GW·MATE

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Sustainable Groundwater Management

Contributions to Policy Promotion

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Appropriate Groundwater Management Policy for Sub-Saharan Africa

in face of demographic pressure and climatic variability

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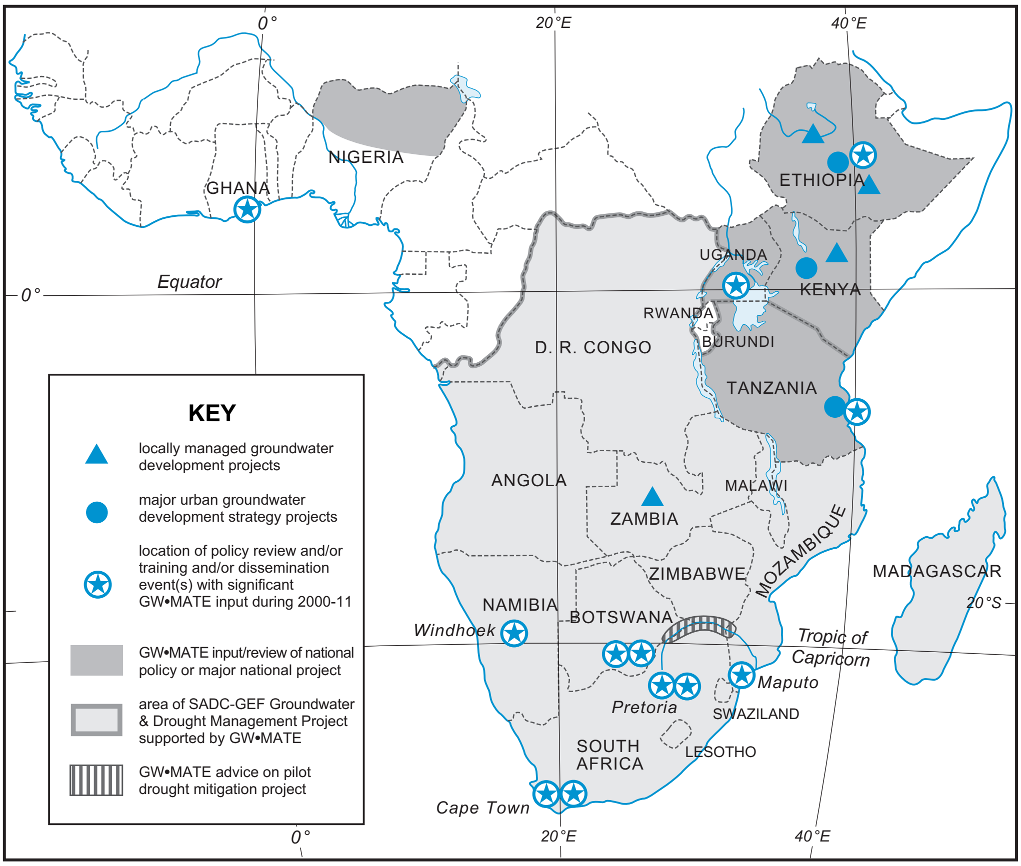
This paper provides an overview of major groundwater issues for Sub-Saharan Africa, with an assessment of their policy implications in terms of potential development and appropriate management. In terms of construction time, capital outlay and drought resilience, groundwater is the preferred source to meet most water-supply demands, despite hydrogeological complexity, natural constraints on waterwell yields and quality, and institutional weaknesses. The 'new developmental agenda' relates to improving urban water-supply security and expanding irrigated agriculture – to meet these challenges many countries need to undertake strategic assessment of their groundwater and prioritize investment on institutional strengthening so as to facilitate appropriately-managed groundwater development. Without effective use of available groundwater resources, improved livelihoods and climate-change adaptation will prove much more difficult to achieve.

CONTENTS

This overview is mainly based on GW•MATE experience during 2001-10 from World Bank-supported projects mainly in eastern Africa (as indicated on map below), together with review of some work in western Africa, and participation in numerous sub-regional workshops. Initially it was questioned whether a 'general overview' was realistic, given the hydrogeologic variability and socioeconomic diversity across the region, but judged valid to identify 'common issues and needs' in the more nations of tropical latitude. It is accepted, however, that there will be some variations, and also countries (like South Africa and Botswana) that have already responded in part to the major challenges described.



GENERAL CONTEXT FOR PAPER
(< The Resource Perspective >)

Groundwater : a Vital Resource for Life & Livelihoods

- Groundwater is the critical underlying resource for human survival and economic development in extensive drought-prone areas of Sub-Saharan Africa. Traditionally throughout this region it has been the accessibility of groundwater through dugwells, at springheads and in seepage areas that controlled the extent of human settlement beyond the major river valleys and riparian tracts – and this groundwater was usually developed through community and/or government initiative.

- Statistics on groundwater use in Sub-Saharan Africa are sparse and incomplete, although very high dependence for rural domestic water-supply, small-scale livelihoods and livestock rearing is undisputable. The introduction of deep drilling rigs and pumping plant from the 1970s enabled the area under human settlement to be extended in response to increasing population and growing pressure on riparian land. Over very large rural land areas, it is the presence of successful waterwells equipped with reliable pumps that allow the functioning of settlements, clinics, schools, markets and livestock posts – and failure to construct and/or sustain such waterwells directly impacts in a number of ways on prospects for achievement of the UN-Millennium Development Goals (MDGs).

- In recent years the following trends have been widely observed :
  - rapidly increasing demand for urban water-supply provision at a range of scales – from improving water services in innumerable small (but rapidly expanding) towns to supplementary public and private water-supply sources in large conurbations
  - growing interest in establishing the feasibility of accelerating groundwater use for agricultural irrigation (both at subsistence and commercial scales)
  - increasing examples of groundwater use locally to underpin industrial and tourist development
  - groundwater being the critical resource for economical development at various sites of major mining activity, with groundwater drainage being an issue at others – but although the socioeconomic effect of such mines is large their hydrogeological impacts are relatively local.

- Groundwater is also one of the preferred options for the provision of vital water supplies for refugee camps endeavouring to cope with (post-) conflict situations. This presents a special set of demands for technological capacity and hydrogeological information which is not the primary focus of this paper, although groundwater resources play a central role in such situations.

Groundwater Resource Availability and Utilization

- The distribution of aquifers is now for the most part reasonably mapped, thanks to long-term programs (during 1965-95) by many governments (supported variously by British, French, German and Dutch technical assistance), and has been well integrated by the IAH/UNESCO/BGR WHYMAP Africa Groundwater Resources Map (2008) (**Figure 1A** being a much somplified version). However, quantitative information on aquifer characteristics, groundwater recharge rates, flow regimes, quality controls and use is still rather patchy, although it is improving in some countries as a result of more recent efforts. The general lack of reliable information, however, has tended to mean that in developmental circles groundwater often has been the subject of 'unreasonable expectation' or not taken into 'serious consideration'.

- With this in mind, a recent DfID-BGS Project has systematically interpreted available hydrogeological information at regional reconnaissance scale (**Figures 1B, 1C & 1D**) in terms of :
  - short-term waterwell yield potential as an indicator of possible uses
  - drainable natural aquifer storage and as an indicator of drought resilience
  - potential rates of diffuse rainfall recharge as an indicator of resource sustainability accepting that for consumptive groundwater use impacts on springflow and river baseflow have also to be considered

  These map derivatives are intended to provide an indication of prospects for drought-resilient groundwater resource use, as a basis for planning investments in detailed local evaluation to guide project development on-the-ground.

- A large part of the Sub-Saharan land area is underlain by one of the following three broad aquifer classes, whose general distribution and characteristics are given in **Table 1** :
  - **weathered crystalline basement** – a very extensive but patchy shallow aquifer system of generally low yield and storage potential, which only consistently provides waterwells with drought yields of 1.0+ l/s (sufficient for motorized pumping) in limited areas of basement depression with overlying colluvial deposits and whose infiltration capacity can reduce recharge rates to below potential
  - **some consolidated sedimentary rocks** – certain limestones and sandstones forming deeper aquifers of uncertain recharge, but with prospects of much larger waterwell yields albeit at higher construction costs

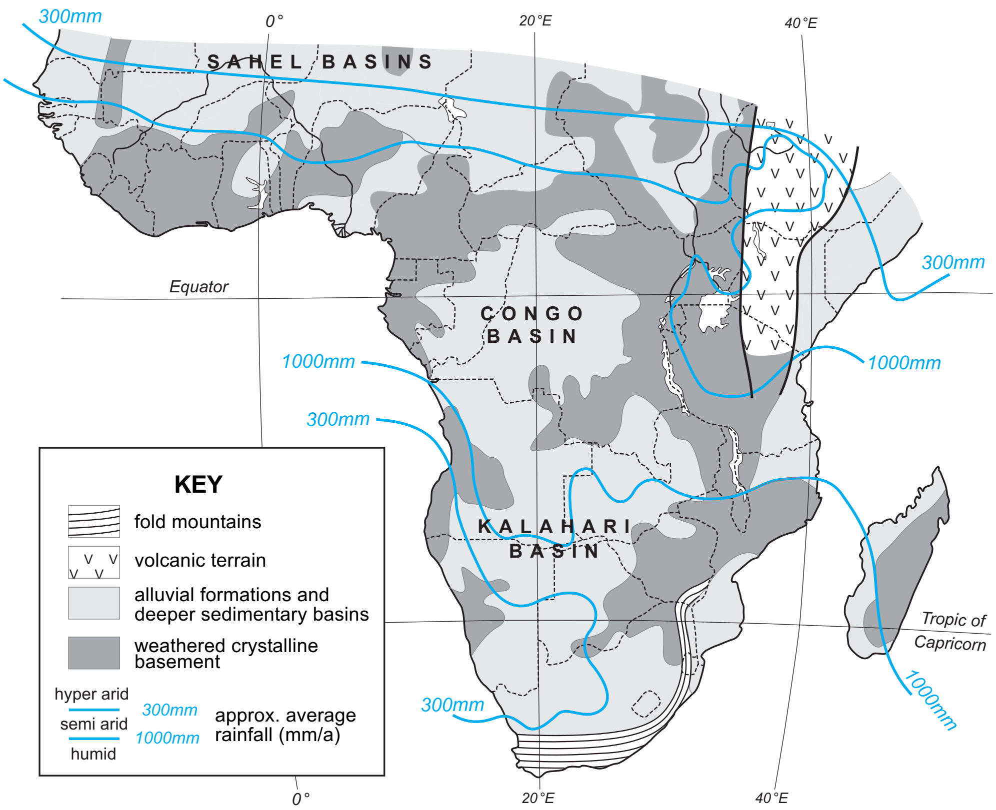
Table 1 : Characterization of main aquifer types in Sub-Saharan Africa from the resource and water-user perspective

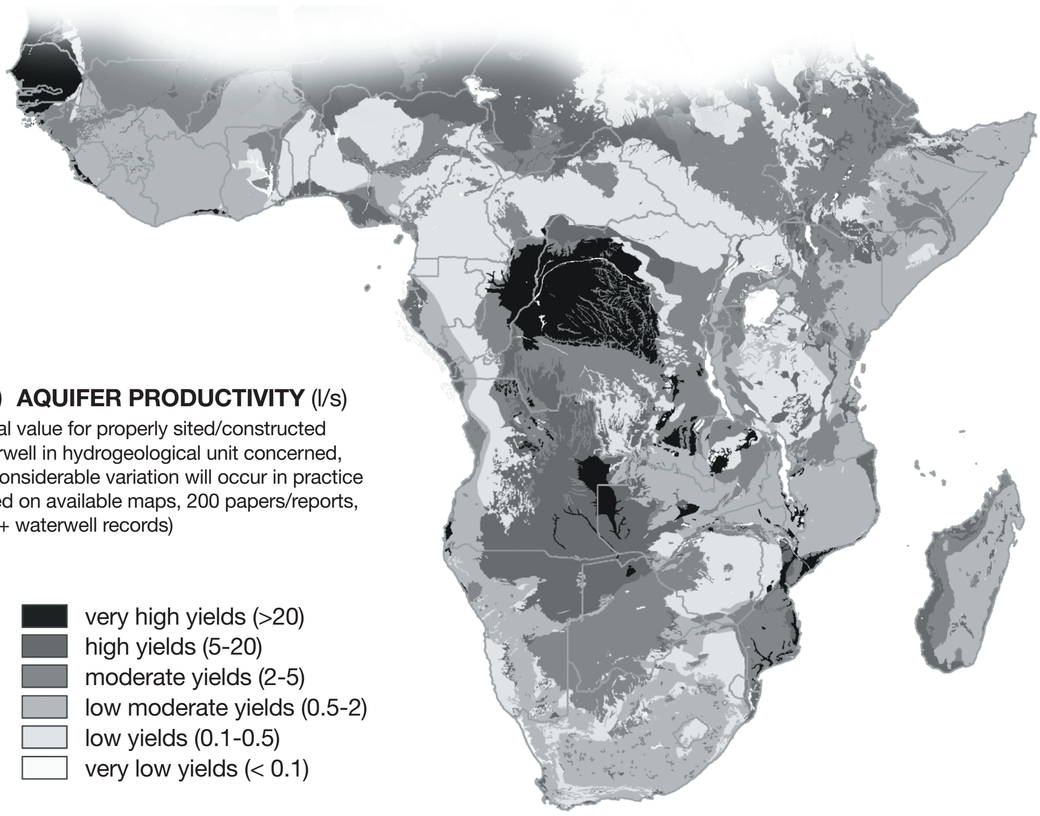
AQUIFER CATEGORIES		Thin Alluvial / Colluvial Formations	River & Coastal Alluvium	Weathered Crystalline Basement	Consolidated Sandstones & Limestones
GROUNDWATER FLOW		essentially local			mainly basin scale
RESOURCE PERSPECTIVE					
land-area coverage		<5%	18%	40%	32%
aquifer type		unconfined	variable	unconfined	mainly confined
depth top of aquifer (m bgl)		0-5	0-30	<50	100-500
aquifer thickness (m)		<20	20-50	20-40	50-200
aquifer productivity (l/s)		1-2	5-50	0.2-1	10-50
dynamic water-level (m bgl)		<5	5-20	10-25	50-200
USE PERSPECTIVE					
siting criteria		local	local/regional	local	regional
typical well success rate	with siting (%)	100	95	75	95
	without siting (%)	90	80	50	80
salinity issues		none	possible	none	possible
pollution hazard		high	medium	high	low
natural water quality		good	some concern	good	some concern
use potential		rural	rural*/urban**	rural/urban**	rural*/urban

** including large-scale irrigation* *** mainly small-scale in-situ uses*

Figure 1: Regional hydrogeological map products for Sub-Saharan Africa

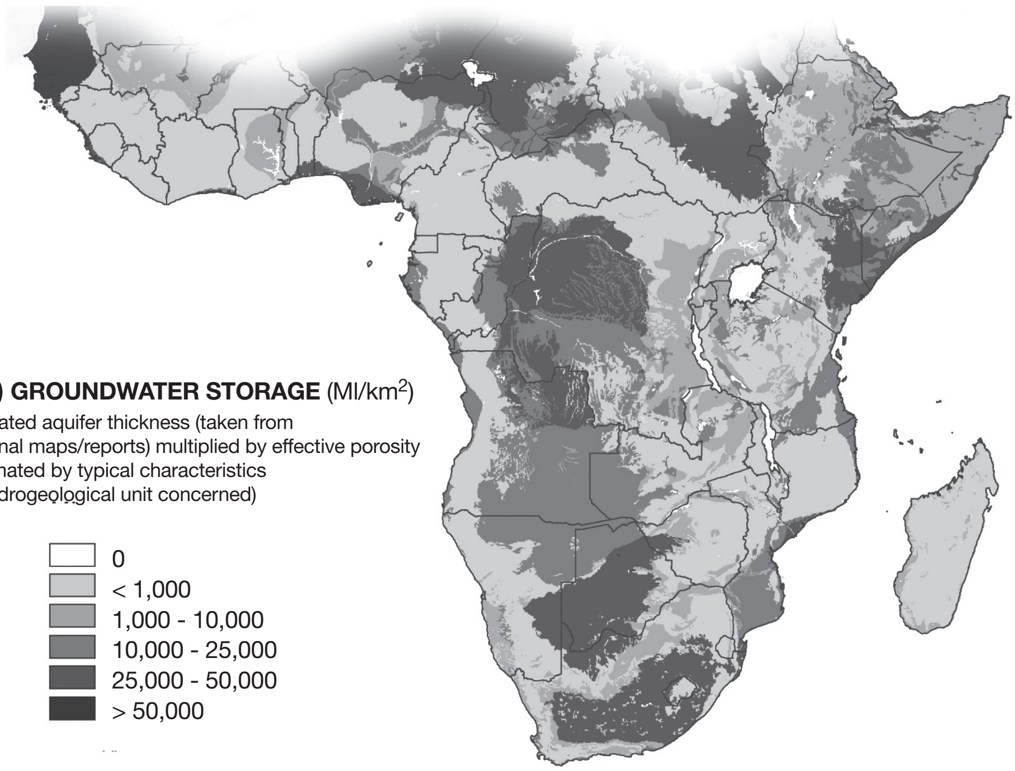
(1A)





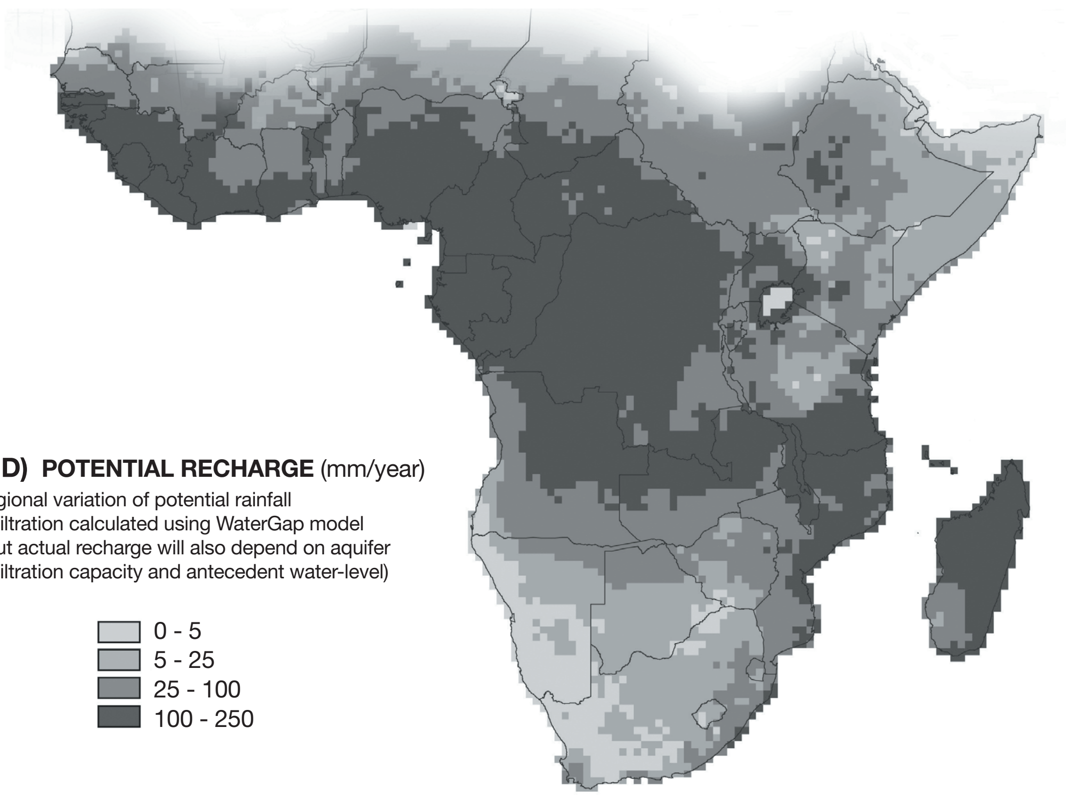
(1B) AQUIFER PRODUCTIVITY (l/s)
typical value for properly sited/constructed waterwell in hydrogeological unit concerned, but considerable variation will occur in practice (based on available maps, 200 papers/reports, 2000+ waterwell records)

- very high yields (>20)
- high yields (5-20)
- moderate yields (2-5)
- low moderate yields (0.5-2)
- low yields (0.1-0.5)
- very low yields (< 0.1)



(1C) GROUNDWATER STORAGE (Ml/km^2)

saturated aquifer thickness (taken from regional maps/reports) multiplied by effective porosity (estimated by typical characteristics of hydrogeological unit concerned)



(1D) POTENTIAL RECHARGE (mm/year)

regional variation of potential rainfall infiltration calculated using WaterGap model (but actual recharge will also depend on aquifer infiltration capacity and antecedent water-level)

- **major alluvial formations and minor alluvial deposits** – forming shallow unconsolidated aquifers, usually providing moderate waterwell yields and having relatively favorable recharge rates, but generally of much more limited extension (except in western Africa where they are more extensive and also support higher population densities).

- An issue which has tended historically to reduce the pressure for groundwater development in Sub-Saharan Africa is the high cost of waterwell construction and operation (**Box A**). The causes are complex – but one easily remedied is inappropriate well design, with excessive drilling depth in some ground conditions and insufficient use of low-cost technology options (**Figure 2**). This observation is not new, having been evident during the 1980s in Malawi and Zimbabwe, but appears to have been overlooked in some countries in recent years. However, various organizations are now working on more cost–effective waterwell construction and maintenance (RWSN, UNICEF, WSP, Water Aid & Practica Foundation), and have formulated recommendations to reduce failures (due to inadequate yield or quality) and improve operational reliability and useful life of waterwells :
  - better evaluation of groundwater conditions for more effective waterwell siting
  - waterwell design and pump testing to achieve 'fitness for purpose' – so as to avoid over dimensioning, use of unsuitable drilling methods, and inappropriate completion materials and waterwell pumps
  - economy of scale through appropriate packaging, coupled with better supervision of waterwell drilling contracts
  - private-sector capacity development through appropriate training, so as to improve service quality and to promote competition to reduce prices
  - network promotion for capacity building and best-practice dissemination.

  There is also a growing need for new capital-financing mechanisms and use of carbon-neutral energy sources for groundwater pumping.

- For the present, levels of groundwater resource development remain generally low (except in localized areas of southern Africa and around some major conurbations), and most of Sub-Saharan Africa is experiencing 'economic water scarcity' due to lack of infrastructure investment (rather than 'water resource scarcity' as reflected by average rainfall and population density). Thus the current priority must be more effective planning and sustainable implementation of groundwater development (often in minor aquifers) to help meet critical social welfare targets and livelihood opportunities. Managed groundwater development, to meet a variety of demands, will be a vital 'cog-in-the-wheel' of the overall future development process – but priorities and rates of implementation will vary considerably with differing national socio-economic trajectories.

Resource Resilience for Climate Change Adaptation

- Many countries in Sub-Saharan Africa are prone to high rainfall variability and severe drought, with severe impacts having been experienced in Ethiopia, Kenya, Burkina Faso, Ghana & Senegal in recent years. Thus better use of groundwater resources to buffer drought impacts in particular, is vital for water (and economic) security. Drought propensity could increase in some scenarios of accelerated climate change, and there is thus :
  - a critical role for groundwater storage in mitigating more frequent and extended drought episodes given that groundwater sources are much less drought prone than surface water sources

Box A
WATERWELLS – THE CHALLENGE OF CONSTRAINING COSTS

Balanced information on the cost of waterwell construction in the countries of Sub-Saharan Africa is not easy to acquire, in part because financial records are dispersed and incomplete, and the fact that costs can vary widely even within the same country. Moreover, waterwell construction costs depend not only on well depth and diameter but a range of other factors :

BASIC WATERWELL CONSTRUCTION COST COMPONENTS	OTHER COMPONENTS (often excluded)
• drilling rig mobilization/demobilization • borehole drilling (depth and diameter) • well lining/screen and completion • waterwell hydraulic development/testing • pump purchase and installation • contractor overheads and profit	• land acquisition • waterwell siting and design • provision of power supply • supervision costs of construction • allowance for drilling unsuccessful wells

The overall cost can show wide variation between different locations. For example, in urban Addis Ababa borehole drilling is the biggest single cost component, but for an identical waterwell drilled at the same time in Adigrat (700 km north) rig mobilization was the main cost component and the total cost was double. The table below gives the typical range of waterwell construction costs from different sources (such as RWSN, UNICEF & Water Aid) tempered by GW•MATE experience – they include pump provision and installation, but have no allowance in respect of waterwell siting, land acquisition or the cost of unsuccessful drilling.

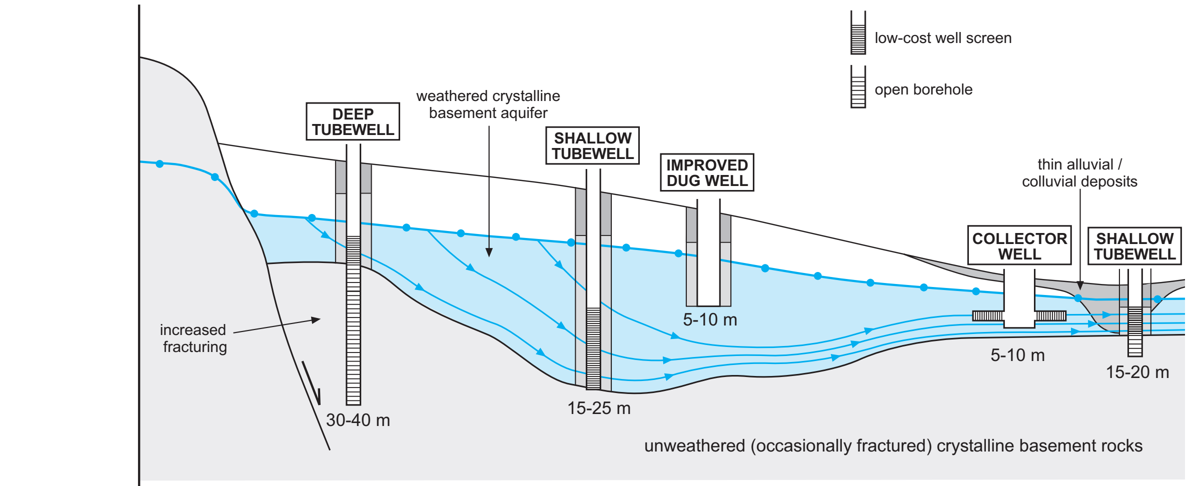
TYPE OF WATERWELL	DEPTH, DIAMETER & YIELD RANGE	CONSTRUCTION DETAIL	TOTAL COST (US $)
shallow tubewells/borewells for domestic and village water-supply	20 - 50 m depth 100 - 150 diameter 0.1 - 0.5l/s yield	• plastic lining & part unlined • hand pump	3,000 -5,000
deeper tubewells for village and small-town water-supply or minor irrigation	50 - 150 m depth 100 - 250 diameter 1 - 10l/s yield	• pvc or steel lining • electric or diesel-engined pump	15,000 - 25,000
deep tubewells for urban water utilities, industrial use or large-scale irrigation	150 - 250 m depth 200 - 400 diameter 20 - 100l/s yield	• purpose-designed • high capacity submersible pump	25,000 - 100,000 *(or sometimes more)*

Waterwell drilling costs in Sub-Saharan Africa are currently expensive compared to those in Latin America, and very much higher than in South Asia (300-600% more for shallow tubewells/borewells). The reasons for this are complex but usually include :

- lack of economy of scale and contractor competition, due to much more limited market
- high mobilization/demobilization costs in remoter areas with poor road network
- excessive drilling depth for some hydrogeological conditions
- high duties on imported equipment often with no local manufacture of spares
- corruption in the letting and execution of contracts.

The recurrent costs of waterwell operation include maintenance charges and energy use for pumping water. These costs are usually born by the beneficiaries of waterwell operation, and can be relatively low (<5% of the capital cost per year) for shallow waterwells with small pumps . For deeper waterwells, the operational costs can become dominant where the depth to water-table is large – and can increase markedly during the lifetime of the waterwell in case of aquifer over-exploitation or well-screen encrustration.

Figure 2: Harmonization of waterwell design with local groundwater conditions in the weathered crystalline basement terrain of Sub-Saharan Africa



YIELD PROSPECTS	very good	good	moderate (drought reductions)	good	good
RELATIVE COST	moderate-to-high	low-to-moderate	very low	moderate	low

VARIATION OF WATERWELL CHARACTERISTICS WITH TERRAIN

- a need to appraise the susceptibility of groundwater systems to climate-change impacts
- a potential for multiple small-scale managed aquifer recharge measures (**Figure 3**).

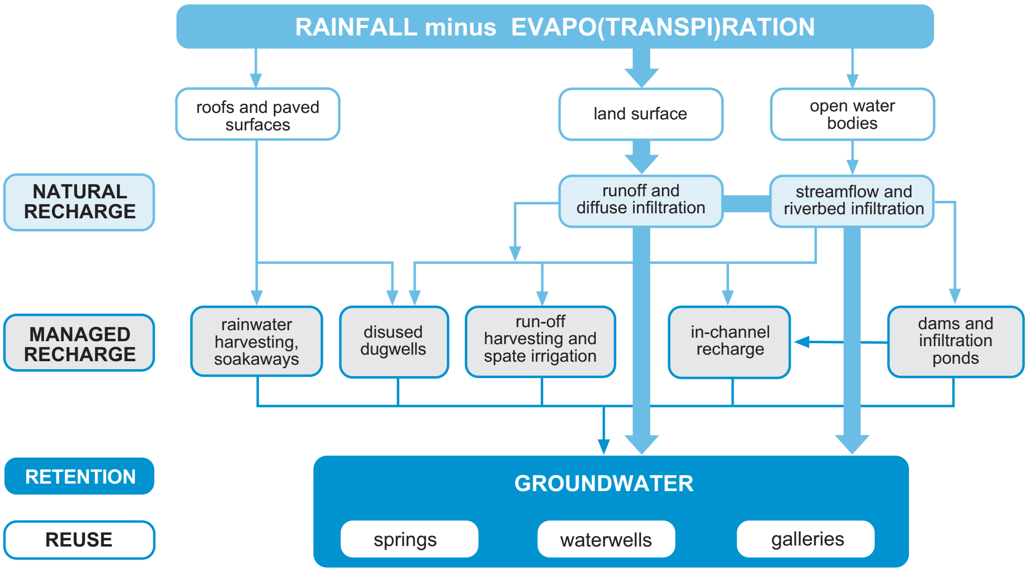
The concept of 'groundwater resource resilience' to extended drought is a function of volume and accessibility of drainable storage of a given aquifer system, period that the current 'use-type' could be sustained from natural storage alone, and time for recovery to the pre-drought condition.

- There is increasing evidence of a direct correlation between drought proneness and persistent poverty in Sub-Saharan Africa – and in reality a lack of investment at all scales in water storage for drought preparedness. It is necessary to achieve greater drought-proofing of rural livelihoods, as opposed to mitigating the failure of local crop production and drinking-water sources. Thus as regards drought preparedness, in terms of water-supply it is important to invest in the appraisal of drought susceptibility of aquifers in advance, with the drilling of new waterwells and the deepening of existing wells with pump re-dimensioning as necessary.

Groundwater-Related Environmental Concerns

- In Sub-Saharan Africa more effort must be put into identifying and evaluating the close inter-relation between groundwater systems and certain terrestrial and aquatic ecosystems. First, soil compaction and/or soil erosion are widely leading to reduced rates of infiltration to groundwater (and increasing flash run-off), and thus loss of environmentally and socially-critical springflows and baseflow to smaller rivers, and of discharge to vegetation in topographic lows ('valley-bottom lands'). There is a need to halt such processes, conserve local soil cover and terrestrial ecosystems, and also to find ways of enhancing groundwater recharge through agricultural land management and small-scale engineering measures (**Figure 3**).

Figure 3 : Schematic illustration of natural and managed processes of aquifer recharge (excluding incidental recharge from irrigated agriculture and urban infrastructure)



- Second, a substantial number of aquatic ecosystems in Sub-Saharan Africa depend upon groundwater discharge from aquifers (eg. the Nech Sar of Ethiopia). This aspect of 'groundwater service provision' (and its potential constraint on other uses) is just beginning to be appreciated. In many areas much uncertainty remains over the level of groundwater dependence of such ecosystems, and their susceptibility to degradation due to resource development and water-table decline. Furthermore some other aquatic ecosystems (eg. the Okavango Swamps in Botswana) are naturally groundwater recharging, as a result of local geological structure. However, such ecosystems also rely upon the maintenance of very shallow groundwater levels for the transpiration of phreatic plants, and inadequately-controlled local groundwater use could also cause significant ecosystem degradation. The occurrence and value of groundwater-dependent ecosystems needs to be better characterized, and the impact of groundwater use for water-supply monitored to arrive at balanced approaches to their conservation.

IMPROVING RURAL WATER-SUPPLY
(< The Continuing Need>)

Historical Evolution and the Current Challenge

- Groundwater (from springs, boreholes and dugwells) is the 'raw material' of improved rural water supplies on a very widespread basis, with a current level of dependency that is put at over 75%. This is the traditional and critical social function of groundwater – and its importance cannot be overstated because successful development for community water-supply has far-reaching benefits in terms of reducing health hazard and improving socioeconomic opportunity by :

  - eliminating dependence on unreliable and polluted surface water sources associated with high levels of mortality and morbidity (e.g. improving waterwells in part of Ghana was the central plank in eradication of endemic guinea-worm infection during the 1990s)
  - reducing the long distances walked and time spent on water collection, which should enable women to engage in more productive activities and children to attend school.

- Traditionally dugwells were used by rural communities to obtain water-supply for domestic use and livestock rearing, but in some hydrogeological conditions they are prone to failure during drought, hence the interest in drilling waterwells deeper than technically and/or economically feasible by digging. For the future it will be essential that groundwater resources be developed further, if the population served by 'minimum adequate water-supply coverage' (currently standing at around 40%) is to be rapidly expanded – since groundwater remains the only viable option for improving water-supply in the rural areas of many African countries. Alternatives, such as surface water from rivers and ponds or rainwater collection, are less reliable and easily contaminated, whereas aquifers and waterwells have a substantial degree of resilience and protection.

- It is recognized that groundwater availability alone does not equate with improved rural livelihoods, but has been a key factor in :
  - water-supply for livestock rearing on which there is a high-level of economic dependence (cattle and goats still widely being both the 'banking mechanism' and 'drought-coping strategy' of innumerable rural communities)
  - village vegetable plots and cultivation of maize/sorghum seedlings to advance planting dates
  - water-supply for village enterprises – such as pottery and brick-making.

- During the UN Drinking Water & Sanitation Decade (1980s) it came to be assumed that small quantities of groundwater adequate for rural water-supply were everywhere readily available and community considerations should be the main criteria for waterwell siting. Whilst not questioning the important role of community management in the sustainable operation and maintenance of groundwater-based rural water-supply facilities, there has been a serious breakdown of this 'decade paradigm', with increasingly high rates of waterwell construction failure. This has been due to insufficient yield and/or inadequate quality (**Box B**), in those areas of more complex and/or unfavorable hydrogeology. Recognition that hydrogeological factors may, in some circumstances be overriding, and better use of scientific expertise and data, are needed to overcome this type of problem.

Special Significance of Weathered Hard-Rock Aquifers

- Weathered hard-rock aquifers (and crystalline basement rocks in particular) occupy very extensive areas of Sub-Saharan Africa (**Table 1 & Figure 1A**), and as such are especially significant for the provision of rural water-supply. The conceptual model of weathered hard-rock aquifers (**Figure 4**), derived from applied research in the 1980s, had important implications for groundwater supply development and cost-effective waterwell construction – indicating the widespread occurrence at shallow depth of a fractured 'saprock horizon' capable of yielding groundwater, overlain by a much less permeable 'saprolite' which provided limited but useful groundwater storage (at least in areas of significant seasonal rainfall and where the weathering profile had escaped excessive erosion).

Box B

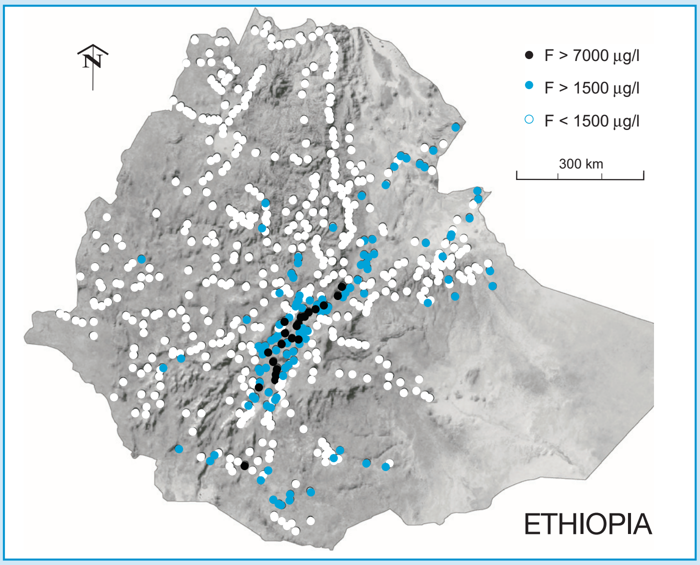
NATURAL GROUNDWATER QUALITY HAZARDS - SCOPE OF PROBLEM AND ITS MITIGATION

Trace elements make up only 1% of the naturally-occurring dissolved constituents in groundwater but in some cases can make it unfit or unacceptable for human or animal consumption. Some trace elements like arsenic and uranium are always harmful to health even at very low concentrations, whilst others like fluoride and iodine are essential for health in small quantities (which may be ingested from drinking water or solid food) but are harmful at higher concentrations. The groundwater quality hazard from fluoride, arsenic and manganese are fairly well known and their occurrence in groundwater is becoming better mapped, although certain other elements (such as nickel and barium) are giving rise to some concern locally and need further investigation locally. It is important, however, to avoid the over-reaction of reverting to microbiologically-polluted and more hazardous surface water sources.

Elevated fluoride concentrations in groundwater are geogenic and arise in low calcium bicarbonate groundwaters where the solubility of fluorite increases and fluoride is stable in solution at high concentrations. This occurs on a widespread basis in volcanic and granitic formations, and thus appears to be the most pressing issue for Sub-Saharan Africa, especially in more arid regions and during extended dry periods. It is a significant problem for rural water-supply provision in Ethiopia, Kenya and Tanzania, where the human impacts of consuming high-fluoride groundwater include severe dental and skeletal fluorosis, and poor nutritional status is believed to have exacerbated the problem.

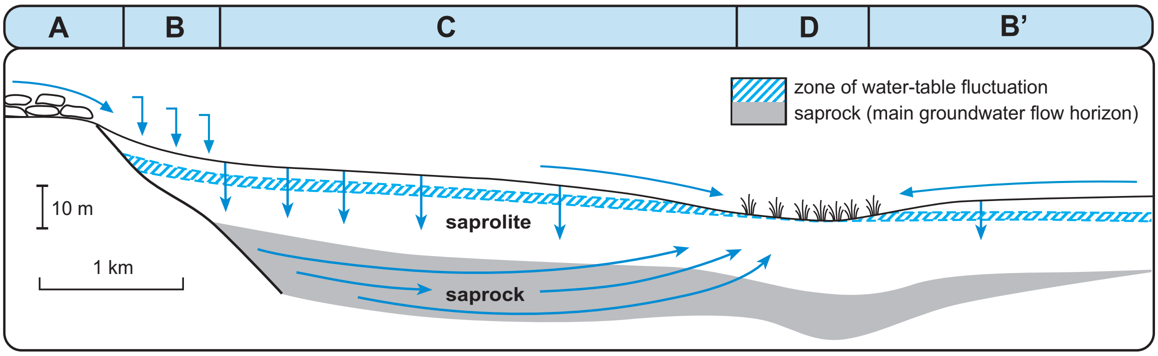
TRACE ELEMENT	WHO GUIDELINE	HEALTH SIGNIFICANCE & USE RESTRICTIONS	HYDROCHEMICAL CONTROL & OCCURRENCE	WATER TREATMENT STATUS*
ARSENIC (As)	10 µg/l*	toxic/carcinogenic hazard (WHO drinking water guideline recently reduced from 50 µgl/)	complex -release from binding on iron oxides under anoxic conditions or during oxidation of sulphide minerals	oxidation /filtration (+coagulation) or use of ion exchange resin or reverse osmosis
FLUORIDE (F)	1500 µg/l	essential element but desirable range narrow, above 1500-2000 µg/l severe risk of dental and skeletal fluorosis	dissolution of fluoride-bearing minerals from granitic or volcanic formations facilitated in some cases by slow circulation	precipitation with gypsum or lime/alum mix with filtration or use of ion exchange resin
MANGANESE (Mn)	500 µg/l* 100 µg/l	essential element but high levels may affect neurological functions; causes staining and imparts metallic taste at lower levels	abundant solid element in soils/rocks and becomes soluble under increasingly acidic and/or anaerobic conditions	precipitation by aeration and filtration usually with prior settlement

** provisional values subject to review*



In Ethiopia, fluorosis is assessed as a risk for a population of close to 8.5 million, with nearly 40% of deep waterwells and 20% of shallow waterwells in the Rift Valley yielding levels of 2-7 mgF/l. The Ethiopian Ministry of Water Resources is hosting a National Fluorosis Mitigation Project, which aims to develop guidelines through identifying safe water-supply sources and/or low-cost treatment methods. One approach under serious consideration is the use of more sophisticated waterwell construction techniques involving only placing well-screens at levels in aquifers that have lower fluoride levels.

Figure 4 : Conceptual model of groundwater occurrence and dynamics in weathered crystalline rocks of Sub-Saharan Africa



GROUNDWATER OCCURRENCE				
A	B	B'	C	D
Little Groundwater	**Seasonal Groundwater Body**		**Perennial Groundwater Body**	
extremely limited groundwater in occasional vertical fractures with wet season run-off as predominant hydrologic process	limited groundwater storage and waterwell yield potential draining rapidly after wet season but can be used for village water-supply* and (where permeability higher) limited supplementary irrigation, with marked yield reduction or failure during prolonged dry periods – spatially variable recharge and run-off during wet season depending on topographic position which influences saprolite vertical permeability		continuous groundwater body of variable extension with modest useful storage providing reliable village water-supplies* and (where permeability higher) possibility of irrigation of dry-season or perennial crops on part of land area (but becomes depleted under intensive use) – some recharge but increasing run-off as distance from 'topographic highs' increases; localised discharge in 'topographic lows' (if not intensively exploited)	
	** although possible natural water quality hazards always need to be considered*			
'RUN-OFF ZONE'	***'RECHARGE ZONE'***	***'RUN-OFF ZONE'***	***'STORAGE ZONE'***	***'DISCHARGE ZONE'***

- In subsequent decades, major investment effort (by national and state governments, multilateral and bilateral donors, international charitable organizations and local communal or individual enterprise) has been put into trying to develop groundwater resources from weathered hard-rock formations. Such experience (for example from Malawi, Zimbabwe and Nigeria) indicated that :
  - groundwater production potential is limited but can be tapped widely with low-cost hand-pump water-wells for rural water-supply – in the areas surveyed in detail more than 80% of tubewells supported hand-pump yields (> 0.1 l/s), but less than 20% allowed motorized pumping (yield >1 l/s) with their siting being dependent upon favorable bedrock lithology, deep weathering and structural features
  - despite uniform bedrock type, geomorphological situation and climatic regime, there are substantial (and unpredictable) local variations in waterwell yields and in aquifer response to pumping as a result of the generally poor connectivity of saprock fractures
  - the upper part of the saprock provides most of the water transmission to waterwells, but the thickness of saturated saprolite above is important since it determines the 'available drawdown' and provides most of the aquifer storage – thus well yield will fall-off dramatically with any dewatering of the saprock
  - dispersed rural water-supply demands put negligible pressure on the resource base, since they result in very low rates of groundwater abstraction (equivalent to 1-3 Ml/km^2/year or 1-3 mm/year).

Strengthening Programmes for Rural Water-Supply Provision

- Programmes serving basic health and livelihood needs of rural communities of 200-500 persons find it difficult to support capital costs in excess of US$ 3,000 per waterwell – and thus to extend and improve rural water-supply coverage it will be necessary to keep unit waterwell costs down by :
  - constructing waterwells as shallow as feasible and with appropriate completion, and selecting low-cost drilling techniques
  - avoiding natural quality problems which could prejudice the use of groundwater supplies for domestic purposes through inability to meet potable water quality standards (due to toxic or troublesome soluble constituents such as F, As, Mn, Fe, $MgSO_4$ or NaCl) (**Box B**).

  This implies planning, surveying and implementing rural water-supply work in such a way as to permit 'rolling projects' (guided by sound hydrogeological and hydrochemical advice, and using appropriate hydrogeophysical equipment) with local learning 'on the job' so as to improve efficiency.

- There remain too many instances in rural water-supply provision of 'drilling blind', constructing unnecessarily deep waterwells, increasing well-yield failure, and failing potable drinking-water quality standards (due to tackling more difficult terrain without adequate hydrogeological information). Such problems are widely increasing the unit cost of rural water-supply provision, and in some areas mean that adequate sources are not being provided. The only way to overcome them is to improve government provisions for procuring (or developing in-house) the required professional and technical expertise, and developing more capacity for using scientific information and equipment to guide waterwell siting and design.

RESPONDING TO THE 'NEW AGENDA'
(< The Investment Perspective >)

- In those countries in a state of 'economic transition' in particular, the range of needs related to groundwater is broadening to include :
  - assessing the potential for major expansion of groundwater irrigation, and appropriate levels of investment and risk reduction to stimulate development – together with the scope for enhancing aquifer recharge and storage use for this purpose
  - developing and protecting new urban water-sources at a range of scales from small towns to large cities to improve water-supply availability and security at lowest possible cost
  - formulating a policy on urban domestic in-situ self-supply from groundwater, and the related issue of exercising controls on urban sanitation and pollution load.

  These interests require systematic planning and proactive management of groundwater resources at government level – 'on top of' the earlier (and still not fully satisfied) agenda related to rural water-supply provision.

Expanding Irrigated Agricultural Production

- Agricultural growth is the key to reducing rural poverty in Sub-Saharan Africa and political leaders have flagged it as critical for future investment. The scope for a major increase in waterwell use to accelerate the expansion of irrigated agriculture is currently an important debate in developmental circles. The debate goes well beyond the (now long-standing) beneficial practice of using excess flows from village hand-pump waterwells for manual 'garden-scale' vegetable irrigation (which involves only very small land areas) to contemplate expanding :

- extensive groundwater use in small-scale irrigation on communal land and by smallholders (using low-cost waterwells) for horticulture and even drought-proofing of some staple-crop production
- more localized intensive use of groundwater as a basis for commercial irrigation investments to produce 'cash crops' for national and international markets.

Current Position on Groundwater Irrigation

- Only a small proportion of the agricultural land of Sub-Saharan Africa is equipped for irrigated cropping, and this is largely concentrated in just a few countries. In particular, current groundwater use for irrigated agriculture is extremely limited – with a recent UN-FAO assessment (based on national survey statistics and satellite imagery) providing an estimate of 0.4 M ha (only about 6% of all irrigated land and less than 1% of all arable land), although national returns can lack adequate definition of irrigation water source and omit much 'garden watering'.

- Nevertheless, a recent IFPRI comparative study of trends in farmer response to climatic stress, suggests that where governments have an explicit policy promoting small-scale irrigation (eg. Kenya & Nigeria) there has been useful uptake, whilst in others, with as yet no specific government initiative (eg. Uganda), little was happening. The intensive use of shallow tubewells on floodplains can add significantly to the growth of irrigated agriculture in fertile drought-prone areas – the best example to date being the World Bank-supported Nigeria Fadama Projects (**Box C**). Another good example of waterwells having been developed informally for small-scale irrigation of cash-crops occurs in the weathered basement aquifer in the White Volta Basin of Ghana.

- Although in general terms groundwater irrigation is little utilized, there are a few areas where excessive resource exploitation for commercial agriculture is occurring. An example is the Kajiado District of Kenya (immediately south of Nairobi), which has a relatively long history of using dugwells equipped with handpumps or motorized pumps for domestic water-supply and garden agriculture. In recent time more than 10% of the 1500 dugwells in the area have become dry, due to the sale of communal land and development of commercial horticulture using deeper borewells and urban sprawl with the drilling of private household waterwells. Similar areas of intensive groundwater use are found in the Limpopo Basin Karst Aquifers of South Africa and similar limestone aquifers in Zambia, Zimbabwe and Namibia. However, commercial groundwater irrigation has often been beset by operational and/or economic problems, such as import restrictions on waterwell equipment and spares, and the absence of a related service sector, and especially by escalating diesel-energy costs and supply problems, inadequate post-harvest crop handling, transport and access to markets.

Scientific and Social Constraints on Development

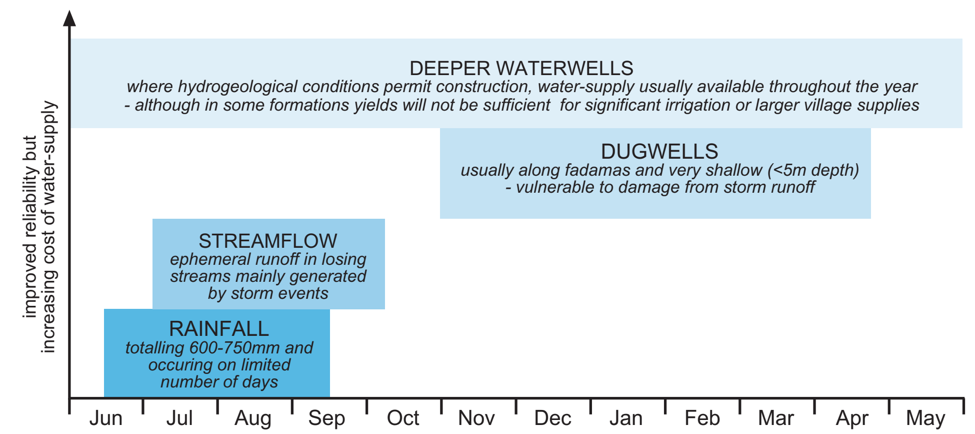
- The Africa Infrastructure Country Diagnostic (AICD - undertaken by the World Bank for the G-8 Infrastructure Consortium for Africa) suggested that investment in small-scale irrigation might be viable on an additional 5.4 M ha of agricultural land to mitigate drought impacts and stem the rising cost of food imports, but this would be highly dependent upon keeping capital cost down to US$ 2,000/ha and focusing on higher-value crops (those raising revenues in excess of US$ 2,000/ha).

Box C
WORLD BANK-SUPPORTED 'FADAMA' DEVELOPMENT PROJECTS IN NIGERIA (2008)

In the Sahel 'fadama' is a local term for land that is seasonally waterlogged or inundated – which geomorphologically may vary from shallow land-surface depressions to narrow alluvial tracts, and even major floodplains (but does not include permanent swamps and marshes). They tend to be underlain by silty coalluvial deposits of generally low transmissivity (< 5 m^2/d), which yield limited water-supplies to dugwells (usually of less than 4 m depth). The practice of digging wells into a 'fadama' to intercept the shallow water-table goes back into early human history and has changed little to the present day – with fadama waterwells always having been the focus of rural population as the most reliable source of water-supply for human consumption and livestock watering. The climate is semi-arid and drought-prone with rainfall concentrated mainly in July-August, followed by a dry season (October-February) and an exceptionally hot season (March-May). During the wet season dugwells are frequently damaged and partially collapse as a result of land flooding, and often have to be re-excavated during October. In many (but not all) areas somewhat deeper tubewells (requiring larger capital investment and running costs) can produce more reliable and higher yields, making more extensive irrigated vegetable cropping possible.

Since 1992 the World Bank has supported community-driven enterprise aimed at expanding irrigated crop production in various Nigerian States through a sequence of 'fadama development projects'. These projects provide grants to increase access to agricultural infrastructure and assets (including irrigation hardware, farming and processing equipment, food storage and market facilities, feeder roads, rural electrification, agrochemicals and seed-types). They place beneficiaries (mainly farmers and pastoralists) in the lead through the mechanism of Fadama Community Associations & User Groups, which oversee the use of local development funds and are empowered through training programs to increase income-generating activities.

An important component was the construction of over 40,000 shallow tubewells equipped with small engine-driven pumps – a 'new technology' locally which improved irrigation water-supply reliability and covered a longer growing-period than dugwells (which if used for irrigation tended to fail with increasing frequency in the hot season). This facilitated much greater commitment to vegetable cultivation, raising crop productivity in the dry savannah by more than 75%. However, this accelerated development has not been without problems. Social tensions have arisen between farmers irrigating crops and nomadic pastoralists, about access to and loss of grazing land and some shallow watering points, together with disruption of traditional waterwell use scheduling (with irrigation pumping in the morning and livestock watering in the afternoon) due to much heavier use and longer water-level recovery periods.



Moreover, the current widespread failure of irrigated production to buffer the volatility of rainfed agriculture and secure national markets, implies a pressing need to structure small-scale irrigation initiatives so as to address local market demands and to enhance crop water-use productivity. The viability of staple-crop irrigation is currently considered to be marginal, but supplementary small-scale low-cost groundwater irrigation of such crops to reduce drought yield impacts could be needed in response to some climate-change scenarios.

- Various factors currently combine to constrain strongly the demand for groundwater irrigation :
  - lack of community tradition in irrigated cultivation, compared to rain-fed arable cropping and extensive livestock rearing (consequent upon a 'land abundant/labour scarce' history), with the implication of need for a major expansion of farmer awareness and extension services
  - current high cost of waterwell drilling and maintenance (**Box A**), as a result of the related service sector generally being very weak
  - very low levels of rural electrification, coupled with the elevated cost and distribution difficulty associated with use of diesel fuel for pumping
  - inadequate access to financial credit for irrigation hardware acquisition and purchasing essential production inputs (such as quality seed and some agrochemicals).

- But the question arises as to what proportion of future expansion of irrigated agriculture might be based on waterwell use – assuming that it would have largely to utilize low-cost motorized pumps rather than manual pumping techniques (hand and treadle pumps). In relation to the specifics of groundwater resources this will depend on :
  - Whether the cost of equipped waterwells appropriate to local hydrogeological conditions be brought down in numerous countries to the level that makes the required investments economically feasible ?
  - How widely will hydrogeological conditions offer good prospects of obtaining sufficient yields for motorized pumping (1.0+ l/s) from low-cost waterwells (of say a maximum of 30 m depth) ?
  - What level of 'irrigation intensity' will be sustainable in areas where the waterwell yield prospects are favorable, given the probable natural rates of groundwater recharge (and scope for their managed enhancement), whilst minimizing conflicts with domestic and livestock water-supply interests and over springflow and/or river baseflow reduction?

- The answer to these questions is not straightforward, and there will be rather wide national and local variations, but a number of hydrogeological factors currently appear to constrain significantly the proportion of the total land area likely to offer good prospects of providing adequate yields (**Figure 1B**) to shallow waterwells and/or sufficient recharge to allow major sustainable development of groundwater irrigation (**Figure 1C**) :
  - the characteristics of the extensive weathered crystalline basement aquifer (especially where the proportion of schistose bedrock is high) are not such as to guarantee that waterwells will provide drought yields in excess of 1.0 l/s, and thus comfortably support motorized pumping, and their rates of replenishment in drought prone areas may also be relatively restricted
  - the deeper sedimentary aquifers (which offer prospects of larger well yields) involve much higher waterwell construction costs and are often geologically complex with low or uncertain replenishment.

- Despite the considerable interest amongst foreign investors (from China, India & the Middle East), the implication is that capital investment in groundwater-irrigated agriculture in Sub-Saharan

Africa remains rather widely subject to significant obstacles and fairly high risks. Important exceptions, however, are the floodplains of major rivers (especially in western Africa) and margins of some lakes, where alluvial formations have shallow water-table, useful annual replenishment and are amenable to low-cost tubewell construction (given that dugwells are prone to collapse and/or drying-up under drought conditions).

Stimulating and Managing Sustainable Groundwater Use

- Another question that arises is what can be done to reduce investment risks in irrigated agriculture – here as far as the groundwater supply and resource sustainability dimensions are concerned, beyond finding ways to bring down waterwell construction costs (Box A). Certain actions can certainly be taken by national groundwater agencies to help stimulate, channel and focus the increasing interest in expanding irrigated agriculture, whilst concomitantly avoiding excessive and unsustainable groundwater abstraction impacting negatively on the potable water-supply function of the resource :
  - further mapping and dissemination of groundwater availability data (potential waterwell yields, sustainable abstraction levels and waterwell development costs) at national or provincial level, collated with information on agricultural soils, to provide baseline planning information on which to judge the feasibility of major public-sector investment and viability of loan-financing to stimulate small-scale agricultural irrigation
  - incorporating groundwater recharge enhancement into rural development projects where feasible to provide additional 'buffering' groundwater storage in the dry season and during drought to support small-scale irrigation (**Box D**)
  - more detailed processing and presentation of hydrogeological information on waterwell yield prospects and groundwater resource potential are needed, in areas within 30 km or so of major market centres and international airports, to reduce the investment risk for private development of commercial irrigated agriculture (this would also be of direct relevance to urban water-supply provision)
  - undertaking multi-disciplinary (hydrogeologic and agroeconomic) post-case analysis of successful (and unsuccessful) examples of crop irrigation with groundwater at all scales from manual garden watering to smallholder waterwell use and commercial groundwater irrigation, would help to build a more robust platform for the planning and design of future investments
  - promoting highly-focused pilot projects in a variety of hydrogeological and socioeconomic settings to guide cost-effective and sustainable expansion of groundwater-based irrigation, including planned conjunctive groundwater management with surface-water sources in major alluvial areas.

Making Best Use of Groundwater for Urban Water-Supply

Urban Groundwater – the General Context

- The rapid growth of urban population (widely in the range 2–7 % per yr) and of water demand (at even higher rates up to 10% per yr) is a current reality in Sub-Saharan Africa – and is likely to be further accentuated in some climate-change scenarios, both as a result of rural migration to urban areas and of increased ambient temperatures. These trends are not just affecting megacities, where periurban areas in particular have extremely high population densities, but are even more pronounced in many hundreds of medium-sized towns. Where suitable aquifers are present expansion of groundwater development is usually the preferred response.

Box D
MANAGED AQUIFER RECHARGE AND STORAGE TO PROVIDE A 'WATER RESOURCE BUFFER'

One of the most distinctive features of groundwater systems is their storage capacity. The storage volume varies widely with geological build but is always such as to make aquifers the planet's large reservoirs. Subsurface storage capacity includes not only groundwater already stored in the aquifer system but also the potential to receive recharge. Natural groundwater recharge (during periods of rainfall excess to plant requirements) represents the main replenishment to groundwater storage which is pumped during dry periods. This natural storage can be augmented by managed aquifer recharge (MAR) or artificial recharge (in contrast to uncontrolled man-made recharge like water mains leakage and excess irrigation seepage which also occurs).

MAR deals with building infrastructure and/or modifying the landscape to enhance groundwater recharge intentionally and retain it for use during dry periods and droughts. Recharge, Retention and Reuse (the three R's) are the pillars for management of the water buffer provided naturally by aquifers and an important option for improving water-supply security and quality. MAR is one of the most significant adaptation options for climate change and hydrological variability, involving identification of suitable subsurface storage opportunities and the most appropriate technical intervention from the following: land spreading, in-channel modification (photo), induced riverbank infiltration and rainwater harvesting. It is finding increasing application in Sub-Saharan Africa, but has also encountered some problems related to inadequate design and maintenance.

Sand storage dams are in-channel modifications whereby a concrete dam is constructed in a dry streambed (typically 15-25m wide and 3-5m high). Upstream of the dam, the thickness of the natural sand deposits is increased by sedimentation during periods of run-off. Infiltration in the sand bed during the rainy periods creates a volume of water stored, which can be used during the following dry period – 500 of these sand dams were built in Kitui, Kenya (at a cost of US$8,000-12,000), each providing a perennial source of water to 150-200 people for drinking, food production, livestock watering and rural industry. The benefits were revealed by increasing household income (table) and expanding brick and basket production (when compared to Koma, a nearby village without sand dams).

INDICATOR	KIINDU (village with dam)		KOMA (village without dam)	
	1995	2005	1995	2005
access to drinking water in dry season	3 km	1 km	4 km	3 km
people exposed to droughts	420	0	600	600
households with irrigated crops	37%	68%	38%	38%
agricultural water consumption	220 l/d	440 l/d	160 l/d	110 l/d
household income (US$/a)	180	290	180	180

- Moreover, various climate-change scenarios imply increased frequency of surface-water drought across wide areas, with potential impacts on the reliability of urban water-supply sources. This is likely to place even greater demand on available groundwater resources as an integral part of climate-change adaptation, since inherently they have better short-term security being less directly and rapidly affected by climatic variability. A good example of the role that groundwater can play in response to serious failure of a surface water-supply system of a megacity utility came from Nairobi-Kenya in 2002 (**Box E**).

- In general terms it can be said (**Figure 5**) that urbanization processes generally impact on groundwater through a tendency to increase contaminant loads and recharge rates (despite land surface compaction and cover), as a result of wastewater returns from in-situ sanitation and of physical water-mains leakage (both in part derived from water 'imported to the city'). In some cases groundwater system change can also impact the urban infrastructure as a result of falling water-table and associated land subsidence. The groundwater-urbanization relation is not stable, evolving considerably with time, and the associated problems can be persistent and very costly – all too often without integrated vision, stakeholder dialogue and coherent planning, 'one group's solution becomes another group's problem' !

- A particular issue for urban groundwater development by municipal utilities has been a widespread failure to implement adequate wellhead protection zones and to identify and conserve recharge areas of the groundwater bodies on which their supply depends. Guides and protocols for such measures are now widely available but their implementation requires integrated action in cooperation with those attempting to control land-use and shape urban expansion.

Assessing Groundwater Availability and Use

- The availability of groundwater resources in Sub-Saharan Africa is constrained by hydrogeological setting and shows wide spatial variation – thus these resources tend to play different roles (and to offer different prospects) in urban water-supply according to the local conditions :
  - the vast majority of small-to-medium sized towns depend on groundwater for their municipal water-supply over a wide range of hydrogeological settings
  - some large cities are underlain by major aquifers which provide the principal source of both utility and private water-supply (eg. Lusaka, Ndola, Dodoma, Kano & Abidijan)
  - a few other major cities have deep aquifers in their vicinity which offer potential to become a major source of urban utility water-supply (eg. Addis Ababa (**Box F**), Dar-es-Salaam (**Box G**))
  - most megacities are underlain by relatively low-yielding aquifers, but these have become increasingly developed for water-supply by a range of users in response to past failures in the utility mains water-supply system (eg. Nairobi (**Box E**), Harare).

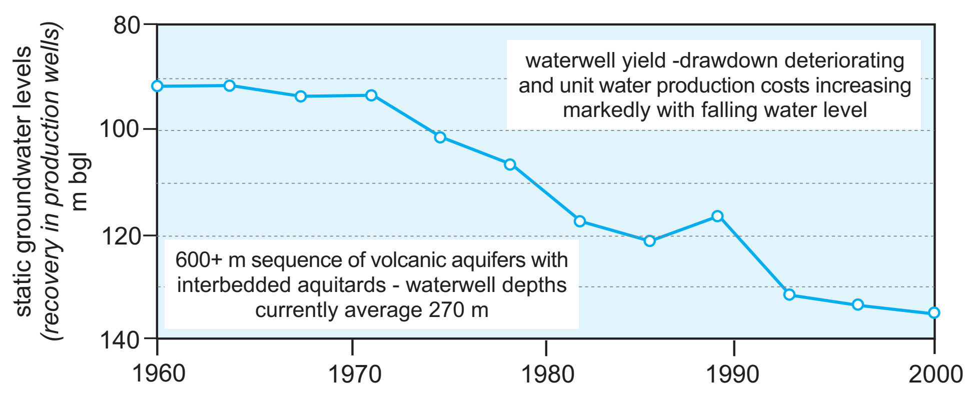
- In order to define realistic local management policy it is essential to understand groundwater use and users. Given the scarcity and dispersion of reliable data, it is far from a trivial task to establish the present level and current trends in groundwater use in the rapidly-urbanizing areas of Sub-Saharan Africa. The most comprehensive information available is contained in AICD Reports of 2007, on household access to and cost of infrastructure services, which is based on 63 large-scale surveys in 30 African countries. From scaling-up these surveys it is estimated regionally that approaching 80% of the urban population have access to an 'improved water source' – although this proportion may actually be declining in recent years due to very rapid urban population growth.

Box E
ROLE OF GROUNDWATER IN NAIROBI DURING WATER-SUPPLY EMERGENCY (2005)

The Nairobi City Council-Water Supply Department is responsible for municipal water-supply in Greater Nairobi – it used to operate waterwells for supplying certain sectors of the city but in 1990 these were closed, when surface water-supply sources in the Tana Basin rated at 520 Ml/d some 50 km distant were commissioned. However, both physical leakages and fiscal losses from the urban water distribution system are very high and it is not able to meet growing demand.

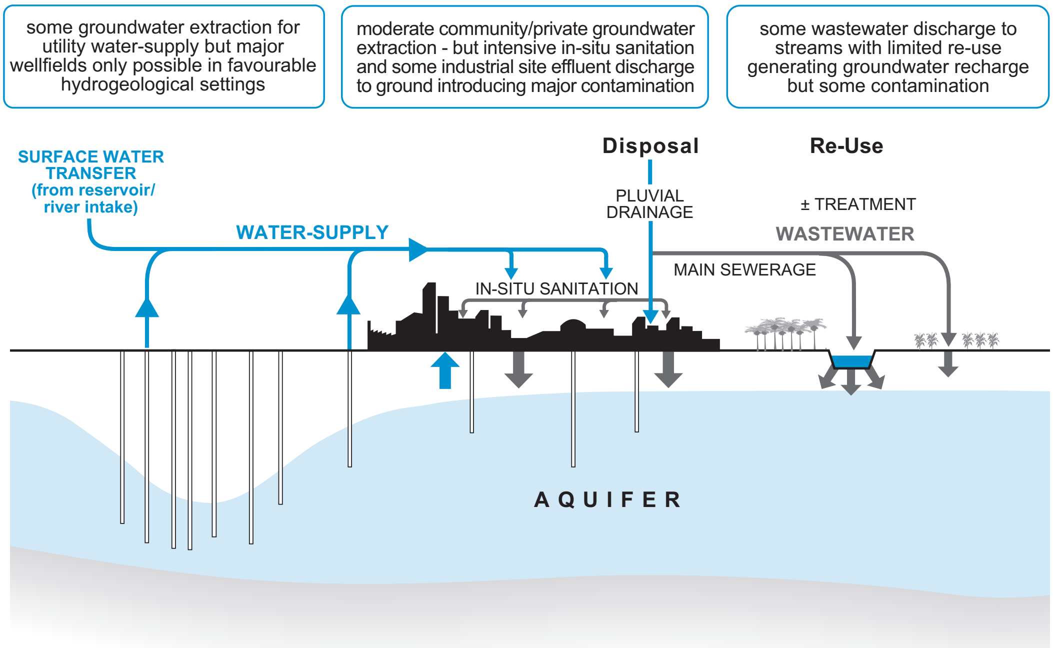
In 2002 a supply-mains failure (due to landslide not drought) further reduced water availability for urban users to under 200 Ml/d for some months. These circumstances led to the drilling of many private waterwells to depths of 200m and more into the underlying rift-valley volcanic deposits, and the capacity to produce about 300 Ml/d now exists. Most waterwells were constructed by large private consumers, such as industrial enterprises and hotel complexes – although their water-supply is often also sold to neighbors and/or to tanker distribution operators (who charge elevated prices).

Groundwater levels, however, have fallen by more than 40m since 1975 and are widely around 130 m bgl, with average abstraction now believed to be at around 85 Ml/d. This is considerably below installed capacity, because declining well yields and greatly increased pumping energy costs are resulting in urban users taking cheaper subsidized main water-supply first and using their waterwells as back-up. However, this still represents about 25% of the water-supply actually received by urban users (after deducting that lost in utility mains distribution). Thus groundwater continues to play an important role in city water-supply, but one whose management has been largely overlooked.



A World Bank–funded strategic assessment concluded that the aquifers underlying Greater Nairobi merit much more investment in monitoring, management and conservation in view of their proven capability as a reserve to help meet emergency situations, arising for the failure (or partial failure) of the municipal surface water sources and supply system. Very preliminary assessment suggests that overall current rates of groundwater abstraction (31 Mm^3/a) are not much higher than estimated average recharge (25 Mm^3/a), and that the declining groundwater levels are restricted to localized areas of more intensive usage and have had no secondary impacts.

Figure 5 : Groundwater and the city – an intimate but complex relationship



- The AICD Water Sector Review showed substantial variation between more and less urbanized countries (**Table 2**), and major differences between different income groups within any country – but the following general conclusions could be reached :
  - on average only 38% of the urban population are served by mains water-supply piped to their dwelling, but a further 29% do have access to a municipal stand-point within 500 m
  - 24% of urban water-supply is collected from waterwells (dugwells and boreholes but not all improved), constructed by the municipality, community or privately, and the balance is made-up by purchase from water vendors and collection from unsafe surface water.

- Stand-alone waterwells (tubewells, borewells and dugwells) thus constitute a major source of urban water-supply, and the predominant one in some large countries like Nigeria. Moreover, the data reveal that this type of source is currently the fastest growing, serving an additional 1.5%/year of the urban population – with various countries (Uganda, Nigeria, Lesotho, Mozambique, Malawi & Rwanda) recording much higher rates in the range of an additional 2.5-6.5 %/year. Stand-alone waterwells for domestic supply, however, do not constitute the only use of groundwater resources, since in some cases waterwells are also used to provide part of the municipal piped water-supply and in many others for reticulation to urban standposts.

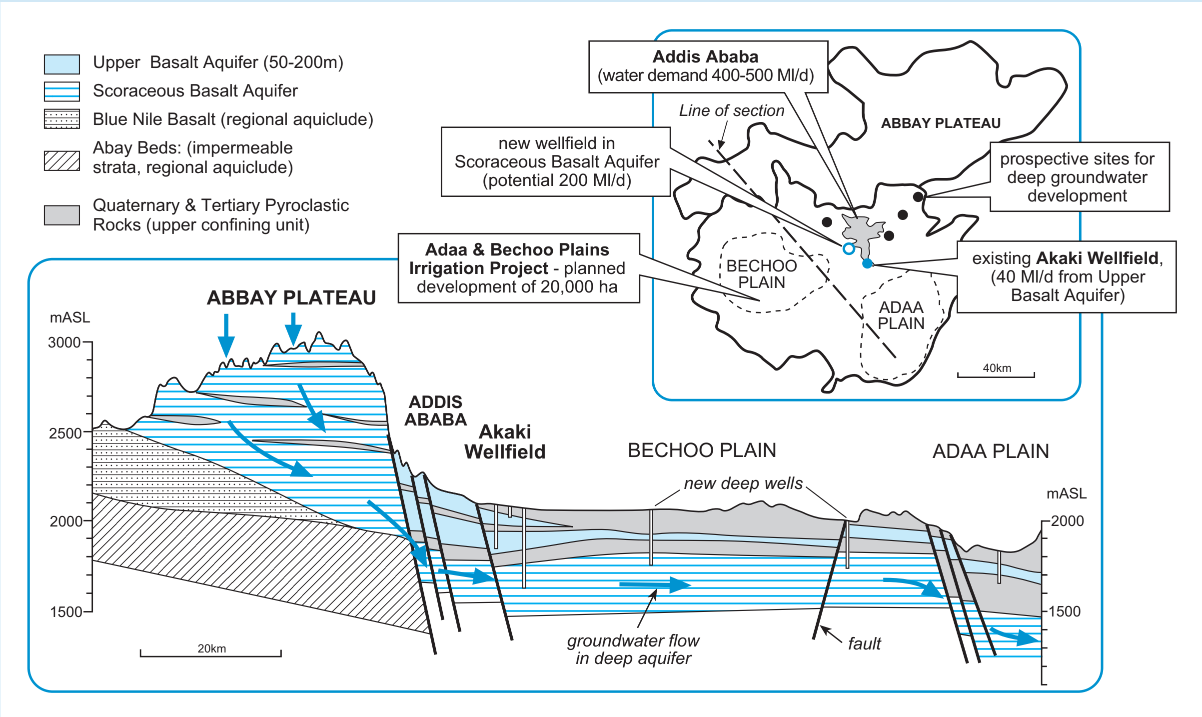
- Moreover, these figures reflect numbers of groundwater users but not volume of abstraction, and they do not consider other urban direct self-supply (commercial and industrial) users, most of which depend on groundwater. No inventory of urban groundwater dependence exists – but substantial public and/or private use is understood to occur in Lusaka, Ndola, Nairobi, Dar-es-Salaam, Addis Ababa, Kampala, Windhoek, Kano, Dodoma, Maputo, Dakar, Abidjan and probably elsewhere.

Box F

PLANNING OF DEEP GROUNDWATER DEVELOPMENT FOR GREATER ADDIS ABABA (2009)

The Addis Ababa Water & Sewerage Authority (AAWSA) faces a serious production shortage due to insufficient availability of water resources to cover the fast-growing demands of the city. The current production is 200 Ml/d from surface water sources and 40 Ml/d of groundwater from the Akaki wellfield in the Upper Basalt Aquifer (150-250m thick), which is only locally recharged and with no prospects for further sustainable expansion. There is urgent need for augmenting the AAWSA supply by at least 150 Ml/d.

A World Bank–supported reconnaissance study for the Adaa & Bechoo Plains Irrigation Project (20,000 ha) in 2006 revealed the presence of a deeper Scoraceous Basalt Aquifer (300-500m thick), which is recharged on the Abbay Plateau and has regional extension. Detailed investigations are being carried out around Akaki and a wellfield of 30 production wells is foreseen in this area with an expected capacity of 200 Ml/d.



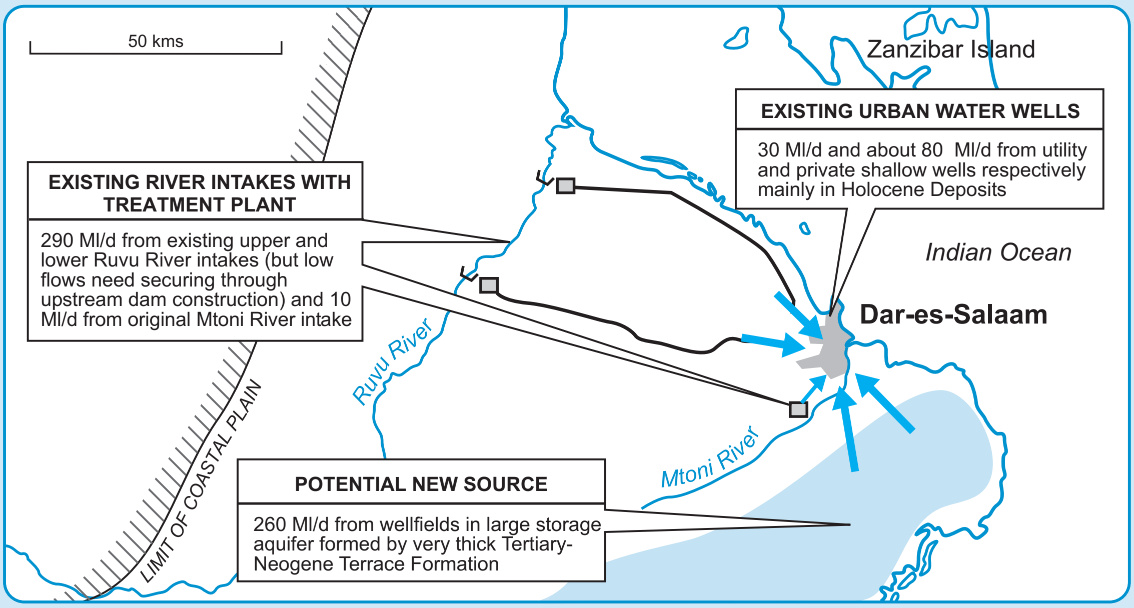
The implementation issues being encountered in expanding grondwater development are that few drilling companies have capacity and experience in drilling at 500+mm diameter to 500m depth – coupled with a lack of contractual standards and supervision ability. The new wellfield is located in the area of the Addis Ababa City Administration and in Oromia Regional State. The water will be allocated to AAWSA for planned irrigation projects in the Adaa & Bechoo Plains and for water-supply to nearby towns in Oromia. A water allocation plan will have to be developed along with joint management and monitoring procedures to cap long-term abstraction rates and preserve the recharge area –which will be achieved through a joint entity called Aquifer Management for Addis Ababa Region (AMAAR).

Box G

IMPROVING DAR-ES-SALAAM WATER-SUPPLY BY NEW MUNICIPAL WELLFIELD DEVELOPMENT (2010)

The Dar-es-Salaam autonomous municipal water-service utility (DAWASA) is responsible for the provision of water-supply to a conurbation with a rapidly-increasing population of more than 3.0 million. It has major intakes on the Ruvu River about 35 km distant, which are rated at almost 300 Ml/d, but threatened by baseflow reduction and sediment load in the upper part of the corresponding catchment. Municipal and private boreholes, mainly to depths of 30-60 m in Holocene alluvial deposits within and adjacent to the city itself, can provide in the order of a further 110 Ml/d – but the utility struggles to meet burgeoning demand especially during drought periods.

The groundwater resources within 50 km radius of the conurbation have only recently been subjected to systematic reconnaissance, with support the NORAD (Norwegian technical assistance) and the World Bank. This has led to the identification of an extensive and thick Tertiary-Neogene sedimentary 'coastal terrace' aquifer in an essentially rural area of low population density 30-60km south and south-east of the city. Limited pumping tests on trial production boreholes of moderate yield and short duration, suggest there is definite potential for the development of a supplementary water-supply of at least 250 Ml/d.



However, successful and sustainable development will require the efforts of DAWASA and the Ministry of Water Resources (through its local river basin agency) in a concerted effort to promote a coordinated action plan involving :

- systematically-staged wellfield development involving initial closely-monitored long-term trial pumping to supply, which should facilitate refinement of overall wellfield design (in terms of production borehole depth, design and separation), together with calibration of an aquifer numerical model to guide development, and evaluate the relationship between deep groundwater and the shallow water table, and assess risk the of coastal saline intrusion
- general land protection to avoid urban invasion and degradation of the aquifer recharge area, and also more localized and specific wellhead protection measures.

Provisional estimates for Nairobi, Dar-es-Salaam and Addis Ababa suggest that total groundwater abstraction in all cases exceeds 100 Ml/d, with private use amounting to 20-30% of total urban supply.

- In some cities of Sub-Saharan Africa the distribution of water by private-sector vendors (at differing scale from bottles to trucks) plays a significant role in urban areas, in terms of bulk-supply and/or the potable component (**Table 2**)– and as such has a special significance in the public-health sense. It is virtually impossible for local public-health authorities to inspect such operations on the basis of 'product quality control' and a much more pragmatic approach ought to be taken involving regular inspections of the suitability of groundwater sources used, their level of wellhead protection, and the process of water handling and distribution. Those that do not meet adequate sanitary standards must be explicitly banned from operation since otherwise they will represent a major public health hazard, especially given that their product is often assumed to be of potable standard.

Table 2 : AICD data on urban household water-supply in selected Sub-Saharan African countries

COUNTRY	WATER-SUPPLY SOURCE popln with piped supply	standpost access	collection from waterwells	water vendors
Burkina Faso	32%	52%	13%	1%
Ethiopia	52%	37%	6%	1%
Ghana	34%	38%	21%	3%
Nigeria	15%	17%	48%	11%
South Africa	88%	10%	2%	0%
Tanzania	22%	45%	19%	8%
Uganda	14%	47%	35%	2%

Sanitation Realities and Risks for Groundwater

- The AICD Water Sector Review revealed the following position as regards urban sanitation :
  - on average 65% of the population are dependent upon in-situ sanitation (mainly the basic pit latrine) and around 10% have no sanitation system whatsoever
  - while 25% of the population are recorded as having a 'flush toilet', some of these are in fact connected to septic tanks, and it is only in the larger cities of middle-income countries (and a few exceptions like Senegal) that waterborne sewerage systems exist, and even here not all dwellings in the nominal area of coverage will be connected.

- In most urban areas only a minor proportion of pit latrines are emptied (and contrary to operational guidelines sometime after construction most are connected to supplementary pits). This implies a very large subsurface contaminant load and threat of groundwater pollution, especially in situations of highly-populated areas underlain by shallow aquifers, as reflected in groundwater pollution studies from a recent UNEP-UNESCO-funded programme (**Table 3**) – the problem of high nitrate concentrations (coupled with other chemical contamination) and the hazard of fecal contamination from pit latrines having been first identified in the small towns of eastern Botswana over 25 years ago. The pollution load from unsewered sanitation will be variously augmented by industrial effluent disposal, hydrocarbon spillage/leakage and leachates from solid-waste tipping.

Table 3 : Summary of urban groundwater pollution case profiles in recent review

CITY/country (population)	HYDROGEOLOGICAL SETTING	LEVELS OF GROUNDWATER POLLUTION nitrate	fecal	other
HARARE Zimbabwe (1.4 million)	weathered crystalline basement in seasonally humid climate	levels widely above 100 mg/l in peri-urban areas	widely present and locally serious	low pH/elevated metals around industrial sites
OUGADOUGOU Burkina Faso (1.2 million)	weathered crystalline basement in semi-arid climate	50% borewells over 50 mg/l but dugwells more heavily contaminated	implied for dugwells but no systematic analysis	nothing major detected
DAKAR Senegal (2.8 million)	marine/aeolian sands and some basaltic flows with moderate seasonal rainfall	widely exceeding 50 mg/l and over 200 mg/l in some areas	50% of wells sampled, reflecting poor well completion	coastal saline intrusion also problem
MOMBASA Kenya (0.7 million)	marine/aeolian sands and limestones in humid tropical climate	30% wells significantly above 50 mg/l but few over 100 mg/l	widespread/serious, especially in densely-populated suburbs	no other problems reported
LUSAKA Zambia (1.2 million)	dolomitic limestones with significant karstic features and moderate seasonal rainfall	widely over 50 mg/l in dry season and exceeding 100 mg/l in some locations	widespread/serious but with marked seasonal variation	no other problems studied

(after Xu & Usher, 2006)

- The risk of fecal pollution of groundwater, however, could and should be limited to the most vulnerable hydrogeological conditions – but currently remains a more widespread problem because of inappropriate in-situ sanitation unit practices and inadequate waterwell sanitary completion. There is pressing need to develop and apply protocols for improved waterwell design and construction, and the operation of more 'groundwater-friendly' in-situ sanitation units (such as dry latrines).

Future Issues in Urban Infrastructure Development

- Groundwater resource development (in one shape or another) will widely represent the lowest-cost water-supply option, and thus (even accepting quality hazards) must always be considered as a potentially important component of future urban development. However, the appropriate type of waterwell, their yield potential, pumping lift and corresponding capital cost will vary widely (by more than an order-of-magnitude) with hydrogeological setting, and further variation may be introduced as a result of local market factors and equipment import levies. It will be such economic drivers that determine the type of development implemented and the actors involved. But the most-probable dominant trend will be expansion of low-cost facilities.

- **Coping with Escalating Small-Town Water-Supply Demand :** Innumerable small-to-medium sized towns do not have adequate hydrogeological data from the construction and operation of existing sources to soundly evaluate the scope for sustainable expansion. Moreover, urban population growth and the vulnerability of shallow waterwells and surficial aquifers to contamination (especially from high-density and/or inadequately-designed in-situ sanitation) are widely leading to the need to locate and develop waterwells with sufficiently large individual yields to support motorized pumps and supply reticulated water-distribution systems – but as a result of poor design, siting and/or maintenance many waterwells developed for small-town water-supply perform considerably below potential in terms of yield provided and/or energy consumed and/or experience pollution. Given the larger future investments that will be necessary, it is vital to put a concomitant effort into efficient waterwell design, local aquifer and wellhead protection (following the protocols for sanitary risk management, wellhead protection and capture area controls described in the GW•MATE Groundwater Quality Protection Guide). This, coupled with much improved groundwater source and aquifer monitoring, will provide a logical basis for designing periodic expansion of municipal water services in years to come.

- **Improving the Security of City Water-Supply :** In a substantial number of cities groundwater is critical to the continuity of the existing water-supply – playing a key strategic role during drought or emergency and an important supplementary role at other times. The main issues and needs in respect of groundwater use for small town water-supply are replicated and multiplied in the larger urban centers. In particular wastewater infiltration (by one route or other) is a growing concern for groundwater quality, and thus aquifer/wellhead protection and improved wastewater management are complementary activities of high priority. A supplementary concern in coastal cities is the susceptiblity of aquifers to saline intrusion when developed without adequate control. In a few cases groundwater use has evolved as part of planned urban water-supply development, but more often it has occurred anarchically in both the public and private sectors in response to water shortage and/or service deficiency – and little formalized conjunctive management of surface water and groundwater is practiced even in areas which are drought prone and water stressed. Where the hydrogeological setting is favorable there may be potential for major new groundwater resources to be developed through wellfield construction in the hinterland of important cities (**Box F & G**) – this has the important attraction of providing access to large natural storage reserves which can act as a 'buffer' in adaptation to climate change. The development of such groundwater resources will require substantial investments, with a systematic approach including stepwise investigation, phased monitored development and concomitant action to preserve recharge areas.

- **Potential Growth of Private In-Situ Domestic Self-Supply :** Waterwell construction costs have tended (incidentally) to moderate the pressure on available groundwater resources from private waterwell construction – but sooner or later, with urban economic development demand for direct self-supply from groundwater by residential, commercial and industrial users, is likely to grow substantially (even in hydrogeological settings offering prospect of only relatively small yields). Moreover, the situation could change rapidly in some countries, if financial support is secured to stimulate private-sector waterwell drilling, and revised standards encourage the use of low-cost waterwell designs and lighter lower-cost drilling equipment. At present waterwell construction costs are high compared to Latin America and South Asia (**Box A**) – but in both these regions private direct-supply from groundwater has mushroomed in many cities, given modest underlying aquifers and relatively inexpensive drilling services. Such large-scale private in-situ groundwater use, almost regardless of quality considerations :
  - has usually been initiated as a 'coping strategy' during times of inadequate municipal utility provision
  - continues as a 'cost alleviation device' (given the 'sunk capital') to avoid paying the higher tariffs of municipal utility services when these are augmented with new costly 'imported water' sources.

- Tools should be developed to facilitate more informed and ordered development of groundwater resources in urban areas and to reduce the risk associated with private investment in groundwater

development. These relate respectively to groundwater availability and use :
- maps of waterwell yield potential and reliability, depth to main aquifer horizons, static groundwater levels (as partial indicator of pumping lift), groundwater pollution vulnerability and natural quality hazards
- order-of-magnitude assessment of the status of groundwater resource abstraction, levels of sustainability and seriousness of risks associated with persistent excessive abstraction
- disseminating protocols requiring rain-water harvesting from roof-top and paved areas with enhancement of aquifer recharge through soakaways and avoiding unnecessary soil compaction in the urban environment at individual plot level.

- Since the demand for self-supply from groundwater by residential, commercial and industrial users is likely to grow substantially, there is need to identify more pragmatic ways of 'living with' urban quality deterioration problems through :
  - providing guidelines on private groundwater use precautions related to quality hazards and incentives for logical use (such as domestic toilet flushing, laundry, amenity irrigation, non-sensitive industries, cooling water, etc)
  - being aware of potential long-term operational and financial problems created by large-scale residential in-situ self-supply, and the potential public health hazard in highly vulnerable aquifers
  - considering measures to reduce subsurface contaminant load (especially regular emptying of existing in-situ sanitation facilities, introducing dry or eco-sanitation units, prioritizing mains sewerage in areas of high aquifer pollution vulnerability and/or industrial effluent generation).

  Moreover, in the longer run it will always be beneficial to register private waterwells and to improve urban waterwell sanitary completion and wellhead protection.

SOCIOPOLITICAL DIMENSIONS OF GROUNDWATER MANAGEMENT
(< The Institutional Response >)

- The emerging developmental agenda in Sub-Saharan Africa will require much greater emphasis on strategic assessment and investment planning for groundwater resources to mediate their managed development in urban water-supply at various scales and for trying to promote sustainable irrigated agriculture, in addition to the continuing need to improve the efficiency of groundwater exploitation for rural water-supply and village enterprises. Responding to this 'new agenda' will require significant strengthening, evolution and, in some cases, reform of the institutional framework for groundwater governance. In the longer run it will also require achieving a sensible (and in some cases delicate) balance between :
  - providing an enabling framework for (and in some cases promoting) much needed 'managed development of groundwater', whilst,
  - regulating groundwater abstraction and potentially-polluting activities to avoid excessive resource exploitation and subsurface contaminant pressure in critical areas.

- Moreover, in many countries, the institutional landscape into which groundwater resource development, management and protection has to be accommodated is also undergoing substantial change as the result of a general trend for decentralization, with the formation of river-basin boards and/or agencies primarily to address 'upstream-downstream issues' of major river systems. This represents both an important opportunity and a significant complication for groundwater governance. Over 60 such boards and/or agencies have been formed, or are in the process of formation, in the SADC Region alone – although only a minority of these have, as yet, significant on-the-ground operational capacity and/or actively include groundwater management and protection.

- The integration of groundwater resources into national policy, so that they can make an appropriate and effective contribution to economic development plans (focusing on issues like food security, urban services and rural livelihoods) requires developing an adequate cross-sector policy dialogue within government. This, and accommodating the particular needs of groundwater within the river-basin board/agency structure, makes it absolutely essential for political awareness of groundwater at the highest level. Thus the SADC initiative for political awareness of the importance of groundwater and the need for investment in its sound governance (to which GW•MATE has made a substantial contribution) (**Box H**), and more broadly the formation of the AMCOW Groundwater Commission, are very welcome steps in this direction.

Defining and Strengthening the Essential Roles of Government

- Broad international consensus now exists that the primary government function must be to act on behalf of civil society as 'custodian', 'guardian' or 'trustee' of renewable natural resources like groundwater, and that the related legislation should be flexible, enabling and enforceable. The essential roles of government are thus best defined in terms of certain fundamental concepts, responsibilities and powers (with the detail being handled as and where appropriate through associated regulations and implementation plans) :
  - **Catchment/Aquifer-Level Resource Planning and Allocation :** establishing sensible boundaries for groundwater management, translating national plans to the appropriate territorial level, providing the general allocation of resource use (including a unified vision of groundwater and surface water) and being in a position to interact on transboundary groundwater issues locally as they arise
  - **Land Surface Zoning for Groundwater Conservation and/or Protection :** making provision for declaration of 'special control areas', critical in resource terms or especially vulnerable in pollution terms, where exceptional measures are necessary to avoid serious resource degradation
  - **Facilitating Stakeholder Participation and Engagement :** since active involvement of groundwater users and potential polluters, and other interest groups, will be necessary to promote balanced development on-the-ground, including elaboration and enforcement of implementable regulations
  - **Administration of Groundwater Use :** according to an over arching allocation plan, including well drilling/construction activity, waterwell registers and abstraction rights/permits (where appropriate and with possibility of resource charging), together with effective sanctions for non-compliance
  - **Licensing of Wastewater & Waste Discharging to Ground :** subject to conditions that prevent or limit groundwater pollution, with effective sanctions for non-compliance
  - **Groundwater Monitoring and Information Provision :** ensuring an appropriate standard of monitoring (aquifer water-levels, groundwater use and quality), together with the periodic evaluation of resource status based on full exchange of data and open provision of information.

  It is, however, much more questionable whether government agencies should retain in-house capacity for waterwell and exploratory drilling, except where exceptional circumstances clearly justify.

- A GW•MATE review of national legal provisions for groundwater (in the SADC countries) indicates that the majority already had most of the above concepts, responsibilities and powers embodied in their legislative framework. However, the institutional capacity required to implement such provisions at local level is rarely achieved because of :
  - serious lack of experienced or well-trained staff in government agencies (and perhaps more generally)
  - inadequate budgets for fundamental activities like waterwell registration and groundwater monitoring
  - insufficient attention to priority setting so as to concentrate on the most critical issues and to create an 'enabling environment' for management with relevant stakeholders.

- Groundwater is essentially a 'local resource' (when it comes to use and protection), and to be effective its day-to-day management has to take place close to its users and potential polluters. There is thus a need for locally-based offices of the responsible government agency – and the existence of local sub-catchment or district water resource offices makes this possible (**Figure 6**), whilst avoiding potential conflicts of interest that can arise if this function is entirely delegated to provincial government.

- However, when it comes to groundwater, decentralization also poses major concerns as regards 'critical professional mass' and 'experienced leadership' – and pragmatic compromises will often be necessary to get the organizational balance right. Local action to manage groundwater will always require some 'top-down' direction to provide an effective technical and economic basis for management, empowerment to take necessary action and an 'overview capacity' to review progress towards agreed objectives – thus a strong national focal-point will be essential. There is also evidence from the SADC Region that decentralization has resulted in a reduced long-term effort and commitment to field monitoring and data archiving, which is especially critical to improving the understanding and management of groundwater resources. Thus it will be important to entrust overall management of the collection, archiving, collation and dissemination of hydrogeological data to a 'dedicated national centre', linked to the decentralized system of groundwater administration.

Building Professional Capacity and the Knowledge Base

- Investment in groundwater development alone is not enough, since both capable expertise and reliable information are required to avoid funds being wasted on constructing unsuccessful or unreliable waterwells, or promoting major unsustainable development. In government offices professional expertise on how to evaluate, develop and manage groundwater appears to have declined in some parts of Sub-Saharan Africa since the 1980s, due to lack of appropriate training, poor professional recognition, organizational change and reductions in public expenditure.

- Existing professional capacity needs to be used more effectively and major efforts made to build additional capacity (incorporating appropriate skills to address the 'new agenda'). Some key requirements in this regard are :
  - continued 'training-the-trainers' on managed groundwater development, as initiated by UNDP-CapNet and AGW-Net, with support of GW•MATE (**Box J**), and 'south-north partnerships' of international associations (like the IAH-Africa Burdon Network) to complement and enhance the provision of national and sub-regional training
  - commissioning 'post-case evaluation' of groundwater development schemes on a routine basis – learning from experience and evolving best-practice standards appropriate to local conditions

Box H (2009)
SADC 'GROUNDWATER MATTERS' POLITICAL AWARENESS INITIATIVE

Managed groundwater resource development will have to be given much higher priority and greater investment if most countries in Sub-Saharan Africa are to have any chance of achieving the UN-Millennium Development Goals, since groundwater represents the only economically-realistic option for improving both rural and urban water-services. Despite the obvious need for, and publicity given to, improving water-supply standards, national funding for groundwater exploration, evaluation, development and management is not necessarily increasing, and in some cases may actually be decreasing, especially now that some international donors have moved to block-funding of 'central budget support' (rather than providing finance for specific water resource and water-supply projects). Since there is usually no 'strong voice' for groundwater in the definition of government priorities, such funds are often channelled into other priorities.

There is thus an urgent need to improve awareness at the national political and policy level of the potential, status and dynamics of groundwater resources, their existing and future significance in socioeconomic terms, the institutional framework required to provide for their sound governance, and related investments needed in qualified personnel and monitoring networks. Too often these requirements are not met in full – for example where a regulatory framework exists, enforcement may be restricted by lack of political support and/or insufficient professional and sub-professional manpower and/or inadequate investment in monitoring installations. Furthermore, awareness raising at the political and decision-making level is critical for the integration of groundwater considerations into national planning (in the different line ministries including finance) to facilitate the budgeting of government funds for groundwater management.

It is thus very important to develop effective communication materials which explain groundwater in 'political language'. In the SADC-GEF Groundwater & Drought Management Program (supervised by the World Bank and advised by GW•MATE), a political primer (4 pages of A5-size) has been published and disseminated, which aims to convey key groundwater messages to senior politicians under the title Groundwater 'Matters'. Its content was selected through interviews with a number of SADC parliamentarians, and one outcome of these interviews was that the primer should not contain any cartoons !

- What is groundwater?
- Why care about groundwater?
- Why does groundwater need management?
- What is the decision maker's role in groundwater management?
- Is groundwater the poor nephew of surface water?
- Key messages and facts about groundwater (including its role in reaching the MDG's)
- Groundwater use in SADC Member States: (a one line statement for each country)

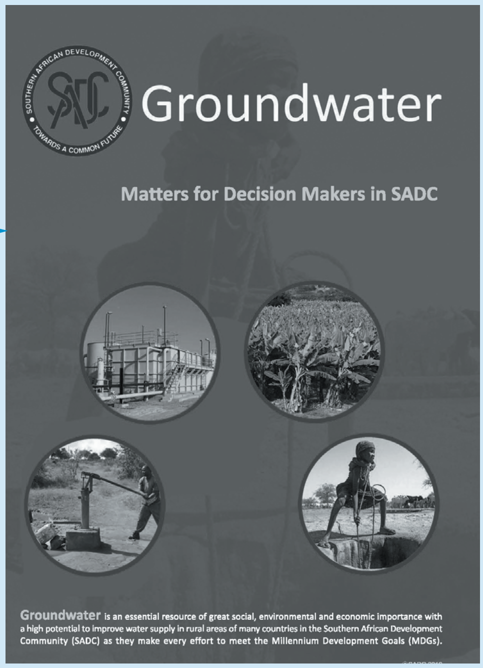
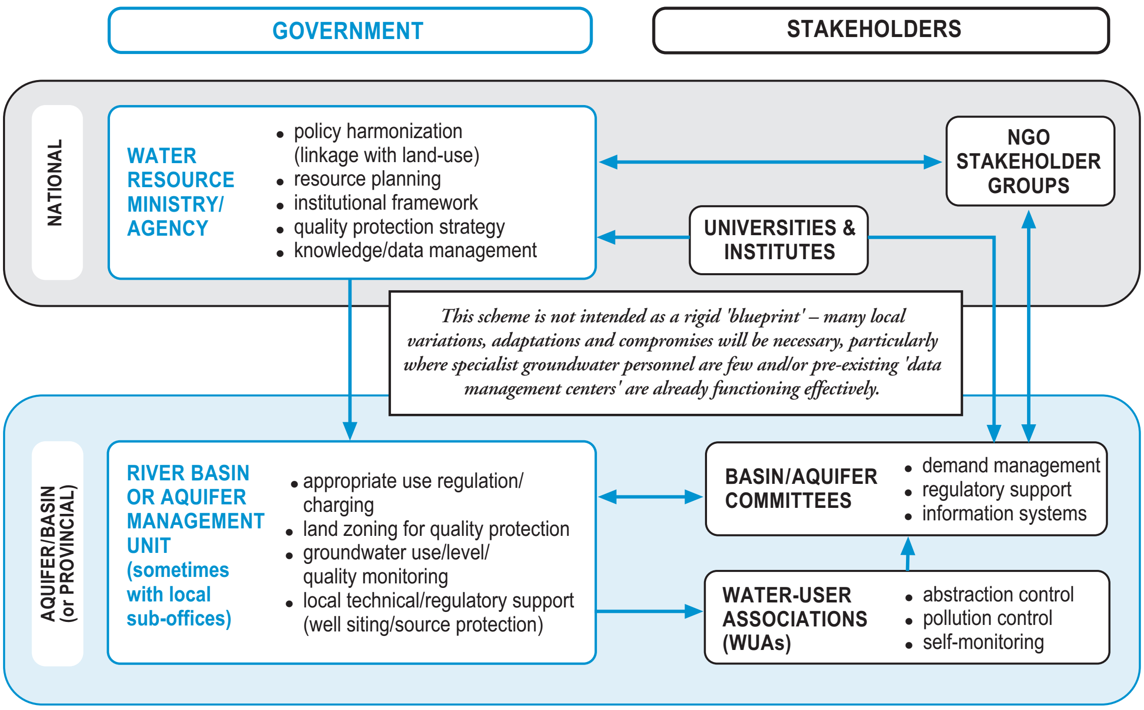


Figure 6 : General decentralized institutional scheme for groundwater governance



- investing nationally and sub-regionally in applied issue-oriented research – in an attempt to connect the academic sector more directly with pressing issues of stakeholder concern about groundwater development and resource management.

Stimulating Successful Private-Sector Participation

- A strong private sector is integral to promoting managed groundwater development, and needs to consistently provide both quality contracting services in waterwell siting, construction and maintenance (at whatever scale and for whichever purpose) and competent professional consultancy services in the surveying, evaluation and monitoring of groundwater. In many African countries this sector is still in its infancy, and there are shortages of both quality drilling contractors and consultancy services, leading to high unit cost and/or poor service. It must be stressed, however, that inherent weaknesses in the procurement of private-sector services can both constrain their effectiveness and impede capacity development. In Uganda, for instance, a major obstacle to improved performance has resulted from :
  - waterwell siting being contracted independently from waterwell construction with payment dependent on successful completion – implying that reputable drilling contractors may have in effect 'to pay the price' of inadequate siting surveys
  - failure to recognise that the best work (especially in difficult hydrogeological conditions) is likely to occur in 'rolling programs' with a degree of learning and adaptation on-the-job.

- Investment programs in groundwater development present important opportunities to strengthen the private-sector in this facet of public works provision, as well as experimenting with the introduction of promising new techniques. By providing training support and financial incentives

Box J
THE AGW-NET INITIATIVE FOR CAPACITY BUILDING AND INFORMATION SHARING

Professional expertise on how to evaluate, develop and manage groundwater appeared to be declining in many parts of Sub-Saharan Africa (especially in government offices) due to lack of appropriate training, poor recognition of groundwater professionals, reduction in public spending, disbanding of some national agencies etc. Significant efforts are required to build new capacity through the provision of training at various levels within the region.

Some encouraging developments have been promoted to consolidate groundwater knowledge and strengthen information sharing. The African Groundwater Network (http://agw-net.org) was established in 2008 to increase awareness of the value of groundwater and contribute to capacity building in the groundwater sector, including management at all levels. AGW-Net functions under UNDP Cap-Net (www.cap-net.org) and has over 100 members from all over the African continent and links with the new African Groundwater Commission (AGWC) established by AMCOW and the new SADC Groundwater Management Institute (GMI) established under the SADC-GEF Groundwater & Drought Management Program.

One of the outputs of the AGW-NET, in cooperation with UNDP Cap-Net and GW•MATE was the development during 2009-10 of a Training-the-Trainers Manual on Groundwater Management in IWRM. The manual was prepared by AGW-Net using GW•MATE Briefing Notes as base material. The manual was tested and used in a series of training courses held in Accra, Dar-es-Salaam, Addis Ababa and Pretoria.

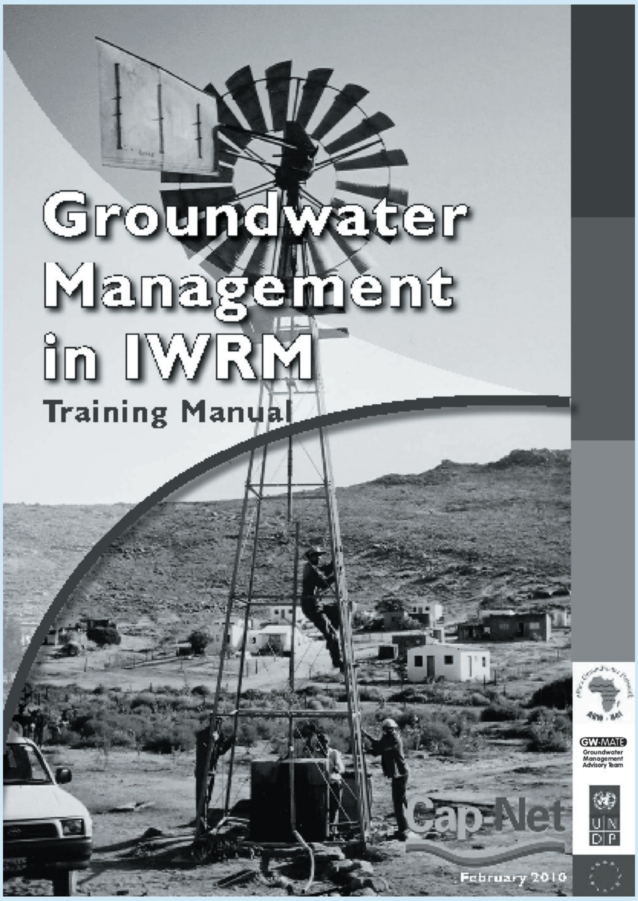


TABLE OF CONTENTS

each module includes references, web reading and exercises through appropriate contract structuring, the stimulation of a healthy private groundwater service sector is possible, and in this way the technological basis for groundwater development in other sub-sectors (urban water-supply and irrigated agriculture) can be indirectly promoted.

- There are several other measures that can also readily be taken in this regard :
  - improving waterwell contract management and supervision so as to eliminate unjustified liability for yield or quality failure
  - amplifying contract time-frames to improve drilling rig productivity and provide stronger incentives for technologically-sound long-term engagement
  - issuing clear work guidelines and realistic time schedules, which can go a long way to avoiding counterproductive disputes which frustrate all parties involved
  - introducing fiscal incentives (such as tax waivers) for purchase of essential waterwell equipment
  - providing educational programs in the area of waterwell drilling supervision.

  The promotion nationally of a 'waterwell trade association' and a 'professional groundwater group' is also very helpful in this context, since both can serve as a 'structured interface' for interaction between government and the private sector.

Promoting Coordinated Urban Groundwater Management

- Urban groundwater tends to affect everyone – but all too often is the clear responsibility of no one! It is evident that in virtually all cases more effort needs to go into the development of appropriate policies for urban groundwater and on evaluating, managing and protecting the groundwater resource – and for this it will be essential to understand the dynamics of present and future use.

- Given the critical role that groundwater plays, or can play, in the water-supply security of many African cities (even in those cases where most of its development has been under private, rather than municipal, initiative) there is an urgent need for strategic (hydrogeologic and socioeconomic) assessment of its current utilisation for water-supply provision and for implementing the management actions needed to ensure future availability and greater integration with surface water-supply. In all such cases an appraisal of groundwater recharge, storage potential and pollution risk will be needed.

- And given the special conditions in fast-growing urban centres this will normally require an integrated effort involving a consortium (or standing committee) of empowered representatives from the water resource regulator (where such exists), the water-supply service utility, the public-health authority and the municipal land-use planning agency. This consortium would benefit from a mechanism for community consultation and the work of a technical support group to investigate and report back on specific issues and potential conflicts.

Focusing and Prioritizing Resource Management Action

- Whilst Sub-Saharan Africa is a long way from experiencing the 'classic problems' associated with excessive groundwater development on a widespread basis, and the need for conventional groundwater resource management is limited to a few 'hotspots', many countries need to address some specific challenges such as :
  - realistic planning, sustainable utilization and effective protection of groundwater resources (often

in minor aquifers) to promote sustainable groundwater irrigation where feasible and confront the urban water-supply challenge, and thereby meet specific social welfare targets and create livelihood opportunities
- dealing with the realities of groundwater resource use at small-scale for rural water-supply over extensive areas, which requires cost-effective waterwell drilling and investing in data collection and information processing to make this possible
- mobilizing communities to value, maintain and protect their groundwater sources, supporting them with budgetry provision and appropriate local guidelines and regulations.

Addressing these challenges will require a number of parallel responses including promoting awareness of the potential and status of groundwater resources, improving the understanding of groundwater dynamics, promulgating appropriate local regulations under the current legislative framework, and investing in adequate monitoring of groundwater. At present these requirement are seldom met in full.

- Conscious of the need to focus and prioritize government actions on 'managed groundwater development' through structured interaction with stakeholders, GW•MATE has developed a pragmatic framework as a tool for policy analysis and definition of development and management plans (**Boxes K**) – including identification of the required investments and of clear institutional responsibility. Once elaborated at national level the framework can then also serve as a reference for application at the more local level of the river basin or aquifer system. A most important aspect of the application of this framework is its use to formulate a limited number of priority actions endorsed by systematic interactive consultation with the main stakeholders.

- The framework has been successfully applied in Sub-Saharan Africa at different levels :
  - in Uganda to define priority actions as part of the national water resources strategy (**Box K**)
  - in Ethiopia at national level and for some States (Oromia, Amhara and Tigray) and for the groundwater bodies in Greater Addis Abba (**Box L**)
  - for the SADC Region in workshop with senior groundwater experts from 12 Member States to define priority management issues and provide a baseline for the formulation of national groundwater development and management frameworks.

- **Taking steps towards the managed development of groundwater resources in Sub-Saharan Africa will contribute greatly to improving human welfare and economic development. The GW•MATE pragmatic framework for managed groundwater development provides a practical approach for deciding on cost-effective and sustainable investment in groundwater development, based on a systematic approach and realistic targets. The 'framework process' should also contribute to better communication between stakeholders and governments, provide a platform to discuss resource allocation issues, and generate a demand for improved for information and monitoring of groundwater.**

Box K

POSITIONING GROUNDWATER IN THE NATIONAL WATER RESOURCES STRATEGY OF UGANDA (2010)

The World Bank was invited by the Government of Uganda to engage with the water sector to develop a national water resources strategy as the basis for defining future loan finance – and GW•MATE supported the elaboration of the groundwater component. Previously a number of studies had been commissioned which provided a rich overview of national water issues, but gave few insights into possible action plans.

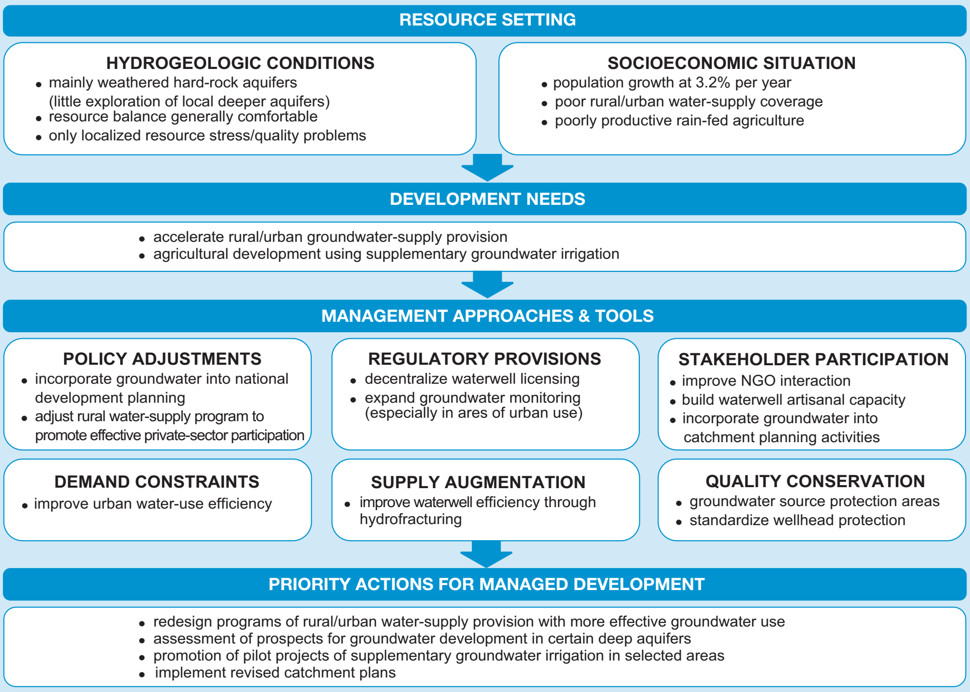
The GW•MATE Pragmatic Framework for Managed Groundwater Development was used to structure the dialogue to establish a priority action plan – it consisted of three sections :

- an assessment of the setting of key groundwater resources, in terms of hydrogeological conditions and socio economic situation, which tend to both define the groundwater problem and constrain its solution
- an appraisal of possible management instruments that might be used to address the groundwater issues identified
- the integration of both the first two sections to identify a priority action plan.

In essence the pragmatic framework is a tool, which if used interactively, facilitates the relatively rapid elaboration of a consistent and comprehensive strategy for managed groundwater development.

Dialogue was staged in the following way : (1) a fact-finding phase involving the MWE-Directorate of Water Resources Management-Department of Water Resource Regulation, the main organization concerned with groundwater management nationally, from which a draft framework resulted, (2) a review phase involving a meeting with the main stakeholders, when the framework was fine-tuned until factually correct, and the 'action plan' discussed and modified by all involved with the following agreed priorities :

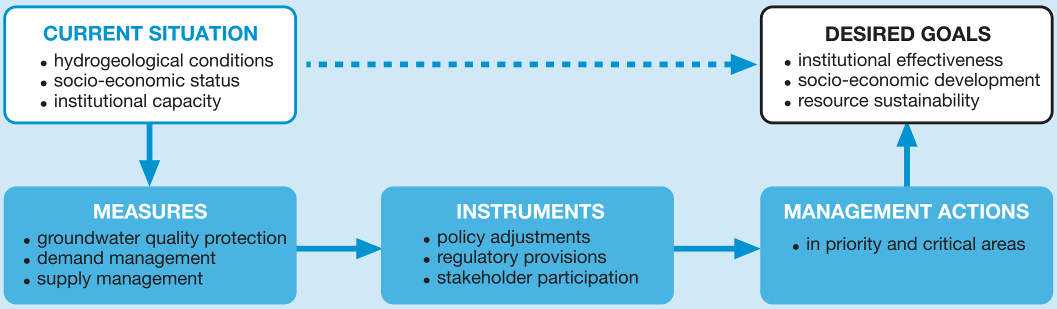
- accelerating rural and urban water-supply provision through strengthening the capacity of the water-service sector
- promoting groundwater use in agricultural development plans in two selected (low-lying) areas
- developing water-resource catchment plans that include detailed consideration of groundwater
- continuing groundwater resource assessment, especially for the deeper aquifers.



Box L
A STRATEGIC FRAMEWORK FOR MANAGED GROUNDWATER DEVELOPMENT IN ETHIOPIA (2010)

The identification of priority management needs and elaboration of a pragmatic action plan to address them is a critical need to allow effective groundwater resource governance. The GW•MATE Pragmatic Framework for Managed Groundwater Development is a valuable tool in this context, which was used an interactive way with the principal stakeholders in Ethiopia. After agreeing on the setting (hydrogeological conditions and socio-economic situation) of specific groundwater bodies, stakeholders were asked to identify appropriate management measures and to agree on priority action plans.

At national level a priority action plan was defined and has now been published by the Ministry of Water & Energy. The plan centres upon identification of groundwater bodies at risk of irreversible degradation, investment required on supply-side and demand-side interventions, and the necessary institutional and regulatory framework to implement them. This national framework would then form a reference for more detailed action plans at provincial or river-basin level.



In Ethiopia the pragmatic framework was utilized at the national level and in five areas – Oromia, SNNPR, Amhara, Tigray and Greater Addis Ababa. The following national priority actions were agreed :

- introduction of managed groundwater development in priority areas
- accelerated professional capacity development and institutional strengthening
- linkage of groundwater resources into national development plans
- standardization of waterwell construction and supervision procedures.

For Greater Addis Ababa the outcome of stakeholder dialogue using the pragmatic framework was agreement on the following actions :

- strengthening and empowerment of water resource regulatory agencies (Addis Ababa Environment Agency and Oromia Water Resources Bureau)
- improvement of groundwater awareness amongst of major stakeholders and political decision makers
- improving groundwater monitoring and information exchange, relating particularly to waterwell abstraction rates, aquifer response and pollution threats and their control
- reduction of water losses and unaccounted-for water through a municipal water-conservation campaign.

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