Rural Water Supply Network

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Perspective

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Sustainable Groundwater Development: use, protect and enhance

Contents

1 Summary

Sustainable groundwater development is absolutely fundamental for universal access to safe drinking water. And yet this is poorly understood. Groundwater is a finite resource that in some countries is under serious threat from pollution causing permanent aquifer damage while in others over-abstraction is resulting in reduced water availability.

This RWSN publication is to help create a better understanding of the crucial importance of groundwater and to highlight the risk to its sustainability. It is intended for politicians, policy makers, government partners and the public. It advocates responsible ground water use and cautions against abuse. It encourages users of groundwater to protect and enhance this precious resource for the long term benefit of the most vulnerable communities who primarily use hand pumps.

It is vital that we better understand the features and functions of groundwater so that together, we can identify solutions for its sustainable development. If we adopt basic guidelines for using, protecting and enhancing ground water we can ensure safe and sustainable water supplies for the next generation. This is illustrated in our vision of how rural water supply may look by 2035.

Political commitment, well-planned actions and the allocation of adequate financial and human resources is needed to secure sustainable groundwater development worldwide for our and future generations. Are you ready to take on this challenge?

2 Introduction

According to the United Nations' Joint Monitoring Programme (JMP) there are still 780 million people worldwide who use unsafe, unimproved water sources (UNICEF/WHO 2012). While the figures and definitions can be argued about, what is beyond dispute is that it is the rural poor, and women and girls in particular, who are disproportionately affected by a lack of access to clean, safe drinking water.

Sustainable groundwater development is absolutely fundamental for universal access to safe drinking water. And yet it is poorly understood. The development of groundwater supplies is particularly important for remote, rural communities to enable equitable access. In some places it is under threat. The JMP figures show the rise of piped systems in many rural areas, typically small towns, and these require motorised pumps. This introduces a new dimension of complexity and a growing risk to the sustainable use of groundwater.

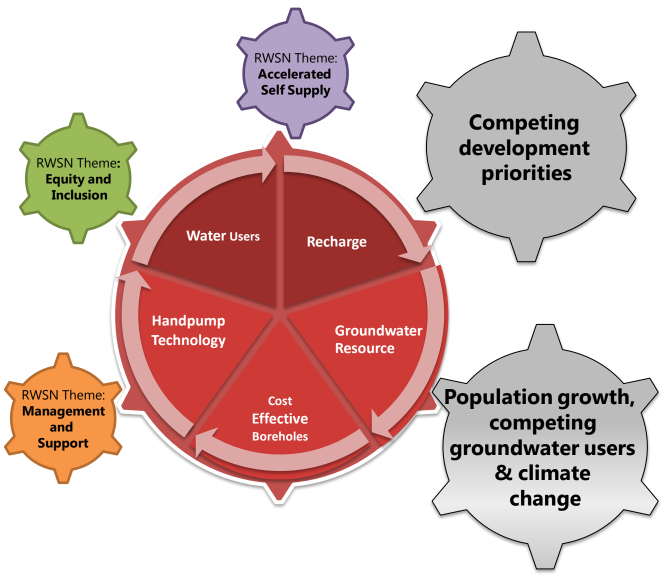
With this publication, we enable reader to understand the features and functions of groundwater and present solutions for sustainable groundwater development. It is our intention that this will catalyse political commitment, specific actions and bring about the allocation of adequate financial and human resources for sustainable groundwater development.

Sustainable groundwater development can be broken down into five stages, which follows (1) rainfall and the entry of water into the aquifer, to (2) groundwater storage (and water resources management), to (3) the borehole, then to (4) the handpump, and finally to (5) the water user, in combination with other factors. The needs and behaviour of water user will in turn affect the quality, quantity and sustainability of the water resource. Sustainable groundwater development competes for financial and human resources with other developmental priorities such as sanitation, health, education environment, good governance, rural development, water management and economic growth. Sustainable groundwater development is one of four themes in the 2012 to 2014 strategy of the Rural Water Supply Network as set out in Box 1.

Box1: Rural Water Supply Network (RWSN) – Sustainable Groundwater Development Theme

Sustainable Groundwater Development is one of four themes in the 2012-2014 RWSN Strategy and there is overlap with the others: Accelerating Self Supply, Equity and Inclusion and Management & Support. As a new strategy period begins the aim is to capitalise on the progress of the network so far, particularly in the areas of handpump technology and cost effective boreholes, and to broaden the scope to address related problems that are hampering the improvement and sustainability of rural water supplies.

The figure (right) shows the five stages of sustainable groundwater development and illustrates that there is an interface with: wider, and often competing, developmental priorities; other key issues, including population growth and climate change; and the other three RWSN themes.



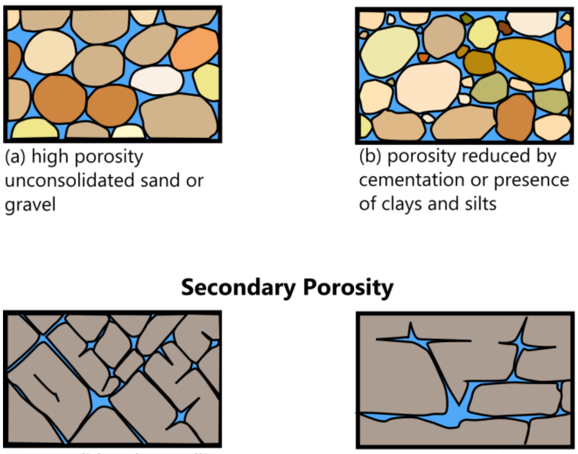
3 Groundwater: Buried treasure

Groundwater has been a good friend to humanity down the centuries. Where rain, river and pond have proven fickle, it is perhaps the well, borehole and spring that have provided clean water for the majority of people. However it is an invisible friend that is poorly understood by most and can cause serious problems if mistreated.

Groundwater can be accessed by digging a large diameter well, tapping a spring or drilling a borehole. Boreholes can be drilled in different ways, depending on the type of ground conditions, the depth and diameter required, ease of access to the site, speed of completion required and budget. In all cases the formation has to be broken, with the debris removed from the hole. The hole is kept from collapsing with the use of casing materials or drilling fluids until it is completed. Whereas mechanised drilling uses rigs and compressors that are diesel and petrol driven, manual, or hand drilling relies on human energy.

Ask most people to describe groundwater and they are likely to talk about underground rivers or lakes. Perhaps they have seen pictures, or even been in dramatic limestone caves with eerie subterranean pools and dripping stalactites. The reality for most aquifers is far less poetic and much harder to visualise. There are two broad categories of water storage in rocks (Figure 1): the first, known as primary porosity, is provided by the void spaces between the grains in unconsolidated sedimentary rocks, such as sandstones and gravels; the second, known as secondary porosity, is the void space in fractures and solution features of consolidated rocks, such as crystalline basement rocks or limestone.

Figure 1: Types of Rock Porosity



Primary Porosity

(a) high porosity unconsolidated sand or gravel

(b) porosity reduced by cementation or presence of clays and silts

Secondary Porosity

(c) consolidated crystalline rock rendered porous by the presence of fractures (e.g. crystalline basement)

(d) consolidated fractured rock with porosity increased by dissolition (e.g. limestones)

adapted from MacDonald et al 2005

One of the many advantages of groundwater is that it is widespread across most land masses. However, not all rock formations hold water, and even some that do don't readily release the water they store. An example is clay, which often expands and shrinks as it takes in and loses water, but the water is so tightly bound in the microscopic clay particles that a well dug into it is unlikely to get anything more than slightly damp. Other rocks, such as basalts or granites may not be sufficiently weathered or affected by tectonic activity to have any fractures. Other rocks, such as volcanic pumice, may have a lot of pores and voids but no inter-connections that allow water to travel through the rock. In this particular case, the rock is very porous, but the permeability, i.e. rate of movement of water, is extremely low.

Groundwater recharge refers to the entry of water into the aquifer. Natural recharge happens as rainfall (and other precipitation, such as snow) percolates through the soil directly or from rivers, wetlands and lakes. It can also happen artificially, either intentionally, using structures like sand dams and soakaways, but more often unintentionally from over-irrigation or leaking pipes and sewers. However, even where you may have a suitable water-bearing rock, it may be capped by an impermeable layer, or layers, so that percolating soil-water cannot recharge it.

Where there is little human interference aquifers discharge their water to rivers, wetlands, lakes and the sea. However, where if human abstraction exceeds recharge then not only can pumping yields decline but natural water features can be damaged too. In extreme cases, over-pumping in combination with a dry spell can cause normally perennial rivers to dry up. Another case is where there is a large aquifer containing a lot of water but with little or no recharge. This is often called 'fossil' water because like fossil fuels it is a non-renewable resource that needs to be used with care.

Water quality can be another challenge; the most well known problems are the high levels of fluoride found in some of the Rift Valley aquifers in Eastern Africa, and the high arsenic levels found in groundwater in Bangladesh and elsewhere. Groundwater can be aggressively acidic or alkaline, which can damage pumps, pipes and other water supply equipment. Even where the water is not harmful, it can have discolouration, taste or smell that causes users to reject groundwater in favour of less safe sources. Iron and manganese are the most common culprits. While water treatment can address these problems (Hartman, 2001), it adds another layer of cost, complexity and risk of failure.

Despite these challenges, the advantages of using groundwater are clear, as shown in Table 1. Aquifers provide a store and a temporal and spatial buffer against drought. In tropical climates with an extreme variation in rainfall, this buffering is the critical characteristic of groundwater, as is the protection from evaporation, which is often a major problem with surface reservoirs. Contamination risks are often less than surface water due to the filtering effects of soil and granular aquifers (such as sandstones). An impermeable layer, such as clay, above an aquifer can protect the groundwater from surface pollution.

So, if the use of groundwater is so advantageous over surface water, why is it taken for granted or understood so vaguely? There are two main reasons highlighted in Table 1 and both are due to the invisibility of groundwater. Because it is beneath the earth it is hard to understand and conceptualise. This gives problems in terms of public understanding of what groundwater is and what it can and cannot do. For engineers and hydrogeologists the lack of visibility is a challenge because the volumes of water are much harder to measure and monitor than a reservoir or river. Aquifers are rarely uniform in their thickness and composition. Hydrogeologists have to extrapolate from limited water level readings in a few boreholes and wells. Even in countries like the United Kingdom, which has a dense groundwater monitoring network with data going back many decades, there can still be substantial unknowns in the understanding of groundwater flows, water balances and picking out long term trends, and whether those trends are caused by abstraction, climate change or some other factor.

4 The challenges of sustainable groundwater development: creating a lasting relationship

4.1 The scale of the problem

As noted in the in the Introduction, the number of people without access to safe, clean drinking water is staggering. Even where water

Table 1: Comparative features of groundwater and surface water resources (Adapted from Tuinhof et al, no date)

FEATURE	GROUNDWATER RESOURCES & AQUIFERS	SURFACE WATER RESOURCES & RESERVOIRS
Hydrological Characteristics		
Storage Volumes	very large but difficult to measure.	small to moderate but can be measured with greater accuracy.
Resource Areas	relatively unrestricted	restricted to water bodies
Flow Velocities	very low (long natural residence time)	moderate to high (disappears quickly)
Residence Times	generally decades/centuries	mainly weeks/months
Drought Propensity	generally low	generally high
Evaporation Losses	low and localised	high for reservoirs
Abstraction Impacts	immediate and localised in confined aquifers, more delayed in and dispersed in unconfined.	immediate
Natural Quality	generally (but not always) high	variable
Pollution Vulnerability	variable natural protection	largely unprotected
Pollution Persistence	often extreme	mainly transitory
Socio-Economic Factors		
Public Perception	mythical, unpredictable	aesthetic, predictable
Style of Development	mixed public and private	mixed public and private

supply infrastructure has been put in, a reliable, high quality service is not assured in many cases. This is not always because pumps break or pipes burst, in some cases they are abandoned because the population itself changes due to migration to urban areas or political instability.

4.2 Lessons learned in rural water supply

The extent of the problem of inadequate clean drinking water has been known for decades, so why has progress been so painfully slow? At first glance, drilling and handpump technology does not appear to be incredibly complicated. However, the combination of technical, social and institutional dimensions means that the provision of a sustainable groundwater resource is actually quite complex. Practitioners working in rural water supply have learned, often the hard way that some approaches are inadequate (RWSN, 2010):

4.2.1 Subsidising hardware is not the best way to use public funds

There has been a common view that it is the obligation of governments the world over to provide free drinking water. This, coupled with the fact that the cost of drilling boreholes and installing pumps is often beyond the means of many rural communities, has meant that governments, donors and Non-Governmental Organisations (NGOs) provide equipment at little or no cost to the end user. However, this has three problems:

- Donors and governments only have limited funds, so this capital-intensive approach limits the number of people who can benefit;
- It largely ignores other sources of funding, particularly from the household or community itself; and
- It often leads to an emphasis on building infrastructure instead of improving institutions, such as local artisans and local government.

Hardware subsidies and give-aways can also undermine local private sector initiatives, which in the longer term can provide a more sustainable service. This applies not just to new equipment but also to spares – in Malawi, a rural retail business, Chipiku Stores, which stocks spare parts for Afridev pumps, was undermined by an international donor distributing free spares (De Saint Méloir, B. 2009). While this may have some benefit to the end user at first, it is not feasible for an external donor to provide a perpetual subsidy. The risk with hardware subsidies and give-aways is that when they are withdrawn, there is no affordable or available alternative so the technology is abandoned and users go back to using unsafe or distant water sources.

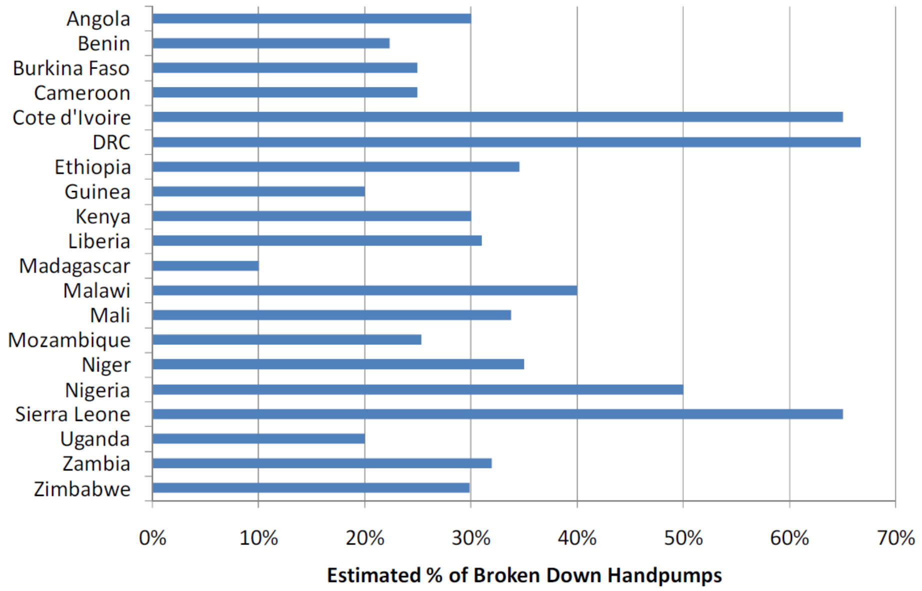
External support agencies, with very few exceptions, are transient short term players who cannot guarantee the long term sustainability of an intervention. They can start innovation, and support communities in the short term, but it falls to government to institutionalise the ways that secure permanent solutions. Increasingly this is done in mutually beneficial partnerships with the private sector.

In contrast, indirect subsidies can bring long-term benefits. This can include building the strength of public and private sector providers or cross-subsidising financially viable business models that reach the very poorest within a community. However, the nature of indirect action means that the cause-and-effect link is clear, harder to measure and more difficult to justify to those funding the process. It may take longer than a typical 2-3 year project funding cycle to see tangible, measurable results, and therefore donors need to have patience and all parties involved need to have clearly defined objectives.

4.2.2 Handpumps break

Because rural water supply coverage has been so poor, the focus of governments, donors and NGOs has often been on numerical outputs of boreholes drilled, handpumps fitted, and the number of people that, by inference, would then have access to an improved water supply. Sadly, however, this is not 'fit-and-forget' technology (Baumann, 2009). Figure 2 shows the picture of handpump breakdowns across Sub-Saharan Africa (RWSN 2010). It is not encouraging. It shows the impact of water quality problems, poor siting and construction and poor management. However, despite these challenges a glass-half-full view is that typically two thirds of handpumps are working and doing their job.

Figure 2: Estimated % of Broken Down Handpumps, for 20 selected countries (RWSN, 2010a)



While RWSN, and its predecessor the Handpump Technology Network, have done a considerable amount of work supporting the improvement and standardising handpump technology, we should not fool ourselves into thinking that we can invent a maintenance-free handpump (Carter, 2009). One of the major issues is that while pumps are generally purchased by government and NGO programmes, it is expected that spares are bought by the community. Actually, the supply of pumps and spare parts need to be linked together, ideally both accessible to rural dwellers by local private enterprises (Harvey, 2011).

4.2.3 Communities are not always capable of managing facilities on their own

During the 1970s and 1980s the dominant idea in water supply thinking was based on the developed country model of water infrastructure being fitted and maintained by government, or statutory water authority, with little or no community involvement in the decision-making process. After sustained action research and lobbying, principally by NGOs, a community-led approach to rural water supply was introduced. The intention was to ensure that communities were involved in the technology choice, planning, siting and construction, thus fostering a sense of ownership in the improved water supply infrastructure and maintaining it. This had some success, but has had its share of problems: while community water committees and their technicians can cope with minor repairs, major problems are often beyond their means. It is not just the physical hardware that wears out over time; the community institutions can run down too, as people lose interest and are less willing to volunteer (Carter, 2009). It has become clear that village water committees need external support, like the pump itself, whether it be training, monitoring and advice, financial resources or technical assistance. Problem-solving is an essential skill to foster and encourage.

4.2.4 20 litres per person per day is not a magic number – multiple water uses need to be considered

20 to 25 litres per person per day is the common design guide for rural water schemes, but the emphasis on clean domestic water supply often ignores the reality that people use water for many purposes, including agriculture and livestock. A community reliance on a single source can cause long journey times to collect water or long queues. In some cases it may be more appropriate to develop a drinking water source that provides 5 litres per person per day, and secondary sources of non-potable water for other uses.

4.2.5 The private sector is neither the great saviour nor the great sinner

When the public sector failed to deliver much needed water services, it was hoped that the private sector might ride to the rescue. In the 1990s this view was buoyed by an enthusiasm, particularly in Europe, for privatising utilities. It was hoped that private sector innovation and efficiency would be able work where public sector bureaucracy had seemingly failed.

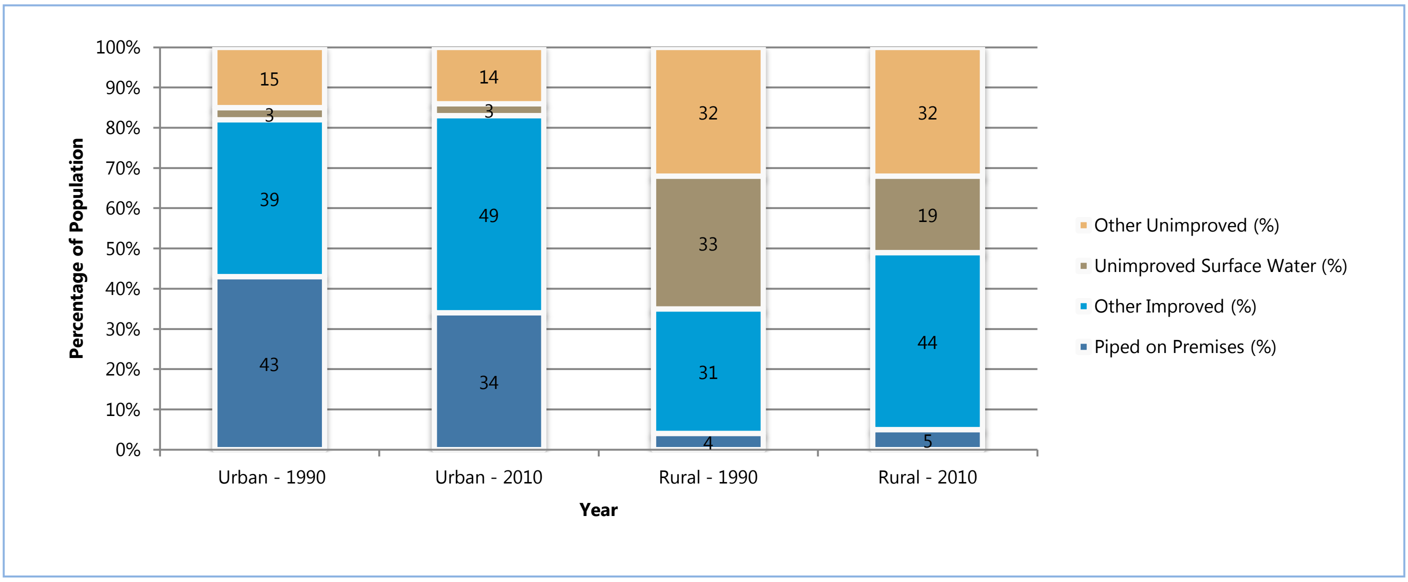
However, large international companies have generally turned their attention to urban areas where the high density of commercial and industrial activity, and population, means that margins are higher and risks are lower. Poorly supervised and large contracts in loosely regulated environments often lead to corruption (WIN, 2011). Some national companies have also become involved in the management and maintenance of urban and small town water supplies, but by and large the role of private companies in rural areas is limited to contractors for government and donor programmes. The markets for improving water supply services directly for rural dwellers is often undermined by programmes with hardware subsidies so there is little opportunity to develop a sustainable business model or make a livelihood. Equally, the distances between water supply systems, their small size, the low income levels of the customers and difficulties in collecting fees makes it very difficult to recover costs.

4.2.6 The opportunities and challenges of NGOs

There is an understandable desire by many around the world to help the world's rural poor and to get out into the field and implement a community water supply project. While their aims may be laudable, the problem with NGO and funding agency intervention is that they often work to their own standards and procedures, which may have nothing in common with what is going on elsewhere in that region or country.

Often, NGOs will ignore the local or national government because they claim that it is too bureaucratic and slow. There is often mutual mistrust between governments NGOs. However, an NGO is invited to work on a rural water supply by the host and sovereign government, not vice versa. It is government that has a mandate to coordinate support within the country. If the capacity to do this is not

Figure 3: Disparity between urban and rural access to improved water sources in Sub-Saharan Africa (UNICEF/WHO, 2012)



there, this needs to be strengthened by suitable partners. Once the NGO leaves, it is the government that will have to provide the support to the community. A further problem with some external interventions is that they often lack transparency and accountability.

In addition, while highly motivated, some NGOs, especially the smaller ones try to provide water supplies without adequate technical competence or knowledge and ignoring the local geology or difficult hydrogeological conditions. This can lead to poor technology choice and unsuccessful wells or boreholes, and disappointed communities. Lack of data collection and handover by NGOs, private contractors and others is also a problem, leading to repeated mistakes and no incremental learning.

All of this is more likely to lead to the water supply system not being maintained and breaking down because there is no one able or willing, to keep it going.

The strengths of NGOs are that they are usually innovative and flexible. As well as practical work, their advocacy and campaigning ensures public and political support for the rural water supply agenda. This supports not just their own work but also influences the priorities of government bilateral donors and large international multilateral agencies. NGO campaigning also increases scrutiny and transparency of development aid spending.

4.2.7 There are no quick fixes

The biggest problem is that there are no quick fixes. It just doesn't work to drill a borehole, fit a handpump, set up a water committee and then walk away. There is no substitute for the long hard slog of political negotiation, education, investment, innovation and building institutions.

The challenge is to see if it is possible to create an enabling environment for rural utilities (public, private or non-profit) that are responsive to customer needs and able to deliver an efficient and affordable water supply service to everyone, including the poorest and most marginalised. Such providers also need to be monitored and regulated in a fair and transparent way, which will also take long term commitment, skills and resources.

5 Why worry about water resources?

Looking at groundwater use through the lens of Integrated Water Resource Management (IWRM) can be instructive in understanding the inter-relationships that often lead to misunderstandings of water problems. It is easy to think about water supply from groundwater as simply a hole from which water is pumped and distributed to the end user and that the costs relate purely to drilling the borehole and installing and maintaining the handpump. However, we need to go back to Table 1 to see the advantages that groundwater has over surface water to see that aquifers perform a number of vital functions: they provide storage, distribution and a degree of filtration.

Take a hypothetical region with a widely dispersed, rural population that had no groundwater potential at all. To provide what an aquifer would provide for 'free' then water would have to be collected in reservoirs, pumped through treatment works and distributed through a vast network of pipes, pumps, and service reservoirs. The cost, both in terms of energy and finance would be enormous. In fact, many rural areas in Europe and North America are not connected to a public mains supply because it is just too expensive.

Therefore, it is imperative, that water supply engineers and planners recognise that groundwater is an incredible gift of natural water supply infrastructure. However, unlike a man-made water supply network, an aquifer is not designed with the human end-user in mind and it doesn't exist in isolation. There are linkages between groundwater, rivers, lakes and wetlands. Therefore whatever is taken for human use may have an ecological impact nearby. Understanding the cause-and-effect relationships requires detailed, long term data collection and study.

An individual handpump is very unlikely to deplete an aquifer because the abstraction rate is so low compared to the replenishment of the resource by the average annual recharge. However the combined effects of dozens, or hundreds of pumps at times of water stress (e.g. at the end of the dry season) may cause problems. Motorised pumps can seem attractive and are increasingly being used for domestic water supplies in some countries but their higher discharge rates can cause high groundwater depletion and so have to be used with care and a good knowledge of the aquifer and also an awareness of other groundwater users.

Because the impact of an individual handpump is so low, there is often little or no interest in water resources planning from many rural water supply practitioners. In many Sub-Saharan countries, the water resources department of government is chronically under-funded, under-skilled and often ignored even when major problems are identified. In other regions, such as India, dense rural populations and intensive agricultural activity are leading to the depletion and contamination of groundwater resources.

However, the more likely, and serious problem is the impact of other abstractions or activities on domestic boreholes. In most rural areas the biggest factor will be agriculture, which has multiple impacts:

- Surface and groundwater abstraction for crop irrigation;
- Surface and groundwater abstraction for livestock water and irrigation of fodder crops;
- Changes to soil structure, organic content, salinity, erosion rates and crucially land use, which in turn affect groundwater recharge.
- Changes to microclimates which can alter local rainfall and evaporation.

Another major threat is mining, which can lead to widespread deforestation, soil erosion and contamination by a range of pollutants, including toxic heavy metals like mercury which has widespread use in artisanal gold mining. This has the potential to make both surface water and groundwater unsafe.

No matter how physically big the storage capacity of an aquifer is, there is no sustainability without aquifer recharge. An understanding of the recharge rate of the aquifer is therefore fundamental. This is a problem in areas of India, where groundwater levels are falling (GoI, 2010). Occasionally the 'mining' of fossil water is deliberate. For example, in Libya, the Great Man Made River Project has been extracting water from a deep aquifer that has been there for thousands years (Abdelrhem, 2008). While unsustainable, it could be argued that the water in this case has no human or ecological benefit where it lies and yet it is of considerable benefit if brought to the surface. Setting clear objectives for groundwater management for an area or aquifer is important.

6 Climate change: threat or distraction?

No discussion of natural resource management can ignore the spectre of climate change. What makes the topic difficult is not the debate about whether it is happening or not, but what influence it exerts on sustainable groundwater management compared to other pressures, such as land use change, over-abstraction, groundwater pollution and biodiversity loss. Because climate change is such a high profile issue there is a risk of uncertain future changes overshadowing the real and tangible water crisis faced by many rural communities around the world now.

There are two sides to climate change: mitigation and adaptation. The first, mitigation, is about activities that reduce the releases of climate-forcing gases such as carbon dioxide, methane and nitrogen oxides. Here we find that there isn't really a problem because the emissions associated with drilling and handpump use, even scaled up across a country or continent, are likely to be negligible compared to other sectors of the economy. Water systems become carbon-intensive when large-scale treatment and pipe-network systems are involved, which require a lot of pumping and energy input. Indirectly, there may be problems if increased water use and economic activity encourages land use change, such as clearance of primary forest or draining of wetlands.

The second element is adaptation and vulnerability to climate change. Here there is great uncertainty on the magnitude and timing of impacts. While global temperatures look likely to rise over the next century, the impact on rainfall is less certain. Research into the long term effects on the major atmospheric cycles, such as the monsoon and the El Niño South Oscillation (ENSO) is far from conclusive but alterations to their behaviour would have very serious implications in many regions of the world, particularly the tropics. Groundwater recharge is highly sensitive to rainfall intensity and rainfall distribution. While in some settings, heavier rainfall can benefit recharge, if it becomes too intense then the soil cannot accept the excess infiltration, resulting in flooding. Flooding can enable contaminated surface water to enter the aquifer through boreholes and open wells. Greater use of artificial recharge methods, such as sand dams which increase water flow into the aquifer may help, at least at local level, and reduce flood risk.

The Intergovernmental Panel on Climate Change (IPCC) concluded that climate change will affect groundwater recharge rates. However, knowledge of groundwater recharge rates is poor in most of the world and very little research has been carried out to assess the likely impacts of climate change on recharge (IPCC, 2007a, Figure 3.1). Notwithstanding the need for more research, it would appear prudent for efforts to be made to enhance recharge, particularly in areas where abstraction rates are high compared to existing recharge.

While one might be drawn to thinking about the impact of climate change on drought-prone areas, such as the Sahel and East Africa, it is probably the rural populations of the islands and atolls of Oceania that are likely to be impacted first because the rural populations are already badly served and what limited groundwater resources are available are at risk from saline contamination from rising sea levels. This will lead to an increasing dependence on rainwater sources, which are unlikely to be reliable all year round without significant investment in water storage.

Adapting to these changes successfully will depend largely on solid data and effective monitoring of rainfall, groundwater and river flows, and a robust conceptual understanding of hydrological systems so that cause-and-effective relationships can be established. However, climate change always needs to be looked at in the context of other changes, such as land use and population growth

Figure 4: Impact of human activities on freshwater resources and their management, with climate change being only one of multiple pressures (IPCC, 2007b, section 3.4.2)

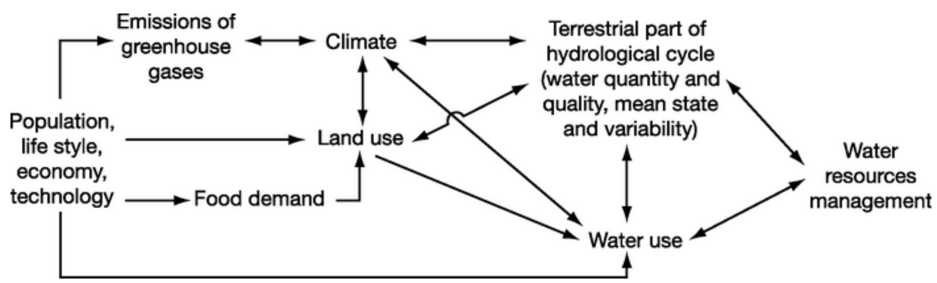
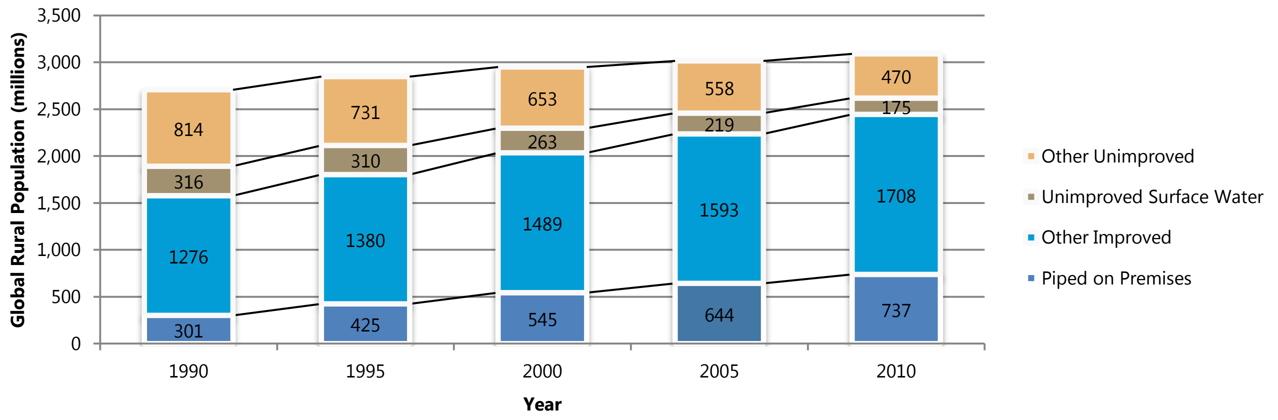


Figure 5: Worldwide water sources in rural areas (excluding Developed Countries) (Figures taken from UNICEF/WHO, 2012)



(Figure 4). For example, the Sahel region of West Africa has seen a dramatic fall in long term rainfall, and yet groundwater levels and river flows have risen, and this has been ascribed to the impact of land use change being more significant than climate change (Lebel *et al*, 2009).

7 Cost Effective Solutions

We have seen that there are daunting challenges facing the rural water supply sector. This will be the case particularly in countries like Uganda, Mali and Ethiopia that are experiencing high rates of rural population growth that in some cases might see a doubling by 2050 (UN-DESA 2010). However, it must be remembered that the situation is not hopeless and that progress has been made in many countries (Figure 5). However, the 2006 Human Development Report (UNDP, 2006) predicted that current trends mean that sub-Saharan Africa will not reach the MDG target for access to water until 2040. But even this may be optimistic as the easier-to serve are provided with safe water and the remote and most hydrogeologically difficult places are left behind. These are costly to serve and unfortunately many private, government and NGO projects avoid them. It should also be remembered that the MDG target is to halve the number of people without access to safe water supplies, which is a long way short of universal access.

RWSN has built up a wealth of knowledge and expertise with which it is hoped to accelerate progress. This section outlines some of the work within the Sustainable Groundwater Development theme that will tackle many of the thorny issues of rural water supply head on.

7.1 Water resource planning and water supply

There has been a push at international level for Integrated Water Resource Management (IWRM) which considers human interactions within the whole of the water cycle, from upland land management to coastal flood risk and groundwater. A holistic approach is often seen as desirable but the huge scope and complexity can often make day-to-day management considerations difficult. The amount of management will depend very much on the situation and the degree of stress that the groundwater environment is under and the amount of competition between water users.

Because political priorities and funding streams in many governments are unlikely to shift towards boosting government water resources departments, there is a need for:

Cost-effective methods for groundwater resources appraisal, planning and management are fully endorsed at national level and monitored

Good practices of groundwater development that are fully endorsed at national level and monitored

Mechanisms to link the two (e.g. through training, guideline, dialogue and joint planning);

The second point has already been addressed in part by the *'Code of Practice for Cost Effective Boreholes'* (RWSN/P/2010/7) and more specifically *'Siting of Drilled Water Wells – A guide for project managers'* (RWSN/P/2010/5). However, the challenge over the next period is to turn knowledge into practice by disseminating this information to professionals on the ground.

The first point is more difficult as implementing effective water resource planning is problematic in many countries. In Uganda, for example, it has been found that organisations set up to take the lead for a particular river basin, struggle to attract sufficient resources and support to be effective (Hydroconseil, 2011). At the other end of the spectrum, there is a danger of having a bureaucracy that produces detailed water planning documents but that doesn't produce tangible results. Hence there is a need for a lean approach to water resources planning that identifies and prioritises the biggest risks and challenges associated with a river basin or an aquifer so that all water (and land) users affected will have a direct stake in the outcome and so will be more willing to engage with the process. The challenge here is to ensure that support agencies support change and that the poorest in society are aware of their rights and take local action to protect and benefit from the aquifers on which their lives and livelihoods depend. River basin planning tends to focus on the big water users, who usually have strong vested interests.

A process of planning and water user engagement means that the opportunities for further groundwater development can be identified so that rural communities can be served without fear of being left with a dry well a few years later.

Finally, data is of critical importance. In many areas there is a lack of hydrogeological information and records. One of the key steps in the *Code of Practice for Cost Effective Boreholes* (see below) is that drillers should submit their borehole records to a government body that collates the information and makes it publically available. Implementing a high quality hydrometric network is also vital but difficult to fund. However, developments in cheap, automated water level measuring equipment may make this more viable.

7.2 Cost Effective Boreholes

The challenge for rural communities around the world is how to make the most of this fantastic water resource beneath their feet. Nothing seems simpler than a hole in the ground, but there are

Table 2: Nine Principles of Cost Effective Boreholes (RWSN 2010b)

Principle 1:	**Professional Drilling Enterprises and Consultants** - Construction of drilled water wells and supervision is undertaken by professional and competent organisations which adhere to national standards and are regulated by the public sector.
Principle 2:	**Siting** - Appropriate siting practices are utilised.
Principle 3:	**Construction Method** - The construction method chosen for the borehole is the most economical, considering the design and available techniques in-country. Drilling technology needs to match the borehole design.
Principle 4:	**Procurement** - Procurement procedures ensure that contracts are awarded to experienced and qualified consultants and drilling contractors.
Principle 5:	**Design and Construction** - The borehole design is cost-effective, designed to last for a lifespan of 20 to 50 years, and based on the minimum specification to provide a borehole which is fit for its intended purpose.
Principle 6:	**Contract Management, Supervision and Payment** - Adequate arrangements are in place to ensure proper contract management, supervision and timely payment of the drilling contractor.
Principle 7:	**Data and Information** - High quality hydrogeological and borehole construction data for each well is collected in a standard format and submitted to the relevant Government authority.
Principle 8:	**Database and Record Keeping** - Storage of hydrogeological data is undertaken by a central Government institution with records updated and information made freely available and used in preparing subsequent drilling specifications.
Principle 9:	**Monitoring** - Regular visits to completed boreholes are made to monitor their functionality in the medium as well as long term with the findings published.

many challenges and risks and cheapest is not always best. This is why RWSN has championed 'Cost Effective Boreholes' and hand dug wells for self supply. A good borehole should last at 20-50 years so it is important to invest in the right drilling methods to maximise this lifespan. That said, a challenge, particularly in Sub-Saharan Africa is that drilling is expensive. For example, in Mali, a borehole in the south can cost as much as US$12,000, and in the north of the country (where the groundwater is deep) it can cost 2-3 times as much with a higher chance of not finding water (Sutton, 2010).

An approach that was tried in the past was for a donor to give a government a fleet of drilling rigs with which to go out and drill hundreds, if not thousands, of boreholes for rural communities. In reality, much less was achieved because many governments lack the management skills and resources to keep an intensive borehole programme going. In addition, heavy truck-based drilling is often over-specified for the job of providing small diameter boreholes for rural handpumps. There is also a tendency for clients to focus their tender documents on the detailed specification of the drilling rig, rather than focus on what is important, which is the end product – a borehole with water in it, that is correctly sized for the pump (Ball, 2004).

There are nine principles in the Code of Practice for Cost Effective Boreholes, which allow the drilling operator, and their clients, to take a logical, stepwise approach through the process of commissioning, drilling and evaluating a borehole project. Table 2**Error! Reference source not found.** sets out the nine principles. It is essential to take full consideration of the immediate and wider context in which they are applied. Work done by RWSN and others has shown that principles do work in a variety of contexts. For example, in Mozambique, UNICEF found that by applying the Code of Practice they were able to reduce the cost of new boreholes by 31%, from US$13,032 in 2008 to US$8,981 in 2009 (Gesti Canuto 2011).

7.3 Professionalising the water well drilling sector

In this publication, we refer to professionalization as raising competence. The emphasis on professionalising in the water well drilling sector has been focused on Sub Saharan Africa because that is where there are the most serious physical and institutional challenges. However there are doubtless lessons to be learned and shared worldwide.

The aim of professionalisation is two-fold: the primary aim is that groundwater development for rural water supply is more cost effective, with wells of high quality constructed at a reasonable price; secondly, that the drilling operators are able to build and sustain viable businesses that are sensitive to customer needs but provide a good livelihood for themselves.

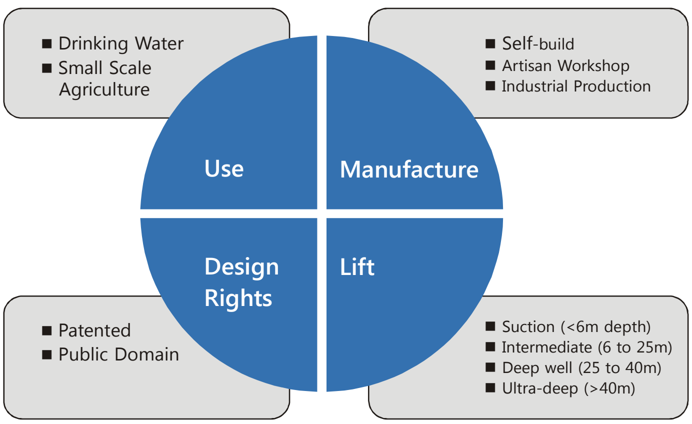
Professionalising water well drilling is not limited to the contractors themselves. Government also needs to be professional in the way it prepares, lets and supervises contracts, regulates operators and sets standards. For example, overly conservative borehole standards can push up borehole costs unnecessarily (Ball, 2004), but not having standards, or not enforcing them, can open the door to bad practices and poor boreholes that not only leave a community inadequately served but also damages the reputation of water well drilling as a solution.

The importance, and professionalism, of hand drilling is important to emphasise, because there is a tendency to see this as the poor relation of mechanised drilling. However, hand drilling is substantially cheaper for shallow boreholes in sedimentary deposits. Some drilling businesses provide both types of drilling systems to maximise their market. While hand drilling can be attractive in many areas, where the water table is deep, or within a hard deposit, such as crystalline basement rocks, a motorised rig is a better option (Adekile et al, 2009).

7.4 Hand pump technologies

For a long time the humble hand pump has been the backbone of rural water supply. There is a diverse range of pumps around the world that can be categorised in a number of ways:

Figure 6: Handpump categorisation (adapted from Baumann, 2011)



The Handpump Technology Network (which evolved into RWSN) developed the basis for national standards for many public domain handpump designs that have been adopted in many countries worldwide (Figure 7). In the coming RWSN strategy period (2012-2014), mechanisms need to be put in place to keep these standards alive and updated through a formal and transparent process.

Experience with many of these popular pumps, such as the Afridev and India MK II & III, is that although they are designed to be maintained by their user communities, in practice there has been inadequate community management or access to spare parts, and external support is needed to keep them going (Baumann, 2009 and Carter, 2009).

Quality control has also been raised as a problem, with some manufacturers not meeting international standards, in an effort to cut costs and sell at a lower price. This is damaging to the manufacturers of good quality pumps and to the end user. Further work is needed on procedures for quality control, with particular focus on India where the majority of handpumps are manufactured.

Handpump standardisation and uptake has been a great success story of the last 25 years. What is critical now is that these standards are maintained, used and adapted to meet changing demands.

Finally, the role of motorised pumps should not be ignored. The JMP figures show the rise of piped systems in many rural areas, typically small towns, and these require motorised pumps. This introduces a new dimension of complexity and a growing risk to the sustainable use of groundwater.

7.5 Water supply services

It is clear that a longer term approach to water supply is needed with an emphasis on building the capacity of local government or other local, permanent organisations to run and manage rural water supply programmes (Harvey, 2011). If they are fully involved from the outset, and have sufficient systems, skills, human and financial resources, there is no longer a need for 'exit strategies' and 'handovers' which are notoriously tricky to get right. A long term approach is needed which avoids arbitrary time-limits and deadlines that create perverse incentives for poorly targeted spending. Work is currently in progress to look how to change thinking away from projects that install a product (e.g. borehole + handpump + community water committee training) towards service delivery that places more emphasis on rural water supply organisations having a long term relationship with the water users and being sustained by workable supply chains and cost-recovery.

Because the profit margin on servicing rural water supplies is likely to be very low and regulation practically non-existent, particularly in the very poorest communities, there is a risk of failure or exploitation. An alternative may be to look for opportunities to have rural water supply services as an addition to another, complementary, business portfolio. For example, retail businesses and suppliers, particularly of hardware and agricultural goods, or where there is electrification and there is the opportunity to send out dual-skilled service technicians.

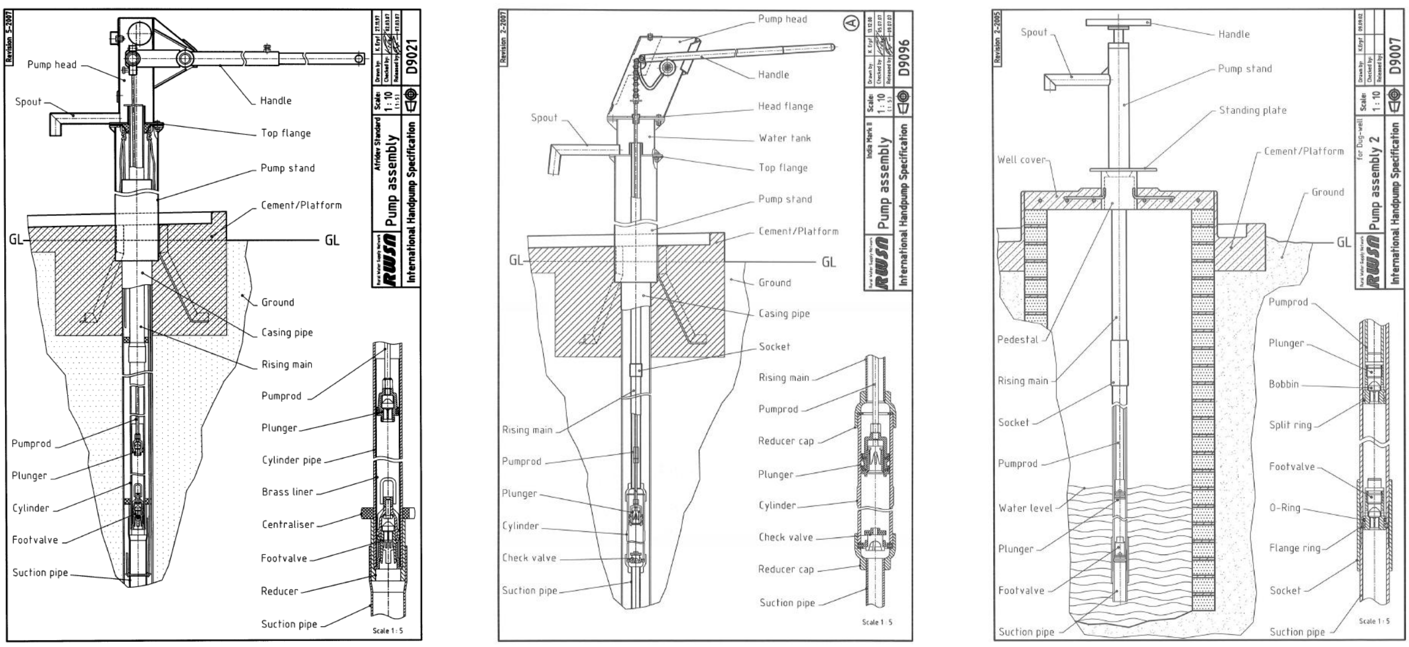
8 Conclusion – a vision for sustainable groundwater development for rural water supplies

This paper has attempted to review the current thinking on sustainable groundwater development for rural water supply. If opportunities and challenges are addressed using the approaches outlined here, what might the rural water supply network might help achieve by 2035? Here is a hypothetic scenario for a country, or region, in Sub-Saharan Africa:

"It is 2035 and 95% of the rural population of our country now has access to an improved water source and does not have to walk for more than 30 minutes to use it. While there is a mix of water sources (including rainwater harvesting and spring capture), most domestic water comes from groundwater. There is a hierarchy of source improvements, from one or two protected wells within a village to small piped networks in the small towns. There are still some hard-to-reach groups in society, particularly nomadic families who use a variety of water sources across the rangelands, which due to their marginal nature have become more vulnerable to the changing climate. These people have different attitudes to water and property rights and responsibilities from the settled population. This can bring them into conflict with settled communities, particularly during periods of drought (Krumova, 2011) and increasingly due to the growth in the settled rural population.

Figure 7: Examples of Public Domain hand pump designs with RWSN international standards

(a) Afridev (Baumann et al, 2007 **(b) India Mark II (Erpf, 2007)** **(c) Malda (Erpf, 2005)**



While some handpumps are maintained by their owners, or volunteer, within a village community, most are maintained by a local business, sometimes as an extension of a hardware retail chain, sometimes as part of a multi-utility service. This means that spare parts for handpumps are cheap and widely available and technicians can easily provide their expertise.

Increasingly, people have their own water source because it is more convenient, they feel more comfortable with having control over where their water comes from, and sometimes for other cultural reasons as well. In some villages and small towns it is common for households to have their own well or shallow borehole. However, while this has positives, it can lead to localised groundwater depletion, or contamination if boreholes are drilled too close to sanitation facilities and other unsealed drainage. Where this happens, the local tier of government has set by-laws and enforcement to protect the wider public interest. In some larger villages, the community has requested outside assistance to upgrade their water supply to a piped system to avoid some of these problems.

There are a large number of drilling businesses in country now, with healthy competition that gives government and private clients a choice. At the top end of the market there are only a few companies with large rigs. They are mainly employed for commercial boreholes for industry and large scale agriculture but they are sometimes employed for very deep or difficult boreholes for rural communities; however the high cost means that these are generally only funded by international donors. The majority of the drilling sector uses manual drilling techniques and small rigs, which can be towed or mounted on pickup trucks. Heavy rigs are used for large-scale projects or in very specific hydrogeological environments where they are the only option.

The Ministry responsible for water manages an increasingly detailed hydrometric network that provides data on groundwater levels, water quality, river flows and the ecological health our rivers, lakes, wetlands and deltas. This data base is also used to ground-truth the remote sensing information that provides spatial information on water distribution and water users.

Our country has an over-arching policy on integrated water resource management, which supports spatial planning and a water plan for each river catchment and aquifer. These water plans summarise the key features, opportunities and risks for each major water body and aquifer. The plans are produced on a regular cycle by a collaboration of local authorities that share a water resource, such as a major aquifer. The national government provides the policy framework and arbitrates where conflict between local partners occurs, but otherwise is 'hands off'. The work for water planning is largely funded through revenue from abstraction and discharge licences from large abstractors.

The state, including the legal system takes the issue of overexploitation of groundwater resources extremely seriously for the sake of national interest. However, water users are at the heart of the water planning and management process so that knowledge is shared and used, and the resulting plan has legitimacy and the principle of doing no harm to others is widely understood and applied without the need for intensive enforcement.

The two big advantages to come from these plans have been, firstly, reduced conflict between water users and with the environment, and secondly, a steady increase in public sector investment in water supplies and increasing user and other private contributions. This greater certainty in funding has led to well planned investment that has delivered lasting results.

It is 2035, and our country didn't achieve the Millennium Development Goal target for water in 2015, but we used a balance of community participation, market forces and strengthened government capacity to achieve near-universal access to water that would have been unthinkable a generation ago. This was achieved through patience and an emphasis on quality."

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Any errors remain those of the authors.

10 Glossary

Abstraction	Taking water out of the environment. Typically pumping from well, borehole, surface water feature, but also includes gravity schemes, such as hillside spring capture.
Aquifer	A layer of rock that does or is capable of containing water that can be abstracted.
Climate forcing gases	Gases in the atmosphere that in sufficient quantities can affect the earth's heat balance between incoming and outgoing radiation.
Confined/Unconfined aquifer	Presence or absence of an impermeable (or low permeability) layer of rock or sediment (such as clay) on top of an aquifer.
Crystalline basement	A geology type that is widespread in Africa. It is very old igneous and metamorphic rock and water collects in its fractures and the weathered material overlying it.
El Niño Southern Oscillation (ENSO)	A climate pattern that occurs, mainly across the Pacific Ocean, every 3-7 years. Its behaviour can cause extreme weather events in the Americas, South East Asia and Oceania, and alter other weather patterns around the world.
Groundwater	Water which occurs in the rocks (aquifers) beneath the surface of the Earth and which can surface in springs
Monsoon	Especially in the area around the Indian Ocean and S Asia: a wind that blows from the NE in winter (the dry monsoon) and from the SW in summer (the wet monsoon), which is accompanied by heavy rains.
Percolation	The downward movement of water from the ground surface, though the soil and unsaturated zone to the water table.
Permeability	The property of rock that allows water to pass through it.
Porosity	The property of a rock that allows water to be stored within it. In Primary Porosity this is the space between grains. In Secondary Porosity this is the space caused by fissures, cracks and where rock as been dissolved.
Primary forest	Forest that has not been cut or cultivated and therefore is likely to have retained its biodiversity and other natural characteristics.
Recharge	The refilling of an aquifer by water (from human or natural sources)
Rock types	***Sedimentary*** – formed from the deposition and compaction of mineral or organic particles. Examples: sandstone, limestone. ***Igneous*** – molten rock that has cooled and solidified. Examples: granite, basalt. ***Metamorphic*** – any rock type that has been subjected to temperatures and pressures that change its characteristics. Examples: marble, slate
Surface Water	Freshwater that occurs on the surface of the Earth, including streams, rivers, lakes, wetlands, ponds, canals and reservoirs.
Sustainability	The ability to perform the required function indefinitely. In the context of groundwater-based rural water supplies this means: **Environmental sustainability:** abstraction within the constraints of groundwater recharge and storage volume
Water Table	The level below which porous rocks are saturated with water.

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