordance with the type of database, the accessibility to the source of information and the quality and quantity of information. In this regard, the Groundwater resources database in *DRCongo* is almost inexistent. Each institution is holding its own data for the purpose of works carried out internally, while experts' reports are published. Data are not readily accessible to public at risk to be spoiled since the format in which they are kept is not adequate.

There is a National Groundwater database in *Ethiopia* named ENGDA which is developed by USGS with a financial support of IAEA. It is placed at the Ministry of Water resources. The database is in Acess-2000 format and includes data for boreholes and spring site information, water levels and water quality data. Site-specific documentation like maps and photographs can be loaded. Different water supply institutions have got data in hard and soft copies but no standardized formats exist.

Currently, over 4000 water points have been stored in the database placed at one location and the Ministry of Water Resources is responsible for managing it. Groundwater monitoring system is not well known in the country. The only available, not regularly monitored time series data are that of Akaki well field in Addis.

In *Rwanda* an adequate groundwater database has been developed in Aquarium environment by SHER in 2005 into Access. The Unity of Water and Sanitation under Minitere is the authority in control of the database.

Sudan has an inadequate groundwater database developed in dBaseIV since 1983. The database system needs updating and inclusion of more parameters.

The database is controlled by The Ministry of Irrigation and Water Resources (MOIWR); The Groundwater and Wadis Directorate of MOIWR is the responsible institute. Access to information need written permission from Undersecretary of the Ministry. Only

Box 6
D R Congo

Capacity building action is highly required in this domain covering training of seniors and professionals in data collection and database management. Cooperation with UNESCO through financial support of French government has initiated a project on water resources database, which is expected to give sound water resources data management.

Box 7
Ethiopia

It is hardly possible to say that users are acquainted with the software. Even regional water bureaus have no idea on the existence of the central database format. Training was only given once for few people. There is no continuity on the training or use of the software. A GEF project proposal is underway to support groundwater information/ assessment.

Box 8

Rwanda

Recommendations: capacity needed include:

1. Trained engineers, technician for operation and maintenance of existing database system

2. Training of local trainer to lead national level training,

3. Enter into cooperation agreement for database regular maintenance and update.

summaries can be provided from the database in different format (as required) to the public at affordable cost. No catchment level data is available. There are very limited networks for groundwater monitoring associated with short-term development projects.

A recent assessment of database management system is supported by NBI recommended coordination among various institutions possessing groundwater data to establish distributed database system accessible to different users.

Relevant training/education of mid level hydrogeologist is not available locally. There is only one agreement within the framework of the transboundary Nubian Sandstone Basin, a GEF/ IAEA assisted project but expectations are not much.

Box 9

Sudan

Recommendation: Establishment of a national catchment based monitoring networks with wide coverage of the major Basins in particular the shared ones.

Provision of Hardware and Software to upgrade the existing database system.

Coordination among different institutions involved in groundwater development.

Training in database management and data handling.

In *Uganda*, a relational National Groundwater Database exists and is based on Access. The database system is fairly adequate and the Hydrogeology Section of the Water Resources Management Department is responsible for updating and maintaining it.

Local training is available in general geology with limited hydrogeological training. The capacity building requirements include groundwater data collection, data analysis and interpretation and groundwater data presentation using GIS. Groundwater database development was funded by the Danish Government as part of national capacity building for water resources management in *Uganda*. The Danish Government has continued its support which has helped to consolidate the operation and maintenance of the database.

Box 10

Uganda

Capacity building through short courses for various organisations involved in groundwater management and development needed. The courses should deal with groundwater data collection, data analysis and interpretation and groundwater data presentation using GIS.

Recommendation: Improvement of groundwater database systems to meet the practical needs of groundwater stakeholders.

Hydrogeology Section of the Water Resources Management Department controls the database. The database and is accessible to anybody including the general public at a small fee. The data is currently available for the whole country but at district level. A national groundwater monitoring network has been in operation since 1998.

- Review of the availability of data

Summery of available groundwater data in the surveyed countries is given in table 6.

Sources of groundwater data, not captured by the national database system

Beside the data available from organisations officially mandated to manage groundwater data, other important sources include donor projects or programmes, academic and research institutions, some NGOs and consultancies, private companies.

Moreover, a great number of development activities that generate additional data are undertaken without notification or knowledge of the groundwater authority, and are thus does not constitute part of the groundwater database.

In *Burundi* for example these sources are associated with some poorly studied areas where existing regional surveys need refining, such as the Belgians in the Rusizi Plain. The purpose was to supply drinking water to rural population because surface water is far from their village and that surface water is not safe for drinking. The water supply utility – REGIDESO – also collects boreholes data in some urban cities.

There is a need to invent/ workout a mechanism for collection of these data sources.

Table 6: Groundwater data Availability at surveyed Country

Data Type	*Burundi*	*DR Congo*	*Ethiopia*	*Rwanda*	*Sudan*	*Uganda*
Groundwater maps (piezo-metric, deepness, thickness…)	Only in Rusizi basin (Gaston) and near Tanganyika Lake. Other publications are available at the Royal Museum of Central Africa (Belgium).	no recent inventory (scattered)	Yes	No	Only on regional scale, and not covering the whole country. A hydrogeological map of Sudan is available only at scale 1:2,000,000	Yes, for about 1/5 of the country but work is continuing to cover the rest of the country.
Geological maps (lithologic and stratigraphic nature of aquifers):	In the same areas above.	Not recent survey available	Yes	Yes	Only on regional scale (1:2,000,000). For few alluvial aquifers detailed maps are available. A recent project by the Geological Research of Sudan produced updated geological maps at limited areas at a scale of 1:250,000, however, they are not accessible to outsiders. For others reproduction from the database is possible.	Yes
Hydrogeological & Hydrological reports (memories, thesis…)	Available but inadequate. Memories and one thesis at University of Burundi Earth's Sciences Department	Reports available at educational institutions and at REGIDESO	yes	yes (report of JICA & a doctoral thesis (Robert Baligira)	yes, to some extent a libraries of the groundwater directorate and faculties of earth sciences.	Yes, for a number of areas over the country
Analysis of the major groundwater systems (recent surveys)	No	No recent analysis has been carried out. Existing analysis is done during the 50s or earlier.	yes	yes in the Eastern and part of western provinces.	No recent surveys	Yes, for about 1/5 of the country but work is continuing to cover the rest of the country

Data Type	*Burundi*	*DR Congo*	*Ethiopia*	*Rwanda*	*Sudan*	*Uganda*
Climatic data, rainfall and ET maps	Yes	Yes	no	Yes, but incomplete	The data can is available at The Sudan Meteorological Authority. No maps.	Yes
Groundwater chemistry data	No	Not recent survey available	Yes	No monitoring	Yes, scattered in various archives but not fully included in the database.	Yes. A national water quality monitoring network and database exists
Groundwater level, EC, pH data etc...	No	Not recent survey available	Yes	Some info	Yes, only when constructing a well, or in association with a research/ consultancy study.	Yes. These are collected from the national monitoring networks and captured in databases
Groundwater recharge rates	Available in limited areas. Done by REGIDESO, Geographical Institute of Burundi and companies that have worked with public services.	Not recent survey available. Lack of an adequate groundwater database renders difficult the evaluation of groundwater potential, dynamics including recharge rate, yield and vulnerability	yes	Some info	No, there are one or two researches on recharge estimation in confined areas. Estimation is hindered by poor quality of data, and lack of remote sensing use in basin water budgets.	Yes, for a few areas. A national groundwater recharge map is under preparation
River runoff data; rainfall and climatic data.	For some areas. Flow rates, pluviometry, temperature, dampness of wind, average sunshine.	Partially available	No	Incomplete since 1990, data collected is poor, need the estimation of missing data	To some extent, yes.	Yes. There is a national surface water monitoring network and database

5. Resource use

Introduction

A major identified constraint to sustainable groundwater use is the lack of Aquifer yield tests due to lack of equipments. Dug wells in hard rock as well as boreholes taping shallow alluvial aquifers sometimes fail at the end of the dry season, and no legislation addresses drying up of groundwater resources.
Also, deep groundwater resources dry up in some places where abstraction is much higher than recharge; and non-renewable reserves are exhausted with no consideration to negative impacts or future alternatives.
Conflict between users (agricultural, industry and domestic sectors) is increasing in many basins/ countries and expected to continue in order to meet growing demand in all sectors.

Other identified constraints to resource use are related to:

- The complex geology and limited understanding of groundwater occurrence and movement, and hence suitable location of wells.
- Not right choice of suitable and locally available groundwater development technology.
- Lack of skilled professional who are able to operate and maintain the water sources appropriately.
- Often lack of monitoring and maintenance has damaging consequences such as land sliding in most of cases.
- Lack of knowledge on estimation techniques of safe reserve quality and quantity, optimum groundwater development, and selection of appropriate groundwater supply technologies that can deliver adequate water and are easily maintained,
- Cost effective water sources construction,
- Lack of measures to deal with the drying of groundwater sources, such as:
  - Recharge estimation studies as well as proper well yield testing upon construction
  - Drilling the wells deep enough and installing pumps at appropriate depths.
  - Control of groundwater abstraction through issuance of abstraction permits helps to control drying of water sources due to overexploitation.

Principal users of groundwater

In *Burundi* principal user is rural population. The purpose is to give the drinking water to rural population where surface water is far from their village and that surface water is not suitable for drinking. REGIDESO also made boreholes in some urban cities.

Groundwater in *DR Congo* is used for industrial and domestic demand and contributes 29% of the total amount of water supply in the country from springs (21%) and drilled wells (8%). Due to the high cost of drilling, only industries and mining are able to afford the cost of Groundwater exploitation. Some private users such as embassies and political authorities use groundwater for domestic purposes. Due to the cost of surface water treatment, the government has set up a strategy of groundwater supply where low income people can not afford the cost of surface water supply. Therefore Groundwater supply in rural areas is in most case free of charge without a cost recovery. The recent implication of SNHR and ZSR have contributed to the rehabilitation of 542 wells and furnishing 659 boreholes in the country.

The major constraint of groundwater use in *DR Congo* is the cost of exploitation and supply, drilling problem and management of boreholes. Electricity also constitutes a limiting factor to

groundwater use. Technical constraints include lack of yield tests due to lack of equipments. Often lack of monitoring and maintenance causes land sliding in most of cases.

Groundwater users in *Ethiopia* involve rural people, urban dwellers and industries. 85% of Ethiopians live in rural area and mainly use groundwater through springs or dug wells for domestic use. The main obstacle is the way they live. They are dispersed all over the rural area and it is not affordable to provide groundwater for each houshold. Groundwater is provided mainly using hand pumps from dug wells and from springs. In the case of villages where population is higher than 5000, motorized pumps are used. The main constraint is financial and technical.

Groundwater in Rwandan is mainly developed for domestic use (people, cattle, in rural area cleaning in urban area - few private boreholes). Constraints are financial, know how, equipment etc..

In *Sudan* groundwater is used for irrigation, human and animal drinking supply and for industry including petroleum. The main constraint is the insufficiency of supply vis-à-vis the demand.
Groundwater is normally provided at a wide range of levels: hand-dug open wells, slim boreholes equipped with hand-pumps, wells equipped with motorised pumps, and wells connected to distribution networks.

Uganda groundwater is used for domestic purposes. Over 80% of the population depends on groundwater.
Capacity constraints in providing groundwater for these groups include location of groundwater in fractured rocks due to complex geology, selection of appropriate groundwater supply technologies that can deliver adequate water and are easily maintained, cost effective water sources construction, optimum groundwater development etc.

Box 11

Recommendation: Provide both formal and on the job training in appropriate use of various geophysical techniques in borehole sitting.

Groundwater is mainly provided through hand pumps especially for rural areas. In towns and rural growth centres, groundwater is provided through use of motorized pumps with a distribution network. For other uses such as industrial and irrigation groundwater is provided using motorised pumps.

- Groundwater use for irrigation

No significant groundwater use for irrigation in *Burundi*. Irrigation is very limited at the moment in the country, but could develop in drier regions.

Agricultural activities in *DR Congo* are based on rain-fed agriculture which benefits from favourable rainfall conditions across the equator. Therefore Irrigated agriculture is limited to the use in Rice farming (case of irrigation schemes carried out by Chinese farmers in DRC and to some extent the irrigation scheme carried out in the plantation of the former president Mobutu using ground water).

Groundwater use for irrigation is not significant for the time being in *Ethiopia*. However, with the extended drought periods followed by occasional extreme flood-events there is strong interest by the government and private sector to use groundwater for irrigation.

Rwanda has no clear plan for groundwater use in agriculture and studies are on going.

In *Sudan* irrigation is the primary user of groundwater (70%-80%).

There is limited use of groundwater for irrigation in *Uganda*.

- Large scale urban use of groundwater, Constraints and problems

The national water and electricity supply company (REGIDESO) of *Burundi* develops groundwater for domestic water supply for Gitega city. Mainly, the regions of the Rusizi plain use the groundwater for domestic/ drinking. No information available on the percentage of groundwater use compared to surface water.

In *DR Congo* large scale urban use of groundwater is for industrial demand especially in Katanga where a lot of industries are implemented.

There is large scale groundwater use for urban supply in *Ethiopia*. The main water supply for all big cities comes from groundwater. The main constraint is quality and quantity problem.

Only One plant in *Rwanda* extracts groundwater in Nyabarong Valley to supply water to Kigali City.

In *Sudan* over 50% of most of the major urban use (including Khartoum) comes from groundwater.

Use of groundwater for meeting urban water supply and industrial needs is on the increase in *Uganda*. Strategy for urban water supply targets use of groundwater as a first priority in areas where it is found.

- Groundwater resources dry up

This is generally depends on the type of aquifer and abstraction level. For example, dug wells in hard rock sometimes fail at the end of the dry season when groundwater levels fall. Other examples occurred in *Sudan* and *Uganda* are related to high abstraction rate compared to recharge. The importance of recharge estimation studies as well as proper well yield testing upon construction is to be considered when planning groundwater development.

In *Burundi* and *DR Congo* as well as *Rwanda* no problems of drying up have so far experienced. Hence no regulations are available to deal with such issue.

While it is very rare that groundwater resources dry up in *Ethiopia*, Dry wells were observed in low productive Precambrian metamorphic aquifers. In general water level fluctuations for 2 to 3 m takes place annually. The only solution is to look for alternative water supply even from very far basin. There is no legislation that addresses drying up of groundwater resources.

In *Sudan* drying wells are encountered only in some of the shallow wells in some alluvial aquifers, which dry up towards the end of the dry season but recovery takes place at the start of the rainy season. People just wait!

In *Uganda* shallow groundwater sources dry up during the dry season, and in some places during big water level fluctuations. Deep groundwater resources dry up in some places where abstraction is much higher than recharge. This

Box 12

Recommendations: Need for provision of regular refresher trainings in groundwater development, well testing, groundwater level monitoring etc. This can be provided as short courses or included in the curriculum of the universities.

has so far been observed in one town where groundwater levels have dropped by over 25 metres in only 8 years of groundwater abstraction. Problems of drying up of shallow groundwater sources due to big water level fluctuations are solved by drilling the wells deep enough and installing pumps at appropriate depths. Control of groundwater abstraction through issuance of abstraction permits helps to control drying of water sources due to overexploitation.

Variation of groundwater use in different regions of a country

Generally, there are variations in groundwater use in different regions depending on the demand, availability of surface water sources, water quality, climate, and dominant water use activities.

In *Burundi*, mainly, the regions of the Rusizi plain use the groundwater for domestic/drinking purposes.

The percentage of groundwater use in *DR Congo* ranges from 6.12% in *Orientale* Province, 7.14% in *Kasai Occidental*, 10.2% in *Kinshasa*, 11.2% in *Equateur*, 17.34% in *Bas congo* and *Bandundu* to 18.4 % in *Kasai Oriental*. Data on *Kivu* are not provided.

Variation in groundwater use in *Ethiopia* is caused the quality. In high fluoride region (Rift valley), there is less use. While on highlands, there is high rate of use.

In the arid and semiarid north, east, and west of *Sudan* (away from the Nile), groundwater is mainly used for human and animal supply. In the central parts where soil factors are favourable, it is also used for irrigation.

Use of groundwater in *Uganda* varies significantly in different regions due to differences in availability of alternative sources of water, differences in populations, differences in water using activities. Use of groundwater is more intensive in areas where there are no surface water sources and where there is high population density.

6. Maintenance

Introduction

Operation and Maintenance of groundwater installations in the Nile countries is generally a State's level responsibility. In the States it is further pushed either to local councils or directly to the community without any support.
The low percent of maintenance are caused by a number of constraints, namely:

- Lack of a unified and consistent policy directive towards the maintenance issue (especially in rural areas).
- Deficiency in maintenance infrastructure, insufficient instrumentation, insufficient number of vehicles and lack of skilled technicians.
- Absence of local manufacturing of accessories/ spare parts, and the wide variety and different make of pumping units (lack of standardization).
- The high cost of spare parts and maintenance expenses and insufficient resources to meet these costs.
- Absence of specialised maintenance centres/ organisations or well rehabilitation facility (sometimes the borehole itself gets clogged).
- Institutions and organization capacity constraint, where inadequate institutional structure hardly leads to effective functioning.
- Low capacity among local committees and authority members (professional & technicians) to properly maintain the installations.
- Lack of capacity in groundwater level monitoring, discharge monitoring, water quality monitoring, design of pump setting depth and pump maintenance.
- Low charges for maintenance of water sources because communities are poor and have limited technical capacity for doing the work in-house.
- Absence of cost recovery mechanisms for groundwater supply service; this has in most case leaded to collapsing the system due to lack of incentives.
- Difficult access to the site (transportation).

A good example of village level operation and maintenance policy –VLOM – is practices in Uganda. Back-up support is provided by the government in form of establishment of regional spare part outlets, creation of a conditional grant to local governments for operation and maintenance and regular training. However, continuous follow-up training, technical and financial support are needed

Institutional responsibilities

District Rural Administrations are in charge of maintenance of groundwater installations in *Burundi*. It does not function successfully. REGIDESO is responsible for maintenance of urban groundwater installations.
Maintenance problems are linked to inadequate monitoring, operation and maintenance issues. Permanent technicians for maintenance are missing in rural regions and financial resources are insufficient to buy spare part.

In accordance with the decree N°03/027 of September 2003 fixing attributions of the services and ministries on water resources issues, SNHR, REGIDESO and ZSR are empowered to carry out maintenance of public ground water installations in *DR Congo*.
These institutions have recently improved the maintenance by involving local communities in to maintenance actions.

Problems are mainly financial sustainability. Cost recovery mechanism for ground water supply service does not exist anymore and this in most case leads to collapsing the system due to lack of incentives.

Water supply and Sewerage authorities and water committees of the rural areas are responsible for maintenance in *Ethiopia*. Private sectors, water works construction enterprise, and other actors are involved too. There is no capacity in the country to maintain water supply systems. Responsible institutions do not function properly and need restructuring and training to improve their capacity and efficiency.

Problems include absence of specialised maintenance centres/ organisations, lack of spare parts/ accessories, local manufacturing of accessories, lack of skilled technicians, etc…

In *Rwanda* maintenance responsibility lies on the Unity of Water and Sanitation/MINITERE; and to some extent Districts where boreholes are located.

Problems of technician, finances, institutions & organization represent the capacity constraint.

Responsibility in *Sudan* is mixed. In urban or semi-urban areas where the supply is metered or flat-rated, the State Water Corporation is responsible for maintenance. In rural areas it could be the State Water Corporation, the local council, or the local community depending on what the State Authorities decide.

However, the existing institutional structure does not always function successfully.

Problems are: The high cost of spare parts and maintenance expenses; The wide variety and different make of pumping units (lack of standardization); Scarcity of skilled maintenance personnel; Lack of well rehabilitation facilities (sometimes the borehole itself gets clogged) and Mismanagement.

In *Uganda* public groundwater installations in rural areas are maintained by the community through a community based maintenance system. The communities form a water user committee which is responsible for maintenance of the water source. The functionality rate of these structures is about 60%. In urban areas, public groundwater installations are maintained by a gazetted water authority appointed by the minister of water resources. The authority may engage a private company to assist in operation and maintenance of the installations and are thus paid for their services.

There are problems of capacity among the committee and authority members to properly maintain the installations. They have limited understanding of groundwater occurrence and movement and are thus not able to operate and maintain the water sources appropriately. They also lack capacity for groundwater level monitoring, discharge monitoring, water quality monitoring design of pump setting depth and pump maintenance.

Box 13

Recommendation: Need for capacity building to private operators, pump mechanics, water authorities and some community members etc in proper operation and maintenance of both rural and urban water supply installations.

- Institutional resources

Generally, lack of sufficient resources is a predominant feature in the six surveyed countries. *Burundi* and *Rwanda* have hardly existing resources for maintaining groundwater supply system, other countries emphasised specific resource needs.

There is lack of human resources (professionals and technicians) and insufficient equipments to deal with demand are identified in *DR Congo.*

More technical staff is needed in *Ethiopia* with up to date and reliable instrumentations. Main constraints are the small number of maintenance crew against large number of water points, insufficient instrumentation for the crew, insufficient number of vehicles, lack of skilled technicians, financial constraints etc..

No sufficient material or skilled human resources in *Sudan*. The main constraint is the lack of a unified and consistent policy towards the issue (specially in rural areas). There is also deficiency in maintenance infrastructure.

In *Uganda* limited financial and human resources within the institutions to maintain groundwater supply systems, and this has lead to low functionality rates. Some of the constraints include low charges for maintenance of water sources because communities are poor and general limited technical capacity for doing the work in-house.

Effectiveness of maintenance for public water supplies

Spare parts, transport and finance are the main constraints in ensuring that boreholes maintenance structures are effective in *Burundi*.

The effectiveness rate of maintenance of groundwater public sources (94 centres for Water supply of REGIDEO) in *DR Congo* evaluated in terms of the percentage of boreholes exploited, those in good maintenance and those out of service varies considerably in various regions. It ranges from 0% in *Kasai Occidental*, *Equateur* and *Orentale* province to 16.7% in *Kasai Oriental*, 40% in *Kinshasa*, 58.8% in *Bas congo*, 64.7% in *Bandundu* and 83.3% in *Katanga*. The maintenance of overall ground water installations in the country is about 38.8%.

The low percent of maintenance of groundwater installations are caused by a number of constraints. Lack of equipment for good maintenance (GMP, grillage GMP, electricity, non conformity to the network, pillage, rupture and lack of GO, impaired materials), lack of technicians, difficult access to the site (transportation) are some to mention.

In *Ethiopia* all public boreholes are functional. However, there is no national maintenance policy for boreholes. Any drilling enterprises try to give maintenance service for boreholes that they drilled or for other service seekers.

Constraints: Spare parts, trained personnel, policy , equipment, transport, finance etc.

An estimate of 60% of public boreholes are operational in *Rwanda*. Nevertheless there is no maintenance policy.

Constraints: Spare parts; know how, financial constraint, trained engineers, technician for operation and maintenance of existing boreholes.

In rural areas of *Sudan* almost 50% of the boreholes can be not working at any point in time. In urban and semi-urban areas the situation could be better. The policy is ambiguous and not successful in guiding on the ground practices and resources allocation.

The problem is a policy constraint in the first place. Once it is settled then the appropriate institutional structure can be established and supported. Operation and Maintenance is now a State level Responsibility. In the States it is further pushed either to local councils or directly to the community without any support.

In *Uganda* maintenance of public water supplies in rural areas follows a community based maintenance system which is ineffective. The percentage of public boreholes not working at any one point is about 30%. Maintenance of public water supplies in urban areas is done by

the private operators who are engaged with water authorities and the functionality rate is much higher because the people pay for water.

The main constraints in ensuring that borehole maintenance structures are effective include lack of access to spare parts, limited technical personnel, low or no community contribution, low income levels leading to high poverty levels.

VLOM –village level operation and maintenance policy

No village level operation and maintenance (VLOM) policy exists in *Burundi, Rwanda* as well as *Sudan.*

The VLOM in *DR Congo* has been operationally identified in term of Rural Health Zone (ZSSR) under by the Ministry of Public Health. So far, the ZSR has a total of 514 circumscriptions called Rural Zone Health.
The ZSR works in good collaboration with SNHR and their intervention policy is vested in the following objectives:

- Assessing water resources availability in rural areas.
- Carrying out the activities of water supply and sanitation in rural areas by creating, repairing and rehabilitating fountains, wells, boreholes, pumps etc.
- Initiating the best practices for water resources management and conservation, rain water harvesting.
- Initiating training of local people in regards to water resources issues and primary health care.
- Promoting creation of local committee developments.
- Assisting local community in conflict resolutions

The strategy used by SNHR and ZSR to achieving the above mentioned involves:

- Participatory approach
  Promotion of self help groups of community development and encouraging participation of beneficiaries by involving them in all stages of the projects.
- Capacity building
  Delivery of vocational training and best practices for protecting ground water installations.
- Cost recovery
  Establishment of reasonable monthly fees from the users and a representative committee for financial management.
- Conflict resolutions
  A conflict resolution approach to deal with conflicting interests of stakeholders based on finding amicable solutions mechanism with a support from the Rural Zone Health (ZSR) agents.

There is no VLOM for boreholes in *Ethiopia*. Rural people are trained to maintain hand pumps through trained committee members.

A village level operation and maintenance policy exists in *Uganda*; but it is not very effective. Training for such programs is normally provided during construction of water supplies and before commissioning. There is however limited follow up support and training resulting in low operation of the VLOM structures put in place. Effectiveness of VLOM is hampered by lack of continuous follow up training and technical and financial support where the communities' capacities have been overstretched. VLOM is practices in the whole country and back-up support is being provided by government in form of establishment of regional spare part outlets, creation of a conditional grant to local governments for operation and maintenance and regular training.

7. IWRM

Introduction

IWRM policies translated into legislative framework, organisational roles, water resources management tools including knowledge base, analytical tools/models, assessment and management indicators, and regulatory/economic instruments are not adopted in groundwater management in all countries, except Uganda.

Major IWRM constraints, which cover Institutional capacities and know-how are among the following:

- Existing national water policies do support the interaction between surface and groundwater. They are treated separately and more importance is given to surface water. Accordingly, no sufficient financial resources are allocated for groundwater development.
- Lack of awareness among water managers on the multidisciplinary nature of water management led to the exclusion of participatory design of well sites, leaving alone involvement of women and gender issues.
- Lack of understanding of gender issues in relation to water policies is highlighted in all countries. There is generally negative attitude towards the involvement of women in water management in all Nile countries. Specific gender policies are thus needed to empower and balance women participation.
- Generally, there is lack of awareness about the need and importance of water demand management and its instruments among water managers. The capacity constraints affecting demand management strategies in the region can be summarised as:
    - Limited knowledge and capacity for groundwater discharge and water quality monitoring. Groundwater quality and level monitoring are not practiced.
    - Absence of demand management policy,
    - Lack of resources (human, legal, financial, equipment, field transportation facilities, etc…) to implement demand management measures.
    - The supply is far behind demand.
    - Absence of monitoring for agriculture and industrial discharges constrain application of demand management measure.
    - Annual fees charged for use of groundwater do not consider the abstraction volume.
    - Limited knowledge and capacity on groundwater, discharge and water quality monitoring by the users, data analysis and interpretation, monitoring of compliance to permit conditions.
    - Inefficient water points associations responsible for monitoring.
    - The absence of private sector to take over professional monitoring, operation and maintenance.

Surface water / groundwater interactions

In *Burundi* the national water policy does not take into account the interaction between surface and groundwater. More importance is given to surface water. The importance of groundwater is very little vs surface water. The groundwater is not recognised as important for domestic water supply, irrigation or industrial sector. Therefore no sufficient financial resources are allocated for groundwater development.

Groundwater in *DRCongo* is used to support the gap of surface water supply especially in rural areas where infrastructures for surface water supply do not exist and the cost of water treatment is likely not to be covered.

Groundwater contributes 8 % to total water supply in the country; this very low percent is due to limited financial support devoted to the sector.

Ethiopia national water policy treats surface and groundwater resources separately. Surface and groundwater interaction is not considered in water resource management. There is wide understanding towards the use of groundwater vs surface water. This is due to the fact that surface water availability is climatically dependent, vulnerable to pollution etc. According to the questionnaire, in terms of financial resources, over 95% goes to groundwater development.

Rwanda has no clear water policy. Institutions are under development and water is now governed by many fragmented laws.

In *Sudan* groundwater and surface water are treated separately and developed as such. Both resources are considered equally important because groundwater is the only source in some areas and vice versa.

Uganda national water policy recognises the interaction between groundwater and surface water and provides for conjunctive use of groundwater and surface water. Groundwater is the main sources of water supply for over 80% of the country's population who live in rural areas. Groundwater is also heavily abstracted for water supply to small towns and rural growth centres. In terms of financial resources, over 70% is spent on groundwater development. Groundwater is more important than surface water because it supplies the needs of over 80% of the country's population and can be abstracted where it is needed and fairly cheaply.

Gender issues

With the exception of little new development, till recently gender is never an issue in the public water policy and programs of any of the Nile countries. This is basically because of low status of women in the region’s culture in a predominately rural population. Also, the lack of awareness among water managers on the multi disciplinary nature of water management led to the exclusion of participatory design of well sites leaving alone involvement of women.

The questionnaire results indicated lack of understanding of gender issues in relation to water policies. This is greatly reflected by the negative attitude to the involvement of women in water management in all Nile countries. Exceptions are found in *Burundi* and *Rwanda*. However, in *DR Congo* after discovering the unsustainability of ground water projects, ZSR and SNHR have opted for a participatory approach involving men and women in e projects of rehabilitation and maintenance of groundwater installations. Yet this approach still suffers from empowerment and unbalanced participation of gender.

Again in *Ethiopia* women do not participate in borehole sites selection, which is considered a pure technical procedure requires scientific study. However, in the management and maintenance of rural water supply, women play very important and leading role. Since women are the main water users in the rural community, they are considered as important in water supply policies.

In *Sudan* specifically in rural water supply most of the maintenance trainees are women and they are increasingly represented in the village (water, health, education…etc) committees. However, site selection is done by professionals who hardly consult women.

Women in *Uganda* are greatly involved in selection of sites for drilling of boreholes for public water supplies. Site selection is normally done through coordination by Local Councils where at least 1/3 of the members are women. Each water user committees responsible for

maintenance of rural water supplies have to have at least 1/3 of its members being women. Specific gender policies are thus in place.

Demand management aspects

No demand management, no fees charged in *Burundi* for groundwater use. Groundwater levels and water quality are not monitored due to the lack of resources (human, equipment…) to implement demand management measures.

Mostly, groundwater supply *DR Congo* is done in very poor areas were the individual income does allow people to afford the cost of water e.g camps of refugees. In this context the demand management such as cost recovery, does not exist. Only the engineering part taking place for borehole site selection as well as for demand management. This has contributed to a very high level of failure of ground water supply project.

In *Ethiopia* nominal fees are in place to cover the running cost of the wells. Water quality and level monitoring programs are not practiced in the country for the purpose of demand management. The main capacity constraints are financing and skilled personnel.

A part from engineering no other dimension of management is practiced in *Rwanda*. No fees for groundwater collection except in the case of *Nyabarongo* Valley treatment plant managed by Electrogaz. Water quality is not monitored in the country.

There is no any form of demand management of groundwater in *Sudan*; and it was never an issue for domestic use as the supply is far behind demand. Water quality monitoring is needed for agriculture and industrial use, however, is not in place yet.

In *Uganda* there is no demand management on groundwater abstracted using hand pumps in rural areas. For groundwater abstracted using motorised pumps, there are annual fees charged for use of groundwater but these do not consider the abstraction volume. Water level, water abstraction volume and water quality monitoring are part of the demand management system. The capacity constraints affecting demand management strategies include limited knowledge and capacity for groundwater, discharge and water quality monitoring by the users and general lack of awareness about the need and importance of water demand management.

Monitoring

The extreme end regarding monitoring is found in *Burundi* where groundwater monitoring is completely absent.

In *DR Congo* the national company of water supply “Regideso” in joint collaboration with SNHR and ZSR has responsibility of monitoring and maintaining ground water installations. Due to lack of fund from government, the level of monitoring is very low. The monitoring of water quality aspect is almost negligible to the extent that groundwater quality data is lacking in the established installations.

The capacity constraint in monitoring mainly deals with lack of fund and technical know how.

There is no groundwater monitoring facility in *Ethiopia*. Pumping rates, water levels, water chemistry etc are done only once right after well completion. Monitoring is not practiced in the country. The main constraints are lack of installing monitoring wells, which are not included in the drilling program due to financial constraint, lack of finance to cover running cost, lack of skilled personnel etc. In big cities like that of Addis Ababa water supply well field, there are monitoring wells but the monitoring program is not practicable due to lack of continuity.

In *Rwanda* water associations for water points are responsible for monitoring. This has been not efficient. Districts are encouraging the private sector to take over the water management.

Neither monitoring network nor metering of abstraction exist in *Sudan*. Main constrains are lack of awareness among all levels involved on the importance of monitoring groundwater, Lack of policy guide, availability of monitoring equipment and monitoring points, analysis tools (hardware/software) and Field transportation facilities.

In *Uganda* monitoring of groundwater in terms of pumping rates, water levels and water chemistry is part of the conditions attached to groundwater abstraction permits. Thus a every permit holder has to monitor these parameters and submit a report to government on a quarterly basis or else his permit will be cancelled. Government however maintains a national monitoring program for key strategic areas. If monitoring indicated a problem, government takes action through reducing allowable pumping rates as part of the national groundwater regulation strategy. The capacity constraints for groundwater monitoring include lack of monitoring equipment, limited technical capacity for monitoring, limited capacity for data analysis and interpretation and limited capacity for monitoring of compliance to permit conditions.

8. Groundwater development

Introduction

Constraints to sustainable and effective groundwater development and management in the region are caused by:

- Insufficient capacity in hydrogeology and geophysics to determine potential borehole sites among involved actors.
- Lack of skilled hydrogeologists and geophysists on integrated hydrogeological investigation methods due to discouraging salary in the public sector.
- Heterogeneity of geology, topography, and environmental condition.
- Enormous lack of skilled technicians and accessories in the drilling sector.
- Limited finances for explorations, and also for topographical surveys and geology mapping.
- The limited number and quality of trained and skilled personnel.

It is recommended to support capacity building in hydrogeology and geophysics to ensure adequate resources assessment and sustainability development.

Moreover, infrastructure and power availability poses further constraints for optimum groundwater development.
Groundwater installations are most of the time far from the towns and are subordinated to availability of transport which includes vehicles and roads infrastructure. Power availability is a major limiting factor to ground water development. Electricity grid is very limited; and if available power fluctuations and unavailability lead to over-pumping or under-pumping in some cases.

Rural water supply depends on diesel power to pump water, however, again roads network is a limited factor. In large parts of the region, due to road interruption in the rainy months, maintenance, operation etc can not be done.
High pumping heads and long pumping distances sometimes limit the depths to which pumps can be installed. These thus affect optimum groundwater development.

Boreholes drilling sector is dominated by private sector, leading to poor quality and very high cost. The sector functions under key constraints, including:

- Limited provision of drilling materials that have raised the drilling cost.
- Lack of sufficient geological and hydrogeological information,
- Low experience of some drilling companies,
- Small salaries, lack of drilling accessories,
- Lack of capacity to drill large diameter wells (>10"),
- High drilling costs arising out of high importation costs of supplies, stiff competition due to small drilling volumes,
- Unscrupulous drilling companies which do shoddy work,
- Irregularities in award of tenders sometimes favouring friends and relatives etc.

Efforts to enhance the drilling sector capacity are constrained with lack of structured training in drilling. The training capacity is very limited and most of the drilling staff learns on the job with very few opportunities for consolidated training.

Recommendation for short refresher courses to build the capacity of drilling firms and enable them improve their performance are addressed by the study.

Again pumps and pump installation and maintenance are mostly handled by private sector.

Pumps are mostly imported, and pump motors fail after short service and replacement is the only alternative to adequate maintenance. Pump maintenance is constraint by absence of capable and specialized workshop and rig maintenance centre.

It is recommended to increase the number of suppliers to satisfy the range of demand in the region.

Capacity building for this sector should focus on implementing a series of short term specialised trainings on pump equipment choice and installation to build a number of highly trained and experienced hydrogeologists and technicians, and ensure adequate maintenance of pumps.

Groundwater location

There is no sufficient capacity in hydrogeology and geophysics to determine potential borehole sites *Burundi*. There are major under-developed groundwater resources and still large areas need investigation to assess major un-developed groundwater resources. There is a demand for additional resources; however no sufficient human resources and financial constraints are main obstacle.

In *DR Congo* the technical capacity in groundwater is very limited to set out groundwater monitoring and address needs related to geophysical investigation, groundwater exploration. However the demand resides in these areas in which technical capacity in terms of equipment and knowledge is lacking.

Quite good number of hydrogeologists graduate from Addis Ababa and Mekele Universities in *Ethiopia*. There is limitation in using integrated hydrogeological investigation methods. In water supply sector the critical problem is lack of skilled hydrogeologists and geophysists due to discouraging salary. In many parts of the country, groundwater is an important source of potable water and there is great demand for additional resources. There is huge undeveloped groundwater in the country. The difficulty of exploiting productive aquifers is typical feature of Ethiopia, which is characterized by wide heterogeneity of geology, topography, and environmental condition. The main constraint is financial. This is generally as the drilling sector has enormous lack of skilled technicians and accessories. The current drilling cost goes up as high as 188 US$/m.

In *Rwanda* most of boreholes sites are located in the alluvial deposit of Eastern province. Finances is considered as the main capacity constraint behind further explorations, but also the area topography and geology.

Capacity in hydrogeology and geophysics is insufficient both in terms of equipment and skilled personnel in *Sudan*.

Most of the major groundwater basins are underdeveloped. There is a great demand for the additional resources but the cost of development is not affordable for the communities in the absence of support.

Uganda capacity in hydrogeology and geophysics is described as fairly limited. Groundwater in Uganda is generally under-developed although information about this is scanty. There is demand for these additional resources but their quantity and sustainability is not known making planning for their use difficult.

Box 14

Recommendation: Capacity building in hydrogeology and geophysics is needed to ensure adequate resources assessment and development to ensure sustainability.

Infrastructure and power availability

Burundi electricity grid is very limited; Roads and infrastructures were destroyed due to 12 years of troubles; Transport is limited. Infrastructure poses a lot of constraints for optimum groundwater development.

The groundwater installations are most of the time far from the towns and are subordinated to availability of transport which includes vehicles and roads infrastructure. On top of this, power availability is a major limiting factor to ground water development in *DR Congo*.

In the 94 centres of REGIDESO, Electric energy supply to 24 centres contributes upto 84% of groundwater production, while 64 centres using thermal energy contributes 11% from 6 centres and gravity energy contributes with 5 % .

In *Ethiopia* there are no problems in power and transport infrastructure to develop groundwater. However, rural water supply depends on diesel power to pump water. In large part of the country, due to road interruption in the rainy months, maintenance, operation etc can not be done.

In *Rwanda* only 6% of the total population has electricity and in rural area only 1% can access electricity.

Power is not available in most of the rural areas of *Sudan*. Transport Infrastructure is poor in most cases. These pose cost constraints on development.

In terms of optimum groundwater development in *Uganda*, power fluctuations and unavailability lead to over-pumping or under-pumping in some cases. High pumping heads and long pumping distances sometimes limit the depths to which pumping infrastructure can be installed. These thus affect optimum groundwater development.

Boreholes & drilling sector

Just one drilling company actually with little equipment is working in *Burundi*. However, it is able to meet the demand. No training capacity available in the country.

Drilling sector in *DR Congo* is composed of REGISESO and private companies such as MIDRILCO, FOLECO, S FA and ADIR. As long as the demand for groundwater supply is low, the existing companies are able to meet the demand. However, the low demand of water supply is mainly due to high cost of drilling.

In *Ethiopia* there are over 23 drilling companies (Governmental and private) with 71 different types of rigs that can drill to the depth of 300m and 10" wells. However the number is not sufficient to meet the demand. The main constraint is provision of drilling materials that have raised the drilling cost. There is no structured training in drilling. Main problems are: lack of sufficient geological and hydrogeological information, low experience of some companies, small salaries, lack of drilling accessories, lack of capacity to drill large diameter wells (>10"), high drilling cost etc..

One drilling company in all *Rwanda*, but Ugandans' companies have contacted drilling project in the country.

There is proliferation in the drilling sector of *Sudan*. Quantity-wise it is able to meet the demand but the quality of its services (in most cases) is below expectations though the cost is very high. Poor training capacity is available and not sufficient to meet the sector need.

Uganda has a viable drilling sector and is able to meet

Box 15

Recommendation: Build capacity of drilling firms through short refresher courses to enable them improve their performance.

the demand. Due small volumes of boreholes to drill and hence very stiff competition, some of the companies are re-locating to other countries. The constraints in the drilling sector include high drilling costs arising out of high importation costs of supplies, stiff competition due to small drilling volumes, unscrupulous drilling companies which do shoddy work, irregularities in award of tenders sometimes favouring friends and relatives etc. The training capacity is very limited and most of the drilling staff learn on the job with very few opportunities for refresher training.

- Pumps and pump installation and maintenance

Burundi has hardly adequate borehole pump sector.

There are few pump suppliers in *Ethiopia*, and no enough stock as per the need in terms of discharge, pump head or diameter. Pumps are mostly imported after order. Pump motors fail after short service and no maintenance except replacement. There is no capable and specialized workshop to handle maintenance and no rig maintenance centre. The number of suppliers should be increased,

Except small technicians no proper supply, maintenance or installation sector available in *Rwanda*.

In *Sudan* most of borehole installation and maintenance is undertaken by the private sector on contractual bases.

Again in *Uganda* there is a viable borehole pump sector and many of the pumps are manufactured in the country. Supply of pumps parts is therefore readily done and efforts have been done by government to facilitate establishment of regional pump distributions and sale centres. Training in pump installation and maintenance is provided to local pump mechanics who maintain the pumps locally.

- Capacity building requirements for this sector

Burundi requires building of technicians for maintenance of pump equipment.

Ethiopia needs adequate number of highly trained and experienced hydrogeologists and trained groundwater technicians, and a series of short term specialized trainings.

The urgent capacity building requirement for this sector in *Sudan* is training of the technical staff for better services.

Uganda capacity building requirements in this sector include refresher training in pump installation and maintenance, determination of optimum pump installation depths, pump servicing and optimum pump selection.

Box 16

Recommendation: Capacity building needed through refresher training in pump installation and maintenance, determination of optimum pump installation depths, pump servicing and optimum pump selection.

9. Groundwater protection and environment

Introduction

Groundwater use sectors usually work in isolation. Lack of coordination among different use sectors is a major constraint facing groundwater protection. Continuous pollution threat within aquifer catchment zones, whereas no sufficient capacity to control and monitor those problems. Threats to groundwater quality arise from sanitation, industry, mining and agricultural activities causing many health hazards reported in different areas.

Threats to the groundwater quality in rural areas are NO3 and bacteria mainly caused by lack of adequate sanitary facility and excessive use of fertilizers, pesticides and herbicides.
Chemical pollution from industrial and urban growth poses additional hazards to NO3 and bacteria in urban centres, while no parallel growth of sanitary systems is planned.

Inappropriate techniques used for mining, and the use of landfill by industries for waste discharge cause serious threat to ground water availability and quality.
Salt water intrusion also constitutes a threat to groundwater quality in coastal zone especially the shallow aquifers.
Over exploitation is taking place in aquifers due to the lack of search for additional resources as the demand increases. This has lead in some basins to increasing salinity level and destruction of natural environments. While the groundwater sector is aware of the problem, there is no sufficient legislative, financial, or technical capacity to deal with it.

Generally, legislation for groundwater protection is inadequate and lacks enforcement measures. Responsible institutions do not have sufficient capacity.
Policing of the legislation is limited by the lack of human and financial resources, limited technical capacity, low awareness among the population etc.
It is recommended to raise the awareness and capacity at various levels of governance such as local governments to participate in policing any law violation.

Groundwater quality / threats

In *Burundi* urbanisation and industrialisation are increasing in Bujumbura, near Tanganyika Lake, with extension in Rusizi plain. Agricultural pesticide and insecticide are used in Rusizi Plain. There is a continuous pollution threat in the lake and in the Rusizi plain, and no sufficient capacity to identify and monitor those problems. Therefore the competency centre for groundwater at University of Burundi is planned to contribute to the solution of these problems.

In *DR Congo* threats to groundwater quality come from sanitation, mining activities, and salt water intrusion.

The national report on water supply and sanitation (WATSAN, 2006) shows that 83% of households in rural areas where much of groundwater installations are concentrated use pit latrines which constitute a threat to ground water quality.

The National report (ETAT ACTUEL DE L'ENV, 1996) pointed out the inappropriate techniques used for mining exploitation causing serious threat to ground water availability and quality and the use of landfill by industries for waste discharge.

Salt water intrusion constitutes a threat to ground water quality in coastal zone especially the shallow aquifers of MOANDA and BANANA which float on a saline water aquifer from

Atlantic sea. A drawdown of 10m depth or when drilling reaches 10 m, there is inland movement of salt water.

In *Ethiopia* the main threats to the groundwater quality in rural areas is NO3 and bacteria mainly caused by lack of sanitary facility and excessive use of fertilizers, pesticides and herbicides. In urban centres besides NO3 and bacteria chemical pollution from industrial and urban growth without parallel growth of sanitary systems.

Box 17

Recommendation: Capacity building needed to identify and monitor potential threat to groundwater due to poor sanitation and waste discharge needed at both national and local levels. Specifically, capacity for regulation of both point and non point source pollution needs to be built.

Over exploitation is taking place in aquifers supplying Mekele town and Akaki well field in Addis Ababa. This is happening due to the lack of search for additional resources as the demand increase.

There is no sufficient capacity to identify/ monitor such problems. The water supply sectors usually work alone.

There is a need to investigate the problem of pollution in *Rwanda* as there is no information to assess the situation.

Sudan groundwater quality threats include oil and other industries, poor sanitation, agriculture causing many health hazards reported in different areas. There were many proposals to monitor, study some incidents and design protection zones, but have not been materialised for lack of funds. In some basins overexploitation created salinity, destruction of natural environments. The groundwater sector is aware of the problem but there is no sufficient legislative, financial, or technical capacity to deal with it.

The threat is very serious from urban waste and sewage, industrial waste including petroleum industry as well as from agricultural pollution.

Groundwater resources in Sudan is generally under-exploited, however, some regions are currently record increasing lowering of groundwater levels and salinity due to excessive pumping. There is very limited capacity to identify/monitor such problem.

The main groundwater quality threats in *Uganda* include pollution from onsite sanitation in both rural and urban areas, industrial and municipal waste discharge, pesticides from agriculture and chemical constituents due to the nature of rock formations. The potential threat from poor sanitation and waste discharge is severe due to limited sewage networks and waste treatment facilities. The capacity to identify and monitor these problems is still very limited and only at national level within the responsible government ministry of water. The groundwater sector is aware of these problems but management, financial and technical capacity to deal with these issues is insufficient.

Groundwater protection

No groundwater protection measures are adopted in *Burundi*.

A number of legislations available in *DR Congo* to protect groundwater from pollution.
The policy on groundwater protection relies on the following legislation:

- Ordinance law of 1st July 1914 on pollution and contamination of sources, lakes, aquifers and rivers. The ordinance forbid installations of manufactures, slaughterhouse, kraal , digging excavations, construing houses , dumping wastes in aquatic areas.
- Ordinance law No 52/443 of 24 Dec 1952 on measures to protecting sources, aquifers, streams and rivers, wastage of water and control of right to use water and ownership. This legislation forbids implementation of activities in the proximity of water bodies at risk of compromising their yield without an authorization of provincial Governor.
- Ordinance law No 74/569 0f 3rd Dec 1958 related to irrigation in order to protect the public sanitation
- Ordinance law No 69/041 of 22 August 1969 related to Nature Conservation.

Most of above mentioned laws apply in accordance with article 1 of the decree of 06 August 1922 inserted in penal Code, Book II, page 98; which describes penalties imposed in case of contravention.

Ethiopia groundwater protection laws have been developed, but not applicable. Existing laws include: Guideline on Environment Quality standards for Ethiopia (EPA Aug 2003); Standards for industrial pollution control in Ethiopia (EPA Sept, 2003); and Ethiopian Water resources Proclamation No. 197/2000.

Rwanda has no legal framework for groundwater protection.

Legislation for groundwater protection is inadequate *Sudan*. The Federal Ministry of Irrigation and the State Ministries for Irrigation and of Physical Planning are the responsible institutions but they do not have sufficient capacity. Legislation is in general terms with no implementation measures.

There is a legislation to protect groundwater from pollution and overuse in *Uganda*. The legislation is adequate but what needs to be improved is its enforcement. The Ministry of Water in addition to the National Environment Management Authority are responsible for policing this legislation. The various levels of governance such as local governments are supposed to participate in policing but their awareness and capacity are still very low. The main constraints to policing of the legislation include limited human and financial resources, limited technical capacity, low awareness among the population etc.

Box 18

Recommendation: Capacity building needed in policing of water legislation increasing and raising awareness among the population on need for groundwater protection.

10. Groundwater Education and Training

Introduction

Looking at the National Institutions providing groundwater education and at the level and nature of training available in the six surveyed countries, it can be concluded that groundwater education is lacking behind the sustainable development needs.

Professionals graduate as generalists from civil engineering and geology departments, and need further specialisation at post graduate level. The later is not available in all Nile countries apart from few opportunities from the limited overseas training.

Complete absence of any competency specialised centre for groundwater at Universities to contribute to the solution of problems faced on the ground.

There is a great need to provide support in improvement of curriculum of universities to include more groundwater content. Assistance to improve teaching of groundwater related courses is needed through training and exposure of university lecturers, support in the delivery of groundwater courses, etc.

The main constraints to catch up with advancements in groundwater management knowledge are related to:

- Limited exchange of visiting professors among universities of the region.
- No any regional training institutions or degree course that is active in a country.
- No agreements with other countries on training programmes or assistance to improve teaching of groundwater related courses needed through training and exposure of university lecturers and support to the delivery of groundwater programmes.
- Lack of support to improvement of curriculum of civil engineering and geology departments to include more groundwater content at undergraduate level.
- Lack of regionally cooperative effort to deploy scholars in the field.
- There is a need to upgrade existing graduate hydrology and water resources programmes to include groundwater training, exploration techniques, groundwater hydraulics as well as computational methods/ tools essential to equip hydrogeologists with skills for assessing, predicting and design development of groundwater.
- There is a need to conduct regular short courses targeting working professionals so that their knowledge is improved and regularly updated.
- The gap in groundwater science and in technical training supporting use sectors such as rural and peri-urban water supply, health sector, sanitation, industrial discharge, institutions and regulatory bodies.
- Groundwater education is not reflecting IWRM issues such as Water security for people, for health, for environmental integrity and quality protection and well as water management instruments such as economic, regulatory and Analytical tools for resource assessment and management.

Box 19

Recommendations: To support the development of collaborative ventures between universities in the south and north in teaching of groundwater courses both long term and short term courses..

- National Institutions providing groundwater education and Level and nature of training available

Table 7 provides an inventory of active institutions in groundwater capacity building in six countries in the Nile Basin. The level and nature of training in each institution is described by the country resource persons.

- Agreements with other countries on training courses

There is limited exchange of visiting professors among universities of the region; however there are no any regional training institutions / courses that are active in the country. Current education in groundwater has been considered by all countries as inadequate to bring better groundwater management practices.

Box 19

Recommendation: Need to provide support in improvement of curriculum of universities to include more groundwater content. Assistance to improve teaching of groundwater related courses needed through training and exposure of university lecturers, support in the delivery of groundwater courses etc.

There is a need to provide support in improvement of curriculum of universities to include more groundwater content. Assistance to improve teaching of groundwater related courses needed through training and exposure of university lecturers, support in the delivery of groundwater courses.

The number of trained and skilled personnel is a key constraint for sustainable groundwater use sectors in the Nile region. Sectors affected include rural and peri-urban water supply, health sector, sanitation, industrial discharge, institutions and regulatory bodies.

In *Burundi* no agreements with other countries on training courses, but on individual level exchange takes place, such as the case of Prof. Hakisa from University of Burundi, who is visiting professor at public University of Bukavu (D.R. Congo) where he teaches the some courses.

In *DR Congo*, agreements exist between countries at regional level (NBI/ATP, SADC) and international level (Belgium Cooperation) to enhance educational level on related water resources issues. However no regional courses taking place within the country on groundwater issues; and a relevant policy to support such initiatives does not exist. The sectors specifically constraint by human resources of groundwater education background can be summarised in accordance with the following field of knowledge:

- Water security: This field of knowledge deals with groundwater exploration, exploitation and maintenance. It comprises the following specializations:
  - Groundwater resources management
  - Soil conservation and land use control
  - Groundwater hydrology and its applications
  - Applied hydrogeology
- Hydro-informatics Analytical tools
  The needs for information, communication and forecasting in groundwater resources management can be covered by the following domains of knowledge:
  - Groundwater modelling (deterministic and stochastic models)
  - GIS and database management with their applications (ground monitoring networks, remote sensing, photogrammetry, mapping, surveying)
  - Climatology and meteorology.

Table 7: National institutions provide groundwater training

Country	Institution	Level and nature of training	Remarks
Burundi	1. University of Burundi	B.Sc. Level in Geology: courses in hydrogeological domain are hydrogeology (60 h), geophysical methods (60 h), environmental geology (45 h).	No sufficient equipment. There is no Technical training in borehole/ pump maintenance; drilling; pump repairs; borehole electronics
DR Congo	1. Public University of Kinshasa	Faculty of Sciences: Department of Geology and Earth sciences offers 5 years BSc Degree and 2 years Masters Degree courses. Faculty of Agricultural Engineering, Department of Soil and water Management provides 5 years BSc degree in Agricultural Engineering. Polytechnic Faculty, Department of Civil Constructions provides 6 years BSc in Civil Engineering.	Apart from public educational programme in groundwater, parallel programmes (short courses, Diploma course etc..) with regards to technical aspect of groundwater exploitation do not exist. The capacity constraints mainly range from lack of policy motivating education in groundwater and lack of fund devoted to education which in turn leads to insufficient human resources (scientists, academician and professional in groundwater resources).
	2. University of Lubumbashi	Faculty of Civil engineering, department of Geology and mines: 6 years BSc in Civil Engineering. Faculty of Sciences: Department of Hydrology offers 5 years BSc degree in Hydrology.	
	3. University of Bukavu		
	4. High learning institutes	Building and Public Works Institute: 4 years advanced Diploma in Civil Engineering	
Ethiopia	1. Addis Ababa University (AAU)	Provides postgraduate training in hydrogeology	Bachelor and Masters levels education exist. Undergraduate level hydrogeology is given as a basic
	2. Mekele University (MU)	Postgraduate training in hydrogeology	

	3. Arbaminch University (AU)	Focuses on surface water and now started undergraduate program in Applied Geology. Postgraduate programme on integrated watershed management	course; while at postgraduate level there are advanced courses in hydrogeology with Thesis work. Technical training for graduates is being given at groundwater training Institute. The main constraint is the lack of training for drilling technicians.
	4. Groundwater training institute of the Ministry of Water Resources supported by JICA.	Provides specialised groundwater training in certificate.	
	5. Geological survey usually in house and on job trainings.		
Rwanda	1. Civil engineering and Environmental technology/ KIST	Part of undergraduate curriculum.	Such training not available. Short term training courses in Netherlands and Belgium are visited by some professionals
	2. High learning institutions.	Post-graduate program offering related courses	
Sudan	1. University of Khartoum	Civil engineering department One course in groundwater occurrence and flow is provided as part of the undergraduate curriculum, Graduate and on job training in groundwater is not available in Sudan sofar. Few course started, but were not relevant to the problems at hand. Geology department Basic courses on geology, hydrogeology, geophysics and geochemistry are provided as part of the undergraduate curriculum. supervised degree research Department of Soil Water and Environment Courses on Water quality and Bacteriological	University level research ranges from BSc, MSc to PhD levels. Technical courses related to drillings, pumps, and borehole electronics are of introductory nature. The capacity constraints are mainly: Lack of qualified trainers and lack of training facilities/aids. There is a need for capacities on advanced practical education to build capacities for adequate groundwater management.

		contamination of groundwater.	Research on groundwater need to go beyond descriptive hydrogeology and introduce computational skills and assessment tools.
	2. University of Sudan	Civil engineering department basic courses are provided as part of the undergraduate curriculum Polytechnic Faculty of Earth sciences	
	3. University of Nilain	Faculty of Earth Sciences basic hydrogeology courses as part of the undergraduate curriculum	
Uganda	1. Makerere University	Some groundwater education is provided in two universities	Some groundwater training is provided as part of bachelors and masters degrees in Geology and Civil Engineering. This is however very limited. There are no technical training courses in groundwater offered in the country apart from some refresher courses organised once in a while by the Ministry of Water. There is thus limited groundwater capacity in the country because of the inadequacy of the courses offered in the country. Save for those who get an opportunity to do postgraduate studies outside the country, many of the people learn to do groundwater work on the job.
	2. Kyambogo University		

- Environmental integrity and quality protection
  The aim of a sustainable development is the use of natural resources for the needs of present and future generations while conserving the carrying capacity.
  This domain of knowledge deals with the application of systematic methods for a perennial exploitation, equitable distribution and water resources monitoring in terms of socio-economic and environmental objectives. It contains the following specializations.
  - Environmental impacts Assessment
  - Water quality monitoring
  - Environmental Management and planning.
  - Project design and evaluation.

There is agreement with Japanese experts to train at the Groundwater Institute of the Ministry of Water resource in *Ethiopia*. The institute provides regional training on numerical groundwater, which is active for water specialists from the Nile countries. This training alone is not adequate as there is a gap in the other sectors of groundwater science and in technician training. There should be regionally cooperative effort to deploy scholars in the field.

Some students from *Rwanda* attend short term training courses in Netherlands, Belgium.

No adequate groundwater education or training institution in the region. There is a need to upgrade existing hydrology and water resources programmes to include groundwater training. Exploration techniques, computational methods, as well as groundwater hydraulics are essential tools needed in *Sudan* to equip hydrogeologists with skills for assessing, predicting and design development of groundwater.

In *Uganda* there are no agreements with other countries on courses but some countries such as the Netherlands has provided annual scholarships that enable qualified candidates to do postgraduate courses in groundwater. There are no regional training institutions active in the country. There is need to beef up current university courses with additional course content so that groundwater education can be improved. In addition, there is a need to conduct regular short courses targeting working professionals so that their knowledge is improved and regularly updated. The limited number and quality of trained and skilled personnel is therefore a big constraint to sustainable and effective groundwater development and management. The constraints are not only related to groundwater exploration, development, monitoring, assessment, regulation but also groundwater teaching.

Box 20

Recommendation: There is needed to support the development of collaborative ventures between universities in the south and north in teaching of groundwater courses both long term and short term courses. Capacity building through regular short courses targeting working professionals is needed in areas related to groundwater exploration, development, monitoring, assessment, groundwater hydraulics & computational methods, regulation but also groundwater teaching.

11. Economic Aspects

Introduction

Water tariff had unknown grounds or rules in most surveyed countries. Industries and agriculture sectors do not pay for water use, while for domestic use people pay for groundwater.
Water tariffs apply only to urban water, however the fees are not reflecting volumetric use.
Rural water supply is usually free with arrangements for covering operation and maintenance costs in certain cases.

Generally groundwater use is rarely measured in all six countries under this study.
The groundwater sources are not installed with meters and thus groundwater use is estimated based on the capacity of the pump and the number of pumping hours per day. Discharge meters are only installed in few areas to measure groundwater use for purpose of study and piloting.

There are generally limited capacities to ensure that groundwater development is carried out in a cost effective sustainable manner. Lack of proper institutional mandate, legal framework and resource assessment tools, in addition to poor know-how, improper local education and training give way to uncontrolled use, unprotected environment, and constrain economic valuation.

Recommendations to enhance the capacity in this sector are
- Estimation of groundwater availability and utilisation,
- Willingness of government to license and control groundwater use.
- Establish mechanisms to meter water usage for industries and agriculture sectors, which do not pay for water.
- Rural subsidy is important to support poor rural community.
- Improve governance, then technical and financial capacities.
- Make use of economic valuation of groundwater, sustainable and cost effective groundwater development,
- Application of economic instruments for groundwater management.

Do users pay for groundwater?

Generally water tariff had unknown grounds or rules in most surveyed countries. In some countries no tariffs at all while other apply fees only to urban water. Rural water supply is usually free with arrangements for covering operation and maintenance costs in certain cases. Considering countries separately, *Burundi* and *Rwanda* apply no user payment to groundwater.

In general, cost recovery mechanism is not applied in rural groundwater supply in *DR Congo*. The cost recovery mechanism is applied only for industrial use of groundwater.

In *Ethiopia* users pay for groundwater in urban areas while in rural areas groundwater users do not pay.

In *Sudan* groundwater for drinking purpose is paid for by the consumer, but the supplier does not. Irrigation and industrial groundwater is not paid for because there is no license system application.

Users in rural areas of *Uganda* make a contribution towards maintenance of a groundwater sources and do not pay for groundwater as such. Users in urban areas supplied by piped water pay for groundwater.

How is groundwater use measured?

Generally groundwater use is rarely measured in all six countries under this study. In most cases, the groundwater sources are not installed with meters and thus groundwater use is estimated based on the capacity of the pump and the number of pumping hours per day. In *Uganda* and *Sudan* discharge meters are installed in few areas to measure groundwater use for purpose of study and piloting.

Capacity for a cost effective sustainable groundwater development

As reflected in the previous sections, clearly there is limited capacity to ensure that groundwater development is carried out in a cost effective sustainable manner. Lack of proper institutional mandate, legal framework, resource assessment, uncontrolled use, unprotected environment, poor know how, improper local education and training are all part of the capacity required for sustainable development.

Additional capacity needs in this sector.

Capacity building needs in relation to economic aspects of groundwater management are identified in *Burundi* as qualified human resources (hydrogeologists, technicians) and equipments. *DR Congo* main capacity requirement is to develop economic instruments for groundwater management based on recognizing water as an economic good that should be priced in regards with Equity and Efficiency principles.

The challenge in *Ethiopia* is retaining skilled man power, willingness of government to license and control groundwater use. Establish mechanisms to meter water usage for industries and agriculture sectors, which do not pay for water. While for domestic use people pay for groundwater, rural subsidy is important to support poor rural community.
Sudan primary need is governance, then technical and financial. *Uganda* capacity needs in the sector relate to economic valuation of groundwater, sustainable and cost effective groundwater development, estimation of groundwater availability and utilisation, application of economic instruments for groundwater management etc.

12. Capacity building requirements for your institution

Introduction

Capacity building needs of different institutions varies according to its mandate. Generally both academic and water management institutions lack office and laboratory equipment.

Available equipments at training institutions are mostly in deteriorating conditions and no longer suitable to support required training and research activities. Laboratories need to be upgraded to handle analysis of heavy metals and pesticides. Provision of office equipment for groundwater data storage, analysis and interpretation such as computers, software and GIS mapping equipment.

A range of laboratory and office equipment of various functions is also needed at local government level to support decentralised water resources management.

Adequate field equipment such as pumping test sets, data loggers & water level recorders/indicators, conductivity/ pH meters, biochemical kits, and full bacteriological field equipment are needed almost in the entire region.

GPS devices, topographic survey equipment, Geophysical equipment including electric resistively meters, electromagnetic resistively meters, gravimeter, borehole geophysical loggers, camping equipment, and vehicles, plus electronic workshop tools are other important category of field equipment are required to groundwater exploration and development.

Drilling equipment required are rotary drilling machines (depth 200 to 500 meters), percussion drillers (up to 200 meters depth), air hammer drillers, truck-mounted pumping test unit(s), soft/ shallow formation augers and hydro-fracturing system(s).

Shortage of vehicles for operation of groundwater monitoring networks and monitoring compliance to permit conditions constrains effective implementation of groundwater activities local offices.

Recommendations involve strengthening the national and district level capacity through provision of laboratory and office equipment to enhance collaboration within basin level and support plans to decentralise some of the aspects of water resources management.

Personnel

Institutions involved in the survey and capacity needs are summarised below in relation to each country. In *Ethiopia*, *Sudan* and *Uganda* the problem is rather the quality not the number of staff. There is no adequate education in hydrogeology or groundwater management in the civil engineering and geology departments; and professional graduate as generalists who need further specialisation. The later is not available in all Nile countries leaving few opportunities from the limited overseas training. Even those few with overseas qualification are not made use of due to absence of competitive employment and promotion system for public jobs. They are then considered as a threat to the ignorant majority leading the public sector; and mostly join the private sector of immigrate for better positions.

In the University of *Burundi* specialised staff includes one professor and 4 assistants who are preparing thesis. 3 technicians are needed. No information about professional staff and

capacities available in all Ministries in charge of surface and/or groundwater in Burundi is shared.

Taking in to account the institutional framework of *DR Congo* and particularly the National Company of water supply which has established 94 centres for water supply in country, the additional needs can be summarised in terms of knowledge required for groundwater resources management. This includes:

- Groundwater security
- Groundwater resources management
- Soil conservation and land use control
- Groundwater hydrology and its applications
- Applied hydrogeology
- Hydro informatics and system forecasting
- Groundwater modelling (deterministic and stochastic models)
- GIS and database management with they applications (Remote sensing, Photogrammetry, mapping, surveying)
- Climatology and meteorology.
- Environmental integrity and quality protection
- Environmental impacts Assessment
- Water quality monitoring
- Environmental Management and planning.
- Project design and valuation.

Additional staff required in *Ethiopia* are hydrogeologists, applied geophysists, groundwater modellers, etc. Most of the institutions have got first degree graduates that are responsible for water supply. Only few MSc holders work in government water supply sector. Most skilled MSc graduates work in private sector.

The working force of the groundwater and wadis directorate of *Sudan* Ministry of Water consists of about 90 geologists, hydrogeologists, and geophysicists, about 20 chemists, 10 civil engineers, 125 technicians, and about 65 supporting staff. In terms of quantity there are sufficient staffs but the need is in orientation and training. The needed fields of training are geophysics, hydro(geo)logy, groundwater modelling, remote sensing and GIS, hydrochemistry, and database Management.

There are currently 12 hydrogeologists in the Directorate of Water Development – Water Resources Management Department of *Uganda* Ministry of Water and Environment. All staff obtained their first degrees in Geology and Civil Engineering with limited groundwater content. 6 of the staff have obtained post graduate qualifications in hydrogeology while others have not yet received any formal training in hydrogeology. This staffs need training in hydrogeology to make them more competent. In additional, the staff needs continuous professional training to update them on new developments in groundwater management but these opportunities are not available in the country. They need training is areas such as groundwater and IWRM, groundwater use efficiency and demand management, groundwater resources use planning, modelling etc. The number of groundwater staff in the institution will soon be increased to about 20 and all these will also require training. Managerial and administrative staff need to be given some training in basin groundwater development and management so that they can appreciate the importance of groundwater and the need for its sustainable development and management.

Office and laboratory equipment

Office equipment at the University of *Burundi* consists of 4 PCs, 1 scanner, 1 printer, equipment for digitizing, software for flow and transport modelling, software for geophysical interpretation and licensed GIS software. However, laboratory equipment is not sufficient.

The existing office and laboratory equipment at the university of Kinshasa are very insufficient for the all established 94 centres in *DR Congo*. adequate equipments such as field vehicles, laboratory equipment, printers, scanners, digitizers, computers with groundwater assessment software, GPS, digital works station, digital camera, generators, supercharger, immersed pumps, motorized pumps, PVC tubes, kit of analysis, cistern vehicles, etc.

Addis Ababa University, Mekele University, Addis Ababa Water and Sewerage Authority (AAWSA), regional water bureaus, Water well drilling enterprise, *Ethiopian* Geological Survey have each got a chemical analysis laboratory but not complete. AAWSA has got bacteriological analysis facility. Atomic absorption, Ion chromatograph, UV visible spectrophotometer, Tritium cintilator, incubator etc..

Office requirements of *Sudan* groundwater directorate (GWWD) include computers, printers, digitizer, plotters, scanners plus software including geophysical interpretation, GIS, groundwater modelling, remote sensing, hydrochemistry, and remote sensing software.

Available at GWWD are about 10 computers, 2 small scanners, 6 printers, and one plotter.
Laboratory equipment required include digital titrater, flame photometer, spectrophotometer, Gas chromatography equipment, Balances, Portable water laboratory (MEL/850), refrigerator, water still, conductivity-pH-temperature-dissolved oxygen meters (bench top), and the necessary glassware.
Available is all the above but in deteriorating conditions.

In *Ugandan* water resources management department there is a fully fledged water quality laboratory for analysis of cations and anions. This laboratory however needs to be upgraded to handle analysis of heavy metals and pesticides. There is some office equipment for groundwater data storage, analysis and interpretation such as computers (5 No.) and GIS equipment (1 set). However the available number is about 1/4 of what is needed. In addition to strengthening the national level capacity, there is a need to provide laboratory and office equipment for use at local government level and later at catchments as plans to decentralise some of the aspects of water resources management take root.

Box 21

Recommendation: Strengthening the national and district level capacity is needed through provision of laboratory and office equipment for use at national and local government level and later at catchments as plans to decentralise some of the aspects of water resources management take root.

Field equipment

Existing field equipment in *Burundi* consists of 1 vehicle (Pick up), Geophysical instrument for electrical method; GPS; sampling pump; water level dippers; agrometeorological station.

DR Congo requirement for field equipment include: field vehicles, GPS, digital works station, digital camera, generators, supercharger, immersible pumps, motorized pumps, PVC tubes, kit for analysis, cistern vehicles.

Sudan required field equipment include data loggers & water level recorders/indicators, conductivity/ pH meters, biochemical kits, GPS devices, topographic survey equipment, and full bacteriological field equipment. Geophysical equipment including electric resistively

meters, electromagnetic resistively meters, gravimeter, borehole geophysical loggers, camping equipment, and vehicles, plus electronic workshop tools.
Drilling equipment required are rotary drilling machines (depth 200 to 500 meters), percussion drillers (up to 200 meters depth), air hammer drillers, truck-mounted pumping test unit(s), soft/ shallow formation augers and hydro-fracturing system(s).
The existing inventory comprises three resistively meters in deteriorating shape, 2 EM devices out of order, one geo-logger out of order, and one hand-auger.

There is a need for drilling and pumping test equipment in *Uganda* to facilitate carrying out of groundwater studies and assessment of groundwater potential. Currently, all drilling equipment is in private hands and this limits its access to its use. There is only one pumping test unit for use in the whole country and this is inadequate. There is therefore a need for at least 1 drilling equipment and 3 more sets of pumping test equipment. Vehicles for operation of the groundwater monitoring network and monitoring compliance to permit conditions are in short supply. There is only one vehicle dedicated to groundwater monitoring in the whole country yet at least 4 are needed. Equipment such as divers (4no.), water level meters (20No.), GPSs (3no.), field water quality kits (2no.) are also limited. The number at least needs to be trippled for effective implementation of groundwater activities.

Box 22

CB recommendation: Capacity building in terms of equipment for pumping tests, water quality analysis, groundwater monitoring, mapping of water sources etc is needed.

CONCLUSION

Sustainable use of groundwater resources would inevitably require enabling institutions and organisational structure, regulation, information, technology, as well as capable human resources.

In the forgoing chapters a review of ground-water management issues related to IWRM and general water sector reforms is analysed indicating a low level of integration of groundwater aspects into national water management strategies in Nile basin countries.

To give a fair conclusion on groundwater management in the Nile region distinction should be made between countries considering the overall situation of water resources management, availability of other forms of water namely, green and blue water as well as the need for groundwater resources.

Countries are at different stages of development in groundwater management, and thus have different type of needs. Two stages are distinguished. Countries in stage1 lack of basic regulations and institutional capacity. In stage2 all institutions & regulatory frameworks are in place, a case that is only relatively taking place in Uganda.

Wet countries as Burundi, Rwanda and DRCong where water resources of different forms are still underdeveloped, and ground water use is below 10% of the supply. In such cases, national water sector strategies have not emphasised groundwater equally to green and blue water management. In fact these countries are still in the stage of formulating its sector strategies.

In countries as Uganda, Ethiopia and Sudan groundwater represents a major source for domestic, industrial as well as irrigation purposes in case of Sudan and to some extent Ethiopia. However, groundwater issues are not addressed properly in Ethiopia and Sudan, while a process of reform is advancing slowly in Uganda.

From the survey results in six countries in the Nile region, integration of groundwater in national water management strategies only started in Uganda, where 80% of the population depends on groundwater for domestic water supply.

An important conclusion of the review is concerning the capacity building for IWRM. Overall, the lack of local knowledge to support integration of water resources management has greatly contributed to the slow implementation of the integrated approach. From the survey it is clear that universities and research institutions are not aware of the aspects of IWRM in groundwater management. It can be concluded that decision making level, although aware of IWRM challenges, it is beyond their capacity to implement the required change and need support. It is completely shocking to witness the ignorance of education and research institutions in up-to-date principles of IWRM and its implementation challenges. A major recommendation is to establish or upgrade groundwater oriented research and education centre for the Nile region.

The study identified constraints and required capacity building actions addressing groundwater management issues under IWRM framework for the Nile region. Various existing and planned country programmes/ projects, which are expected to support sound groundwater resources management are identified for possible cooperation.

Three capacity building approaches are recommended. Recommendations involve individual skills building, improving the organisational capacity as well as engaging with a number of interventions with local capacity building institutions, or directly with communities, local governments and groundwater use sectors.