FINAL REPORT (Draft):
KENYA GROUNDWATER GOVERNANCE CASE STUDY

It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them. (Nicolo Machiavelli, The Prince [1515])

I know many countries where people value water. I hasten to say that there is no country which has developed without making proper use of water. (The Hon. Jakoyo Midiwo (Gem, ODM), speaking in Parliament on 21st January 2009)

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KENYA GROUNDWATER GOVERNANCE CASE STUDY

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<td>ASALs</td>
<td>Arid and Semi-Arid Lands</td>
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<tr>
<td>AWSB</td>
<td>Athi Water Services Board</td>
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<tr>
<td>BCM</td>
<td>Billion cubic metres (hence BCM/yr)</td>
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<td>BHN</td>
<td>Basic human needs</td>
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<td>BGS</td>
<td>British Geological Survey</td>
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<td>CAACs</td>
<td>Catchment Area Advisory Committees</td>
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<td>CCN</td>
<td>City Council of Nairobi</td>
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<td>CMS</td>
<td>Catchment Management Strategy</td>
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<td>CoPs</td>
<td>Codes of Practice (for groundwater)</td>
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<td>Case Study Aquifer</td>
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<td>CSAMT</td>
<td>controlled source audio magnetotellurics (geophysical method)</td>
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<td>CSOs</td>
<td>Civil society organisations</td>
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<td>CTL</td>
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<td>CWSB</td>
<td>Coast Water Services Board</td>
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<td>DHTV</td>
<td>downhole television camera</td>
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<td>DRASTIC</td>
<td>Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone media, hydraulic Conductivity of aquifer</td>
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<tr>
<td>EC{25}</td>
<td>electrical conductivity (as µS/cm)</td>
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<td>Environmental Impact Assessment</td>
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<td>El Niño/Southern Oscillation</td>
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<td>fluoride</td>
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<td>Groundwater-Dependant Ecosystems</td>
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<td>Groundwater confinement, Overlying strata, Depth to groundwater</td>
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<td>GRACE</td>
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<td>Groundwater Resources Assessment under the Pressures of Humanity and Climate Change</td>
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<td>GWO</td>
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<td>International Association of Hydrogeologists</td>
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<td>IGRAC</td>
<td>International Groundwater Resources Assessment Centre</td>
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<td>IHP</td>
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<td>ILEC</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>ITC</td>
<td>International Institute of Aerospace Survey &amp; Earth Sciences, Enschede, The Netherlands</td>
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<td>IWRM</td>
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<td>IWRM &amp; WE Plan</td>
<td>Integrated Water Resources Management &amp; Water Efficiency Plan</td>
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<td>JICA</td>
<td>Japan International Cooperation Agency</td>
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<td>k</td>
<td>hydraulic conductivity (m/d)</td>
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<td>KCC</td>
<td>Kwale County Council</td>
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<td>Kenya Bureau of Standards</td>
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<tr>
<td>m</td>
<td>Metre</td>
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<tr>
<td>m bgl</td>
<td>Metres below ground level</td>
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<td>MAR</td>
<td>managed aquifer recharge</td>
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<td>MCM</td>
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<tr>
<td>mg/l</td>
<td>milligrammes per litre</td>
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<td>mm</td>
<td>millimetre</td>
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<tr>
<td>MLD</td>
<td>megalitres per day (1 megalitre is 1,000 cubic metres)</td>
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<td>ppm</td>
<td>parts per million</td>
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<td>Sub-Catchment Management Plan</td>
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<td>SEI</td>
<td>Stockholm Environmental Institute</td>
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<td>SKM</td>
<td>Sinclair Knight Merz (2009 groundwater and climate change report)</td>
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<td>Stakeholder Relations Officer</td>
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<td>SWIM</td>
<td>Saltwater Intrusion Meeting</td>
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<tr>
<td>$S_y$</td>
<td>specific yield (dimensionless) in an unconfined aquifer</td>
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<tr>
<td>$T$</td>
<td>transmissivity (m$^2$/d)</td>
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<td>TDS</td>
<td>total dissolved solids (mg/l or ppm)</td>
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<td>TI</td>
<td>Transparency International</td>
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<td>ToT</td>
<td>Times of Travel (of water from a possible pollution source to a borehole)</td>
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<td>TPZ</td>
<td>Total Protection Zone (of a groundwater resource)</td>
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<td>United Nations</td>
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<td>United Nations Environment Programme</td>
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<td>UNESCO</td>
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<td>$US$</td>
<td>United States dollar ($1 ≈ KShs. 80)</td>
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</tr>
<tr>
<td>WASREB</td>
<td>Water Services Regulatory Board</td>
</tr>
<tr>
<td>WRM</td>
<td>water resources management</td>
</tr>
<tr>
<td>WRMA</td>
<td>Water Resources Management Authority</td>
</tr>
<tr>
<td>WRUA</td>
<td>Water Resources Users Association</td>
</tr>
<tr>
<td>WSB</td>
<td>Water Service Board</td>
</tr>
<tr>
<td>WSP</td>
<td>Water Service Provider</td>
</tr>
<tr>
<td>WUA</td>
<td>Water Users Association</td>
</tr>
<tr>
<td>yr</td>
<td>Year</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS AND CONTRIBUTIONS

This report was prepared as part of the World Bank Group’s economic and sector analysis (ESW) on “Improving groundwater governance: The political economy of groundwater policy and institutional reforms”. However, the report describes a study of groundwater governance solely in the Kenya context; it was prepared by Professors Albert Mumma and Edward Kairu, and Mr Mike Lane.

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Last but by no means least, our thanks go to Dr. Dan Olago; in addition to his role as Workshop Facilitator, Dr. Olago has been of great help in describing training capacity and needs for the groundwater sector; and as the Chairman of the Geological Society of Kenya he has, perhaps unwittingly, contributed to this study on a broader, cross-sectoral level.
SECTION I: CHARACTERISTICS AND USE OF GROUNDWATER

1 Groundwater: a common pool resource

1.1 Introduction

In the year 2010 the world faces enormous challenges in meeting human and ecological needs for water. Population growth, urbanisation and rising standards of living across the globe put water resources under increasing stress, while at the same time catchment degradation and poor waste management reduce freshwater availability. Further uncertainty is imposed by climate change.

Global annual precipitation is 577,000 km$^3$/yr; 79% of this rain falls on the oceans, 2% on lakes and 19% on land. The vast proportion of what falls on land is lost to evaporation or runoff, leaving only 2,200 km$^3$ (2%) to percolate into the groundwater store (Shiklomanov 2002). However, when aquifer storage is taken into account, groundwater still makes up 97% of global freshwater (excluding ice), and is the most intensively-exploited natural material in the world. Increasing demand for water, allied to technical developments in drilling and pumping technology, has driven groundwater development.

The use of groundwater has spurred agricultural growth across the world: the top three groundwater-abstracting states are India, the United States and China, which between them account for over 50% of global groundwater abstraction (442 km$^3$/yr of an estimated 840 km$^3$/yr) (World Bank 2010a; Margat 2008). The value of India’s agricultural output rose from 28.3 to 49.9 billion $US from 1970/73 to 1990/93; at the start of this period, groundwater contributed only 4.4% of this value, while by the mid-1990s it contributed to 14.5% (Letitre 2009). In 1951 India had an estimated 4 million groundwater abstraction points; by 1997 the number had risen to nearly 17 million (Llamas et al 2004), and by the end of the first decade of the present century, India accounted for 230 km$^3$/yr, over 25% of global groundwater use (World Bank 2010a).

The initiative to develop groundwater on this scale, particularly for agricultural purposes, was largely taken by water users, not governments. It has been largely unregulated, with government funding in groundwater resources management far out of proportion to its benefits and far smaller than equivalent or proportional funding for surface water development and management. Indeed, the growth of intensive groundwater abstraction has in most cases been largely unnoticed by governments (op. cit.). This evolution has been called the “silent revolution” (Llamas et al 2004: 2005), and has been of immense benefit to rural populations in arid and semi-arid countries; however, the silent revolution has also had its costs: –

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased food production and income</td>
<td>Depleted groundwater storage in many aquifers</td>
</tr>
<tr>
<td>Reduced water shortages</td>
<td>Increased abstraction costs</td>
</tr>
<tr>
<td>Reduced risk of crop failure</td>
<td>Salinisation of groundwaters, increased pollution</td>
</tr>
<tr>
<td>Increased area of land in productive use</td>
<td>Destruction of groundwater-dependent ecosystems</td>
</tr>
<tr>
<td>Improved domestic water supply</td>
<td>Land subsidence</td>
</tr>
<tr>
<td>Increased employment … etc</td>
<td>Water use conflict … etc</td>
</tr>
</tbody>
</table>

... improved **resilience** against drought etc … … increased **uncertainty** for the future

The uncertainty over the future of intensive groundwater use is aggravated by the lack of knowledge about groundwater and the common perception that because it is a common pool...
resource (Ostrom 1990) it faces unique and possibly insuperable management challenges. However, despite the costs listed above, groundwater has enormous potential to mitigate the looming global water crisis, given appropriate management and a better understanding of its costs, benefits and limitations on the part of water users, regulators, the private sector and the political cadre\(^1\). Appropriate groundwater use will also do much to mitigate the impacts of climate change, and underlies the cross-sectoral nature of groundwater resources management.

Shah \textit{et al} (2007) identified six key attributes of groundwater. These were given in the context of groundwater for irrigation, but the same attributes apply equally to other groundwater uses, especially small-scale water supply: –

- Groundwater is very nearly ubiquitous;
- Groundwater abstraction systems can be developed quickly;
- Although operating costs are typically higher, the capital costs of groundwater systems compared to conveyancing surface water are much lower;
- Groundwater systems offer great drought-resilience, especially in large storage aquifers;
- Groundwater systems provide water on demand;
- Groundwater systems face smaller transmission and storage losses than surface water systems.

Groundwater offers numerous socio-economic advantages to both developed and developing nations. However, its development and use require management, and that is the core theme of this study.

\subsection*{1.2 Case Study background}

The World Bank Group commissioned this Case Study as part of its economic and sector analysis (ESW) on “Improving groundwater governance: The political economy of groundwater policy and institutional reforms”. The objectives of the study are: –

- Describe the groundwater resource settings for select aquifers i.e. characteristics, groundwater use patterns and drivers, user profiles and socio-economic factors influencing groundwater use;
- Describe the governance arrangements for managing groundwater in Kenya;
- Identify the relevance of these arrangements in defining strategies for coping with impacts of climate change.

The Kenya case study analysis has been carried out at both strategic, policy and planning; and at local institutional levels. Four aquifer systems are examined in detail in order to illustrate issues relating to the objectives.

\subsection*{1.3 Groundwater Governance}

In this study, groundwater governance refers to those political, social, economic, and administrative systems that are explicitly aimed at developing and managing water resources and water services at different levels of society that rely solely or largely on groundwater resources. In this definition are included all related mechanisms relating to financing, knowledge and technical capacity and the rights and responsibilities of sector players (including water users).

\footnote{“Somehow we must put water at the very top of the agenda of politicians at federal and local levels. They need to have a continuous stake in the process of conserving and managing our water resources – they don’t today, and we need to tell them why (and how) they must”. Arjun Thapan, Asian Development Bank (WEF 2009).}
“Bad governance” includes any of the following activities, attitudes or approaches to groundwater resources management: –

- Inadequate policies, strategies and legislation relating to groundwater resources and their management; or the ineffective application of those policies, strategies or legislation;
- Inadequate technical and financial capacity to support groundwater resources management;
- Lack of professional integrity, transparency and accountability in the apportionment of water and the management of groundwater projects;
- Failure to enforce laws relating to allocation and groundwater use;
- Ignoring stakeholders’ rights to equitable access to groundwater resources;
- Poorly-managed groundwater projects;
- Inherent corruption in groundwater management processes – nepotism/favouritism in awards of water permits or construction contracts in groundwater projects;
- “Quiet corruption” – low-level, small-scale corruption at the water service provider (WSP) / water user interface (World Bank 2010b).

1.4 Linkages in groundwater development

Groundwater is widely considered to be a seriously under-valued resource (World Bank 2009). The complexity of groundwater as a resource and the linkages between groundwater resources, threats to it, governance and management arrangements are encapsulated in Figure 1 below.

**Figure 1 Linkages in groundwater development**

**Threats to groundwater**
The silent revolution aspect of the modern groundwater development paradigm has been discussed above – groundwater development in recent decades has been rapid, and largely unplanned, unmanaged and unnoticed.

A second threat is that groundwater governance is weak and under-funded, and does not recognise the value of groundwater as a resource and as a development driver. Groundwater management agencies are often weak and deprived of political and financial support. The emphasis has been on resource development rather than resource management. This must change.

A third threat is the widespread perception that groundwater is a “private” resource – private land is considered by its owner to give him or her an absolute right to the water beneath it, irrespective of what legislation may say (GW•MATE 2009). This encourages the unsustainable use of groundwater, to the ultimate cost of all.
1.5 The land use-groundwater interface

1.5.1 Introduction

A critical linkage in groundwater occurrence, management and conservation is the intimate relationship between land and land use on the one hand, and groundwater on the other. While an aquifer is primarily a geological function (see S. 3.2 below), it does not exist in isolation. All aquifers are recharged from the land surface somewhere, and that land surface is critical to the maintenance of the groundwater system it sustains. For aquifers to continue to serve man’s needs and the ecosystems on which he depends (for water supply; for maintaining baseflow; and for diluting waterborne wastes: Lerner et al 2009), the recharge function must be maintained (though it may increase or decrease in light of climate change).

It follows that if the use of a land surface that acts as the recharge zone to an aquifer changes – if forest is cleared, or wetlands drained, or a city constructed on it – then volumetric recharge or water quality will change. Land conversion is inevitable in human development, but if inappropriate conversion occurs, the impacts on associated groundwater systems can be far-reaching and long-term (Scanlon et al [2007] reported that globally, recharge through cropped land was up to two orders of magnitude greater than under natural conditions, and baseflow up to one order of magnitude greater). Similarly, changes in land use may change water demand patterns, which can lead to either an intensification of or reduction in groundwater abstraction. Some Kenyan examples serve to illustrate the range of possible effects.

1.5.2 Kenyan examples of land uses impacting groundwater

Natural contamination

Groundwater is traditionally considered a “safe” water source, being typically free from surface pollution. This is a generalisation that does not always hold good for Kenya. Natural contaminants – notably fluoride – often render groundwater technically non-potable; the national standard for fluoride in drinking water is 1.5 mg/l (KEBS 2007), but a study carried out by KEBS in 2009/10 found that 33% of boreholes for which fluoride concentrations were available exceeded this value (KEBS 2010); fluoride concentration in drinking water has even entered the political arena (Hansard 2010a). Excessive fluoride mostly but not always occurs in groundwaters from volcanic aquifers. We estimate that about 10 million Kenyans are potentially at risk from excess fluoride. Other natural contaminants may exist, but are rarely tested for; arsenic in groundwater, a major health problem in the Bengal Basin and Bangladesh (IGRAC 2006), is not routinely tested for in Kenya – however, some data show that excessive arsenic may be present in some Marsabit District groundwaters (Aquasearch Ltd 2010; Mbaria 2005).

Pollution

Naturally high dissolved nitrate (NO$_3^-$) also occurs in parts of Kenya; a major livestock die-off that occurred at Kargi in 2000 was attributed to excessive dissolved nitrate in groundwater from a borehole that had been out of commission but was repaired during the La Niña drought that was affecting the country at that time. 7,000 livestock died drinking water with dissolved nitrate concentrations of 450 to 900 mg/l (Mbaria et al 2005). The source of the nitrate was not established. Nitrate is also present in shallow groundwaters in Wajir, but are due more to leaching from a palaeosol (Swarzenski et al 1977) than to anthropogenic pollution, which
currently certainly takes place; all shallow well waters sampled in a 1986 study were contaminated by \textit{coli}form bacteria (MoWRM&D 2003).

Groundwater resources have also been degraded by the acts of man or his animals; over-abstraction has led to both water level decline (Nairobi; the Dadaab Merti; Rongai, Nakuru District) and water quality deterioration (Nairobi; the central Merti). Over-abstraction has also led to salinisation of coastal groundwaters (by both vertical and horizontal movement of the halocline, the fresh/saltwater interface); this has been observed in the Mombasa/Mombasa north coast, and Lamu areas (WRMA 2009a; UNICEF KCO 2004; Aquasearch Ltd 2004; Munga \textit{et al} 2006: Kuria 2008).

Point-source nitrate pollution at livestock watering points has also occurred; for example, shallow wells constructed in sandy \textit{laghas} in Baalah (north west of Korr, Marsabit District) are excessively high in dissolved nitrate (750 to 890 mg/l as NO$_3^-$). Livestock drink from troughs at wellhead, and their \textit{faeces} release nitrate into the sand aquifer when recharge occurs (Aquasearch Ltd 2005).

Groundwater pollution has also been observed in a variety of aquifers across Kenya: high-density informal settlement and/or an absence of sewerage infrastructure has been associated with bacterial contamination of groundwaters beneath Mombasa (Munga \textit{et al} 2006); Kisumu (Cronin \textit{et al} 2006); Eldoret (Kimani-Murage \textit{et al} 2007); and Wajir (MoWRM&D 2003).

Salt manufacturing, sand harvesting and over-abstraction in the Gongoni area (north of Malindi) threaten the Timboni wellfield, the sole source of water for this area (UNEP 2009: Opiyo-Oketch \textit{et al} 2000). Wells are unprotected and polluted as a consequence; the storage capacity of the shallow unconfined aquifer is threatened by sand harvesting and at risk of halocline invasion.

**Changes in abstraction and/or recharge**

Depletion has been observed in a number of Kenya’s aquifers, most notably the Nairobi Aquifer System (NAS). The NAS has been exploited since the 1930s, initially for public water supply, private domestic and industrial uses. Initially, the number of boreholes was small, but by 1953 depletion was acknowledged to exist in the Ruaraka area and a conservation area was established there. In 1958 this was extended to cover peri-urban Nairobi and part of Kamiti (Gevaerts 1964). The area was defined in subsidiary legislation in the Water Act 1972 (GoK 1972), and remains a Groundwater Conservation Area (GCA). However, it has failed to curb depletion; by 2009 depletion had been observed in Karen, Lang’ata, Embakasi, Thika District, Muthaiga, Upper Hill, the Yaya Centre area, Gitanga Estate, Ruaraka and Kamiti; the greatest rate of depletion was recorded in 2006/08 in WRMA/ACB/593 in Lang’ata Location, at 14 metres per year (WRMA 2009a).

Much smaller declines have been observed in the Merti aquifer beneath the Dadaab refugee camps, amounting to about 2 metres over the past 18 years (UNICEF KCO 2004: pers. comm. Owen 2010). Water quality has changed in the Dadaab Merti, with waters becoming more mineralised (GIBB (Eastern Africa) Ltd 1999).

The Naivasha Basin basal aquifer has experienced static water level decline of up to 14.4 m in the period 1999 to 2004, and some mineralisation (Rural Focus Ltd 2006). A 1950s borehole in Rongai (north of Nakuru) had to be replaced because nearby intensive abstraction for irrigation had lowered water levels to the point where the borehole could not meet demand (Aquasearch Ltd 2004); total depletion was 12.2 m at the time the borehole was replaced with a deeper one.
In a broader sense, catchment degradation – deforestation, landmass degradation, land use change etc – is likely to alter recharge conditions, and so the sustainability of groundwater resources. No studies of recharge variation as a consequence of land-use change have been conducted that we are aware of; Kuria (2008) obliquely refers to it in the context of urban development on the Lamu sand dune aquifer system.

1.5.3 Urban land-use management in Kenya

Policy and legislation in relation to land use and planning are discussed in detail in Section 2. Here we discuss the limitations of existing practices insofar as they relate to groundwater use and recharge. There is limited recognition in Kenya of a linkage between land use and groundwater, although some professionals in the groundwater sector understand its significance.

Planning and groundwater protection
Councils – the chief land use planning agencies in the country – do not consider the implications of different types of development on groundwater quality, and they rarely if ever consult the statutory authorities responsible for groundwater management when developing land zoning plans. Environmental managers have in the past failed to adequately recognise and protect groundwater features (such as springs and wetlands – cf. Daily Nation 2 August 2010), a situation that is exacerbated by uncertainty over the mandates of different sector actors.

There is uncertainty among developers and land owners about their legal obligations in respect of “sensitive land”, thus riparian zones may be developed or wetlands drained. The role of Councils is also poorly understood, and in the case of the City Council of Nairobi (CCN) the “Planning and Zoning Policy” to which public sector planners refer is not apparently in the public domain. In relation to water and wastewater, in the CCN Application for Approval [of] Plans the only requirement is to indicate the water supply source, and the type of wastewater disposal proposed.

Planning and groundwater abstraction
In the same way that Councils do not consult statutory authorities in respect of groundwater protection, nor do they do so for abstraction. When an application for a water permit (for groundwater) is made within the City of Nairobi, the applicant is technically required to obtain a “no objection” from the WSP (the Nairobi City Water and Sewerage Company); however, this is not always applied for or obtained. While the Council Planning Department has no formal role in this process, at the same time it gives planning permission for developments in areas where it knows full well that there is insufficient public water supply – and therefore that the developer will have to rely on another water source (which in the Nairobi area is almost always a borehole, particularly for large-scale commercial developments such as shopping malls, office development and housing estates). This is a fundamental disconnect between land and water resources management.

There is very limited recognition by planning authorities and commercial developers that the groundwater resource beneath Nairobi is finite and diminishing.

1.5.4 Rural land-use management in Kenya

Rural land uses are less of a pressure on groundwater resources than urban land uses, though there are obvious exceptions to this: intensive commercial groundwater irrigation in the Naivasha, Rongai and Mt Kenya areas has led to depletion, water quality change or both.
Conversion of natural land into productive agricultural land inevitably affects water resources. Kenya is a largely agricultural economy, and has a paramount need to expand agriculture – either in area or efficiency, but ideally in both – to meet food self-sufficiency. While surface water has greater potential to meet water demand for irrigation, the fact that there are intensive groundwater-reliant commercial irrigation operations indicates that groundwater has a place in expanding irrigation across the Republic. These operations have already degraded some aquifers, so expanding groundwater use in irrigation will increase groundwater vulnerability.

2 Kenya’s water resources

Kenya is water-scarce; the resource endowment of 650 m$^3$ per capita per year at the start of the decade had fallen to 534 m$^3$/cap/yr in 2009 and is projected to fall to 235 m$^3$/cap/yr by 2025.

2.1 Water resources availability

Water resources in Kenya are irregularly distributed in both space and time, a situation exacerbated by considerable climate variability (see Table 2 below and Appendix 2); cycles of drought and flood (El Niño/La Niña) wreak havoc with physical infrastructure, human life and development (World Bank 2004); 80% of the country is arid or semi-arid, yet hosts 34% of the human population and 50% of its livestock (UN-Water 2005). These natural conditions are vulnerable to climate change.

Table 2: Water resources availability by catchment

<table>
<thead>
<tr>
<th>Basin</th>
<th>Area (km$^2$)</th>
<th>Rain (mm/yr)</th>
<th>Runoff (mm/yr)</th>
<th>Surface water ($10^6$ m$^3$/yr)</th>
<th>Groundwater ($10^6$ m$^3$/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>46,229</td>
<td>1,245</td>
<td>149</td>
<td>11,672</td>
<td>116</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>130,452</td>
<td>535</td>
<td>6</td>
<td>2,784</td>
<td>126</td>
</tr>
<tr>
<td>Athi</td>
<td>66,837</td>
<td>585</td>
<td>19</td>
<td>1,152</td>
<td>87</td>
</tr>
<tr>
<td>Tana</td>
<td>126,026</td>
<td>535</td>
<td>36</td>
<td>3,744</td>
<td>147</td>
</tr>
<tr>
<td>Ewaso Ngiro</td>
<td>210,226</td>
<td>255</td>
<td>4</td>
<td>339</td>
<td>142</td>
</tr>
</tbody>
</table>

|               |               |              |                |                                |                               |
|               |               |              |                | 19,691                         | 618                           |
|               |               |              |                |                                |                               | (IWRMS&WE Plan MoWI 2009c)

Different sources have given different values for available water resources:

Table 3: Water resources availability values from different sources ($10^9$ m$^3$/yr)

<table>
<thead>
<tr>
<th>Source</th>
<th>Surface water</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual resource (BCM)</td>
<td>“Safe yield” (BCM/yr)</td>
</tr>
<tr>
<td>MoWD / JICA (1992)</td>
<td>24.6</td>
<td>0.65</td>
</tr>
<tr>
<td>UNESCO (2004)</td>
<td>17.2</td>
<td>3.0</td>
</tr>
<tr>
<td>MoWI (2007)</td>
<td>19.6</td>
<td>7.4</td>
</tr>
<tr>
<td>MoWI (2009c) as Table 2</td>
<td>19.7</td>
<td>7.4</td>
</tr>
</tbody>
</table>


In 2009 it was estimated that of the 1.04 BCM/yr considered “safe” groundwater yield, only 0.18 BCM/yr was used (17.3%). 0.18 BCM is 0.18 km$^2$; Kenya’s groundwater abstraction is only 0.02% of global groundwater abstraction.

$^4$ The most useful definition we have seen of “safe” or “sustainable yield” is from Evans (2002): the groundwater extraction regime, measured over a specified planning time frame that allows acceptable levels of impact and protects the higher value uses that have a dependency on the water.
2.2 Legacies

Kenya suffers the colonial legacy of sharing over 50% of its water resources with other states, much complicating their management; this is more significant for surface waters than groundwaters, but even so, there are five significant transboundary aquifer groups (UNESCO 2009)\(^5\).

Catchment degradation and inadequate investment in water development have led to reductions in *per capita* volume of water in storage, and this trend must be reversed if Kenya is to achieve Vision 2030 (NESC 2007). Water insecurity/vulnerability is one of the biggest impediments to poverty eradication and development, which will only be exacerbated by climate change.

2.3 Water in Kenya’s economy

While Kenya is water insecure and vulnerable, water is at the same time critical to the economy. Kenya is a largely agricultural economy, contributing 27% of GDP, employing an estimated 80% of the workforce and providing 57% of exports (MoA 2009; MoWI 2009b). Most agriculture is rainfall-based, but of a potential 498,000 ha of irrigated area, only 184,000 ha are developed\(^6\).

Without the bulk water sources that keep it supplied with water, the City of Nairobi would not be able to grow and meet the needs of a growing and dynamic economy; both surface (Ruiri, Sasumua and Ndaka’ini Dams) and groundwater (Kikuyu Springs and thousands of boreholes) are used to meet Nairobi’s water demand. Nairobi generates approximately 50% of Kenya’s GDP (KIPPRA 2008), and the City has at times been held hostage to restricted water supply (as a result of the legacy of inadequate investment in water supply infrastructure). Because of this, many domestic, commercial and industrial water users rely on their own boreholes as a coping strategy in the face of inadequate municipal supply (abstraction across the Metropolitan area is estimated to be 160 MLD or 58 million m\(^3\)/yr [MCM/yr]: WRMA 2010a).

Similarly, the investment legacy has meant that water supplies to the major population centres of the Coast have often been under stress. All the significant water sources that provide water to the port, industry, tourism, commerce and residential population at the Coast are groundwaters (Lamu sand dune aquifer, Baricho aquifer, Mzima Springs, Marere Springs and Tiwi aquifer), which puts this vital component of Kenya’s economy at the mercy of climate change.

2.4 Groundwater in Kenya

It is estimated that of the 1.04 billion m\(^3\) (BCM) of renewable groundwater available to Kenya annually, only 0.18 BCM is made use of (about 500 MLD, or 17% of the resource: MoWI 2009c). As this IWRMS & WE Plan states, “Although groundwater exploitation has considerable potential for boosting water supplies in Kenya, its use is limited by poor water quality, over exploitation, saline intrusion along the Coastal areas and inadequate knowledge of the occurrence of the resource”.

2.4.1 Groundwater use

Reference has already been made to the importance of groundwater in the economy of the Nairobi Metropolitan area, but other population centres across Kenya are even more reliant on

\(^5\) Rift Valley aquifers; Elgon aquifer; Merti aquifer; Kilimanjaro aquifer; Coastal sedimentary aquifers.

\(^6\) According to the Minister for Water, in August 2010 the area under irrigation was 120,000 ha, of a potential area of 539,000 ha (presentation of 2010/2011 Estimates: Hansard 17\(^{th}\) August 2010b).
groundwater. Public water supply in the Coastal strip is almost entirely dependant on groundwater (as described above), and many domestic, commercial and industrial water users rely on groundwater to meet their needs in the South Coast, Mombasa and the North Coast (Kilifi and Malindi). Numerous towns in Kenya rely largely or exclusively on groundwater for public and private water supply; obvious examples include Naivasha, Nakuru, Wajir, Mandera and Lodwar, and there are many others.

Rural centre water supplies overwhelmingly rely on groundwater resources, even (perhaps surprisingly) in the humid highlands. Much of North Eastern Province relies on groundwater for human and livestock needs (the Merti aquifer; Daua Parma alluvium; and aquifers in the Jurassic limestones of Mandera District). Hand pump-equipped boreholes meet water needs in villages across the Republic; village borehole water supplies are the norm in Western and to a lesser extent Nyanza Provinces, and past rural water supply projects in Turkana, Samburu, and the Ukambani districts have led to considerable reliance on groundwater in these areas.

Water sources for smallholder (86,500 ha) and public irrigation schemes (18,900 ha) is typically sourced from surface waters, but a significant proportion of water used by private schemes (78,500 ha) comes from boreholes, particularly around Lake Naivasha and in the north west Mt Kenya area. MoWI (2009c) states that only 5% of water used in irrigation is groundwater, in localised areas in north eastern Kenya; this may be an under-estimate, given the reliance on groundwater by private sector irrigators in Central, Rift Valley and Eastern Provinces. This irrigation master plan acknowledges that future growth will include private sector-driven groundwater-based irrigation, because of the high capital cost of surface water storage; it calculates that 0.2 BCM/yr of groundwater could be allocated to irrigation.

Groundwater is extensively used by industry, especially in Nairobi, Nakuru and Thika; volumes used are not known, but an estimate made in 2009 suggested that 27 MLD is pumped daily from boreholes in the Nairobi-Athi River industrial area alone (9.8 MCM/yr) (WRMA 2010a).

Ecological uses of groundwater are numerous but in Kenya, at least, are poorly understood. The draft National Wetlands Policy (GoK 2008) is mute on groundwater-dependent ecosystems (GDEs), but explicitly acknowledges the importance of wetlands in both the recharge and discharge of groundwater. GDEs are points of interaction between the land surface and groundwater; most wetlands are GDEs by definition, except where they are seasonal and exist solely because of an impermeable soil (Ng’weno 1999). GDEs are most easily classified according to their geomorphological setting, so (GW•MATE 2002-2006): –

- natural outflow from deep groundwater flow systems as discrete springs (e.g. Mzima, Njoro Kubwa);
- wetlands that occur as a result of discharge from shallow or perched aquifers in depressions (e.g. Lari Swamp, Limuru);
- baseflow from extensive aquifers provide dry-weather flow in the upper reaches of river systems (most upland rivers in Kenya);
- brackish coastal lagoons fed by natural discharge;
- terrestrial ecosystems without open water that host phreatophytes extracting moisture directly from the water-table (e.g. the Kibwezi “groundwater forest”);
- upland surface-water fed marshes forming natural groundwater recharge zones (e.g. Ondiri Swamp, Kikuyu).

In the Case Study Aquifers (CSAs) there are certainly GDEs – the Ondiri Swamp mentioned above is in the NAS, and the draft Water Allocation Plan for the NAS gives a long list of GDEs.
for this aquifer; it estimated that baseflow accounts for between 34 and 44% of streamflow across the NAS (WRMA 2010a).

However, the most significant historically is the Lorian Swamp, a formerly perennial feature south east of Habaswein, overlying the Merti aquifer. When first described it covered an area of 150 km² (Haywood 1913), and in 1960 it covered 39 km² (Bestow 1963) but today it is strictly seasonal and only exists after significant flooding in the Ewaso Ngiro River; Swarzenski et al (1977) state that there was permanent swamp vegetation into the early 1950s, and that flow into the swamp occurred when flow at Archer’s Post exceeded 35 to 40 MCM/month. It probably once played a role in maintaining recharge to the Merti aquifer in this area, or at least maintaining recharge to near-surface aquifers in the zone Habaswein – Sabena (op. cit.).

The natural discharge from the Nairobi aquifer system occurs as baseflow, but there are also a number of springs that discharge from the western side of the Athi River in the Munyu area (Grabowsky & Poort BV 1997); at Baricho the natural discharge from underflow east of the waterworks contributes to baseflow as well as possibly contributing to the recharge of the underlying Kambe Limestones.

Throughout the Tiwi area there are numerous small wetlands that flood entirely during and after wet seasons; these areas are very likely to contribute recharge to the Tiwi aquifer itself, and if so perform an important ecological function by not only providing habitat for aquatic life, but also partly purifying surface water as it recharges.

2.4.2 Issues in groundwater resources management

Water sector as a whole
The water sector as a whole still faces policy and regulatory issues that have yet to be adequately addressed; within the sector there is conflict regarding roles and responsibilities, which the sector has been aware of for at least five years but which remain unaddressed. There are also mandate issues with other sector institutions, which require harmonisation of legislation relating to the environment and public health sectors in particular, but also in relation to protected areas (forests, reserves and national parks).

There is a sector bias in favour of water supply development, with less interest in sanitation development, and little or no interest until the early years of the present decade in water resources management. The water supply/sanitation gap has been recognised, and an environmental health policy introduced in 2007 (MoH 2007), though it has been criticised for not proposing the harmonisation of legislation and failing to provide clear mandate direction (MoWI 2007). Kenya is a signatory of the eThekwini Declaration (AfricaSan 2008) though this was signed by Kenya’s Minister for Water, not Health. The MoWI developed a draft water sector sanitation concept in 2009 (MoWI 2009a) which provides a working framework for linking sanitation to health, water resources development and water resources management, including groundwater.

Institutional issues in groundwater
The groundwater sector remains the neglected sibling in the hydrology/hydrogeology sisterhood, both in terms of resource allocation and of public understanding. As a hidden resource – out of sight and difficult to quantify – groundwater is easy to neglect yet difficult to protect in the face of widespread ignorance about it. Groundwater is typically considered a common pool resource by its users, and in the absence of a rational management regime is open to abuse by individuals or groups pursuing their own interests that are not necessarily of long-term benefit (cf. the
“Tragedy of the Commons”: Hardin 1968). This is very much the case for a number of the more heavily exploited aquifers in Kenya, most notably the NAS.

Another aspect that remains an issue (though less so than in colonial times) is the lack of knowledge about Kenya’s aquifer systems. That this remains the case is not because there is inadequate technical ability, but because there are limited resources available for conducting the kind of resources assessment needed; the undeniable complexity of some of Kenya’s aquifer systems merely exacerbates this situation. To an indefinable extent this situation is accentuated by the lack of recognition of the value of groundwater resources in the development process.

2.5 Groundwater governance and climate change in Kenya

The current understanding of climate change impacts in Kenya are that higher temperatures will become prevalent, and that greater rain and drought intensity will become common. More precipitation in shorter periods of time will increase the likelihood of floods, while longer dry seasons will increase the likelihood of droughts worse than have been experienced to date (Boko et al. 2007). However, the intensity of climate change impacts will vary across the country (GoK 2010).

The future annual cost of climate change to Kenya’s economy has been estimated to be 2.6% of GDP annually by the year 2030, though the uncertainty of this figure is acknowledged; this excludes the cost of current climate variability, which may already cost the country up to a maximum of 2% of current GDP (SEI 2009). Inappropriate land uses (such as dwellings constructed within floodplains) also contribute to this annual cost.

Kenya has only relatively recently developed a National Climate Change Response Strategy (NCCRS: GoK 2010), which was driven by the Ministry of Environment and Mineral Resources and which involved consulting sector stakeholders through the second half of 2009. The NCCRS is necessarily a broad-brush document that brings together all the relevant sectors. In relation to water, it proposes the following interventions (NCCRS S. 4.1.3 Water):

1. Inter- and intra-basin water transfers of water from water-rich to water-scarce area;
2. Investment in water recycling facilities to reduce water wastage;
3. Enforcement of laws and regulations required for efficient water resource management;
4. Increasing rainwater harvesting;
5. Develop and maintain adequate water infrastructure (dams, water pans, distribution);
6. Improve the capacity for water quality monitoring;
7. Develop a strategic fund to purchase chemicals for disinfecting community wells and shallow boreholes during flood / drought episodes when water quality is threatened;
8. De-silting rivers and dams to improve carrying capacity, water storage and water quality;
9. Protecting / conserving water catchment areas and river-banks from degradation and contamination (levies to generate funds for investment in conservation of water catchment areas);
10. Heightening awareness of the importance of sustainable use of water resources;
11. Developing artificial recharge schemes for threatened aquifers;
12. Protect flood plains by constructing dykes and dredging rivers;
13. Develop and maintain an appropriate hydrometric network;
14. Introduce financial instruments to promote technologies that use water efficiently.

---

7 The Nairobi Aquifer Suite is a case in point; it comprises numerous unconfined and confined beds of lava, Old Land Surfaces and Lake Beds, which in boreholes that are deep enough may amount to as many as five separate aquifer units.
None of these proposed interventions are in any way unusual, and in many cases already exist in one form or another in water sector policy, legislation or strategy (3, 5, 6, 8, 9, 10, 11 and 13 above). The NCCRS clearly sees groundwater as one possible climate change adaptation strategy, by making better use of aquifer storage by enhancing recharge; however, artificial groundwater recharge as a management approach should not be restricted to aquifers under threat, but be treated as just one of the suite of management tools that improve climate change resilience. The NCCRS is mute on aspects such as the conjunctive use of surface and groundwater.

Some of the proposed interventions, such as inter-basin transfers, are potentially contentious; there is considerable ill-feeling in the Naivasha Basin at the diversion of less than 21 MLD (7.7 MCM/yr) from the Malewa out of catchment to Nakuru; and in late August 2010 Central Province politicians were demanding economic recompense for the supply of water to Nairobi from reservoirs in the upper Tana catchment (Sasumua and Ndaka’ini).

While the NCCRS is a very timely summary of the interventions needed to mitigate climate change, the important thing will be its implementation. The Strategy includes an Action Plan with an annual budget of KShs. 236 billion, of which a relatively small KShs. 6 billion/yr is specifically allocated to the water sector; however, this sum excludes substantial cross-sectoral expenditure proposed for the agriculture, energy, forestry and regional development sectors, all of which are relevant to water.

The NCCRS also stresses the need to introduce an overall policy to drive measures to adapt to and mitigate the effects of climate change. This is needed as a matter of urgency.

3 Characterisation of groundwater resources and aquifers

3.1 Introduction

In the first instance, the availability of groundwater is determined by the physical environment – its hydrogeological characteristics.

However, groundwaters and the geological material that host them (together making up an “aquifer”) are influenced by mans’ use of his environment, so groundwater availability and use depends on much more than the natural environment alone (see Table 4 overleaf). It is apparent from this that the natural physical environment component represents a potentially small proportion of the total number of influencing factors. However, it is the most important single component – if the conditions do not exist for groundwater to occur, anthropogenic influences are irrelevant.

3.2 Aquifer characterisation

Aquifers may be characterised in a number of ways; in terms of their geogenesis; their use, their importance to an economy and so on. The most logical approach is geogenic, as shown in Figure 2 overleaf.
### Table 4: Factors influencing GW availability, utility, sustainability and equitable use

<table>
<thead>
<tr>
<th>Physical or technical influences</th>
<th>Anthropogenic influences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic characteristics, such as: –</td>
<td>The socio-economic environment comprises: –</td>
</tr>
<tr>
<td>• Transmissivity (T)</td>
<td>• The nature &amp; range of economic activities</td>
</tr>
<tr>
<td>• Hydraulic conductivity (k)</td>
<td>• Population density</td>
</tr>
<tr>
<td>• Storage coefficient / specific yield (S / Sₚ)</td>
<td>• The uses of groundwater and abstraction intensity</td>
</tr>
<tr>
<td>Aquifer geometry (areas, thickness, structure etc)</td>
<td>• Societal norms</td>
</tr>
<tr>
<td>Rainfall &amp; recharge</td>
<td>The institutional environment, comprising: –</td>
</tr>
<tr>
<td>Runoff</td>
<td>• The legal environment, itself covering:</td>
</tr>
<tr>
<td>Natural discharge (baseflow, springs, oceanic front discharge)</td>
<td>o Roles &amp; responsibilities at national &amp; regional levels</td>
</tr>
<tr>
<td>Soil type &amp; thickness</td>
<td>o Definition of groundwater (public or private)</td>
</tr>
<tr>
<td>Natural land cover</td>
<td>o Approaches to groundwater rights</td>
</tr>
<tr>
<td></td>
<td>o Water rights &amp; land ownership</td>
</tr>
<tr>
<td></td>
<td>• The administrative environment, comprising:</td>
</tr>
<tr>
<td></td>
<td>o Rules, regulations, enforcement &amp; agencies responsible for these</td>
</tr>
<tr>
<td></td>
<td>o Presence of a “Groundwater Guardian” agency, &amp; its powers, mandates &amp; implementation capacity</td>
</tr>
<tr>
<td></td>
<td>o Inter-relationships between different agencies with mandates including groundwater</td>
</tr>
<tr>
<td></td>
<td>• The macro-economic environment, including Sector policies that indirectly or directly influence groundwater (such as land use planning or irrigation policies)</td>
</tr>
<tr>
<td></td>
<td>• The political environment, including:</td>
</tr>
<tr>
<td></td>
<td>o Democratic tradition &amp; system maturity</td>
</tr>
<tr>
<td></td>
<td>o Level of understanding among political cadres</td>
</tr>
<tr>
<td></td>
<td>o Incentives for transparency &amp; equitability</td>
</tr>
<tr>
<td></td>
<td>o Political feasibility of specific policies &amp; reforms, &amp; the consequent management measures required</td>
</tr>
</tbody>
</table>

### Figure 2  Key characteristics of common aquifer types

All of these generic aquifer types are represented in Kenya; a somewhat similar typology of Kenyan aquifers and aquifer types is shown in Appendix 3, from an approach adopted by the WRMA (WRMA 2009a).

(From: GW•MATE 2005a)
3.3 Case study aquifers

Four case study aquifers (CSAs) were selected for detailed examination of both technical and socio-economic aspects. Aquifer locations are shown in Appendix 4, and aquifer details given in Boxes 1 to 4 at the rear of this report. All are important groundwater resources, considered by the WRMA to be Strategic, Major or Special. The WRMA defines aquifers in terms of their human or socio-economic importance in the following terms: CSAs are shown according to their importance:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
<td>Aquifers used to supply significant amounts/ proportions of water to a given area and for which there are no available alternative resources, or where such resources would take time and money to develop. Major transboundary aquifers.</td>
<td>Merti; Nairobi</td>
</tr>
<tr>
<td>Major</td>
<td>High-yielding aquifers with good quality water.</td>
<td>Tiwi; Baricho</td>
</tr>
<tr>
<td>Minor</td>
<td>Moderate-yield aquifers with variable quality water.</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>Low-yield aquifers with poor to reasonable quality water.</td>
<td></td>
</tr>
<tr>
<td>Special</td>
<td>Aquifers or parts of aquifers designated “special aquifers” by the WRMA.</td>
<td>(Merti)</td>
</tr>
</tbody>
</table>

**Note:** The Merti aquifer is divided into two units: the broader aquifer, which is considered Strategic: and the Dadaab area, which is considered Special because it hosts the UNHCR refugee camps and faces unique management challenges.

The WRMA further classifies aquifer status in terms of the level of threat they face:

<table>
<thead>
<tr>
<th>Status</th>
<th>Threat</th>
<th>CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm</td>
<td>Water levels declining, water quality deteriorating (stress, pressure or threat identified)</td>
<td>Nairobi</td>
</tr>
<tr>
<td>Alert</td>
<td>Stress, pressure or threat identified or anticipated</td>
<td>Tiwi (Merti)</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>No immediate stress, pressure or threat</td>
<td>Merti; Baricho</td>
</tr>
</tbody>
</table>

The CSAs occur in a variety of climates (from arid to semi-humid), and cover a range of geological conditions. One (the Merti) is a transboundary aquifer, flowing eastwards into Somalia.

3.4 Groundwater vulnerability

There are a variety of ways in which aquifers may be considered “vulnerable”: in most contexts, vulnerability is considered to relate to pollution by man’s surface activities, but two other definitions are also used here; aquifers may be vulnerable to over-abstraction, leading to conflict between users; and an aquifer may be inappropriately used, thus denying potential development benefits; this is here considered a knowledge shortfall.

3.4.1 Vulnerability to pollution

There are numerous ways of determining the vulnerability of an aquifer to pollution, ranging from simple and cheap methods (GOD, DRASTIC etc) to complex and expensive (numerical 3- and 4-D modelling). In this study the limited data available for the Case Study aquifers prevents the application of complex methods. A simpler method, GOD, developed by workers in South America (GW•MATE 2002), combines relative indices for Groundwater confinement, Overlying strata and Depth to groundwater. The product of the three gives a vulnerability index; for example, a confined aquifer (low hazard = 0.2), overlain by consolidated lavas (moderate hazard = 0.6), at a depth of 150 m (low hazard = 0.6) gives a vulnerability index of 0.1, or negligible. The vulnerability indices for the four CSAs are shown in Table 7.
Table 7:  Case study aquifer pollution vulnerabilities (GOD)

<table>
<thead>
<tr>
<th>Groundwater confinement</th>
<th>Merti</th>
<th>Nairobi</th>
<th>Tiwi</th>
<th>Baricho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overlying strata</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Depth to groundwater</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
<td>0.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>0.1</th>
<th>0.1</th>
<th>0.3</th>
<th>0.6</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Aquifer Pollution Vulnerability</th>
<th>Negligible - Low</th>
<th>Negligible - Low</th>
<th>Low - Moderate</th>
<th>High</th>
</tr>
</thead>
</table>

DRASTIC is a method widely used by the USGS and USEPA, and elsewhere. DRASTIC stands for the hydrogeological factors that are considered, namely: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone media, and hydraulic Conductivity of the aquifer (Aller et al 1985). DRASTIC was used to compile a groundwater pollution vulnerability map of the Mombasa Island and Kisauni aquifers, which includes material similar to the Tiwi aquifer (Munga et al 2006); they concluded that the Pleistocene sands were of “medium” vulnerability.

A simpler descriptive methodology is provided by Vrba et al (2006):

Table 8:  Descriptive vulnerability (Vrba et al 2006)

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Aquifer type</th>
<th>CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligibly vulnerable aquifers</td>
<td>Deep, confined non-renewable aquifers which under current conditions are not part of the hydrological cycle; and where the unsaturated zone consists of impermeable or low permeability rocks.</td>
<td>Merti</td>
</tr>
<tr>
<td>Low vulnerability aquifers</td>
<td>Deep, confined aquifers overlain by impermeable soil and a thick low permeability unsaturated zone (greater than 30 m)</td>
<td>Nairobi</td>
</tr>
<tr>
<td>Moderately vulnerable aquifers</td>
<td>Shallower water table aquifers or semi-confined aquifers overlain by a less permeable soil and thicker low permeable unsaturated zones (10 to 30 m)</td>
<td></td>
</tr>
<tr>
<td>Aquifers highly vulnerable to lateral saline intrusion in coastal areas</td>
<td>Water table aquifers in coastal areas in which vulnerability to seawater intrusion increases as a result of intensive exploitation, depending particularly on drawdown produced by over-pumping, proximity to the shoreline and depth of abstraction boreholes</td>
<td>Tiwi</td>
</tr>
<tr>
<td>Highly vulnerable aquifers and settings</td>
<td>Near-surface water table aquifers overlain by permeable soils and a thin and permeable unsaturated zone (to 10 m); deeper aquifers connected to near-surface vulnerable aquifers; aquifers directly linked to surface water bodies; karst aquifers; and aquifer recharge zones</td>
<td>Baricho</td>
</tr>
</tbody>
</table>

Morris et al (2003) provide a further descriptive approach to vulnerability through pollution (Table 11, p. 42), based on travel time in different aquifers.

3.4.2  Vulnerability to saline intrusion

There are a number of digital simulation programmes that may be used to determine the vulnerability of a coastal aquifer to halocline invasion; however, as with aquifer vulnerability, the data available for the CSAs are insufficient for their use.

A modification of DRASTIC was developed by Bocanegra et al (2004), which allows the qualitative assessment of halocline movement risk and is called SEA-GIndex. It replaces the vertical movement of pollutants in GOD and DRASTIC with the lateral movement of the halocline. SEA-GIndex is based on three weighted classes; piezometric head, lithology and distance from the oceanic front. Using the SEA-GIndex matrix for the Tiwi aquifer yields a halocline invasion vulnerability index of 0.5, or “moderate”. The matrix yields an index of less than 0.1 for the Baricho wellfield, or negligible vulnerability.
3.4.3 Vulnerability to over-abstraction

Morris et al (2003) summarised the effects of over-abstraction, drawing from earlier work by Foster et al (1988); this is tabulated below.

Table 9: Effects of over-abstraction

<table>
<thead>
<tr>
<th>Reversible</th>
<th>Consequences of excessive abstraction</th>
<th>Factors affecting susceptibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pumping lift / costs increase</td>
<td>Aquifer diffusivity characteristic</td>
</tr>
<tr>
<td></td>
<td>Borehole yield reduction</td>
<td>Drawdown below productive horizon</td>
</tr>
<tr>
<td></td>
<td>Springflow / baseflow reduction</td>
<td>Aquifer storage characteristic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reversible or irreversible</th>
<th>Phreatophytic vegetation stress</th>
<th>Depth to groundwater water table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aquifer compaction/transmissivity reduction</td>
<td>Aquifer compressibility</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irreversible</th>
<th>Saline water intrusion</th>
<th>Proximity of saline/polluted water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ingress of polluted water from shallower aquifer or river</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land subsidence and related impacts</td>
<td>Vertical compressibility of overlying/interbedded aquitards</td>
</tr>
</tbody>
</table>

NOTES:
1. Transmissivity ($T$) divided by storage coefficient ($S$).
2. Storage coefficient ($S$) divided by mean annual recharge ($R$).
4. May be reversible in the long term (decades to centuries).

After Morris et al 2003 (Table 6)

More recently, Vrba et al (2006) proposed a number of different quantitative descriptors for depletion (groundwater level decline), which is a reflection of over-abstraction (over-abstraction being defined as abstraction that produces irreversible impacts on groundwater quantity, quality, ecosystems or geotechnical stability). These comprise:

a. Areas with high borehole densities
b. Changes in water level
c. Changes in baseflow
d. Changes in water quality
e. Land subsidence.

They proposed a “depletion impact index”, derived from:

$$\frac{\sum \text{area with groundwater depletion problem (any of a to e above)}}{\text{Total aquifer area}} \times 100$$

It is difficult to calculate this index for the two aquifers in which degradation is known to have occurred, as the areas impacted are not known with any accuracy. In the case of the Merti aquifer the index number is likely to be small – ~50 km² of the aquifer is known to have been impacted by water level or water quality changes (the aquifer underlying the Dadaab area refugee camps), out of an area 61,000 km²; this gives an index of 0.08.

In the case of the innermost 2,140 km² of the Nairobi aquifer system, densities greater than 10 boreholes/km² cover a total of 61 km² (Rural Focus Ltd 2010); in one of these areas (Karen), water levels are known to be falling (WRMA 2009a). This gives an index of 2.9 for this inner area alone, though we believe it likely that the total aquifer area actually impacted by depletion and water quality change is very much larger than 61 km².

There is no evidence that either the Tiwi or Baricho aquifers are suffering from over-abstraction.
3.4.4 Case study aquifer characteristics

Key characteristics of the CSAs are tabulated below.

**Table 10: Case study aquifer characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Merti</th>
<th>Nairobi</th>
<th>Tiwi</th>
<th>Baricho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer type (as Figure 2)</td>
<td>(Semi)-consolidated sedimentary</td>
<td>Inter-montane valley fill</td>
<td>Major alluvial</td>
<td>Major alluvial</td>
</tr>
<tr>
<td>Lithology</td>
<td>Clays, sands &amp; sandstones; limestones</td>
<td>Lavas &amp; lake sediments</td>
<td>Clays &amp; sands</td>
<td>Alluvial sand &amp; gravel</td>
</tr>
<tr>
<td>Dominant flow regime</td>
<td>Inter-granular</td>
<td>Inter-granular / fissure</td>
<td>Inter-granular</td>
<td>Inter-granular</td>
</tr>
<tr>
<td>Scale</td>
<td>Regional/Transboundary</td>
<td>Regional</td>
<td>Local</td>
<td>Local</td>
</tr>
<tr>
<td>Surface area, km$^2$</td>
<td>60,900</td>
<td>6,500</td>
<td>~30</td>
<td>~2</td>
</tr>
<tr>
<td>Transmissivity, m$^2$/d</td>
<td>0.2 – 840 (median 275)</td>
<td>0.1 – 158 (median 3.4)</td>
<td>120 – 600</td>
<td>3,000 – 10,0000</td>
</tr>
<tr>
<td>Storage coefficient, ratio</td>
<td>$4.3^{\circ}$ – $6.7^{\circ}$</td>
<td>$1.2^{\circ}$ – $4.20^{\circ}$ (median 1.11$^{\circ}$)</td>
<td>$9.3^{\circ}$ – $8.0^{\circ}$ (n = 3)</td>
<td>0.15 to 0.285 (specific yield)</td>
</tr>
<tr>
<td>T/S, ratio</td>
<td>4650 – 1.25$^{\circ}$</td>
<td>370 – 830 (300)</td>
<td>1,500 – 2.0$^{\circ}$</td>
<td>20,000 – 67,000</td>
</tr>
<tr>
<td>Recharge, MCM/yr</td>
<td>≈30 (but 3.3 MCM annually)</td>
<td>109</td>
<td>21</td>
<td>≈83</td>
</tr>
<tr>
<td>Abstraction, MCM/yr</td>
<td>5.3</td>
<td>58</td>
<td>4.8</td>
<td>22</td>
</tr>
<tr>
<td>Recharge/abstraction ratio</td>
<td>5.7 (0.6)</td>
<td>1.9</td>
<td>4.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Pollution vulnerability</td>
<td>0.1 Negligible - low</td>
<td>0.1 Negligible - low</td>
<td>0.3 Low - moderate</td>
<td>0.6 High</td>
</tr>
<tr>
<td>Halocline vulnerability</td>
<td>N/A</td>
<td>N/A</td>
<td>0.5 Moderate</td>
<td>0.1 Negligible</td>
</tr>
<tr>
<td>Depletion vulnerability</td>
<td>Moderate/local</td>
<td>Serious/extensive</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Dominant water use (in approximate order of volumetric use)</td>
<td>• refugee camps; livestock; domestic; public W/S</td>
<td>• domestic; commercial; industrial; irrigation; public W/S</td>
<td>• public W/S; public W/S</td>
<td></td>
</tr>
<tr>
<td>WRMA Type</td>
<td>Strategic / Special</td>
<td>Strategic</td>
<td>Major</td>
<td>Major</td>
</tr>
<tr>
<td>WRMA Status</td>
<td>Satisfactory / Alert</td>
<td>Alarm</td>
<td>Alert</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

Vulnerability indices are derived from Ss. 3.4.1 and 3.4.2 above. Pollution vulnerability refers explicitly to pollution from the land surface, while halocline vulnerability refers to the vulnerability of a given aquifer to movement of the halocline. Neither the Merti nor the NAS are vulnerable to oceanic halocline movement; however, the Merti is potentially prone to movement of more saline water from the peripheral finer facies aquifer (see Box 1 at rear).

3.4.5 Summary

In essence, threats to any groundwater body can be reduced to three scales or typologies (GW•MATE 2009): –

- **High risk:** extensive quasi-irreversible aquifer degradation and potential for water user conflict (intensively exploited; vulnerable to diffuse pollution; or groundwater “mining”);
- **Medium threat:** potential water use conflict but less vulnerable than high risk (intensifying exploitation; vulnerable to point-source pollution; transboundary resource);
- **Low or uncertain threat:** where insufficient is known about aquifers to drive their use for the benefit of development (development opportunities foregone; natural contaminants; scope for broader, conjunctive use).
The Table below summarises the three typologies and their application to each of the CSAs.

### Table 11: Typologies and threats to case study aquifers

<table>
<thead>
<tr>
<th>Typology</th>
<th>Situation / process</th>
<th>Merti</th>
<th>Nairobi</th>
<th>Tiwi</th>
<th>Baricho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users</td>
<td>Intensive exploitation (leading to land subsidence, saline or polluted water intrusion)</td>
<td>+++</td>
<td>++++++</td>
<td>+</td>
<td>- - - -</td>
</tr>
<tr>
<td></td>
<td>Vulnerable to pollution from land surface (vulnerability, pollution)</td>
<td>- - -</td>
<td>- - -</td>
<td>+++</td>
<td>++++++</td>
</tr>
<tr>
<td></td>
<td>Depletion of non-renewable storage (in aquifers with low contemporary recharge)</td>
<td>+++</td>
<td>+++</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Potential water use conflict but not at risk of quasi-irreversible aquifer degradation</td>
<td>With growing large-scale abstraction (especially in aquifers with high T/S ratios)</td>
<td>N/A</td>
<td>N/A</td>
<td>- -</td>
<td>- -</td>
</tr>
<tr>
<td></td>
<td>Vulnerable to point-source pollution (vulnerability, pollution)</td>
<td>- - -</td>
<td>- - -</td>
<td>+++</td>
<td>++++++</td>
</tr>
<tr>
<td></td>
<td>Shared transboundary resource</td>
<td>++++</td>
<td>- - -</td>
<td>- -</td>
<td>- -</td>
</tr>
<tr>
<td>Insufficient (or inadequate use of) scientific knowledge to guide development policy &amp; process</td>
<td>Potential to improve rural welfare &amp; livelihoods (not fulfilling MDG potential)</td>
<td>++++</td>
<td>- - -</td>
<td>+++</td>
<td>++++++</td>
</tr>
<tr>
<td></td>
<td>Natural quality problems (e.g. As, F)</td>
<td>++</td>
<td>+++</td>
<td>- -</td>
<td>- -</td>
</tr>
<tr>
<td></td>
<td>Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture)</td>
<td>++</td>
<td>- - -</td>
<td>++++</td>
<td>++++</td>
</tr>
</tbody>
</table>

**Key**

- - - - -       - - - -       - - -       - -       -       +       ++       +++       ++++       +++++

- No risk / hazard
- Certain risk / hazard

The Table illustrates the broad range of risks and potential benefits in the four CSAs.

The Merti is a large fossil groundwater resource that is at risk of irreversible damage by abstraction – but only over a very long period of time (hundreds to thousands of years); an aquifer management plan should be developed to ensure that the most effective use is made of this resource, which is of critical value to North Eastern Province. It is not vulnerable to pollution from the land surface, and has considerable potential to contribute to meeting MDGs and in the development of the region through small-scale use (rural centres). It has minor natural water quality issues, which at present appear manageable. The scope for large-scale conjunctive use is limited, though this aquifer may ultimately be developed to supply towns in the region with water (such as Wajir: MoWRM&D 2003). Its potential as a source of irrigation water is limited, because of a combination of poor soils and intrinsic groundwater quality. It is a transboundary resource that was hitherto of some importance to the downstream state (Somalia), though no joint strategies exist for its management at present (see S.5.1.1 and Box 1 at rear).

The NAS is a socio-economically important resource that is the most seriously stressed of the CSAs, principally because of localised over-abstraction. Recharge occurs at its western edge, and groundwater beneath the City of Nairobi is of the order of a hundred years of age, so it is at some risk of irreversible degradation through abstraction though at limited risk of pollution from the land surface. Given that it is currently under over-abstraction stress, it offers little potential to meet MDGs or contribute to national development in any but a short time-frame; however, with suitably-targeted artificial groundwater recharge, it offers some conjunctive use potential. Naturally high dissolved fluoride concentrations exceed national standards for this ion, which technically could limit its use (see Box 2 at rear).

The Tiwi aquifer is a relatively small but important aquifer that is dedicated entirely to public water supply at present, supplying part of the South Coast with water. It is currently at limited risk of degradation from over-abstraction or loss of storage, but is vulnerable to diffuse pollution from the land surface if sand-harvesting or significant changes in unregulated land use occur. It is at greater risk from point-source pollution than either the Merti or the NAS, but less so than Baricho; however, it is at the greatest risk of halocline movement of any of the CSAs, although the risk is relatively small. With no natural water quality constraints it has significant potential to
meet greater water demand for urban water supply, but probably not for large-scale irrigated agriculture; similarly, it has some potential to help meet rural MDGs and improve local livelihoods (see Box 3 at rear).

The Baricho aquifer is a small, highly efficient aquifer of major importance as a source of water for the North Kenya Coast. It is under insignificant risk of degradation through over-abstraction but is significantly vulnerable to pollution via recharging Sabaki River waters; aquifer storage is at no risk of depletion under the current abstraction regime, and the aquifer offers considerable scope for meeting urban and rural water demand in the North Coast, so improving livelihoods and addressing MDGs. Although it is very vulnerable to point-source pollution, there is no evidence that this is a problem as yet; natural water quality is excellent (see Box 4 at rear).

4 Aquifer values

4.1 Introduction

It is particularly difficult to determine the economic value of an aquifer for non-monetary costs and benefits. This is partly because we have a poor understanding of our aquifers, but also because many of the non-numeraire “amenity values” that exist for a surface feature – a lake, a wetland, a game reserve or a mountain – simply do not exist for a resource that is out of sight and consequently all too often out of mind.

ILEC (2005) developed a list of use values for surface waters, which included the following; not all are applicable to groundwater, as will be seen:

<table>
<thead>
<tr>
<th>Table 12: Economic value of lakes – ILEC 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL ECONOMIC VALUE</strong></td>
</tr>
<tr>
<td>Use values</td>
</tr>
<tr>
<td>Direct values</td>
</tr>
<tr>
<td>• Consumptive use</td>
</tr>
<tr>
<td>• Non-consumptive use</td>
</tr>
<tr>
<td>Indirect values</td>
</tr>
<tr>
<td>• Ecosystem services</td>
</tr>
<tr>
<td>Option values</td>
</tr>
<tr>
<td>• Premium placed on possible future use</td>
</tr>
<tr>
<td>Non-use values</td>
</tr>
<tr>
<td>Bequest values</td>
</tr>
<tr>
<td>• Benefits for future generations</td>
</tr>
<tr>
<td>Existence values</td>
</tr>
<tr>
<td>• “Knowing it is there”</td>
</tr>
</tbody>
</table>

Use values – groundwaters

- Consumptive use provides revenue from consumers (to WSPs as water tariffs and to the WRMA as water charges); tax revenue to Government; and improved health, education and economic opportunity.
- Non-consumptive uses often have an economic value – hydropower or fish-farming, for example; however, these rarely apply to groundwater.
- Indirect values (ecosystem services – the Reserve) relate to springs, wetlands, baseflow; and to climate change mitigation.
- Option values (future generational uses; cf. inter-generational equity) are of limited applicability if deferred development of an aquifer imposes present-day costs or development foregone ("development now is preferable to development tomorrow").

Non-use values, groundwaters

- Bequest values are similar to option values above.
- Existence values are rarely applicable in a groundwater context, and unless an aquifer contributes directly to an amenity (e.g. a spring visited by tourists), it has no amenity or existence value.
Employing the ILEC approach is not applicable to groundwater resources – at least, not for the CSAs.

4.2 Placing values on Kenyan CSAs

Given the problems associated with determining the “value” of a groundwater described above, a simplistic method is used to indicate the relative value of the CSAs.

The value of the Merti aquifer abstraction is taken to be equivalent to water charges that would be paid by Category B, C or D water users (greater than 20 m$^3$). As we have no breakdown of applications or actual water use, we assume that 75% of abstraction falls into Categories B, C or D and users would then pay KShs. 0.50/m$^3$ as the minimum water use charge. For the economically most significant (the NAS), the revenue forgone by the WSP is calculated, using only the first tariff band (KShs. 18.71/m$^3$); this is compared with water charge revenue that the WRMA would expect to get if all water users in categories B, C and D were paying the minimum water use charge\(^8\) (KShs. 0.50/m$^3$), though in reality the actual earnings would be considerably higher than this minimum figure. For Tiwi and Baricho, we compare the tariffs used by the Water Companies and compare the value so calculated with the water use charge for public water supply (KShs. 0.50/m$^3$); as all use is high-volume abstraction, all water use is chargeable. We acknowledge that 100% revenue collection is not possible in the real world; however, this is a simplistic determination of aquifer value.

**Table 13: Relative value of abstraction from CSAs (million KShs.)**

<table>
<thead>
<tr>
<th>Volume (MLD)</th>
<th>Merti</th>
<th>Nairobi</th>
<th>Tiwi</th>
<th>Baricho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion charged</td>
<td>75%</td>
<td>81.6%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Volume charged (MLD)</td>
<td>10.9</td>
<td>129</td>
<td>13</td>
<td>60</td>
</tr>
<tr>
<td>Water charge (KShs./m$^3$)</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Value using water charge (KShs. Million/yr)</td>
<td>2.0</td>
<td>23.5</td>
<td>2.4</td>
<td>11.0</td>
</tr>
<tr>
<td>Tariff (KShs./m$^3$)</td>
<td>-</td>
<td>18.71</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Volume charged (MLD)</td>
<td>-</td>
<td>158</td>
<td>13</td>
<td>60</td>
</tr>
<tr>
<td>Value using tariff (KShs. Million/yr)</td>
<td>-</td>
<td>1,079</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

It should be noted that these “values” (particularly those based on water charges) represent an absolute minimum value. Irrigators place a far higher premium on their water supply; optimal net returns from water used by a range of irrigators in the Naivasha Basin ranged from $US 0.054/m$^3$ for irrigated grass to $US 4.4/m^3$ for greenhouse flowers (KShs. 4.3 to 350/m$^3$) (Sayeed 2001). Groundwater abstraction in 2005 in this basin was estimated to exceed 43.5 MLD (~16 MCM/yr) (Rural Focus Ltd 2006), of which about 80% was used for irrigation: the “value” of groundwater for commercial irrigation users is a huge sum.

Even ignoring the non-numeraire benefits (health, education, economic opportunity), it is clear that the CSAs have considerable economic value:

- In the Merti, the ability to access water is literally a matter of life or death; numerous small rural centres would largely fade away in the absence of groundwater, as happened at Wel Merer when its borehole failed in the 1980s and was re-established after a successful borehole was constructed there in 2002 (Aquasearch Ltd 2002). Poor aquifer management – the approval of boreholes in valuable grazing lands, for example (cf. Oxfam 2002) – can lead to grazing land use conflicts, however.

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\(^8\) 687 applicants for Category A water permits (10 m$^3$/d or less), out of a database of 3,737 applications is 18.4%. Therefore, 81.6% of abstraction is assumed to be in Categories B, C or D: (WRMA 2007).
• The NAS is commercially far more valuable than the indicative economic values above would suggest; the highly-profitable private sector commercial and residential building boom that the City of Nairobi has seen in the past eight or so years would largely fail were it to rely on mains water – so it relies on groundwater. Estate-type water supplies are often expensive, yet still cheaper than the purchase of bowser water: the actual cost of pumping water from a borehole and distributing it around an Estate in western Nairobi was KShs. 104 per m³ in early 2008 (pers. comm. Kisembe Estate Ltd).

• Both the Tiwi and Baricho aquifers are indispensable resources in their own right, supplying a significant proportion of drinking water to the Coastal strip.

These values need to be considered in light of the level of funding that groundwater development and management currently receives (Chapter 10 discusses financing). Detailed information on what resources are spent on groundwater as a whole is unclear, and the resources devoted to individual aquifers not known at all. Better accounting procedures need to be initiated, so that the level of investment – in development and management – of Kenya’s aquifers better reflects their value.
SECTION II: GROUNDWATER GOVERNANCE

This section focuses on governance arrangements for groundwater. It looks at the exercise of power by, and the actions of, the agencies that have mandate and authority over groundwater management and use. Governance is exercised through the formulation and implementation of policies, laws and regulations; the establishment of institutions with properly-defined functions and mandates; and ensuring that those institutions are adequately resourced and have proper knowledge, financial and technical capacity.

Kenya does not have policy, legislation and institutions dedicated specifically to the management of its groundwater. Rather, groundwater management is subsumed under broader policy, legal and institutional frameworks dealing with the management of water resources, or more broadly, natural resources, and with land use and physical planning. Policy and legislation relating to groundwater management must therefore be gleaned to the extent possible from policy statements on water resources, natural resources or land use planning. This section therefore discusses national policies on water resources management, environmental management and land use planning, in order to ascertain the extent to which they deal with groundwater management. The overall conclusion is that the policy, legal and institutional frameworks that exist are somewhat deficient from the perspective of groundwater management. An overhaul would be required to bring them in line with the requirements of frameworks for sound groundwater management.

This section is organised around the following six components: –

- Policy
- Legislation and regulations
- Institutions
- Rights and responsibilities
- Knowledge and capacity; and
- Financing.

In this section, lengthy and technical descriptions of policy and legislation have been assembled in Annexes for referral should such detail be required.

5 Policy

The following policy documents have been reviewed for the groundwater management perspective: –

- National Policy on Water Resources Management and Development
- Irrigation Master Plan
- Proposed policy on groundwater protection
- National Land Policy
- Policy on Environment and Development
5.1 National Policy on Water Resources Management and Development


1. To preserve, conserve and protect available water resources and allocate it in a sustainable, rational and economic way;
2. To supply water of good quality and in sufficient quantities to meet the various water needs, including poverty alleviation, while ensuring safe disposal of wastewater and environmental protection;
3. To establish an efficient and effective institutional framework to achieve a systematic development and management of the water sector; and
4. To develop a sound and sustainable system for effective water resources management, water supply and sanitation development.

A number of issues addressed by the policy have implications for groundwater management. These relate to: –

- The availability and vulnerability of groundwater resources;
- The institutional arrangements for groundwater management, including groundwater management capacity and financing;
- Integrated water resources management; and
- Groundwater quality management.

(i) On groundwater the policy recognises that surface and groundwater resources are unevenly distributed both in space and time, due to rainfall variability and diverse climatic and geographical conditions. As a result the flow regimes of rivers and streams as well as groundwater flow vary considerably.

The policy notes that groundwater resources are vulnerable to human and land use activities. It states that intensifying human activities, particularly in water catchment areas, have resulted in the deterioration and loss of areas under forest and constitutes a threat to the country’s water resources, not only in respect of siltation, but also as regards run-off, the water balance and groundwater recharge. The effect has been the diminution of renewable water resources. It identifies the solution to these problems to be the conservation and development of national water resources. In regard to groundwater this will be through the identification of groundwater conservation zones.

No groundwater conservation zone has been developed, apart from that around Nairobi that predates this policy statement. There has been an effort to develop a groundwater conservation zone around Lake Naivasha which has yet to be gazetted.

(ii) On institutional frameworks, the policy identified the problems existing in water resource organisation at that time to include: –

“over-centralised decision making processes, inappropriate and run-down monitoring network, inadequate database, discontinuous assessment programmes, uncoordinated source development, non-operative water rights, absence of special courts to arbitrate on water use conflicts and a generally weak institutional set up.” [para 2.2.1]
This remains the position to date, notwithstanding the enactment of the Water Act, 2002. What this highlights is that the problem is not an absence of policy, or of a proper diagnosis of the problem, but rather of the will to implement the solutions that would lead to meaningful progress towards a solution.

One of the consequences of institutional weakness is a poor groundwater database. The policy states that information flow in the water sector is characterised by data gaps due to discontinuous water resource assessment programmes, weak monitoring systems and an inadequate user database. It notes that the solution to these problems lies in setting up mechanisms for the continuous assessment of water resources, which includes strengthening the institutional capacity of the agencies responsible for the collection, storage and analysis of water resources data. This should be followed by the establishment of a fully-fledged hydrological, hydrogeological, water quality, water permit and socio-economic database at all water resource management levels [para 2.7.4].

No such database has been established as yet for groundwater data. The WRMA is embarking on a survey of groundwater abstraction in Nairobi, which will go some way to providing the required information at least with regard to the NAS (WRMA 2010b).

The policy makes the point that inadequate financial resources for water management generally, and by implication groundwater management, is because water has been perceived as a free commodity to be supplied freely and has not been regarded as a major source of revenue. Water revenue has been inadequate due to limited revenue base, ineffective revenue collection mechanisms and low water tariffs. The policy therefore states that water abstraction in its natural form will be charged a fee commensurate with the amount of water abstracted and the funds so generated will be used for assessing, monitoring conservation and management of water resources. This is in line with the “Dublin Principles” (WMO 1992).

Although the Act and Rules introduce water use charges on raw water abstraction, the collection of this charge from groundwater had been inadequate. Revenue collection data is not disaggregated on the basis of groundwater or surface water, so it is not easy to ascertain specific levels for groundwater; anecdotal sources suggest that the collection of water use charges has been undermined by the widespread belief that raw water is a free good which the WRMA has no justification to charge for (since the WRMA has not created storage or other works to augment the water available to justify its levying a charge). This is particularly so for groundwater, widely viewed as the private property of the landowner.

Finally, on groundwater management capacity, the policy states that the Government will encourage private sector-led drilling initiatives through competitive tendering procedures. The Ministry for Water will retain some capacity in drilling to allow for specific interventions during emergencies. The Ministry will also monitor and give guidelines on groundwater extraction and utilization.

The importance of groundwater in augmenting surface water supplies is recognised, but commensurate funding is not provided to safeguard and conserve it. The role of the private sector in the development of groundwater resources is recognised – indeed, ten years on the sector now is characterised by a large number of private drilling contractors who drill boreholes, often haphazardly; regulating private sector drillers to ensure that their actions are within the legal framework has become a major regulation issue. Public sector involvement in drilling is limited to the activities of the National Conservation & Pipeline Corporation, which under the Act is the Ministry’s contracting arm.
(iii) The policy also deals with IWRM and proposes that a National Standing Committee to deal with cross-sectoral issues will be established with representatives from all main water and related sector actors under the guidance of the Ministry in charge of water affairs. This Committee will spearhead the formulation of a policy on land, water and forests [para 2.3.3].

No such Committee has been set up. Indeed, far from developing a joint policy on land, water and forests, each of the sectors has developed its own policy. The ministry in charge of land has developed its own policy, just as the forest sector has its own policy. Whereas they call for cross sectoral linkages none of these policies provides any concrete mechanisms for fostering such linkages, with the consequence that the management of water resources, including groundwater resources, has continued to be carried on in isolation from the management of land and other land based resources.

(iv) Para 2.6 deals with water quality issues and states that pollution of surface and groundwater resources has become a major problem due to human activities; however, all the solutions proposed relate to surface water. They include strict stream effluent discharge standards, a process of water quality monitoring (which could extend to groundwater) and prior authorisation of discharge of undesirable substances in the water system. There is no express mention of groundwater.

From the perspective of groundwater management, the National Water Policy is deficient in achieving the four policy objectives listed above. It recognises groundwater as an integral component of Kenya’s water resources, but this recognition is muted, and inadequate attention is paid to the significance of groundwater as a source of potable and irrigation water in a water-scarce country. This is the case particularly in arid and semi-arid lands and also in major urban centres, such as Nakuru and Mombasa, where the role of groundwater in public water supply is critical to meeting water demand in these areas. The policy paper recognises the conjunctive management of groundwater with surface water particularly in augmenting water supplies, but adequate mention is not made of groundwater conservation and management.

Notwithstanding that groundwater is increasingly being resorted to by landowners to meet water demand, the water policy does not specifically address rights of access to groundwater. Similarly, the policy does not make reference to groundwater allocation mechanisms. Consequently, water allocation and access to it are subsumed under the general references made in the policy to the need for rational water resources management. The unique features of groundwater as a dispersed water resource are not recognised or addressed in the policy.

Significantly, the policy paper does not make provision for water resources management plans, including groundwater management plans. However, it discusses the identification of GCAs, which it puts forward as the solution to the problem posed by the potential risk of depletion of groundwater resources arising from human activities. The objective of identifying GCAs is taken forward into the Water Act, 2002.

Provision for the identification and designation of groundwater conservation zones is made in section 44 of the Water Act, 2002 but as already pointed out no new GCAs have been gazetted since the Act’s entry into force.

The policy recognises the potential for pollution of water resources including, by implication, groundwater resources, as a result of waste discharge. It makes provision for water quality control, but does not specifically make reference to groundwater recharge zone
protection. However, the designation of GCAs provided for in the Water Act could allow groundwater quality to be protected.

The policy does not make any reference to the impacts of climate change on groundwater and opportunities for adaptation. This could be explained by the fact that the issue of climate change had not, at the time the policy was formulated, become a key national policy issue. More recently a strategy on climate change has been formulated, which was discussed in S. 2.5 above.

The water policy recognises local groundwater management arrangements and stakeholder participation. However, focus seems to be given to local water supply, rather than local water management arrangements. Para 4.1.4 states that the Government will support private sector participation and community management of services backed by measures to strengthen local institutions in sustaining water and sanitation programmes. In practice, the role of the private sector together with that of non-governmental organisations has been confined principally to that of constructing boreholes, rather than involvement in the management and conservation of groundwater.

It is clear that the attention given to groundwater is not commensurate with its important role in water supply in Kenya. This becomes even clearer in view of the way in which groundwater management has been handled in practice.

These National Water Policy shortcomings insofar as it deals with groundwater could have been addressed by the draft groundwater protection policy, had this policy paper been adopted and implemented by the Government (see S. 5.2 below). However, as things stand, the groundwater protection policy, formulated by the WRMA, still remains a proposal that the Government has not yet formally adopted as a policy paper.

5.1.1 Transboundary groundwater resources management

Although National Water Policy recognises that Kenya has shared water resources, no specific proposals for the management of shared groundwater resources are included in the policy objectives. This weakness covers surface water, in regard to which there are no provisions for cooperative management with neighbouring countries either. More recently, in 2009, the Ministry formulated a draft policy paper on shared water resources (MoWI 2009d). However the policy paper has not given particular prominence to shared groundwater resources, either.

Kenya has five transboundary aquifers (footnote 5, p. 8); the key challenges in respect of transboundary aquifers have been identified as including the following (Mwango nd):

- No Memoranda of Understanding or Agreements yet exist;
- They are poorly documented and understood in hydrogeological terms;
- There is scarce regional information on their potential;
- Poorly-developed institutions and inadequate capacity and awareness make issues uncertain;
- Mechanisms to jointly manage recharge areas in sharing states need to be established;
- Appropriate institutional structures do not exist in some sharing states;
- Transboundary human resource capacity needs to be enhanced;
- Effective decision-support tools such as models need to be developed.

The Merti is a transboundary aquifer (Mwango et al 2004) which flows from north eastern Kenya into Somalia’s Lower Juba Region. This area was once partly reliant on Merti groundwater,
which becomes progressively more saline with eastwards progression (Lane 1995); by 1987, 42 boreholes had been constructed in both the fine and coarse facies Somali Merti (Faillace et al 1986-87), compared with 68 non-refugee camp boreholes in the Kenya Merti at present.

There is no formal transboundary management strategy in place; as the Merti is a non-renewable groundwater resource under current conditions, a long-term plan for its use needs to be developed; this should recognise that while ultimately the resource will become exhausted (the most conservative estimate suggests about 600 years: Lane 1995), its use should balance current development priorities with inter-generational equity. Decisions on this use need to be jointly developed and agreed by both States.

### 5.1.2 Irrigation Master Plan

Sustainable groundwater management is also glossed over in the Irrigation and Drainage Master Plan (MoWI 2009c), which states that it aims to achieve sustainable socio-economic development in line with the Millennium Development Goals and the country’s Vision 2030.

The Master Plan discusses the role of irrigation in the achievement of the country’s socio-economic development aspirations. It notes that the irrigation potential is estimated to be 497,000 ha of which over 300,000 ha are still undeveloped. It states that, to promote agricultural activity the area under irrigation and drainage will increase from 140,000 to 300,000 ha. It proposes as one of the strategic interventions to tap into this potential enhancing groundwater recharge and increasing the potential for groundwater irrigation. The Plan estimates groundwater resources at 0.65 BCM/yr, of which 0.2 BCM/yr is proposed be utilised for irrigation purposes.

Significantly, the Plan makes no reference to the potential for depletion of groundwater resources in consequence of more intense abstraction to meet the demands of increased irrigation. Consequently, it makes no provision for cross-sectoral linkages with the groundwater and environmental management institutions.

### 5.2 Proposal for a Policy for the Protection of Groundwater (PPPG)

In 2006, the WRMA formulated a policy paper specifically on groundwater governance (WRMA 2006). The paper discusses a framework for the sustainable development of Kenya’s groundwater resources by protecting legitimate uses of groundwater and providing a common framework to: –

(a) Conserve groundwater resources by balancing sustainable use and national development;
(b) Protect groundwater quality by minimising the risks posed by pollution (S. 1.4).

The paper proposes an approach that spells out statutory responsibilities for protecting and conserving groundwater resources. This includes specific measures to: –

(a) Ensure that all risks to groundwater resources are handled within a common framework;
(b) Provide a common national basis for decisions affecting groundwater resources;
(c) Encourage a common approach to groundwater protection by all relevant statutory bodies.

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9 A non-renewable groundwater is a “groundwater resource available for extraction, of necessity over a finite period, from the reserves of an aquifer which has a very low current rate of average annual renewal but a large storage capacity” (UNESCO 2006).
Chapter 4 considers how groundwater protection can be achieved in terms of the role of the WRMA; the paper sets out the general objectives of the policy as follows:

- Groundwater protection will consider sustainable development and socio-economic factors, and make decisions based on sound science and taking a long-term view; risk and doubt will be handled through the precautionary principle and by adopting a risk-based approach;
- The management focus will aim to prevent groundwater resources degradation though pro-active rather than retro-active measures;
- Groundwater protection needs cross-sectoral understanding and support, so where it has no statutory powers the WRMA will use its knowledge and influence to protect groundwater;
- The Authority will use risk-based methods to ensure that controls on groundwater use are proportional to the risk to the resource of a development. Activities that may impact groundwater resources may be inspected and monitored to ensure groundwater protection;
- The Authority will promote activities that are compatible with long-term groundwater protection and which maintain ecosystems and groundwater quality;
- The Authority will promote the restoration of degraded groundwater resources.

The National Water Resources Management Strategy (NWRMS) requires that water resources be classified, so the Authority will:

- Define and describe groundwater bodies in Kenya (✔);
- Define and quantify the Reserve for each groundwater body (✘);
- Identify groundwater bodies which are at risk of over-abstraction or water quality deterioration (✔);
- Produce a hydrogeological map of Kenya (✘);
- Produce a groundwater vulnerability map of Kenya, in detail as and where required (✘);
- Identify groundwater bodies which have been subject to significant pollution (✘);
- Develop a classification scheme for Kenya’s groundwater resources (✔);
- Develop a robust and representative monitoring network for groundwater quantity and quality in order to monitor the status of groundwater resources in the Republic (✔ and ✘);
- Develop a coherent and comprehensive overview of the status of groundwater quantity and quality in Kenya (✘).

Some of these have already been achieved, some not (indicated by ✔ or ✘ above): the NWRMS was published in January 2007, and the groundwater allocation thresholds document with both aquifer classifications and aquifer status in October 2007 (as Tables 5 and 6 above).

A key Authority role is the allocation of groundwater resources. The Authority will accomplish this through an allocation process that works in conjunction with a monitoring process. The objective of this is to allocate available groundwater resources (except the Reserve) to maximize economic development while safeguarding long-term groundwater resource sustainability. This addresses the shortcomings of the National Water Policy in specifically dealing with rights of access to groundwater and allocation of groundwater issues.

The Authority will therefore:

- Ensure that there is a sustainable balance between abstraction, the needs of GDEs, groundwater recharge and baseflow;
- Encourage the efficient use of groundwater;
• Prevent changes in groundwater flow where this leads to unacceptable changes in groundwater quality;
• Develop and apply criteria for defining wellhead protection areas that preserve groundwater resources for public groundwater supplies;
• Ensure that new allocations do not compromise resources allocated to existing abstractors;
• Report groundwater abstraction status in the NWRMS.

The Authority has not yet developed a water resources allocation plan for any groundwater or surface water resources, except with respect to Lake Naivasha and Nairobi. But even in those two cases, the allocation plans have not yet been formally adopted and implemented. The Nairobi WAP explicitly deals with groundwater allocation; the proposed Lake Naivasha WAP focuses on the allocation of the waters of the lake and of the groundwater resources in the area.

The paper notes the largely uncontrolled growth in large-scale groundwater development in the Republic, so monitoring water quality is a key aspect of the Authority’s water resources management mandate. The Authority will therefore maintain groundwater quality: –

• To avoid harm to human and animal health by chemical or bacterial agents;
• To avoid harming GDEs;
• To avoid damage to property (including the value of land); and
• To avoid impairment of amenity or other legitimate uses of the environment.

In order to safeguard public water supplies that rely on groundwater resources, the Authority will identify groundwater bodies supplying water to the public and will designate resource protection areas to safeguard against pollution. The Authority will also identify and work towards reversing pollution in groundwater resources using best available technologies that are not disproportionately expensive. Groundwater quality status will be reported periodically in the NWRMS.

The paper addresses many of the shortcomings of the National Water Policy from the perspective of groundwater management. However, it remains a proposal that has not been officially adopted by the Government as representing the country’s policy on groundwater management. Formulated by the WRMA, the policy was forwarded to the Ministry in charge of water and irrigation; however, the Ministry has not yet taken an official position with regard to it. Therefore officially the country still does not have a groundwater protection policy.

The lack of any meaningful action to adopt and implement the proposed groundwater policy – for four years - underscores the low priority given to the management of groundwater resources in official government policy, which can also be seen in the areas of financing, personnel and technical support.

5.3 National Land Policy

Groundwater use and protection is affected to a great extent by land use and land use change. Kenya does not have a national land use policy at present, but the law provides for the formation of regional and local physical development plans, which in effect provide the framework for land use planning in areas where these have been formulated. However, there is in place a land policy, which is a precursor to the formulation of a national land use policy. A number of its policy objectives are pertinent to groundwater management, particularly in areas of institutional
frameworks. It identifies as key institutional weaknesses the absence of a coordinating framework for cross-sectoral issues, the lack of effective land use planning and limited management and technical skills for natural resources management. It calls for putting in place the necessary mechanisms for effective coordination across sectors. Notably, however, no concrete steps have been taken to put in place such coordinating mechanisms, and therefore the policy statements remain mere aspirations (see Annex 1 on National Land Policy).

The key issue is that notwithstanding the recognition of the need for coordinated management of land-based resources, no action has been taken to achieve the policy objective. Land based resources are still managed on a sector specific basis. This undermines the sustainable management of groundwater resources.

5.4 Policy on Environment and Development

Another important policy paper in the context of groundwater management is the environmental management policy (GoK 1999c).

The national policy on environment and development has as its overall goal the integration of environmental concerns into national planning and management processes. Its objectives include conserving and managing Kenya’s natural resources. Whereas specific mention is made of the protection of water catchments and wetlands as objectives, no mention is made of groundwater conservation. Groundwater resources are not addressed even in the context of the discussion on rangeland resources, whose effective utilization is often dependent on groundwater resources. Groundwater is also not dealt with in the discussion on land degradation, drought and desertification (para 4.2.6). Therefore the management and protection of groundwater as an aspect of the policy on environment and development can only be implied from the mention made of natural resources generally.

Among the principles for environmental conservation which it outlines is that sustainable development and a higher quality of life can be achieved by reducing or eliminating unsustainable production and consumption practices.

Under land and land-based resources (discussed in Chapter 6.1.5), the policy states that an integrated and coherent approach to planning and management of land resources is essential to sustainable resource utilization. This is a point that has been made repeatedly in policy papers and yet no meaningful progress towards putting it into effect has been made.

The discussion on water resources (para 4.3) focuses on surface water resources, although some mention is made of the groundwater potential, which it estimates at 619 MCM/yr; however, no policy commitments are given for managing and conserving groundwater.

Therefore the environmental management policy misses the opportunity to address issues that are critical to sustainable groundwater management. These include mechanisms for preventing adverse ecological impacts on groundwater resources arising from environmentally damaging action, such as catchment degradation and the disposal of polluting liquids into groundwater resources. Nevertheless, it contains important policy objectives, such as its call for an integrated and coherent approach to planning and management of land resources.
5.5  **Policy on Climate Change**

At present there are no over-arching policies or legislation explicitly for the management of climate change. The National Climate Change Response Strategy (GoK 2010) proposes that the EMCA is reviewed in light of the need for response to climate change. The Kenya climate change response strategy in respect of water resources was discussed in S. 2.5.

5.6  **Summary of Policies**

In summary, the policy framework recognises groundwater as an important land based resource. However, the treatment of groundwater in policy statements is cursory. Groundwater is dealt with under the general umbrella of water resources, and its significance is muted. No specific policy statements are made which would facilitate the sustainable use and management of groundwater resources. These shortcomings are reflected in the priority given to groundwater in the actual management of land based resources, where surface water has a far higher profile.

6  **Legislation and Regulations**

6.1  **The perceived “private” nature of groundwater**

The common law, which applies to Kenya, essentially governs the landowner’s rights of access and use of water resources on the basis of the principle of reasonable use. This requires a landowner to put surface water resources to which he has access to reasonable use [see Annex 2 on Common Law Rights to Water].

The common law doctrine of reasonable use does not however apply to water which is not in a defined channel, or which is sub-surface percolating water. Such groundwater is dealt with under the common law principle which gives to the landowner proprietary rights or ownership over *all that lies beneath the earth and above the surface of the ground*. In effect, under the common law, a landowner has a right of absolute ownership over groundwater resources beneath his/her land.

Consequently, a landowner may appropriate for his/her own use all the water that is on his/her land if it does not percolate onto neighbouring land. A landowner similarly may appropriate groundwater, even if such appropriation causes groundwater which is under neighbouring land to drain on to the first landowner’s land, notwithstanding that it otherwise would not have done so, and appropriate that too (for instance by drilling a borehole), to the extent of draining the water that was on neighbouring land.

Thus, there is marked distinction between the common law principles governing the use of surface water and those governing the use of groundwater. This arises from the perceived difference between the two types of water: surface water is “something visible and no one can interrupt it without knowing whether he does or does not do injury to those who are above or below him”\(^{10}\). In contrast, to prove an interruption of groundwater flow would require scientific evidence.

The effect of the common law on groundwater is that a private landowner effectively owns the resource and can abstract it and put it to his own use without having to take account of the wide social requirements. This underscores the perception that groundwater is a private resource. This

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\(^{10}\) See the court decision in the Irish case of *Ewart v Belfast Guardians* (1882) 9 L. R. Ir. 172, 194 as per C. B. Pallas.
common law position has been qualified by the statutory provision dealing with groundwater management. This is discussed below.

6.1.1 Water rights and water permits

Legislation (including the new Constitution) has qualified the common law by vesting ownership of all water resources, including groundwater, in the state, and thus revoking the absolute rights of the private landowner. Although it has qualified the common law on water rights, the statutory framework on water rights has been heavily influenced by the English common law, from which it draws its main principles on groundwater resources use and management. This is discussed further in Annex 3 (Ownership Rights over Water Resources under Legislation).

The current position under legislation is that water rights may only be acquired through the Act through a permit [including groundwater resources]...” Section 27 makes it an offence to construct or use works to abstract water without a permit. Section 26 of the Act gives three exceptions to the permit requirement, one of which relates specifically to the use of groundwater.

So statutory law deals with groundwater in a way that is markedly different from surface water, notwithstanding that the ownership of both groundwater and surface water is vested in the State. But unlike in cases of surface water use, the use of groundwater does not ordinarily require a permit. A permit will only be required in the specific instances which are set out below.

(a) Where the works are situated within one hundred metres of surface water (other than an inclosed spring). This is a useful protective mechanism in instances in which the groundwater and the surface water are inter-linked but it leaves a gap in the management arrangements for protecting groundwaters which are not linked to surface water.

(b) Where the works are situated within a GCA. An area is declared by the WRMA to be a GCA where it is satisfied that special measures for the conservation of groundwater are necessary in the public interest. This is significant given that there is only one conservation area in the country – Nairobi.

(c) A permit is also not required for the abstraction of groundwater in an inclosed spring. This is a spring which is situated wholly within the boundaries of land owned by any one landholder, or which does not naturally discharge water into a watercourse abutting on, or extending beyond the boundaries of that land.

Thus, although statute has vested ownership of groundwater in the State, decisions on its abstraction are (with a few exceptions) left primarily to the landowner, unlike in the case of surface water use. This position in legislation underscores the “private nature” of groundwater resources. This limits the extent to which the state can intervene to conserve groundwater, particularly in the absence of groundwater management plans and where GCAs have not been declared.

The potential environmental impacts of the abstraction of groundwater require to be considered as part of the permit process. Under section 29(4) of the Rules, which deals with the procedure for obtaining a water use permit, an application for a permit shall be subject, where applicable, to an environmental impact assessment in accordance with the requirement of the Environmental Management and Coordination Act, 1999 (EMCA: GoK 1999b). This requires a prospective developer to carry out an assessment of the potential impacts of the development on the environment, and to apply for an Environmental Impact Assessment (EIA) license from the National Environment Management Authority (NEMA). In practice few people seek EIA licences prior to drilling boreholes for the abstraction of groundwater.
6.1.2 Regulating the construction of wells and boreholes

The construction of wells and boreholes are regulated under the Fourth Schedule to the Water Act which contains rules governing the abstraction of groundwater, which apply even in areas that fall outside GCAs. The Rules require that the person constructing a well/borehole shall:

(a) give notice of his intention to the WRMA and shall comply with such requirements as may be imposed by the WRMA;
(b) keep a record of measurements relating to the strata passed, levels at which water is struck and quantities of water obtained, and upon cessation of the construction submit the records to the WRMA;
(c) allow the WRMA’s officers access to the well to inspect it and take specimens and documents;
(d) if required by the WRMA where the well is being constructed within 800 metres of an existing well to apply tests to the existing well and supply the results to the WRMA;
(e) not waste groundwater by, for instance, abstracting water in excess of his reasonable requirements;
(f) deal appropriately with defective wells;
(g) prevent, minimize and control contamination and pollution of groundwater; and
(h) case artesian wells to prevent waste.

Through these requirements the WRMA would be in a position to regulate the abstraction and use of groundwater. The weakness of this system, however, is that it is dependent on landowners coming forward with the information regarding their intention to abstract groundwater. Since boreholes are located within the boundaries of private property, there is a good chance that the WRMA and neighbouring landholders may not know that a borehole has been drilled. The WRMA’s ability to enforce these rules through its own inspection and monitoring efforts and collaboration with neighbouring landholders in providing information therefore becomes critical to the effectiveness of the rules.

Part IV of the Water Resources Management Rules (LN 171, GoK 2007) supplements the provisions of the Fourth Schedule to the Water Act on the governance of groundwater. The Rules impose rules in regard to the development of boreholes, and require that an application for authorization to construct a well intended to be equipped with a motorized pump shall be accompanied by a hydrogeological assessment report. In practice, applicants may not prepare such a report, which they view as an unduly onerous requirement; the WRMA has not yet been able to universally enforce this requirement.

The Rules further state that –

(a) All new boreholes and wells to be equipped with motorized plant shall be subjected to test pumping and shall be constructed under the supervision of a qualified water resource professional; and
(b) Upon completion of construction of the borehole, the applicant shall submit to the WRMA a borehole completion record and approval or a permit to abstract groundwater shall not be given has until the WRMA has analysed the data.

There is explicit recognition that abstraction from neighbouring boreholes may affect each other, so drilling contractors are required to monitor neighbouring boreholes when a new borehole is tested. This is rarely done, because a) the client is typically reluctant to pay the additional costs of such activities, b) this requirement is very rarely enforced because the WRMA simply does not
have the capacity to do so, and c) even when attempts to do so are attempted, more often than not neighbouring boreholes have no dipper tubes (access to water level), or are themselves being pumped.

6.1.3 Wastewater licensing

Artificial recharge can potentially threaten the quality of groundwater. Regulation 78 of the Water Resources Management Rules (GoK 2007) deals with artificial groundwater recharge and states that no person shall undertake to construct works for purpose of conducting artificial groundwater recharge of an aquifer in a GCA unless the person has been authorized by the WRMA to do so. This enables the WRMA to regulate the practice of artificial recharge.

Wastewater licensing is dealt with under both the water resources management rules and the environmental management rules.

Part V of the Rules give the WRMA power to control the pollution of water, impose a requirement for an effluent discharge permit and stipulate that effluent may only be discharged into a water resource if it meets prescribed standards. The subsequent rules impose requirements for effluent discharge records to be maintained and for an effluent discharge control plan to be developed to support an application for an effluent discharge permit. These provisions can be used to regulate discharges of waste water which potentially could threaten the quality of groundwater.

Under The Environmental Management and Coordination (Water Quality) Regulations (GoK 2006), NEMA has imposed wide-ranging controls on water pollution which duplicate the water pollution control powers exercised by the WRMA. Rule 6 prohibits the discharge of effluent from sewage treatment works, industry or other point source pollution without a valid effluent discharge licence issued in accordance with the provisions of EMCA. Rule 11 prohibits discharge into the aquatic environment unless such discharge complies with [set] standards.” These rules similarly can be used to regulate potentially polluting discharges of wastewater which can threaten the quality of wastewater.

The Environmental Management and Coordination (Waste Management) Regulations L.N No 212 of 2006 imposes requirements for the sound management of hazardous waste. Regulation 19 requires every person who generates hazardous waste to dispose of leachate in accordance with conditions set out in the licence or in accordance with guidelines in the licence. The Regulations require operators of waste disposal sites to operate the sites in an environmentally sound manner and to comply with licence conditions.

The rules give power to control discharges which can degrade the quality of groundwater. However, for these rules to provide the protection required it would be necessary to identify strategic and vulnerable aquifers and groundwater abstraction points and focus the implementation and enforcement of the rules on such aquifers for maximum effect. This is because the implementing agencies do not have the capacity to provide uniform protection to all aquifers throughout the country. Focusing on vulnerable aquifers would therefore add most value. However at present these rules have not been applied to any of the CSAs, and therefore their potential protective effect has not yet been felt.
6.1.4 Controls on development in recharge/discharge zones and pollution

The protection of recharge and discharge zones of groundwater from pollution could also be achieved under the powers given to water service boards (WSBs) by section 73 to make regulations, for among other things, for the purpose of protecting against degradation, any water, whether on the surface or underground, which belongs to him or which for the time being he is authorized to take. The regulations would define the area within which the licensee deems it necessary to exercise control; prohibiting or regulating the doing, within that area, of any act prescribed by such regulations; and prescribing penalties.

Regulations made by a licensee may empower the licensee to require the owner or occupier of any land or premises within a prescribed area within the licensee’s limit of supply to execute and keep in good repair such works or take such other action as the licensee considers necessary for preventing the degradation of such water. Section 73 (7) provides that the licensee shall pay compensation on just terms to the owner or occupier of any premises within the prescribed area in respect of any curtailment of or injury to his legal rights by restrictions impose by such regulations; and any expenses incurred by him in complying with a requirement to construct and maintain any works, take other action, which would not, but for the provisions of the Water Act, lawfully have been required.

However if a person has not appealed against the requirement and the time for appeal has lapsed or the appeal has been dismissed but he nevertheless fails to comply with the requirement, the licensee may execute and keep in good repair the works and recover its expenses (other than expenses in respect of works the construction of which could not lawfully have been required otherwise than upon payment of compensation) as a debt from the person concerned.

Under section 75 a licensee may, on land belonging to him, or over or in which he has acquired an easement or right, construct and maintain drains, sewers and other works for intercepting or disposing of any foul water arising or flowing upon such land or otherwise for preventing water belonging to the licensee or which he is for the time being authorized to take, from being polluted.

Although these regulations are appropriate for protecting groundwater from pollution, no WSPs have gazetted any regulations to protect the groundwater from which they abstract water for public water supply. This is the case even in vulnerable aquifers such as Tiwi and Baricho, critical public water supply sources for the Coastal strip. In the groundwater context this implies wellhead total protection zones (TPZs: ARGOSS 2001; WHO nd) and the concept of “times of travel” from potential pollution source to abstraction point (ToTs: Norken 2005) to prevent contamination. Threats have been identified (see Boxes 3 and 4 at rear), and these resources at least do need protection.

6.1.5 Groundwater management plans and land use planning

Land use planning is undertaken under three different pieces of legislation, all of which operate independently of each other, thus highlighting the point made earlier about a lack of coordinating mechanisms. These are: –

- the Water Act 2002,
- the Physical Planning Act, 1996 and
The Water Act, 2002 creates mechanisms for planning, but these do not focus specifically on planning for groundwater management. Section 11 of the Water Act, 2002 provides that the Minister shall formulate a national water resources management strategy in accordance with which water resources of Kenya shall be managed, protected, used, developed, conserved and controlled. Additionally, the strategy shall provide for:

(a) determining the reserve;
(b) classifying water resources; and
(c) identifying areas which should be designated protected areas and groundwater conservation areas.

The determination of the reserve and the classification of water resources are mechanisms which could apply to surface water as well as to groundwater. However, not surprisingly, these concepts and tools have not so far, been applied to groundwater. Indeed there is an underlying assumption that they apply principally to surface water.

Thus the WRMA has the mandate to formulate a catchment management strategy for the management, use, development, conservation, protection and control of water resources within each catchment area. Among other issues, the strategy shall:

(a) Contain water allocation plans which set out principles for allocating water; and
(b) Provide mechanisms and facilities for enabling the public and communities to participate in managing the water resources within each catchment area.

Properly speaking a catchment area plan ought to contain plans for the use, allocation and management of groundwater resources in the area. This is because groundwater is an integral part of the water resources which should be addressed in the plan. Depending on the significance of the groundwater use in the particular area the plan can deal with groundwater either in a chapter or in an annex. However, groundwater has not featured prominently in catchment area plans; whose main focus has been surface water management and allocation, and catchment protection.

So legislation provides for the formulation of water resources management plans, which are referred to as catchment management strategies (CMS) and sub-catchment management plans (SCMPs). There is no different treatment accorded to groundwater, though at the same time there is no specific mention of groundwater management planning. There is therefore a risk that groundwater resources would not be dealt with adequately in a CMS or SCMP whose key focus is surface water resources; however, this is more an issue of awareness of the important role of groundwater rather than a lack of legislative framework.

The Water Act and the rules made under it also provide a framework for planning in regard to development of groundwater. Regulation 73 states that for the regulation of groundwater development the WRMA will determine in the allocation plan for a given aquifer the spacing of boreholes or wells to be equipped with motorized plant.

It will be guided by:

(a) Existing borehole or well spacing;
(b) Individual aquifer characteristics, including water quality;
(c) Existing aquifer use; and
(d) Existing bodies of surface water.
Section 44 provides that where the WRMA is satisfied that, in any area, special measures for the conservation of groundwater are necessary in the public interest for the protection of public water supplies or water supplies used for industry, agriculture, or other private purposes, it may, following public consultations, by order published in the Gazette, declare the area to be a GCA. The WRMA may impose such requirements and regulate or prohibit such conduct or activities in or in relation to a GCA as it may think necessary to impose, regulate or prohibit for the protection of the area and its groundwater.

The issues to be addressed in regard to the GCA are set out in Part XI of the Rules. These are discussed in Annex 4 (Rules for Protected Areas and Groundwater Conservation Areas).

Another important legislation that addresses land use planning, and is relevant for groundwater management planning, is the Physical Planning Act, Chapter 286 which mandates the Director of Physical Planning, an officer in the Ministry of Lands, to:

(a) formulate national, regional and local physical development policies, guidelines and strategies; and
(b) be responsible for the preparation of all regional and local physical development plans.

Among the matters set out in the First Schedule which may be dealt with in a regional physical development plan are “natural resource endowments” of the area. Among the matters set out in the Second schedule which may be dealt with in a local physical development plan is the conservation of the natural beauty of the area, including lakes and other inland waters, banks of rivers, foreshores of harbours, and other parts of the sea, hill slopes and summits and valleys. In both respects, these matters concern water resources management.

No specific mention is made of the conservation of groundwater resources as a relevant consideration in formulating physical developments plans, and yet whenever housing development occurs in a situation where the provision of water services is unreliable, developers typically will resort to drilling boreholes to supplement water supply, particularly in urban areas. This is a particularly acute problem with respect to the NAS, which is subject to intense exploitation. To date the only physical plan that has made any meaningful effort to address groundwater management issues has been that prepared for the Karen Langata area of Nairobi, which though gazetted, is not officially recognised by the City Council of Nairobi (the development control authority) and which therefore has not been enforced (MoLH 2006).

EMCA also gives a mandate for environmental planning. Section 37 of EMCA establishes a National Environmental Action Plan Committee to prepare a national environmental action plan for consideration and adoption by the National Assembly. Similarly Provincial and District Action Plans are to be prepared by the respective committees every five years. It is these which are to be collated into the National Environmental Action Plan. Again there is no reference to the need to include groundwater as part of these plans.

As this review of legislation and regulations shows, the Water Act and the Water Resources Management Rules together with other sectoral legislation, such as the Physical Planning Act, include specific groundwater provisions. Notwithstanding that the common law has dealt with groundwater as a private resource, the Water Act has dealt with it as a public resource vested in the State and subject to control by the Minister, as is the case with surface water. Legislation specifically regulates the construction of wells and boreholes. There are rules regulating waste waster discharges insofar as it affects groundwater and groundwater pollution.
These provisions form a sound basis for managing groundwater resources. However the key weakness is that GCAs have not been designated anywhere in the country, including in respect to strategic aquifers. Of the four CSAs, the NAS has been a GCA from before the enactment of the Water Act, 2002. The others have not been so designated. Secondly, groundwater management plans have not been prepared and the attention has focused primarily on surface water.

There are however significant weaknesses in the implementation and enforcement of the legal provisions and the rules. In a number of cases the rules duplicate each other, particularly those rules made under the Water Act and the ones made under the Environmental Management and Coordination Act. Each of the organisations lacks the institutional capacity to discharge its statutory mandate adequately. Further, the priority given to groundwater, in contrast to that given to surface water, has been low. At the same time there are limited inter-sectoral coordination mechanisms, which undermine cooperation between the various implementing agencies.

### 6.1.6 Stakeholder participation

The Water Act, 2002 provides for public consultation over key decisions (including decisions on issuing abstraction permits) as one of the mechanisms for involving stakeholders in water resources management. Section 107 of the Act and Part II of the Water Resources Management Rules make provision for involving stakeholders in decision making.

Regulation 28 requires that the WRUA give comments on an application for a water use activity. Therefore the WRMA shall submit a copy of every relevant application to the WRUA for comment. Additionally, the Authority shall cause to be published in a national newspaper a list of permit applications that fall into categories C and D. The Authority shall also display a notice of all applications received at the offices of the district commissioner, the district officer and the chief and at its own regional office.

A person may raise an objection to the application within thirty days of the public notification. Where an objection has been received then the Authority may hold a public meeting at the site with the relevant stakeholders and the WRUA to consider it.

A third way in which users and stakeholders are involved in water use decisions is that the Authority is required to maintain a register of authorisations and permits, which shall be open to the public. One may obtain a copy on payment of a prescribed fee.

The Water Act also provides for the establishment and operation of water resources users associations (WRUAs), and envisages that where the water resource in question is a groundwater resource, the WRUA would be formed in regard to the management of that particular groundwater resource. No distinction is drawn between groundwater and surface water resources, both being treated alike.

WRUAs are not traditional organisations. They are associations set up specifically to bring together users of a given water resource. They could certainly be based on traditional arrangements, but as water resources are allocated by means of abstraction permits rather than on traditional rights of access, WRUAs tend not to revolve around traditional use rights.

### 6.2 Strengths and weaknesses of current legislation

There is a comprehensive legal framework for the management of groundwater resources. The laws recognise groundwater as a water resource that is distinct from surface water resources.
Groundwater resources are vested in the State, and its control is vested in the Minister in charge of water. There is an express provision requiring authorisations and permits to be obtained for the abstraction and use of groundwater, notwithstanding that it may lie beneath the land of a private landowner. Furthermore, the law recognises the value of groundwater and imposes a charge for its abstraction and use.

Provision is made for groundwater conservation plans, which give a framework for taking special measures for the protection of groundwater – in cases where there is a risk of over abstraction, for instance. In the context of groundwater conservation zones, it is possible to designate recharge protection zones and aquifer protection zones to protect the aquifer from water pollution, for instance from the discharge of waste water.

However, the legislation has weaknesses; enforcement has been weak, and many of the provisions have not been implemented. By way of example, despite there being provision for the designation of groundwater conservation zones, none has been declared since the Water Act 2002 came into effect. Furthermore, many groundwater abstractors do not have permits do not pay water charges for groundwater abstracted. Weak implementation is due to a perception that groundwater is an inexhaustible resource, because of poor knowledge of groundwater resources, weak institutional capacity, poor funding and weak political commitment at senior policy-making level. The result is that over-abstraction and poor management has continued. In this sense the statement made in the National Water Policy remains substantially true in regard to groundwater today, and we repeat this, that the groundwater sub-sector is bedevilled by: –

“over-centralised decision making processes, inappropriate and run-down monitoring network, inadequate database, discontinuous assessment programmes, uncoordinated source development, non-operative water rights, absence of special courts to arbitrate on water use conflicts and a generally weak institutional set up.”

6.3 Recommendations for possible future changes

Addressing the problems affecting groundwater does not require additional or new legislation, except in respect of an over-arching policy for climate change. It requires action on key recommendations and policy objectives which have been made in policy statements over the years, the lack of attainment of which has been known for a considerable number of years.

Key among these is the development of a functioning mechanism for coordination of actions relating to groundwater across diverse sectors which affect the sustainable management of groundwater resources, including land, environment, and water resources.

Secondly, it will be necessary to give priority to groundwater management in the activities and programmes of groundwater management institutions. This requires providing the resources – human, technical and administrative – necessary to discharge their mandates effectively.

Third, action to enforce the rules regarding the requirement for authorisations, permits and water charges, and to improve compliance needs to be taken. Such action would need to target influential individuals and strategic public sector institutions which have operated under a framework of impunity in regard to groundwater abstraction. Success depends therefore principally on political will and commitment, since the legal framework which is in place has the basic elements required to manage groundwater sustainably. If the political will is present, the institutions mandated to manage groundwater resources would be provided with the technical and managerial capacity they require to succeed.
7 **Institutions (administrative/technical capacities at national and basin levels)**

7.1 **Extent to which groundwater is integrated with surface water**

Water management institutions manage surface water and groundwater alike, with no particular distinction made for groundwater. At both WRMA and the MoWI groundwater staff are designated, with roles built into the organisational structure of these institutions. The Table overleaf shows institutional roles and responsibilities, and these include both surface water and groundwater.

The National Policy endorses conjunctive use, while surface waters are “protected” from abstraction by nearby boreholes by the 100 metre buffer (S. 6.1.1 above). This does not, however, stop such boreholes from being drilled – at Baricho abstraction is quite explicitly a form of surface water abstraction, as is abstraction from the Daua Parma alluvial aquifer in Mandera District. Despite the 100 meter buffer rule, using bank infiltration or inducing recharge is not poor water resources management *per se*, provided it is planned and managed.

Although groundwater and surface water management is undertaken by the same institutions, the two functions are not integrated, but operate in parallel. So when a surface water abstraction application is made, the implications for groundwater recharge are not factored into the decision making, and *vice versa* – at the day-to-day practical level, there is very limited recognition that surface or groundwater resources may be affected by abstraction from one or the other, which accentuates the “invisible divide” between hydrology and hydrogeology.

### Table 14: Roles and responsibilities of water sector institutions

<table>
<thead>
<tr>
<th>Institution</th>
<th>Roles and responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Water and Irrigation (MoWI)</td>
<td>Development of legislation, policy formulation, sector coordination and guidance, and monitoring and evaluation.</td>
</tr>
</tbody>
</table>
| Water Resources Management Authority (WRMA) | Planning, management, protection and conservation of water resources.  
Planning, allocation, apportionment, assessment and monitoring of water resources.  
Issuance of water permits.  
Water rights and enforcement of permit conditions.  
Regulation of conservation and abstraction structures.  
Catchment and water quality management.  
Regulation and control of water use.  
Coordination of the IWRM Plan. |
| Catchments Area Advisory Committees (CAACs) | Advising WRMA on water resources issues at catchment level. |
| Water Resource Users Associations (WRUAs) | Involvement in decision making process to identify and register water user.  
Collaboration in water allocation and catchments management.  
Assisting in water monitoring and information gathering.  
Conflict resolution and co-operative management of water resources |
| Water Services Regulatory Board (WSRB) | Regulation and monitoring of Water Services Boards.  
Issuance of licenses to Water Services Boards.  
Setting standards for provision of water services.  
Developing guidelines for water tariffs. |
| Water Services Boards (WSBs) | Responsible for efficient and economical provision of water services.  
Developing water facilities.  
Applying regulations on water services and tariffs.  
Procuring and leasing water and sewerage facilities.  
Contracting Water Service Providers (WSPs). |
<p>| Water Service Providers (WSPs) | Provision of water and sewerage services |
| Water Services Trust Fund (WSTF) | Financing provision of water and sanitation to disadvantaged |</p>
<table>
<thead>
<tr>
<th>Institution</th>
<th>Roles and responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. The Water Appeals Board (WAB)</td>
<td>• Arbitration of water related disputes and conflicts.</td>
</tr>
<tr>
<td>10. National Water Conservation and Pipeline Corporation (NWCP)</td>
<td>• Construction of dams and drilling of boreholes</td>
</tr>
<tr>
<td>11. Kenya Water Institute (KEWI)</td>
<td>• Training and Research</td>
</tr>
<tr>
<td>12. National Irrigation Board (NIB)</td>
<td>• Development of Irrigation Infrastructure</td>
</tr>
</tbody>
</table>

The effect of not having a dedicated groundwater management institution has been to further marginalise groundwater management, since greater priority is given to surface water in terms of both human and financial resources, than to groundwater.

7.2 Devolution to regional institutions

Section 7 of the Water Act 2002 establishes the Water Resources Management Authority. Its functions are set out in section 6. Groundwater is included by virtue of the definition of water resources in section 2 of the Act.

Under section 14 of the Water Act, 2002, WRMA may designate a defined area from which rainwater flows into a watercourse to be a catchment area for purposes of the Act; Section 10 requires WRMA to establish regional offices in or near catchment areas.

Kenya has five hydrological basins. However, the WRMA has defined six catchment areas out of these five basins by dividing one of these, Lake Victoria, into two catchment areas, Lake Victoria South and Lake Victoria North. The other catchment areas are Athi, Rift Valley, Tana and Ewaso Ngiro North. All of these institutions were set up during 2005 (following the commencement of the Water Act, 2002) and have been operational for a period of six years now. Each catchment area is headed by a Regional Manager. For the purposes of groundwater management, WRMA has deployed to each regional office one hydrogeologist, with the exception of Athi region (within which the Nairobi aquifer is located) where there are three.

In defining the catchment and sub-catchment areas account has not been taken of the groundwater resources and how these might affect the definition of catchment or sub-catchment areas. Consequently, certain groundwater resources underlie two catchments and many more sub-catchments. This factor is not taken into account in the institutional arrangements that exist, all of which are based on surface water systems. Similarly, for reasons of international law, catchment areas are confined wholly to Kenyan territory. An example of such a case is the Merti, which traverses two WRMA regions (Ewaso Ngiro North and Tana), and also crosses the border between Kenya and Somalia.

There are no catchment areas or other institutional arrangements for managing trans-boundary groundwater resources. These require the development of cooperative framework between the countries with which Kenya shares a water resource. Currently, there are efforts to develop cooperative frameworks for the Mara River Basin between Kenya and Tanzania (including the establishment of a transboundary water resources users association) and for the Sio-Malaba-Malakisi River Basin between Kenya and Uganda. In both these cases the catchment area has been defined on the basis of surface water catchment areas, and not on the basis of groundwater basins. There are no arrangements underway to develop a cooperative framework for the management of shared groundwater resources, such as the Merti, which is shared with Somalia.

The WRMA is in place at the regional (RO) and sub-regional (SRO) office levels, but is not as effective as it might be due to institutional, human resource, technical capacity and finance limitations. Its groundwater manpower in particular is severely limited, and in only one case
does an aquifer have any groundwater staff dedicated to it (see S. 7.4 below for manpower issues).

7.3 Links between GW management and other sectoral institutions

There are limited formal frameworks for coordinating the activities of groundwater management institutions and the activities of other sectoral institutions. The key ones are the following institutional mechanisms:

- Catchment Area Advisory Committees (CAACs);
- District and Provincial Environment Committees; and
- District and Provincial Physical Planning Liaison Committees.

CAACs were established under the Water Act, to advise WRMA regional managers on water resources management issues in the catchment. The CAAC has a statutory membership of fifteen persons drawn from stakeholders including sectoral institutions in government, the private sector and civil society which are relevance to water resources management. Members may be drawn from the ministries responsible for lands, forests, mines, agriculture and others. Non-governmental organisations working in the area of water supply, many of whom construct boreholes, could also be represented. However, in making appointments to CAACS no special attention has been paid to representation by persons dealing particularly with groundwater management issues. This is the case in the catchment areas within which the four case study aquifers fall. This shortcoming ought to be addressed, particularly in those catchment areas in which where there are strategic and other important aquifers.

A common complaint emanating from CAACs is that, being advisory in nature, they have limited influence on decision making; WRMA ROs are not obliged to heed advice tendered by their CAACs, and are not accountable to the CAACs for their actions. This could be enhanced if greater attention was given to the need for enhancing the effectiveness of coordinating mechanisms.

The environmental management committees at provincial and district levels also bring together a wide range of stakeholders, including government representatives, non-governmental organisations and the private sector that have a role in environmental management. This institution could also facilitate coordination in managing groundwater resources. The key constraint faced by environmental committees, from the perspective of groundwater management, is that the potential scope of their mandate is so overarching that their ability to focus on a specialized issue like groundwater and its interconnection to environmental management is limited.

Physical planning liaison committees also have a membership that represents a diverse stakeholder group from within and outside government. However this institution is not a standing body; the law states that it is to be convened as and when the need arises. It has therefore rarely been functional and its impact has been limited.

The CAACs have been of limited relevance in respect of the CSAs. In the specific case of the NAS, guided tours of critical water resources issues shows that the Athi CAAC membership has a very clear understanding of the problems facing water resources management, and that they also have ideas for improvements; however, as they have no statutory powers or innate implementation capacity, their practical inputs have not been taken into account, and
information-sharing is poor – for example, information requests made by the Athi CAAC are often not responded to.

In summary, the capacities of the CAACs have not been made full use of, and because they have no powers, they are not always able to influence decision making in WRMA. Consequently, their effectiveness in respect of CSA or other aquifer management has been limited.

7.4 Human resources (skills and experience in groundwater management)

WRMA inherited the majority of its staff from the MoWI, many of whom joined WRMA on secondment. The staff complement at WRMA headquarters and in the regional and sub-regional offices is set out in Table 15 below.

Table 15: WRMA staff complement, 2010

<table>
<thead>
<tr>
<th>Regions</th>
<th>Staff Permanent (No.)</th>
<th>Staff Casuals (No.)</th>
<th>Groundwater staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRMA HQ</td>
<td>40</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Lake Victoria North Catchment Area</td>
<td>56</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Lake Victoria South Catchment Area</td>
<td>45</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Rift Valley Catchment Area</td>
<td>73</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Athi Catchment Area</td>
<td>70</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Tana Catchment Area</td>
<td>82</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Ewaso Ngiro North Catchment Area</td>
<td>55</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>421</strong></td>
<td><strong>37</strong></td>
<td><strong>1 + 6</strong></td>
</tr>
</tbody>
</table>

Whereas available information suggests that the number of groundwater staff (geologists, drilling inspectors and superintendents, groundwater inspectors and groundwater assistants) working in the Ministry are approximately 100, only nine hydrogeologists are deployed by WRMA as groundwater (management) officers. Each regional office has one groundwater officer, apart from Nairobi SRO (within which the Nairobi aquifer is located) which has two groundwater officers. Given the vastness of the areas to be covered by its staff the capacity of WRMA to effectively manage groundwater abstractions is limited.

Additionally, there is limited groundwater management capacity in the private sector, which employs a number of hydro-geologists as consultants. Occasionally, on specific assignments, these consultants are engaged on undertaking studies and other assignments on groundwater issues on behalf of WRMA.

It is clear that understaffing in the groundwater sector within WRMA is a significant problem. However, there are additional aspects that need also to be considered, in particular the relative “groundwater permit burden” a specific area has. Nairobi Sub-region has to police approximately 4,000 groundwater permits alone; compare this groundwater permit burden with Lake Victoria South Region, which has a total of about 1200 permits, both groundwater and surface water.

Whereas no workload analysis was available to inform this study, given the geographical scope of the catchment areas it is a reasonable supposition that there is significant understaffing within WRMA in regard to the management of groundwater resources.

EIAs in respect of groundwater are regulated by the NEMA. NEMA has District and Provincial Environmental Officers at district and provincial levels respectively. These officers act as secretaries to the District and Provincial Environment Committees. EIAs are discussed by these committees, although the decisions are made at headquarters. Consequently, NEMA’s capacity to
deal with EIA applications in respect to the development of groundwater from across the country and to monitor compliance is limited since there is only one officer at the district and one other at the provincial level. The focus on groundwater management is limited since few borehole drillers seek EIA licences.

The institutional arrangements for physical planning and development control are contained in the Physical Planning Act, Chapter 286. Section 4 establishes the office of the Director of Physical Planning which is responsible for formulating national, regional and local physical development plans. Part III establishes physical planning liaison committees at national, provincial and district levels. These bodies are set up as appeal and advisory bodies over physical planning matters. The development control function is vested in local authorities, within which the physical planning department is responsible for technical evaluation of applications for planning permission. Groundwater development would be considered in the context of planning permission applications. However, the local authorities retain physical planners and not hydrogeologists. Therefore their capacity in regard to addressing groundwater issues is non-existent.

Thus the human resource capacity within the groundwater management institutions for groundwater management is deficient. This underscores the marginal position of groundwater issues overall.

In the context of the CSAs, the specific allocation of Groundwater Officers (GWOs) is as follows:

- Merti: two Regional GWOs based in Ewaso Ngiro North (Nanyuki) and Tana (Embu) Regions respectively. Neither RO is closer than 250 km from the nearest part of the aquifer; Dadaab, the area of most intensive abstraction, is over 320 km from both ROs.
- Of the CSAs, Nairobi is best served: two GWOs are deployed at Nairobi SRO, within the aquifer. Neither of the other SROs within the NAS has a GWO deployed (Kiambu and Tana Region’s Murang’a SRO).
- Both the Tiwi and Baricho aquifers are managed from Athi Region’s Mombasa SRO, which has no GWO deployed (the GWO at Mombasa was re-deployed to Nairobi SRO); the Tiwi aquifer is located 10 km, and the Baricho aquifer 110 km from Mombasa. There is also a Regional GWO at Machakos RO, which is over 300 straight-line km from the coast CSAs. The CWSB has recently recruited an hydrogeologist who should contribute to the better management of the two Coast CSAs.

We exclude Ministry-deployed geologists from the above as they are neither formally nor actually working as groundwater resource managers.

7.5 Technical capacity

In the parlance of the sector, all GWOs are geologists (and have had some formal hydrogeology training). University curricula are modern and address emerging issues (except perhaps the integration of policy and governance into groundwater planning and management). The groundwater sector within WRMA suffers from a lack of technical equipment and logistic support; the ability of staff to generate aquifer models is constrained more by lack of data and operating platforms than a lack of ability.

There is, however, a limited understanding of the need to manage groundwater, at both the strategic (national water security) and local (aquifer management) levels. This is partly due to more attention being paid to day-to-day regulatory functions than to maintaining a strategic
outlook which, to be fair to Regional and Sub-regional GWOs, has not clearly been made part of their responsibilities; it should be, to the limits imposed by their relative geographic scale; the additional resources they need to do this should be made available. So, the capacity of technical staff within the public water sector is not as developed as is desirable, and insufficient groundwater staff are available to meet aquifer management needs within the WRMA. These are discussed in S. 7.5.1 below. Facilities for training groundwater engineers and scientists within Kenya are reasonably good and capacity is improving all the time (S. 7.5.2), but are still insufficient to meet Kenya’s needs. The need for a dedicated research function has been identified, and is discussed in S.7.5.3.

7.5.1 Capacity limitations

The nature of training of hydrogeologists and hydrologists in Kenya and the shape of career paths in the public and private sectors accentuates differences between these two disciplines, rather than encouraging their working together; this has led to the perception among both private and public sector hydrogeologists that groundwater is separate from surface water (and sometimes even considered “infinite”). Public perceptions are broadly similar.

None of the CSAs are recognised as discrete entities that are specifically “managed”; consequently, there is no information dissemination protocol developed for any of them. In the cases of Tiwi and Baricho there is very limited liaison between the CWSB and the WRMA, and WRMA are in possession of very limited data regarding these resources. In the Merti, the release of groundwater information by refugee camp management has until very recently been poor.

Within the sector, a number of shortfalls in groundwater sector capacity have been identified; these include the following:

Table 16: Capacity shortfalls in the groundwater sector

<table>
<thead>
<tr>
<th>Communication &amp; education</th>
<th>Data and information</th>
<th>Institutional</th>
<th>Technical training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding of GW management within the GW sub-sector is poor</td>
<td>Laboratory facilities/capacity inadequate</td>
<td>Institutions within water sector need to be integrated (mandate, data in particular)</td>
<td>Some additional technical training for GWOs required</td>
</tr>
<tr>
<td>Hydrogeology/hydrogeologists poorly understood within water sector</td>
<td>GW data availability inadequate for water allocation decisions</td>
<td>Greater Ministry support for WRMA needed</td>
<td></td>
</tr>
<tr>
<td>Public/political understanding about GW very poor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political support for GW management poor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant political influence in GW sector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public communication strategy needs to be developed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.5.2 Technical training capacity in Kenya

The University of Nairobi hosts Kenya’s only hydrogeology courses: at post-graduate level it produces two to six trained professionals a year (Hydrogeology and Groundwater Management). 25 to 40 B.Sc. Geology graduates are produced annually, but only a proportion of these go into the groundwater sector. This is inadequate to meet national needs, particularly at the post-
graduate level; consequently, the University is preparing an undergraduate taught course in hydrogeology, and proposes to establish a strong Hydrogeology Group under its own Chair.

The Kenya Water Institute (KEWI) is a semi-autonomous corporate body funded by MoWI, serving the Kenyan water sector. It conducts a range of training and research activities, and has recently been selected by UNESCO/IHP to host a Regional Centre for Excellence in training \(^{11}\) (GoK 2010c). It hosts the Applied Water Research Unit, which was transferred from the Ministry for Water in November 2004. Although it covers certificate, diploma and higher diploma courses that include groundwater elements, none is exclusively devoted to groundwater or its management.

### 7.5.3 Research needs

There is a clear need for a dedicated research function to serve the needs of the groundwater sector (indeed, the water sector in general) at a capacity greater than is available at present. There is considerable research capacity in Kenya’s universities, and latent capacity exists within KEWI. It is recommended that the MoWI arrange a meeting with, or solicit the views of, all the sub-sector and cross-sectoral stakeholders and draw up a joint research strategy. This would prioritise research themes (such as aquifer definition) in a rational framework.

However, while at present the universities conduct a wealth of water sector-related research, there is limited research coordination and no formal framework for its management and dissemination, either to the water sector or the public at large. Professional water engineers are poor at expressing themselves in terms that non-technical people and the public at large can understand. Therefore in addition to strengthening basic and applied research (which will require funding), the groundwater sector should also develop a research dissemination strategy.

Finally, there is no reason why WRMA cannot conduct or commission its own targeted research, within the financial resource constraints it faces – indeed, it already does so.

### 7.5.4 Summary

In summary, while the technical capacity generally exists in terms of skill-sets, inadequate staff numbers and limited resources, allied to a lack of strategic focus, means that groundwater management at the national and CSA level is ineffective. There is reasonably good training capacity in the country though more capacity is needed; and academic research into water-related issues is strong. However, research is not coordinated, and planning and additional human and financial resources are needed to coordinate and implement a more groundwater sector-specific research agenda.

### 7.6 Corruption

#### 7.6.1 Definitions

Corruption in water resources management as falls into three distinct groups (Transparency International 2008): –

- **Corruption related to water allocation and sharing** (bribing for obtain water permits, or to cover up illegal water use; patronage or policy capture to skew WRM decisions; allocations favouring specific interests in exchange for money or political support);

\(^{11}\) Dr. Dan Olago at the Workshop on 2\(^{nd}\) September 2010 at the Kenya School of Monetary Studies
• **Corruption related to water pollution** (bribes to cover up pollution events or to influence environmental assessments; policy capture or bribes to approve deforestation);

• **Corruption related to public works and management** (bid-rigging, collusion among contractors, embezzlement of WRM funds, buying appointment / promotion in WRM agencies, or favouring construction of projects because of policy-makers benefits).

This source also lists the outcomes of corruption in WRM: –

• **Impacts on economic efficiency**; because of its cross-sectoral economic importance (agriculture, fisheries, industry, transport, tourism), corruption can distort the productive or equitable allocation of water and inflating the overall cost of water supply.

• **Impacts on social equity, cohesion and poverty reduction**; water allocation is a form of power, so policy capture can create WRM rules that favour specific ethnic groups or business interests. This leads to adverse consequences for poverty reduction, social equality and political stability.

• **Impacts on environmental sustainability and health**; corruption leading to pollution or over-abstraction has serious consequences for human and animal health and sustainability; it also contributes to degradation of ecosystems, leading to long-term consequences for livelihoods, development, and natural resources conservation.

Corruption in groundwater governance is the subject of a specific study which is expected to be completed in mid-October 2010, and which will be reported separately.

8 Rights and responsibilities

8.1 Community-based organisations

Under section 15 of the Act, WRMA is required to formulate a catchment management strategy for each catchment and, under section 16, it shall appoint a catchment area advisory committee for each catchment area. The catchment area management strategy shall among other things, provide mechanisms and facilities for enabling the public and communities to participate in managing water resources within each catchment area. Section 15(5) deals more specifically with the institutional arrangements for community participation and states that “the catchment area management strategy shall encourage and facilitate the establishment and operation of water resources users associations [WRUAs] as fora for conflict resolution and cooperative management of water resources in each catchment area”.

Table 17 below shows the registration status of WRUAs by region as of mid-2010.

<table>
<thead>
<tr>
<th>Region</th>
<th>WRUA Establishment</th>
<th>WRUAs registered by AG</th>
<th>WRUAs registered by Social services</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Potential</td>
<td>Target</td>
<td>Achieved</td>
</tr>
<tr>
<td>Lake Victoria N</td>
<td>100</td>
<td>-</td>
<td>32</td>
</tr>
<tr>
<td>Lake Victoria S</td>
<td>-</td>
<td>80</td>
<td>36</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>-</td>
<td>51</td>
<td>47</td>
</tr>
<tr>
<td>Athi</td>
<td>60</td>
<td>50</td>
<td>57</td>
</tr>
<tr>
<td>Tana</td>
<td>840</td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>Ewaso Ngro N</td>
<td>-</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>&gt;1000</strong></td>
<td><strong>286</strong></td>
<td><strong>273</strong></td>
</tr>
</tbody>
</table>

(Source: WRMA)

For a WRUA to be considered for registration by the Authority, it should be legally registered as a society, have a constitution conducive to the collaborative management of the water resources
of a particular resource and which promotes public participation, conflict mitigation, gender mainstreaming and environmental sustainability [Regulation 10].

A number of WRUAs have proved to be effective in resolving water use conflicts, particularly in those catchments which are prone to water use conflicts. However, WRUAs are voluntary associations and therefore they are not uniformly spread across the country. Groundwater management WRUAs are rare, although two groundwater-specific WRUAs are under formation in the Tiwi and Gongoni areas in the Athi catchment; and three exist in the Tana catchment (at Lamu, Hindi and Mpeketoni/Lake Kenyatta).

8.2 The rights of access to groundwater

Rights of access to groundwater are obtained through a permit or authorisation issued under the Water Act, 2002 and the Water Resources Management Regulations, 2007 [see Section 6.1 above on Water Rights].

The permit is for a defined period of time limited to five years although it may be renewed at the request of the holder [see regulations 39 and 44]. The permit holder is required to maintain a record of the water abstracted and give the date, time, quality, quantity and purpose for which the water was used. The conditions subject to which the permit is issued will specify the quantity of water to be abstracted and the purpose for which it may be abstracted. The nature of the access therefore is fixed quantity and time based access.

In practice many water users do not install measuring devices, such as water meters for measuring the abstraction of groundwater. The result is that many have no accurate record of abstraction volume; at least one study shows that many abstractors abstract far more than is permitted, and use the water abstracted for purposes other than permitted, where the authorisation was for domestic use (WRMA 2010a).

Many landowners in Nairobi with groundwater permits sell water to neighbours, even though they do not have water service agreements with the Athi WSP allowing them to supply water to others. Consequently, the quantities they abstract far exceed “domestic” abstraction. However, as the WRMA does not have data on quantities abstracted and as its enforcement capacity is limited, abstractors defy the regulations with little fear of repercussions.

8.3 Involvement of water users and stakeholders

The Water Act enables water users (organised as WRUAs) to participate in water resources management. Additionally, the general public may participate in water resources management decisions, particularly as regards water use (i.e. abstraction etc) by lodging objections and comments when an application for a water use is made. These mechanisms enable the public generally and interested stakeholders, particularly the WRUAs to be involved in decision making.

The key weakness of these mechanisms is that they depend on pro-activity by members of the public, and have tended to be used largely by professional persons rather than members of the public per se. Registers of WRUAs are in many cases not established, notwithstanding the clear legal provisions. The WRUAs that have been set up have set out to deal with conflicts and management of surface water rather than groundwater resources, and mainly in those areas that are prone to water use conflict. There are no WRUAs specifically dealing with groundwater
management in the NAS, notwithstanding that there is intense water abstraction from that aquifer.

8.4 Participatory management

Ostrom (1990) described the basic requirements for the management of common pool resources as requiring the following “ground rules” to be agreed and adopted: –

(i) Rules should clearly define who has what entitlement;
(ii) Adequate conflict resolution mechanisms should be in place;
(iii) An individual’s duty to maintain the resource should stand in reasonable proportion to the benefits;
(iv) Monitoring and sanctioning should be carried out either by the users themselves or by someone who is accountable to the users;
(v) Sanctions should be graduated, mild for a first violation and stricter as violations are repeated;
(vi) Governance is more successful when decision processes are democratic, in the sense that a majority of users are allowed to participate in the modification of rules;
(vii) The right of users to self-organise is clearly recognized by outside authorities.

Existing WRUAs do not have the autonomy and powers that Ostrom’s management approach requires, although some progress has been made by WRUAs that are both well-financed and motivated. CAACs are not at present mandated to participate in grass-roots community-based water sector management, so in Ostrom’s sense are not potential common pool resource managers.

8.5 Level of authority accorded to representative groups

CAACs are groups that represent catchment level interests. However, there has been a complaint by many CAAC members that they are not effectively involved in decision making, and that their advice is often not taken account of. Some members of CAACs have expressed the desire to become fully autonomous boards as a way of enhancing their influence.

The level of authority accorded to WRUAs has been less than is provided for in the Rules, in particular regulations 7 and 8. These state that the Authority may enter into an MOU with a WRUA for purposes of collaborative management of water resources. This MOU may provide for the role of the WRUA including data collection, collection of levies and monitoring of water use. WRUAs have indicated that they would like to have an enhanced role in water resources management, going beyond the activities which WRMA has been engaging them in to date. Overall WRMA has not made use of the full potential of WRUAs to manage water resources – and equally, water users and other stakeholders have not grasped the opportunities offered by WRUAs. However, this may change, as the example provided by WRUAs in the Lake Naivasha basin shows (see text box below).

WRUAs in basin water management – the Lake Naivasha case

In the early part of the present decade, water users in the Lake Naivasha Basin had become increasingly aware of the unsustainable level of abstraction from the hydrological system, a situation which was nearly impossible to quantify due to poor and inaccurate hydrological records; lack of accurate information on actual abstraction; weak water permit data; and poor compliance with and weak enforcement of water laws.
Commercial water users led the way in commissioning a water allocation plan, and by 2005 were working with the WRMA to develop this and improve the transparency and accountability of water uses in the Basin. Water user interests were to be taken on-board through the development of Water Resources Users Associations (WRUAs).

The Lake Naivasha Water Resources Users Association (LANAWRUA) is a blanket WRUA that includes the 12 WRUAs in the Naivasha Basin (the upper sub-basins of the Malewa, Gilgil and Wanjohi and others; and the Lakeside zone). Since its inception, the WRUAs have

- Conducted abstraction surveys (both surface and groundwater);
- Water Permit compliance surveys (both);
- Monitored and checked flowmeter status (both);
- Sensitised water users on water use regulations and their obligations (both);
- Provided direct feedback to the WRMA on applications for water permits (both); and
- Provided a forum through which water conflict can be resolved.

Partly as a result of the WRUAs, new Rules have been developed that proposes both catchment and groundwater protection (The Lake Naivasha Catchment Area Protection and Groundwater Conservation Area Rules), and under which the Lake Naivasha Catchment Area Water Allocation Plan will be gazetted. This is planned to be during 2010.

At present, the powers of the WRUAs are limited to what is allowed under existing legislation, but under the proposed Rules they are expected to be key in education, checking water use compliance and in promoting water use efficiency. They will be appointed Agents of the WRMA, “for the purposes, inter alia, of assisting the Authority in gathering information about water resources within its area of operation; monitoring the use of water; inspecting compliance to this rules; enforcing compliance with the conditions of water use permits”.

These Rules have yet to be passed into law, and it remains to be seen how effectively they will work in practice; however, this is the first time a GCA has been proposed under water legislation since before independence, and may show the way forward for participatory groundwater resources management in Kenya. However, a 1,200 ha area overlying a sand dune aquifer was declared the “Lamu Water Catchment Area” under The Antiquities and Monuments Act (Cap. 215) in the Kenya Gazette of 28th March 2002.

8.6 Opportunities for participatory management in the CSAs

8.6.1 The current situation

At present no WRUAs or other organisations are active in the management of groundwaters in any of the CSAs. This is partly because WRUAs generally become established in response to a conflict or potential conflict situation (this has very much been the case in the formation of the earliest WRUAs that were established prior to the Water Act 2002 in the north western catchments of Mt Kenya). Because groundwater is “out of sight, out of mind”, and because of a lack of understanding of the need to manage it, conflict is not observed and so there is no perception of a management need.

In the Merti aquifer there are both Water User Associations (WUAs), which have formed around community-owned boreholes for water supply management purposes; and Pastoralist Associations (PAs), broader, community interest organisations that necessarily include issues relating to water and related conflict resolution and which also manage water supplies (FAO
2006: Oxfam 2002). However, neither of these types of body is involved in groundwater resources management.

The NAS is unique among the CSAs due to its largely urban character. The common pool nature of the resource and ownership perceptions means that there is little interest in groundwater conservation, and widespread ignorance of the impacts the aquifer has already sustained means that those bodies that might be able to contribute to participatory management focus more on water resources that have been visibly affected. Thus the Mbagathi River WRUA (to the west of the City) was established to stem degradation of the Mbagathi River; while its membership is aware that groundwater management is an issue, it is not of a sufficiently high profile to be considered a major WRUA priority. The Athi CAAC has been involved in reviewing applications for groundwater permits, and in several cases has recommended rejecting some of these.

In the case of the Tiwi and Baricho aquifers this is partly because aquifer use is restricted to public water supply (although a WRUA is being formed in the Tiwi area), but principally because neither CSA has become degraded.

8.6.2 Potential for participatory management in the CSAs

At present, there is limited real participatory management for a host of reasons; the most significant of these are:

- Lack of recognition of the need a) for aquifer management in the first place, and b) for that management to be participatory;
- Lack of support for groundwater management in general;
- Although the instruments exist for a WRUA to be a participant in water resources management, their powers – in terms of controls or vetoes over additional abstraction – are too weak to encourage sector actors (water users and the public at large) to participate.

Is there scope for participatory management in any of the CSAs? In short, yes – subject to a number of significant caveats. In the Merti limited impacts on the aquifer (which are mostly restricted to the refugee camp area) mean that there has not been the degradation or depletion that would drive sector players together to manage it. This will change in the long term, and will bring with it a need for both regional management (at the aquifer scale) and local-level management (essentially abstraction management).

The NAS is the aquifer most in need of pragmatic management, but its urban nature, the practical value of groundwater to commercial developers and a lack of a rational groundwater allocation process all conspire against participatory management. This will have to change if the best use is to be made of this resource, but first of all an aquifer use policy needs to be developed, to guide further groundwater use.

The Tiwi aquifer does have some scope for participatory management, with the key stakeholders being the CWSB/KWASCO, Kwale County Council and the NESC (in the context of the South Coast Resort City and V2030). As it is currently not degraded, and as it is likely that in the medium to long-term greater abstraction from it is likely, a strong case can be made for the initiation of a planning and groundwater management process immediately (see Section 14.4).

However, for any meaningful participatory management to take place, the regulatory and support environment needs to change. This is discussed elsewhere in this report.
8.7 Opportunities for women

The Government has a gender mainstreaming policy which requires that women take up 30% of positions. Further WRUAs are supposed to demonstrate that they have provided opportunities for women to participate. The Water Act also provides that, in making appointments to the Board and to CAACS, the Minister shall take account of the need for gender equity. In practice this has not been complied with, although there is a positive trend towards providing opportunities for women in decision making in water resources management issues.

8.8 The private sector in groundwater management

The private sector plays a key role in borehole drilling. Others are qualified water resource professionals, i.e. geologists/hydrogeologists, engineers and so on. They are regulated under the Part XIII of the Rules. These require that qualified water professionals and contractors be licensed by the Ministry. The Ministry is required to introduce Codes of Practice for compliance by the professionals and the contractors, but to date this has not been done.

The Ministry therefore acts as the regulator of the professionals and contractors. A number of commentators have expressed the view that WRMA, which issues permits and monitors the activities of the professionals and contractors, should regulate the professionals. The experience has been that the fact that the Ministry is the regulator has undermined WRMA’s authority and ability to impose its requirements on these contractors. Thus where a contractor drills a borehole without an authorisation, which does happen, all that WRMA can do is report the matter to the Ministry, where the likelihood of punitive action is small. Indeed, there is no recorded instance since the commencement of the Water Act, 2002 in which the Ministry has taken disciplinary action against a drilling contractor for drilling a borehole without an authorisation. Furthermore, proposed Codes of Practice to ensure compliance by water sector professionals and drilling contractors with good practice, forwarded to the Ministry by WRMA, have not been gazetted.

There is no stakeholder consultation in the registration of professionals and contractors, and no inputs from the professional groundwater fraternity.

8.9 Inventory of groundwater users, uses and use status for the CSAs

Boxes 1 to 4 (at rear) provide information on water users and use for each of the CSAs. In brief, under the status quo there is little detail about groundwater users, use or use status (breakdown by use or volume of use), except for the Tiwi and Baricho aquifers (which in this context are exceptions to the rule, as they are used exclusively for public water supply through the Coast Water Services Board). At Tiwi and Baricho the details should be easy enough to compile; however, as there are no water permits issued for either of these aquifers and water uses, and as no water use charges paid, the WRMA does not have any details other than approximate abstraction data.

In the NAS it is estimated that approximately 15% of all water users abstract water in accordance with the law (i.e. they possess water permits and pay water charges) (WRMA 2010b). It is expected that this situation will change in the wake of a borehole inventory study that is currently being conducted.

In the Merti the major single water user – the UNHCR and refugee camp NGOs – is known and abstraction is also known with reasonable accuracy. However, water charges are not paid, apparently because of an agreement between the UNHCR and the Government of the Republic of
Kenya. This is inconsistent in terms of international agreements, since the United Nations was the progenitor of the Dublin Principles (WMO 1992) and the organising host of the Earth Summit in Rio de Janeiro (UNCED 1992 and Agenda 21).

9 Knowledge (and capacity at the local level)

9.1 Science and the knowledge base

A knowledge shortfall could potentially rob Kenya of its ability to make the best use of its groundwater resources, thus affecting wealth-creation strategies and the achievement of the Millennium Development Goals (MDGs: UN 2000b). Thus, for example, if an aquifer has not been identified, or if the resource potential of an aquifer has been underestimated, then a development opportunity may have been lost or deferred.

Has this happened in Kenya with respect to groundwater resources? We cannot state with any certainty that it has not, simply because we do not know what it is that we are still ignorant of. Table 10 above showed that the Tiwi aquifer appears to have a significant volume of renewable water resource unexploited (annual recharge exceeds current annual abstraction), with the recharge/abstraction ratio at 4.4.

Under current legislation (GoK 2007 §127 – 129), the WRMA is required to determine the Reserve (that proportion of a water resource that must not be abstracted but which goes to meet ecological and basic human needs [BHN]) for all water resources. This has not yet been done for any of the Case Study aquifers; however, in the Tiwi case, current abstraction amounts to 23% of the renewable resource, so additional resources should be able to be abstracted without ill-effects anticipated. In this particular case it might be argued that development may have been delayed because this balance has not been exploited. The Coast WSP has reservations about further utilisation of the Tiwi wellfield for management reasons – difficulties faced include unreliable revenue collection from the WSP (Kwale Water and Sewerage Co Ltd); unreliable electrical power; and high energy cost per m³ of water.

The conservative rule of thumb applied previously allowed groundwater users to pump at 60% of test yield for no more than 10 hours a day; this is equivalent to 25% of tested yield; on this basis, additional abstraction from the Tiwi aquifer could rise to 5.3 MCM/yr, or an increase of 500,000 m³/yr (1,370 m³/d).

The 25% recharge/abstraction ratio is conservative; in draft water resources management legislation it was proposed to set the Reserve at 40% of mean annual recharge leaving 60% for use; in the Tiwi case this would allow the abstraction of a further 7.8 MCM/yr (21,400 m³/d). This draft provision was amended to allow the Authority to set its own Reserve values on the basis of individual aquifer parameters, which is preferable to applying a blanket rule by recognising that each aquifer is unique, and that management tools should be developed for each aquifer as appropriate.

It is certain that we do not know sufficient about our groundwater resources to be able to optimise their use; few of Kenya’s aquifers have been subjected to the kind of detailed analysis required to do so – indeed, the very fact that the WRMA has yet to ascribe reserve values for specific aquifers is implicit acknowledgement of this fact.
9.1.1 Hydrogeological maps

This study illustrates how difficult it is to “define” an aquifer; of the four case study aquifers considered, only one has been the subject of an intensive investigation which reveals the detailed geometry and extent of the aquifer unit (Baricho); the other three are defined in water chemistry terms (Merti) or on the basis of simple geophysics/geology/hydrogeology (Nairobi and Tiwi).

Simple “aquifer maps” exist for Lake Victoria North, Tana and Athi catchments (WRMA CMS documents 2009); and for North Eastern Province (WRMA 2009b) and the Nairobi aquifer area (at 1: 500,000 scale: WRMA 2010a); however, these are too coarse for day-to-day groundwater resources management, which requires precise boundaries on a large scale map (1: 50,000 or better). The national hydrogeological map is not of a scale that individual aquifer management decisions can be readily made.

A felt need expressed by WRMA sub-regional staff is for hydrogeological maps of specific areas or, ideally, aquifer units themselves. The development of hydrogeological maps (sensu stricto Struckmeyer et al 1995) is an expensive exercise, even when there are adequate data available for their compilation; a hydrogeological mapping exercise conducted in Zambia’s Southern Province, an area of 85,500 km², covered a period of 30 months and was conducted by an interdisciplinary team of about 10 (Bäumle et al 2007).

Improving the situation will require substantial financial and technical resources; the former is the more significant issue – Kenya has the technical capacity to develop hydrogeological maps, albeit perhaps with some technical assistance in the formative stages. The Japan International Cooperation Agency National Water Master Plan update currently being planned should include, at the very least, a pilot hydrogeological map component. To this end, WRMA should prepare a priority list of aquifers requiring hydrogeological maps, after appropriate consultation, for submission to the Ministry for review and incorporation into the pending NWMP update.

9.1.2 Downhole television cameras

A second felt need is for downhole television cameras (DHTVs); these would be invaluable for establishing construction characteristics of boreholes for which records are lost, or for checking the quality of construction of a borehole. DHTVs are relatively cheap (~$US 5,000 for a basic black and white set), and their procurement on a limited scale is recommended.

9.1.3 Digital models

Aquifer modelling is a standard groundwater resources management tool in developed countries, but due to technical capacity and more significantly, cost, very few aquifer models have been developed for Kenyan aquifers. Digital aquifer models exist for Baricho (NWCPC 1995), Nairobi (MoLRWD/BCEOM 1998), part of the Msambweni aquifer (GSK 2005), and Mombasa / Kisauni (Munga et al 2006); there may be others. The validity of the 1998 Nairobi aquifer model is considered debatable (GW•MATE 2005c). All models could be used for active aquifer management purposes.

Key aquifers (STRATEGIC and some MAJOR aquifers) must ultimately be modelled if their management is to be meaningful and directed. Given their great importance to the local and national socio-economic sphere, the Nairobi and Tiwi aquifers should be modelled as a matter of urgency.
In order to achieve this, additional financial resources will be needed, as well as an improvement in technical capacity. There is a growing body of younger groundwater professionals with the training to develop and calibrate digital groundwater models, but they have limited scope to practice their skills.

9.2 Monitoring

Groundwater monitoring – both water level and quality – is an essential element in the effective management of an aquifer, and commensurately more so in an aquifer that is vulnerable. Monitoring water resources should cover all hydrological parameters (streamflow, climate etc). We concentrate here on groundwater monitoring – why we do it and what we learn from it. We exclude hydraulic tests conducted on a borehole after it has been completed – these are a form of baseline monitoring, but more properly belong to aquifer characterisation than monitoring.

There are essentially three different types of monitoring, each relevant in different contexts:

- **Baseline monitoring** (or proactive monitoring) is conducted to determine the responses of an aquifer to natural environmental conditions; this is useful to establish natural variation in water quality and water level fluctuation. The longer a baseline record is, the better; however, some consider five years to be the minimum desirable (ACWI 2009).
- **Trend monitoring** (or reactive monitoring) is conducted to determine the responses of the target aquifer to changing conditions imparted as a result of land-use change, abstraction or possible pollution; it should take place after a baseline monitoring period, though in Kenya most monitoring starts – or will start – as trend monitoring, as we are most usually monitoring a hotspot zone (or anticipated hotspot).
- **Project-specific monitoring** varies according to context; it may be conducted in order to monitor in detail a pollution event; or the movement of a halocline inland; or to develop a groundwater model; or for a proposed large-scale groundwater abstraction scheme that is expected to impart changes that need to be watched. Monitoring as part of research would also be “project-specific”.

The frequency of monitoring depends on aquifer and environmental context, and the following aspects need to be considered when drawing up a monitoring programme:

**Table 18: Variables that influence groundwater monitoring frequency**

<table>
<thead>
<tr>
<th>Environmental condition</th>
<th>Less frequent</th>
<th>More frequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer type</td>
<td>Deep, confined</td>
<td>Shallow, unconfined</td>
</tr>
<tr>
<td>Groundwater flow rate / recharge rate</td>
<td>Slow</td>
<td>Rapid</td>
</tr>
<tr>
<td>Abstraction rate</td>
<td>No abstraction</td>
<td>Intensive abstraction</td>
</tr>
<tr>
<td>Climate variability</td>
<td>Less variable climate</td>
<td>More variable climate</td>
</tr>
</tbody>
</table>

(After: Taylor et al 2001)

The current monitoring frequency varies from aquifer to aquifer and from region to region; thus water levels in monitored NAS boreholes is monthly, reflecting the concern that WRMA has for this resource. Chemical parameters at Baricho are measured bi-monthly, and at Tiwi bi-annually. The current monitoring frequencies reflect personnel and equipment limitations and are not the outcome of earlier plans, which envisaged not less than quarterly monitoring of key parameters (levels and indicative chemistry).

The density of monitoring points is also context specific, and should be denser the more heavily-utilised an aquifer is; and more dense in shallow or unconfined aquifers than in deep or confined aquifers. The USA had about 3,000 monitoring wells in 1933, 20,000 by the end of 1954 and
42,000 in 2001 in its major aquifers (Taylor et al 2001), though it would be pointless to recommend emulating this level of density in Kenya. The National Water Quality Assessment programme in the USA advocates an ultimate maximum density of one borehole per 100 km², a density that Kenya could not emulate in the short- to medium term. For the time being, monitoring well density should be decided on a case-by-case basis, depending on abstraction intensity, aquifer vulnerability and available financial and technical resources.

9.2.1 Water level monitoring

Until recent years, the regular monitoring of groundwater resources was not carried out or only carried out on a somewhat ad hoc basis. WRMA has now instituted a monitoring programme which targets most of the important Kenyan aquifers. The principal disadvantage of the monitoring network currently in place is that the majority of boreholes used are production boreholes; this means that the operator must be trusted not to pump for the time necessary for water levels to return to static levels prior to measurements being made.

Eleven dedicated monitoring boreholes are in the process of being constructed in a variety of aquifers across Kenya:

Table 19: Dedicated monitoring borehole network

<table>
<thead>
<tr>
<th>Region</th>
<th>Monitoring BH location</th>
<th>Depth</th>
<th>Aquifer</th>
<th>Class</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Victoria N</td>
<td>Bungoma Town</td>
<td>100 m</td>
<td>Kavirondan (Bungoma)</td>
<td>MAJOR</td>
<td>Alarm</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>Bahati Kabatini, Nakuru</td>
<td>160 m</td>
<td>Nakuru Town</td>
<td>STRATEGIC</td>
<td>Alert</td>
</tr>
<tr>
<td></td>
<td>Rongai Town, Nakuru District</td>
<td>180 m</td>
<td>Rongai</td>
<td>SPECIAL</td>
<td>None</td>
</tr>
<tr>
<td>Athi</td>
<td>Kenya High School, Nairobi</td>
<td>300 m</td>
<td>Nairobi</td>
<td>STRATEGIC</td>
<td>Alarm</td>
</tr>
<tr>
<td></td>
<td>Mbagathi Ridge, Nairobi</td>
<td>310 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kenya Polytechnic, Nairobi</td>
<td>300 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mombasa</td>
<td>18 m</td>
<td>Coral limestones &amp; sands</td>
<td>MAJOR</td>
<td>Alarm</td>
</tr>
<tr>
<td>Tiwi</td>
<td>Mombasa</td>
<td>18 m</td>
<td>Coral limestones &amp; sands</td>
<td>MAJOR</td>
<td>Alarm</td>
</tr>
<tr>
<td>Tana</td>
<td>Kenol, Mukuyu</td>
<td>200 m</td>
<td>Nairobi</td>
<td>STRATEGIC</td>
<td>Alarm</td>
</tr>
<tr>
<td>Ewaso N'iro N</td>
<td>Dagaahaley Refugee Camp</td>
<td>150 m</td>
<td>Merti</td>
<td>SPECIAL</td>
<td>Alert</td>
</tr>
<tr>
<td></td>
<td>Merti Town</td>
<td>70 m</td>
<td>Colluvial (alluvial)</td>
<td>POOR</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

(Source: pers. comm. World Bank 21 August 2010; & WRMA 2007)

These monitoring boreholes will be equipped with digital loggers, which will provide more reliable data than hitherto – and allow flexibility in determining how frequently data are collected.

WRMA attempts to manually collect water level and quality trends quarterly, which is a reasonable compromise for a developing nation; however, for intensively-utilised aquifers such as the NAS, water level measurements are collected monthly; 20 monitored boreholes are spread unevenly across the NAS, and equate to one well per 273 km². Water levels are collected weekly to monthly in the Dadaab Merti by CARE Kenya (CDC 2009: these boreholes have been monitored since 1992, and constitute the longest continuous groundwater level data set in the country). Limited water level monitoring is about to commence at both Tiwi and Baricho. As we learn more about each aquifer, it will be necessary to modify the monitoring frequency to suit each aquifer.
The figure above depicts water level data for three Nairobi boreholes. It illustrates possible depletion trends, if one is comfortable in believing that measurements are truly static water levels. However, closer examination reveals doubts about this. Most KICC and half of the Riverside Park data adopt a trend of “lows” with occasional “highs”: we may infer from this that most readings are for dynamic conditions. The University dataset has four seriously anomalous “low” values, suggestive of dynamic levels – so the trend represented by the majority of data may represent true static water level.

9.2.2 Water quality monitoring

Water quality data are also collected for a selection of groundwater sources. For the coastal aquifers, this is limited to pH, colour, EC25, TDS, chloride, salinity, total alkalinity, total hardness, magnesium and calcium; we recommend that nitrate and total phosphorus be added to the parameters analysed (as indirect indicators of pollution). At Baricho, monitoring should include iron and manganese, and include periodic testing for pesticide metabolites and a selection of trace metals.

Water from the Dadaab Merti is tested by annually by CARE Kenya (CDC 2009), but is restricted to the basic suite of analyses conducted by the Ministry of Water and Irrigation’s Central Testing Laboratory (CTL); despite past recommendations to do so (op. cit.; and UNICEF KCO 2004), repeat tests for selected heavy metals have not been carried out.

Groundwaters from the Nairobi aquifer are tested at intervals, and samples from boreholes used by the NCWSC are tested more frequently for parameters of interest to health (including fluoride).
9.3  Sharing information

What should be done with monitoring (and other) data once it has been collected? It must be analysed for in-house purposes (such as for an aquifer management plan or water balance and allocation purposes), and archived. It should then be made available to interested users, and summaries circulated in public through the press.

9.3.1  Groundwater data stakeholders

Data has a variety of potential users. Within the public water sector these range from senior policy makers, who need to see data summarised and trends explained, to technical staff at the Regional or Sub-regional level who need it to make aquifer management decisions; the latter would typically need to have the data in its raw state. Elsewhere in Government, other Ministries may need summaries for input into plans or strategies of their own. Students at State universities may need raw data for study or research purposes.

Hydrogeologists and water resources analysts in the private sector also need data – not only monitoring data, but information on the specific boreholes in the vicinity of an area they are working in; they may need to access the Catchment Management Strategy for a basin, or the Sub-Catchment Management Plan for a particular sub-basin. Development partners may need data for a specific purpose (such as this study), and foreign researchers may also want to use it (such as the many ITC students who have been active in the Rift Valley for nearly two decades). Water users or applicants for water permits have an interest, as technical studies conducted on their behalf by private sector professional are of better quality with than without the appropriate data.

It is clear that there are a large number of “data stakeholders”; how can they be best accommodated? The act of collecting and archiving data has costs, often not appreciated by the end users. It also needs space, a place (be it filing cabinets or in digital form), which also has costs. It is therefore entirely reasonable for the collection body to charge users for its use, and to select a scale of charges that reflects its value to different users.

9.3.2  Groundwater data storage and use

In Kenya, water resources and allocation data of all kinds are theoretically available for purchase, at costs described in the Rules (GoK 2007). However, in reality these data are often difficult or impossible to obtain; some are held by the Ministry of Water and Irrigation, some by the WRMA and some by the WSBs/WSPs. There is no centralised repository of data, nor is there anywhere a detailed listing of which agency has what data (and at what cost). This means that water allocation decisions may be based on incomplete data or no data at all. It means that the private sector may attempt to cut corners in the preparation of reports which, technically at least, are required to contain data that may prove difficult to obtain. Clients – for example, developers who want a Hydrogeological Assessment Study carried out in support of an application for a groundwater permit – may be reluctant to spend money on data purchase.

It matters little which agency or agencies are responsible for archiving, maintaining and selling groundwater data, although legislation makes this the principal responsibility of the WRMA. It matters rather more how much such data costs, but provided stakeholders are made to understand that data collection and archiving has costs, and that the level set for data purchase can be justified objectively, charges should be made for data.
The current situation is a state of near chaos, and it is imperative that the Ministry of Water and Irrigation act to end it. WRMA has a most definite need for groundwater data, and even if not to be responsible for its archiving, must have ready access to it. The Ministry – which is responsible for the “development of legislation, policy formulation, sector coordination and guidance, and monitoring and evaluation” (MoWI 2007a) – certainly needs groundwater data to perform its role, but not necessarily in its raw form.

9.4 Resource-directed measures (supply side)

Resource-directed measures (RDM) are measures dedicated to a) better understanding and in consequence b) better management of resources – here, groundwater resources. There are three key elements in RDM:

1. Resource classification; in Kenya, the main aquifers have been classified (Table 5 and 6 above), but not at the level of detail called for by RDM or groundwater management planning;
2. Establishing a Reserve value (in Kenya, the Reserve is explicitly devoted to meeting BHN and ecological needs);
3. Establishing resource quality objectives (RQOs cover both the quantity and quality of water in a groundwater resource).

RDM are implicit in any groundwater management plan, and can lead to outcomes such as novel resources being found (cf. the Kimbiji aquifer, Tanzania: Apolkarpi 2007); recharge being enhanced (see S. 12.4); and recycling wastewater and using marginal quality water (see S. 13.2.2). It may also lead to stronger conjunctive use measures, such as intra- or inter-basin water resources transfer; or the construction of additional surface water storage.

9.5 Demand management measures

Demand management is “Any measure or initiative that will result in the reduction in the expected water usage or water demand” (WASREB 2009). It does not necessarily mean that less water is used, but that water saved may be put to other beneficial uses.

Demand management and its planning and incorporation into day-to-day water resources management is in its infancy in Kenya, but steady progress is being made into not only a broader understanding of what it means, but also how it should be put into place. Demand management measures must continue to grow in application in Kenya, from the water service regulator right down to the household level (the NCWSC is already considering both supply-side and demand management: Danilenko et al 2010c). Many rural and some urban households in Kenya collect rainwater today, for a variety of uses; this is a simple and direct demand management measure.

In the broadest sense, demand management aims to make better use of what water we have, in all its forms (fresh, salt, brackish; wastewater etc), thus embracing IWRM & WE concepts (GoK 2009c). It includes, but is not necessarily limited to, the following: –
Table 20: Water demand management initiatives

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>ACTIVITY / MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>National / governance level</td>
<td>Revising, streamlining or creating new policies, strategies and laws</td>
</tr>
<tr>
<td></td>
<td>Improving institutional capacities</td>
</tr>
<tr>
<td></td>
<td>Creating novel financial support (pro-poor or marginalised groups)</td>
</tr>
<tr>
<td></td>
<td>Promoting regulation (water allocation process, permits and water charges)</td>
</tr>
<tr>
<td>WSP / management level</td>
<td>Treatment / reuse of waste water</td>
</tr>
<tr>
<td></td>
<td>NRV / UAW strategies (water audits, leak detection / elimination, pressure management)</td>
</tr>
<tr>
<td></td>
<td>Reduce illegal connections</td>
</tr>
<tr>
<td></td>
<td>Stipulate and enforce prohibitions (e.g. use of treated water for irrigation)</td>
</tr>
<tr>
<td></td>
<td>Tariff structure (metering, billing, collection) efficiency and equitability</td>
</tr>
<tr>
<td></td>
<td>Data collection, management and use – and dissemination of information to the public</td>
</tr>
<tr>
<td></td>
<td>Infrastructure maintenance (O&amp;M)</td>
</tr>
<tr>
<td></td>
<td>Performance monitoring (e.g. no. connections per staff member)</td>
</tr>
<tr>
<td></td>
<td>Training and capacity building</td>
</tr>
<tr>
<td>Consumer level</td>
<td>In-house efficiency improvements (new and retrofitted): dual-flush toilets, low-pressure showers, etc</td>
</tr>
<tr>
<td></td>
<td>RWH</td>
</tr>
<tr>
<td></td>
<td>Supplementary water sources (shallow well, borehole, stream abstraction)</td>
</tr>
<tr>
<td></td>
<td>Water re-use (grey water use)</td>
</tr>
<tr>
<td></td>
<td>Water-wise gardening (e.g. sprinkling at night; appropriate plant species)</td>
</tr>
<tr>
<td></td>
<td>Education from the youngest school age</td>
</tr>
<tr>
<td></td>
<td>Research and development</td>
</tr>
</tbody>
</table>

9.6 Emerging technologies and data sources

Technological development occurs at all levels in all spheres of human activity; groundwater management is no exception. There are a number of new methods that might be considered for adoption in Kenya’s groundwater management framework.

GRACE (the Gravity Recovery and Climate Experiment) measures small changes in earth gravity, from which changes in flux of water can be measured (Tapley et al 2004). It allows the semi-quantitative measurement of groundwater storage and soil moisture changes (Rodell et al 2007); it has been applied experimentally in Uganda (Taylor nd) and may have a place in groundwater management once scale effects have been resolved. Other remotely-sensed data sets can be used for aquifer definition, such as those made available under the European Space Agency/UNESCO TIGER initiative (UNESCO/IHP 2010), which are useful tools for groundwater resources delineation.

UNESCO’s GRAPHIC project (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change) provides a platform for exchange of information through case studies, thematic working groups, research, and communication (UNESCO-GRAPHIC 2007). It is a potentially useful source of information on new methods, as well as presenting the results of studies and research.

The British Geological Survey (BGS) initiated a project in early 2010 on “Groundwater resilience to climate change in Africa” (BGS 2010), which will generate: –

- An aquifer resilience map for Africa (based on existing geology and hydrogeological maps);
- Two hydrogeological case studies of aquifer resilience to climate change;
- A socio-economic case study, examining the linkages between water use and household economy;
- Peer reviewed research papers and policy briefings.

The outputs of this programme will be of value when Kenya comes to developing a national groundwater management strategy.
The vastly improved availability of relatively cheap micro-processor power has encouraged the development of advanced methods of data processing, which has revolutionized modern hydrogeophysics (e.g. Auken et al. 2006). 2-, 3- and 4-D tomography (Kuras et al. nd), magnetic resonance (Durán 2007), airborne EM (Paine 2000) and controlled source audio magnetotellurics (CSAMT; Hasbrouck et al. 2003) all offer greater resolution and greater depth penetration than has previously been available. The WRMA, the Kenya Army Engineers, the University of Nairobi and some of the WSBs have 2-D resistivity equipment, which will be of great value in groundwater management plan studies (such as that proposed as a pilot plan in S. 14.4 below). As new technology appears, it should be reviewed for its appropriateness to Kenya, and applied if budgets allow.

10 Financing

10.1 Introduction

Section 8(g) provides that WRMA may determine charges to be imposed for the use of water from a water resource. Section 79 provides that the Authority may, with the approval of the Treasury, retain some or all of the revenue from water use charges payable under a permit to be applied in meeting the costs of performing its functions. Such charges include charges for abstraction of groundwater, although WRMA does not segregate the charges it collects from groundwater and surface water.

Part VIII of the Rules deals with water use charges. Regulation 104 stipulates that any person in possession of a valid permit or who is required to have a valid permit shall be required to pay water use charge. Regulation 108 provides that an additional five percent shall be added to the water use charge for any water abstraction or diversion within a GCA to cover the cost of the greater management needs of such areas.

WRMA may review water use charges taking account of:—

(a) Inflation rate;
(b) Cost of managing the water resources and water catchment areas;
(c) The use of water charges as a tool for water demand management; and
(d) The use of water as a social and economic good.

The Rules are designed on the basis of self-assessment. Under Regulation 106 the water user shall make a fair assessment of the quantity of water used with respect to each permit and shall submit the assessment together with supporting records and calculations to WRMA. Where the user does not make a fair assessment WRMA shall make a fair assessment of the quantity of water used. Water use charges may be paid directly to WRMA or to an appointed revenue collection agent. Failure to pay water use charges is a breach of the conditions of a permit and may be a basis of revocation of the permit.

The system of self-assessment is difficult to enforce because the locations of groundwater abstractions are all too often not known, and many groundwater users are unlikely to come forward of their own volition and make payment, as the fear of detection and subsequent penalties is low.

WRMA has experienced a serious shortfall in financial resources ever since it was established. Its development budget for 2009/2010 is tabulated overleaf.
Table 21: WRMA development budget, 2009/2010

<table>
<thead>
<tr>
<th>Region</th>
<th>Development Budget (Million KShs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRMA HQ</td>
<td>450.714</td>
</tr>
<tr>
<td>Lake Victoria North Catchment Area</td>
<td>25.000</td>
</tr>
<tr>
<td>Lake Victoria South Catchment Area</td>
<td>24.969</td>
</tr>
<tr>
<td>Rift Valley Catchment Area</td>
<td>35.858</td>
</tr>
<tr>
<td>Athi Catchment Area</td>
<td>31.004</td>
</tr>
<tr>
<td>Tana Catchment Area</td>
<td>36.463</td>
</tr>
<tr>
<td>Ewaso Ngiro North Catchment Area</td>
<td>35.000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>639.008</strong></td>
</tr>
</tbody>
</table>

Of this, WRMA was able to collect less than KShs. 400 million from water use fees. It received no allocation from the Treasury, thus has had to live with a budget deficit of 37%. This compares with Ministry of Water and Irrigation budgets (actual and projected, billions of shillings – see below), and illustrated as a graph overleaf.

Table 22: MoWI budgets, 2004 – 2013 (KShs. billion)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
<td>Printed</td>
<td>Estimate</td>
<td>Projection</td>
<td>Projection</td>
</tr>
<tr>
<td>Recurrent</td>
<td>2.090</td>
<td>2.325</td>
<td>2.239</td>
<td>2.669</td>
<td>3.574</td>
<td>4.171</td>
<td>5.689</td>
<td>9.450</td>
<td>5.419</td>
<td>7.078</td>
</tr>
</tbody>
</table>


Average MoWI recurrent budget utilisation 2003/04 to 2007/08 was 89.4% while the average development budget utilisation over the same period was 69.1% (IEA 2008); underutilisation was ascribed to long disbursement procedures from development partners; and the low capacity and limited competence of implementing institutions. Given the greatly increased development budget proposed for the period 2010 to 2013, these shortcomings will have to be addressed if these resources are to be spent properly.

Figure 4 Ministry of Water and Irrigation actual and proposed budgets 2004-2013
In terms of the apportionment of finances between groundwater and surface water, there is little information, since expenditure is not normally categorised into surface water and groundwater related expenditure. This potentially can exacerbate the low priority given to groundwater as opposed to surface water in the activities of WRMA.

The WRMA has been able to extract form their database the expenditure on groundwater management since its inception, which is tabulated in Table 23 below. Its shows that in 2009/10 actual expenditure on groundwater management expenditure, as compared to the budgeted amount, was less than 10% at just under Kshs. 4 million.

### Table 23: Analysis of expenditure on groundwater activities

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>2009/10</th>
<th>2008/09</th>
<th>2007/08</th>
<th>2006/07</th>
<th>2005/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Budget</td>
<td>55,000,000</td>
<td>100,260,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Actual expenditure</td>
<td>3,918,558</td>
<td>26,821,242²</td>
<td>0</td>
<td>3,588,340</td>
<td>0</td>
</tr>
<tr>
<td>Variance</td>
<td>51,081,442</td>
<td>73,438,758</td>
<td>0</td>
<td>-3,588,340</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Funds used for purchase of six sets of geophysics equipment for use in the six Regional offices. Source: WRMA.

During 2008/09 when over Kshs. 26 million was used on groundwater management the monies were used to purchase geophysics equipment, and therefore fall under the development budget rather than under routine groundwater management. As a proportion of expenditure on WRMA’s overall expenditure, less than 1% is devoted specifically to groundwater management activities.

10.2 Sources and extent of funds for managing the CSAs

There is no explicit provision for individual aquifers to have their “own” budget; resources are deployed by the Regional or Sub-regional office as water resources managers deem appropriate. Within WRMA, 50% of the revenue collected from water users (applications for water permits; permit fees; and water use charges) is retained by the Sub-region, and 50% is returned to Headquarters towards the costs of its management.

10.3 Charges for water use and wastewater discharge in the CSAs

Given the current status of water user inventories in the CSAs (8.8 above), the revenue returns from water charges are a fraction of what they should be – in the Nairobi case, an estimated 15% of water users are fully compliant, as stated previously. This is because of the perception that groundwater is a “private” resource, and as a result groundwater users – especially in urban contexts – are resistant to verifying their water use status and obtain water permits (and so pay water use charges).

10.4 Special provisions for groundwater access by the poor and disadvantaged

There are no explicit provisions for access to groundwater by the poor and disadvantaged, except that the Category A permit threshold level (which varies from water resource to water resource and from region to region: WRMA 2007), was selected so as to encourage small-scale and subsistence water users to use groundwater (and surface water) for socio-economic betterment. Category A thresholds are set low enough that they are considered of limited impact on a water resource, but are high enough to allow subsistence water uses (such as small-scale irrigation, for example).

The Pro-Poor Implementation Plan for Water Supply and Sanitation (PPIP–WSS: MoWI 2007c) is exactly what it is entitled; it does not include any pro-poor groundwater resources access strategy (or any for surface water, for that matter); nor does it claim to.
In this closing section of the study we examine cross-sectoral issues and consider whether – and how – groundwater can contribute to adaptation to climate change.

11 The Status Quo

At present, Kenya does not score highly in an evaluation of groundwater governance (in the context of the CSAs and national institutional capacity).

Table 24: Evaluation of groundwater governance for CSAs and in national capacity

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Criterion</th>
<th>Context</th>
<th>Merti Provision</th>
<th>Nairobi</th>
<th>Tiwi</th>
<th>Baricho Provision</th>
<th>Inst. capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Aquifer maps</td>
<td>ID GWR</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hydrogeological maps</td>
<td>Aquifer classification</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Groundwater level network</td>
<td>Resource status</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pollution hazard assessment</td>
<td>Quality risk</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Numerical models</td>
<td>Management</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Quality monitoring network</td>
<td>Pollution</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Permits / water rights</td>
<td>Large/small users</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Reversing GW abstraction</td>
<td>Closure/constraints</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Preventing GW abstraction</td>
<td>ALARM/ALERT aquifers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sanctioning illegal drilling</td>
<td>Penalties</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Legal / Institutional</td>
<td>Water use charges</td>
<td>Resource charge</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Land use controls</td>
<td>Controls on pollution</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Pollution charges</td>
<td>Incentive for pollution prevention</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Govt Agency as “GWR Guardian”</td>
<td>Cross-sectoral powers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Community aquifer management</td>
<td>Mobilising communities</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cross-sectoral</td>
<td>Coordination with agriculture</td>
<td>Water savings / pollution control</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Urban/industrial planning</td>
<td>Conserve / protect GWR</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Compensation for GW protection</td>
<td>Land-use constraints</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Operational</td>
<td>Public participation</td>
<td>Control exploitation / pollution</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>GW management action plan</td>
<td>Measures and instruments</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent. ID GWR = characterisation of groundwater resources

11.1 The need for a paradigm shift in thinking

Despite attempts to reform the water sector, together with the development of an integrated water resources management strategy and water efficiency plan (MoWI 2009c), there remains inadequate understanding by water sector professionals and the public of the association between surface and groundwaters. This must change, and in the first instance change must come from within the sector.
This means that mandate problems must be acknowledged, addressed and fixed – without doing so, any attempts at restoring a balance between the policy-making, regulating Ministry on the one hand, and the implementing agencies on the other (WRMA for resources management; and WASREB, the WSBs and WSPs for water supply on the other), will fail. This is of critical importance in respect of data provision and handling; the current lack of a transparent, accessible, coherent database makes water resources management of any type – and of groundwater resources in particular – simply impossible.

Once internal problems have been rectified, similar “bridge-building” initiatives with other sector players – notably NEMA, Health and Sanitation, Agriculture, Lands and the natural resource managers KFS and KWS – must be initiated.

Secondly, the WRMA must be given the tools it needs to properly manage the groundwater resources it is responsible for. At present the Authority does not have the staff, technical or financial resources to manage aquifers individually; furthermore, the current structure of the Authority does not lend itself to individual aquifer management, though this could be changed relatively easily. The Stakeholder Workshop was universally of the view that any “aquifer management organisation” should be maintained within the existing WRMA structure, for a variety of practical reasons; this will require strengthening existing policies and the capacity of the Authority.

Finally, and allied to the second point above, there must emerge the recognition that groundwater resources are not amenable to centralised regulation and management. Furthermore, without local participation by both groundwater users and other stakeholders any management measures are likely to fail; aquifers should be managed at the aquifer scale, with the caveat that trans-catchment and transboundary aquifers need an over-arching consultative framework.

We describe the development of a national groundwater management strategy and a pilot groundwater management plan in Chapter 14 and recommend that these be carried out in Chapter 15. These are “no-regret” measures that should be implemented as part of ordinary IWRM, and not necessarily as explicit climate change mitigation measures – although they will help build climate change resilience. The proposed strategy would provide a starting point to discuss and develop the nature and role of “aquifer management organisations”, their position within the Authority structure and powers that might be vested in it.

12 Groundwater management and climate change

“Adaptation to climate impacts on groundwater resources in developing countries has not received adequate attention. This reflects the often poorly understood impacts of climate change, the hidden nature of groundwater and the general neglect of groundwater management”

(from Sinclair Knight Merz [SKM] 2009)

Few water sector professionals doubt that climate change will affect Kenya – indeed, there is ample evidence that it already has (GoK 2010). The NCCRS has outlined the ways in which the water sector (in the broadest, cross-sectoral sense), should address adaptation and mitigation,

12 Alternative structures could be established, but would require new legislation, with the delays that this would entail. The delegation of some of the Authority’s powers to an aquifer management organisation could be made by the Minister for Water under §110 (2) (a), if the groundwater management role cannot be hosted within the Authority.

13 According to the IPCC “no regret” measures are measures that would generate net social and/or economic benefits whether or not climate change occurs (Danilenko et al 2010).
though more detailed implementation plans will be required following the necessary policy and legislative changes required to put the strategy into effect (S. 2.5 above).

12.1 Consequences of climate change – threats

SRES A1B is the middle-of-the-road emissions scenario developed by the IPCC $^{14}$ Its implications are tabulated below.

**Table 25: East African regional temperature, precipitation and extremes for SRES A1B**

<table>
<thead>
<tr>
<th>Season</th>
<th>Temperature response (%)</th>
<th>Precipitation response (%)</th>
<th>Extreme seasons (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min 25 50 75 Max</td>
<td>Min 25 50 75 Max</td>
<td>Warm Wet Dry</td>
</tr>
<tr>
<td>DJF</td>
<td>2.0 2.6 3.1 3.4 4.2</td>
<td>-3 6 13 16 33</td>
<td>100 25 1</td>
</tr>
<tr>
<td>MAM</td>
<td>1.7 2.7 3.2 3.5 4.5</td>
<td>-9 2 6 9 20</td>
<td>100 15 4</td>
</tr>
<tr>
<td>JJA</td>
<td>1.6 2.7 3.4 3.6 4.7</td>
<td>-18 -2 4 7 16</td>
<td>100 - -</td>
</tr>
<tr>
<td>SON</td>
<td>1.9 2.6 3.1 3.6 4.3</td>
<td>-10 3 7 13 38</td>
<td>100 21 3</td>
</tr>
<tr>
<td>Annual</td>
<td>1.8 2.5 3.2 3.4 4.3</td>
<td>-3 2 7 11 25</td>
<td>100 30 1</td>
</tr>
</tbody>
</table>

**Explanation:** (Based on: Table 11.1, Christensen et al 2007)

East African Region averages of temperature and precipitation projections from a set of 21 global climate models based on the SRES A1B scenario. Values given are the likelihood of change from a baseline of 1989-99 in the period 2080-99; values are shown only when at least 14 of the 21 simulations are in agreement.

The Table shows that in Kenya temperatures are virtually certain to rise and precipitation may increase. Overall, wet seasons are likely to be wetter than hitherto; the likelihood that dry seasons will be more intense is less than for wet seasons. Runoff is projected to increase (Bates *et al* 2008), which will lead to more erosion. More intense rainfall in ASALs is likely to lead to higher volumetric recharge, as recharge typically only occurs after soil field capacity is met. Increasing water scarcity (temporal and spatial) will increase the risk of corruption (TI 2008). Sea level rise will threaten coastal aquifer systems (halocline transgression) (though it is possible that the Kenya Coast may not be affected as severely as hitherto believed: Han *et al* 2010).

Groundwater systems react in different ways to climate change; shallow aquifers with short residence times will react more quickly to changes in recharge, while deeper aquifers (particularly those with large storage) will react more slowly – they are better buffered against climate change (BeBuffered.com 2010: Bates *et al* 2008).

Of the CSAs, the Merti is probably the most resistant to climate change; as little modern recharge occurs, changes in storage will reflect natural and anthropogenic discharge and not changes in climate (however, if significantly more frequent flooding of the former Lorian Swamp occurs, local recharge may lead to the invigoration of the shallow aquifer reported by Swarzenski *et al* [1977] in the Habaswein – Sabena area).

The NAS may benefit from future increased natural recharge in the western uplands, but in the short term this will not be observed in the main abstraction areas because of the long flow path and travel time; the main driver of change in storage will be anthropogenic abstraction.

The two coastal CSAs are more directly linked to the surface environment and are more likely to show variation brought about by climate change. Tiwi will benefit from more recharge and so

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$^{14}$ “The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies)” IPCC 2000.
may be enhanced as a water supply source. Baricho will almost certainly benefit from higher discharge than at present, which will draw from almost the entire Athi Basin; again, this translates into greater abstraction potential.

While these direct outcomes appear positive, there will be negative effects, too; increased rainfall intensity will increase sediment load in rivers, which may ultimately affect the Baricho aquifer by reducing the hydraulic conductivity of the river bed. Landslides will become a greater threat than they already are at present, putting at risk water monitoring, supply and wastewater infrastructure (as well as roads, bridges etc).

12.2 Assessing the vulnerability of Kenya’s aquifers to climate change

Vulnerability is defined as: “The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”


Given the relatively poor level of understanding of our aquifers, it is difficult to determine the degree to which they are sensitive to climate change. We discussed CSA vulnerability to degradation in Chapter 3; here we examine approaches to assessing aquifer vulnerability to climate change.

In order to guide the decision-making process and determining aquifer protection priorities, it is clearly important to determine which aquifers are likely to be the most vulnerable. SKM (2009) describe a vulnerability assessment framework which can be applied in both data-rich and data-poor environments, and at any scale; this is shown in Appendix 5.

This is a risk-based assessment approach, and calls for a five-step process: –

1. Establish the context: –
   o geographic scope, social and institutional boundaries and timeframes;
   o identification of stakeholders, their engagement and their issues;
   o groundwater management and development objectives;
   o success criteria indicators and values;
   o aquifer characterisation (as Chapter 3), plus recent and historic climate conditions / ENSO, and groundwater system drivers;
   o Climate change scenarios from one or more models.

2. Identify the relevant climate change hazards for each applicable climate change scenario. This will include average and extreme precipitation, temperature, potential evaporation, storm surge and sea level; and seasonality, intensity and frequency predictions.

3. Assess the vulnerability of the groundwater system as it is (i.e. without further adaptation measures, but including existing adaptation), for each climate change scenario, by: –
   o Reviewing existing climate risk controls, describing existing adaptations and their success;
   o Considering the consequences of climate change by assessing potential impacts on groundwater assuming existing conditions. By using the success criteria and objectives in 1 above, determine a qualitative risk-consequence for each, using a five-point value system (insignificant, minor, moderate, major, catastrophic);
Assessing the **likelihood** of each groundwater management objective being met from the current baseline and with existing adaptations; using a five-point scale (almost certain, likely, possible, unlikely, rare);

Combine the **consequences** and the **likelihoods** in a risk-rating matrix (see Table below: SKM 2009): a four- or five-point rating system may be used – low to extreme, or very low to extreme (we suggest the latter):

<table>
<thead>
<tr>
<th>Table 26: Consequences / likelihoods matrix (after SKM 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Likelihood of impact</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Almost certain</td>
</tr>
<tr>
<td>Likely</td>
</tr>
<tr>
<td>Possible</td>
</tr>
<tr>
<td>Unlikely</td>
</tr>
<tr>
<td>Rare</td>
</tr>
</tbody>
</table>

4. The assessment continues by determining what adaptation measures could be implemented, and repeating the consequences and likelihoods exercise from this “adapted” viewpoint. However, before the repetition, it is worth reviewing risk ratings. Evaluate the risk by questioning the reasonableness of the risk ratings in conjunction with stakeholders. If it appears reasonable that some ratings be changed, change them. The objective of this risk rating is to determine groundwater management aspects that are at the greatest risk, and which should therefore receive the most attention. This risk-rating assessment process must also take into account the degree of uncertainty associated with each impact (the generally poor level of understanding of our groundwater systems means that impact predictions will be bedevilled by uncertainties).

Uncertainties should be gauged against an uncertainty matrix (below):

<table>
<thead>
<tr>
<th>Table 27: Climate change impact uncertainty matrix (after SKM 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ambiguity about risk</strong></td>
</tr>
<tr>
<td>• Uncertainty or unknown impacts</td>
</tr>
<tr>
<td>• No impact models</td>
</tr>
<tr>
<td>• Uncertain how to value consequences</td>
</tr>
<tr>
<td>• Lack of concern</td>
</tr>
<tr>
<td><strong>Ignorance about risk</strong></td>
</tr>
<tr>
<td>• Rapidly changing climate</td>
</tr>
<tr>
<td>• Unknown groundwater systems</td>
</tr>
<tr>
<td>• Complex dependencies</td>
</tr>
<tr>
<td>• Insufficient data</td>
</tr>
</tbody>
</table>

Impacts that are uncertain (both consequences and likelihoods), should then be subjected to further study and research.

5. Test the risks by identifying adaptation options for each scenario; develop objectives and criteria for each of these (as 1. above). Then assess these by repeating the consequences / likelihoods and uncertainty matrices for an “adapted” groundwater management scenario, and compare the two.

With a list of priority measures that can be implemented, the actual adaptation phase starts – projects, works, education, etc. The process should be monitored, and periodic reviews carried...
out. Reviews repeated over time should result in better identification of effective adaptation measures, and will also inform research into reducing the uncertainties of risk assessment.

Clearly a methodology should be developed for Kenya, and this could readily draw on the process summarised above (and illustrated as a process schematic in Appendix 5). We recommend that an aquifer be selected for a pilot assessment project, to prove the approach.

Ultimately, aquifer vulnerability to climate change assessments should be carried out for all strategic and major aquifers, possibly as part of the CMS process and definitely whenever a Sub-catchment Management Plan (SCMP) is drawn up for a sub-catchment in which groundwater plays (or may be expected in future to play) a role in the socio-economy.

At the national or regional level, the Ministry should consider carrying out drought and flood vulnerability mapping (cf. Eriyagama et al 2010). WRMA should also consider developing drought security maps for climate-vulnerable parts of the Republic (cf. MacDonald et al 2001 – water security mapping in Ethiopia).

12.3 Groundwater as a climate change mitigation agent

*The large water storage capacity of aquifers allows facing interannual precipitation variability. Aquifers become an efficient solution to overcome or mitigate drought impacts.*

(Article 3, Valencia Declaration UNESCO et al 2002)

Groundwater offers very real opportunities for adapting to climate change. Specific measures include:

- Making use of groundwater resources in dry periods in anticipation of wet season recharge, by making use of aquifers’ natural buffering capacity; this includes the deliberate drawdown of aquifers that are recharged bi-annually, to create storage prior to wet season recharge. This measure is best used conjunctively with surface water – the latter are used during wet seasons and floodwater is stored for use into dry periods, with groundwater use increasing as water in storage declines in volume. Clearly this is only effective in aquifers that experience annual or biannual recharge that are in close hydraulic continuity with the land surface (both temporally and in terms of distance below ground); however, large areas of Kenya are underlain by crystalline Basement which hosts poor aquifers – but aquifers that are admirably suited to this proactive buffering approach to groundwater management;
- Managed aquifer recharge (this is discussed in more detail below);
- Promoting recharge as part of spate irrigation projects;
- Making better planned use of conjunctive groundwater and surface water (Chapter 13 below);
- Ancillary management measures can also contribute to better use of groundwater resources; enhancing natural vegetation in degraded catchments can restore recharge rates to pre-degradation levels, and contribute to other water sector objectives such as water quality objectives, maintaining the Reserve and preserving ecosystem services;
- Bunding fields or pasture will pond rainwater, encouraging infiltration and enhancing soil moisture, thus improving crop yields or grass quality. Finally, re-using water (of all types) takes some of the pressure off water resources in general, and completes the “3R” trio (water recharge, reuse and retention: BeBuffered.com 2010).
Broader, catchment-wide measures also contribute to climate change adaptation and mitigation: –

Table 28: Adaptation measures for water resources (UNFCC 2007)

<table>
<thead>
<tr>
<th>Reactive adaptation</th>
<th>Anticipatory adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Protection of groundwater resources</td>
<td>• Better use of re-cycled water</td>
</tr>
<tr>
<td>• Improved management and maintenance of existing water supply systems</td>
<td>• Conservation of water catchment areas</td>
</tr>
<tr>
<td>• Protection of water catchment areas</td>
<td>• Improved water [resources] management</td>
</tr>
<tr>
<td>• Improved water supply</td>
<td>• Water policy reform, including pricing and irrigation policies</td>
</tr>
<tr>
<td>• Groundwater and rainwater harvesting and desalination</td>
<td>• Development of flood control and drought response tools</td>
</tr>
</tbody>
</table>

12.4 Managed aquifer recharge

Managed aquifer recharge (MAR) or artificial groundwater recharge (AGR) “systems are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to augment groundwater resources” (Bouwer 2002). There are numerous ways in which this can be achieved, and the appropriate method is almost always aquifer-specific (WRMA 2009a: NWCPC 2006). This measure is of limited utility in aquifers where the travel path and time from natural recharge zone to zone of use is very long, unless direct recharge methods (such as borehole injection) are carried out in the zone of use.

MAR has a number of potential applications, including: –

- storing water for future use;
- stabilising or recovering groundwater levels in over-exploited aquifers;
- reducing losses by evaporation;
- managing halocline invasion or land subsidence;
- making use of waste or storm water through soil-aquifer treatment (SAT) (Foster et al 2004).

MAR has both advantages and disadvantages compared with other forms of water resource development: –

Table 29: Advantages, disadvantages and issues with MAR and small and large reservoirs

<table>
<thead>
<tr>
<th>Groundwater storage</th>
<th>Small reservoirs</th>
<th>Large dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small evaporation loss.</td>
<td></td>
<td>Large, reliable yield.</td>
</tr>
<tr>
<td>Ubiquitous distribution.</td>
<td></td>
<td>“Carryover” capacity.</td>
</tr>
<tr>
<td>Operational efficiency.</td>
<td></td>
<td>Low cost per m³ stored.</td>
</tr>
<tr>
<td>Available on demand.</td>
<td></td>
<td>Multipurpose.</td>
</tr>
<tr>
<td>Water quality.</td>
<td></td>
<td>Flood control/hydropower.</td>
</tr>
</tbody>
</table>

| Limitations          |                  |            |
| Slow recharge rate.  |                  | Complexity of operation. |
| Groundwater contamination. |          | Siting. |
| Cost of extraction.  |                  | High initial investment cost. |
| Recoverable fraction. |                | Long lead-in time. |

| Key issues           |                  |            |
| Declining water levels. |                  | Social and environmental impacts. |
| Rising water levels. | Adequate design.  | Sedimentation. |
| Management of access and use. |       | Dam safety. |
| Groundwater quality change. |         | Environmental aspects. |
| Groundwater pollution. |                  | Dam safety. |

(After: Keller et al 2000)

Small-scale MAR – at the household or village level – offers considerable potential for mitigating drought; Kitui District has pioneered the bank recharge of Basement aquifers by the
construction of sand dams, which have raised communities formerly reliant on state food assistance during drought to small-scale commercial farmers (BeBuffered.com 2010; WRMA 2009a; Borst *et al* 2006; GW•MATE 2005b).

The complexities of scale mean that in only a very few instances can MAR schemes involve the kinds of volumes that large dams deal with. The Table below lists just a few successful MAR schemes, which indicates the range of annual volumetric recharge that is possible.

**Table 30: Selected MAR schemes and annual recharge**

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Country</th>
<th>Recharge/yr</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam/Leiden/Castricum</td>
<td>The Netherlands</td>
<td>∼100 MCM</td>
<td>Stuyfzand <em>et al</em> 2004</td>
</tr>
<tr>
<td>Windhoek</td>
<td>Namibia</td>
<td>28.3 MCM (ultimate)</td>
<td>Murray 2006</td>
</tr>
<tr>
<td>Lee Valley</td>
<td>UK</td>
<td>27.4 MCM (maximum)</td>
<td>IWES 1986</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>USA</td>
<td>13.3 MCM (mean)</td>
<td>Pyne 1995</td>
</tr>
<tr>
<td>Omdel</td>
<td>Namibia</td>
<td>9 MCM (maximum)</td>
<td>Tredoux <em>et al</em> 2003</td>
</tr>
<tr>
<td>Atlantis</td>
<td>South Africa</td>
<td>4.5 MCM</td>
<td>Wright <em>et al</em> 1996</td>
</tr>
<tr>
<td>Gujarat</td>
<td>India</td>
<td>56,200 m³</td>
<td>Gale <em>et al</em> 2006</td>
</tr>
<tr>
<td>Pernambuco</td>
<td>Brazil</td>
<td>10,000 m³</td>
<td>GW•MATE 2005b</td>
</tr>
<tr>
<td>SASOL, Kitui</td>
<td>Kenya</td>
<td>4,000 m³</td>
<td>Borst <em>et al</em> 2006</td>
</tr>
</tbody>
</table>

This table does not indicate the costs of such schemes, which range from $US 7,500 for a Kitui sand dam to $US 1,000,000s for treatment, injection and abstraction costs for the UK and US schemes. Windhoek is a special case – the recharge water is partly tertiary-treated sewage, injected into a quartzite aquifer and withdrawn thousands of metres away.

The SASOL Foundation has constructed in excess of 500 sand dams in Kitui District, and illustrate MAR at its simplest and (we would suggest) most elegant. With low maintenance costs and a lifetime of ∼50 years, its potential for improving livelihoods is proven and the technology entirely domestic. Sand dams are especially suited to crystalline Basement rocks, which cover much of Kenya, and are a sound climate change adaptation strategy, as the Kitui example shows. They are in no way “managed” as part of a formal water development programme and personify the philosophy of the “silent revolution”; they have now acquired a momentum of their own and are managed at the local level by water users for water users.

More imaginative use of groundwater will reap dividends for Kenya as the effects of climate change become more serious. The implementation of managed aquifer recharge at the local level brings with it a need to decentralise aquifer management, and the acknowledgement that local management – at the water user level – is the most appropriate approach. This is perhaps the strongest argument in favour of greater liberalisation of the groundwater sector.

Improved formal management of groundwater as part of climate change and conjunctive use strategies is as yet inadequately explored in Kenya, partly because many of our aquifers are relatively poor in terms of the efficiency of their water production and the cost of abstraction; however, if periodic drought becomes commonplace, even the less efficient aquifers will become vital components in small town water management strategies. Again, the creation of increased groundwater storage in anticipation of wet season recharge will be an important part of such strategies.
13 IWRM and conjunctive use in GW Management

13.1 Integrated water resources management

“IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.”

(from GWP 2000)

13.1.1 The IWRM concept

IWRM as a concept coalesces around the Dublin Principles (WMO 1992), which state: –

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good (described as an economic and social good in Agenda 21: UN 1992).

IWRM is not so much a process as an approach, a philosophy. It seeks to integrate land and water, surface and groundwater, upstream and downstream, and the river basin in its entirety (from source to ocean). It addresses governance issues as a core activity, and fits perfectly into the context of a groundwater governance study. Integrated water resources management is a potentially potent instrument of adaptation to climate change. Successful integrated water management strategies include (Moench et al 2003, with amendments relevant to groundwater in Kenya): –

- Capturing society’s views and getting the public on-board in day-to-day water resources management;
- Reshaping planning processes, as described elsewhere in this report – aligning policies, strategies and legislation, and create management bodies that ensure all sector players are reading from the same list of ultimate objectives;
- Coordinating land and water resources management, by implementing the PPPG (WRMA 2006), or something that achieves the same ends;
- Recognising water quantity and quality linkages through imaginative application of demand management measures, for example;
- Conjunctive use of surface water and groundwater, from the informal reactive approach adopted at present, to a proactive, climate change-responsive and measured approach that makes the best use of our limited water resources;
- Protecting and restoring natural systems by applying the Reserve and resource-directed measures.

13.1.2 Kenya’s IWRM & WE Plan

Kenya has spent five years developing its Integrated Water Resources Management and Water Efficiency Plan (GoK 2009c), after a broad stakeholder consultation process, and it should be implemented as soon as is practicable. The NWRMS (GoK 2007a) recognises the “… IWRM & WE Plan as a national priority with obligations for participation and empowerment of stakeholders and decentralized management at the lowest appropriate level”. 
Despite its undeniably high anticipated cost, the Plan’s over-arching management approach to water management across all sectors will yield higher dividends in terms of the greater availability of water per head than most of the initiatives outlined above. It will, inter alia, involve extensive cross-sectoral liaison and synergy, so the policy environment called for by the NCCRS and discussed in Chapter 5 above needs to be developed as soon as possible, and must take into account the IWRM & WE Plan when it does so.

13.1.3 Groundwater in the IWRM & WE Plan

IWRM explicitly requires the integration of groundwater and surface water management processes, and the IWRM & WE Plan does so. The principal activities in respect of groundwater in the Plan are:

- To improve monitoring and data collection networks;
- To identify potential sites and aquifers for artificial groundwater recharge (MAR);
- To map strategic aquifers and conjunctive water uses;
- Prepare project designs for … aquifer exploitation;
- To harvest aquifers to increase supply from groundwater;
- To identify GCAs.

None of these activities are an impediment to groundwater management processes – indeed, any groundwater management strategy or plan is ultimately subordinate to the IWRM & WE Plan.

13.2 Conjunctive use in water resources management

Conjunctive use is the planned use of both surface and groundwaters to meet water demand. Conjunctive use does not necessarily mean that both waters are used simultaneously – indeed, the seasonal nature of surface water and the typically large storage capacities of groundwater systems often makes it more logical to use surface water during flood periods and groundwaters in dry periods. A properly-managed conjunctive use scheme maximises available water resources, optimises costs and minimises water scarcity in a water supply system.

13.2.1 Conjunctive use in Kenya

A number of Kenyan towns and cities operate conjunctive use schemes, though sometimes as a coping strategy and not as a planned approach to meeting water demand:

- Nairobi is largely supplied from surface water sources; however, its long use of the Kikuyu Springs (since 1913), a groundwater supply system serving Kabete in the 1950s/60s, local supply boreholes in Karen and Lang’ata up to the early 1990s; and from 2009, 32 public water supply boreholes operated by the NCWSC constitutes conjunctive use of water. The volume of groundwater used for public water supply is small in comparison with demand – approximately 10 MLD, against approximately 513 MLD supply (AWSB 2008). The construction of boreholes in the past year and a half has been an emergency response and not part of a planned conjunctive use strategy.

- Nakuru relies on a combination of surface water from the Malewa (∼21 MLD) and Mereroni (5.6 MLD) Rivers and groundwater from four wellfields, which provide approximately 34.5 MLD (pers. comm. WASREB 13/5/10). The Rift Valley WSB has made a concerted effort to increase the volume of groundwater serving the Town, which together with the construction of the Chemususu Dam will help further diversify conjunctive water use.
Machakos Town relies on a combination of sources, including Nol Turesh Spring (1 MLD), boreholes (0.5 MLD) and the Maruba Dam (8.7 MLD after rehabilitation).

Current construction projects that will create planned conjunctive use schemes include the Kiserian Dam (5.3 MLD) which will supplement existing groundwater supplies to Kiserian, Ongata Rongai and Ngong Town (2.1 MLD); the Badasa Dam (Marsabit) will add ~3 MLD to existing groundwater supplies (the Bakuli Springs, 0.3 to 0.8 MLD).

The Kenya Coast (as already described) is totally reliant on groundwater resources, and will have to resort to conjunctive use if it is to develop along the lines of Vision 2030 (which envisages the creation of two coastal resort cities). The Mwache Multipurpose Development Project (water supply, 400 ha of irrigation and 34 MW of potential hydropower: MoRDA 2009) is expected to meet a proportion of the Coast’s water demand, along with a rehabilitated Mzima Pipeline.

The private commercial irrigation sector often uses both surface and groundwater conjunctively: prime examples are the Naivasha and North West Mt Kenya areas; in the latter, irrigators store surface floodwater for dry season use, while relying on groundwater to meet domestic and process needs, but also retaining groundwaters as drought-response irrigation water sources. At least one horticultural project opted to start with groundwater (because of the speed of implementation), with surface water use commissioned three years after start-up.

The key to effective conjunctive management of surface water and groundwater resources is more a question of appropriate capacity building, efficient organisation, and better information sharing and communication. It also requires that groundwater and surface water are managed as a single entity, rather than as two, effectively separate, sub-sectors.

13.2.2 Opportunities for conjunctive use in Kenya

There are numerous possibilities for conjunctive use in Kenya, in addition to the examples given above. These include, but are not necessarily limited to, the following (GW•MATE 2010; World Bank 2006): –

- Ensuring that surface water irrigation projects both make better use of what water is available (i.e. water use efficiency improvements), and use infrastructure (canals, reservoirs) as groundwater recharge sources where suitable target aquifers exist. This might be applied in the Mwea area, for example, to expand the area of rice under irrigation in dry periods.
- Making MAR targets of intensively-abstracted aquifers that are used for irrigation. This could be applied in those parts of the Naivasha area that are currently depleted, where a project to recharge greenhouse runoff as a recharge water source has been proposed (Abdulwahab 2006).
- Enhancing recharge in aquifers that active management could make better use of; an example would be the Basement/colluvial aquifer at Oda, which could better serve Moyale Town in the extreme north of Kenya if it was actively managed;
- Using marginal quality water for irrigation where soil characteristics allow it (HR Wallingford 1997);
- Using treated wastewater for irrigation (this already takes place at the informal level – for example in urban Nairobi – but wastewater is not treated: HR Wallingford 2001);
- Improve urban water supply by using rainwater, surface water and groundwater conjunctively. To a variable extent, many Nairobi residents use surface water (from the NCWSC), groundwater (from privately-owned borehole) and harvested rainwater (from their own roofs) to meet water needs. This needs to be formalised and encouraged.
14 Planning for sustainable groundwater management

The need for some form of groundwater management process is not in doubt for any of the CSAs, all of which face risks that can be mitigated by means of a groundwater planning process; there are other aquifers that could benefit from a targeted management approach now as well: Naivasha and Nakuru/Rongai are immediately obvious examples. However, no Kenyan aquifer is at present managed by a plan, formal or otherwise.

14.1 Responses and solutions

Groundwater management plans must be integrated into not only catchment management planning processes, but also in water supply development initiatives. A framework for measured and logical groundwater resources management is shown below (pers. comm. Albert Tuinhof 3rd September 2010):

Table 31: Logical groundwater management framework

<table>
<thead>
<tr>
<th>Current situation:</th>
<th>Desired situation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogeology</td>
<td>Strategic targets</td>
</tr>
<tr>
<td>Socio-economic conditions</td>
<td>IWRMS &amp; WE Plan</td>
</tr>
<tr>
<td>Operational</td>
<td>MDGs and Vision 2030</td>
</tr>
<tr>
<td></td>
<td>Resource sustainability</td>
</tr>
</tbody>
</table>

Instruments:  
- Policy changes  
- Regulatory provisions  
- Stakeholder participation

Measures:  
- Water quality  
- Supply management  
- Demand management

Management actions:  
- GW management plans  
- Planned conjunctive use  
- CC adaptation

This process must take place at the aquifer level, possibly through the subordinated management of aquifers by some form of aquifer management organisation, and it requires the appropriate policy and regulatory framework to be in place. It would be hosted by the CMS or, more appropriately, at the SCMP level (particularly for smaller aquifers). The precise management vehicle would be developed in an aquifer management plan such as that proposed for the South Coast aquifers (see S. 14.4).

14.2 The application of logical groundwater management in Kenya

Not all the groundwater management tools (policy/legislation, technical capacity and financing frameworks), are currently in place in Kenya at present; more accurately, some sectoral realignments would be required for the appropriate management and technical conditions to be met. In addition to these measures, the water sector and other stakeholders must recognise that:

- Groundwater should be protected;
- Groundwater quality should be conserved;
- Groundwater and surface water are parts of a single resource;
- Groundwater protection will not work without proper land use planning;
- Water users must understand the need for groundwater protection.

Once these basic precepts are recognised, then developing an aquifer management plan is relatively straightforward. The GW•MATE Strategic Overview paper on groundwater governance (GW•MATE 2009), presents a pragmatic and rational approach to aquifer management planning (see Figure overleaf).
The framework can be applied at national as well as local levels, though most of the management instruments are broadly similar at national and local level; we consider how this approach might be applied to Kenya in detail in the sections that follow, with appropriate amendments to account for Kenyan conditions.

The framework embraces an approach which is truly multi-sectoral, and which takes into account the views and interests of all the key stakeholders, including the public and water users. Ideally, it should be compiled by a workshop or in a similar environment. In developing a draft approach to a strategy (see below), we have taken into account the findings of this study as well as the dialogue and views expressed in the Kenya Groundwater Governance Workshop conducted on 2nd September 2010 in developing the framework; however, we stress that this is solely our interpretation. It serves as a basis to be considered and amended in a future workshop or other appropriate forum.

We shall first use the approach to develop a framework for a national groundwater strategy for managing Kenya’s groundwaters. We shall then outline a pilot groundwater management plan process for the South Coast of Kenya.

14.3 Kenya national groundwater management strategy

Section I of this report considered the technical dimension of groundwater protection in Kenya; section II assessed the governance framework currently in place in Kenya, and proposed measures to improve it in the light of increasing threats to groundwater. These sections inform our approach to the proposed groundwater management strategy.
14.3.1 Institutions and linkages

The strategy would be overseen by the MoWI through its sector agencies, with the technical water resources management element overseen by WRMA and the water services side overseen by WASREB. The Ministry would create the linkages between cross-sectoral stakeholders at the national/Ministerial level, and subordinate MoWI agencies would carry this down the water management hierarchy to regional and local levels.

14.3.2 Groundwater management strategy

A national groundwater management strategy for Kenya might look like the Table shown in Annex 5 (Framework for a National Groundwater Management Strategy).

Once revisions have been made to the relevant institutions and the appropriate capacity vested in the WRMA and CAACs, a national groundwater strategy for Kenya should be developed as a matter of haste. It must incorporate and build upon the initiatives proposed by the NCCRS and IWRM & WE Plan, and must include a groundwater vulnerability to climate change component.

14.4 Pilot groundwater management plan for the South Coast aquifers

Here we use the same approach as developing a national strategy to outline the groundwater management plan process for the South Coast peri-marine aquifers. We propose this area for a number of reasons: –

- It hosts the Tiwi aquifer, which is not accurately defined in the technical sense (geographic extent, flow model, etc). The Tiwi is a major aquifer which is considered by the WRMA to be in an ALERT state (WRMA 2007);
- It is reasonably easy to define, comprising the Magarini Sands, the Pleistocene Kilindini sands and coral limestones, and alluvium; its eastern boundary is the oceanic front and its western boundary is the contact with the much older low permeability Jurassic and Permo-Triassic rocks;
- Groundwater is a particularly important resource in the area; threats to it have been defined (sand harvesting; unregulated wastewater disposal; future growth in abstraction);
- It is under specific development pressures that may give rise to these threats (the proposed South Coast Resort City envisioned in V2010);
- Further socio-economic development of this area would be better guided by a plan that protects groundwater than continuing with the current ad hoc, reactive approach;
- It has easily-identified local stakeholders who already actively pursue participatory planning processes.

Key stakeholders

- WRMA SRO Mombasa and Athi CAAC
- CWSB/KWASCO
- KCC
- Cross-sectoral partners: MoH; MoL; MEMR; MoA; Local Government; Tourism; Planning & National Development; KWS; KFS
- Local stakeholders: SCRA; MCTA; SCHA; Base Titanium; KISCOL
- … and others
Once the development of the national groundwater protection strategy is well advanced, the framework for a pilot South Coast Groundwater Management Plan described above and tabulated in Annex 6 should be initiated.

15 **Recommendations**

This closing chapter summarises the measures required for effective groundwater management to take its place in the management of Kenya’s water resources. What follows provides a starting point; some recommendations relate to problems the resolution of which is absolutely essential if effective groundwater management is to come about; others are more generalised, typically relating to cross-sectoral issues. It is acknowledged that these recommendations will need to be reviewed in light of the provisions of the new Constitution of Kenya.

**15.1 Amending and streamlining sectoral and cross-sectoral policies**

Generally, policies currently in place are not an impediment to improving groundwater management, but they do require harmonisation and implementation to effectively capture cross-sectoral involvement. However: –

- There is no cross-sectoral groundwater protection policy, a deficiency that should be remedied as swiftly as possible;
- The development of a cross-sectoral climate change response policy is also required to give effect to the NCCRS.

**15.2 Streamlining legislation and regulations**

- The groundwater protection policy must be given effect by amending existing laws or creating new ones. This particularly involves land use planning agencies, which remain critically ignorant of the consequences of some of their actions.

**15.3 Clarifying institutional mandates**

- Grey areas exist in the mandates of the environment and water sectors, particularly in wastewater management. Mandates must be clarified and legislation enacted if necessary, to eliminate the confusion and double-charging that exists.
- The level of support for WRMA provided by its parent Ministry is inadequate; necessary measures include vocal public support for WRMA in respect of water permits and water charge collection; and making available the information that WRMA needs for groundwater resources management decisions.
- The NWCPC role needs to be clarified; as the Ministry’s contractor, it should not be permitted to develop groundwater resources yet ignore the permit and water charge provisions required by law. To a degree, the same situation exists with respect to groundwater development by the Kenya Army Engineers, though in both cases this is improving.

**15.4 Aspects relating to rights and responsibilities**

- The public as groundwater users have a very poor understanding of their responsibilities as water users, a deficiency that must be remedied by targeted sensitisation and education programmes.
• Many WSPs and other public sector water users do not acknowledge that they must have water permits and pay water charges, in defiance of the laws governing groundwater use. This is not out of ignorance, but out of apathy or lack of interest. WRMA is unable to enforce the WRM Rules with such entities, principally because of limited support by the Ministry to resolve the impasse. The Ministry should lead its subordinate agencies in verifying its own water use (§. 17 of the Rules), and be seen to be doing so.

15.5 Aspects relating to knowledge and capacity

• Current understanding of Kenya’s groundwater resources is patchy; some are well understood while others are essentially entirely unknown. An improved knowledge base is an essential pre-requisite for groundwater management, for which more financial and technical resources are required.
• The distribution of groundwater professionals in the public sector is imbalanced, with approximately four times as many in the Ministry (legislation, policy, coordination and M&E), as in the WRMA (water resources management). This must change, to the level where ultimately STRATEGIC and MAJOR aquifers have not less than one hydrogeologist/geologist dedicated to their management.
• Those WSPs that rely on groundwater resources should deploy a sufficient number of hydrogeologists to support their water supply function, in full collaboration with the WRMA.
• The technical capacity of WRUAs need to be enhanced; if the CAACs are to be empowered for a more active role in groundwater management decisions, they too will need considerable capacity enhancement, especially in technical areas.
• Technical support in terms of equipment required for groundwater management (geophysical equipment, downhole cameras and loggers, monitoring equipment etc) is inadequate to provide the WRMA with the tools it needs to manage groundwater.
• The existing groundwater monitoring networks are inadequate to support groundwater resources management; the WRMA’s current efforts to expand these must be supported by the Ministry.
• A number of Codes of Practice (CoPs) for groundwater activities have been formulated in draft, but no action has been taken to implement them; some basic standards are required for private sector groundwater players if the continuing decline in the quality of borehole siting and drilling is to be reversed.
• Technical training facilities for the groundwater sector are good though more capacity is required; curricula may need some revision in order to take on board emerging issues, such as groundwater protection and adaptation to climate change.
• New groundwater management technologies should be reviewed for their applicability in Kenya; their use has financial implications, so additional financial resources would be required if they are to be deployed.
• The senior political cadre must be educated as to the importance of their role as legislators; the body politic at all levels need to be sensitised on the interface between groundwater and land, the importance of groundwater in Kenya’s economy, and encouraged to disseminate key groundwater resources management messages.

15.6 Information sharing

• The level of understanding by the public of the role and importance of groundwater in Kenya’s economy is very poor; measures should be taken to fast-track public information and educational programmes, starting in primary school, and extending to the grassroots level.
• The transparency of groundwater allocation and management decisions is poor; mechanisms for dissemination of information exist but are not applied (mainly for reasons of cost).
• The process by which groundwater professionals and drilling contractors are vetted and registered by the Ministry is opaque; broader stakeholder consultation is recommended, as well as more openness as to process.

• Technical information management is very poor, with both the Ministry and the WRMA maintaining their own databases, which in the latter case are patently incomplete; this makes it impossible for WRMA to make reasoned and justifiable water allocation decisions. It is recommended that formal responsibility for archiving and maintaining a database should rest with WRMA, with an absolute right of access by the Ministry. WRMA must integrate the database into MIKE BASIN, the software platform used for water resources management.

• A groundwater information and communication system should be developed, not only for technical information but also as a guide to the numerous public agencies, groundwater users and other stakeholders involved in water management.

• The WRMA must step up efforts to explain to the public why they should pay water charges, and explain the importance of water resources management. The Ministry must publicly support this initiative.

15.7 Financial aspects

Inadequate funding is the biggest impediment to groundwater management in Kenya. It is clear that WRMA requires additional funding, either as direct budgetary support from Government or through improved revenue collection (which requires strong political support).

• At present the groundwater sub-sector is under-funded, which indirectly reinforces the public view that groundwater is a “private” resource. More financial resources need to be made available for groundwater management.

• The level of capture of groundwater users is poor (water permits and water use charges), though variable. The entire sector must acknowledge that water permits are required and water charges should be paid – otherwise WRMA will continue to be under-resourced. Failure to do so sends entirely the wrong message to the public, and strenuous efforts must be made to reverse this.

• Funding mechanisms need to be developed for developing hydrogeological maps, and the proposed national groundwater management strategy and pilot groundwater management plan.

15.8 Groundwater management strategy / local groundwater management plan

In light of the above, it is recommended that a national groundwater management strategy be developed, and once this process is well-advanced, that a project to develop a groundwater management plan for a pilot area be initiated. The South Coast is proposed as a pilot study area.

15.9 Opportunities offered by the National Water Master Plan update

The Japan International Cooperation Agency (JICA) has undertaken to support the updating of the 1992/98 National Water Master Plan (NWMP), which offers considerable opportunities to strengthen groundwater management. We strongly recommend that the Ministry and its sub-sector agencies develop a series of proposals for inclusion in the NWMP.

The following aspects arise out of this study and the Workshop held on 2nd September 2010, but there are undoubtedly opportunities in other aspects of the water sector: –

• Develop the National Groundwater Management Strategy (S. 14.3 above);
• Pilot the groundwater management plan for the South Coast area (S. 14.4 above);
• Draw up a list of priority aquifers and select those for which hydrogeological maps are urgently required; incorporate all or a number of these into the revised NWMP process (S. 9.1.1 above); some possibilities, of various scales (from small to large) include: –
  o The Timboni aquifer (S. 1.5.3)
  o The Rongai aquifer (S. 1.5.3)
  o The sedimentary aquifer at Lodwar, Turkana District
  o The Nakuru aquifer (S. 1.5.3);
There are many more aquifers that would benefit from detailed hydrogeological mapping.
• Draw up a list of aquifers for which water allocation plans are urgently required, and incorporate these into the NWMP process (S. 5.2); any of the aquifers listed in the previous bullet point would be possible examples, as well as the CSAs;
• Select an aquifer and develop and conduct a climate change vulnerability assessment (S. 12.2);
• Take the opportunities offered by the publicity surrounding the NWMP to educate and sensitise water users and the public at large of the vital role that WRMA has to play in water resources management in the Republic (S. 15.6 above);
• Insofar as the NWMP process allows, include capacity-building processes for WRMA technical staff and the CAACs.

POSTSCRIPT

In 1960, the United Nations published Large-scale Groundwater Development. It was written by a group of eminent hydrogeologists against a background of intensive development in irrigated agriculture accompanied by borehole mechanization, and the beginnings of urban expansion in response to population growth. It was full of clear advice on groundwater development, recognizing social and economic values and presenting well-thought-out practical steps and principles that would lead to sustainable development of groundwater resources against these changing consumption patterns.

Little of this advice was heeded (UN 2000a):

“The evolution of groundwater management systems is a long-term process”