Urban Groundwater in Africa: a dialogue for resilient towns and cities

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ISBN: 978-978-56367-4-4

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Suggested citation: Healy, A.; Tijani, M.; Grönwall, J.; Eichholz, M.; Villholth, K.G.; Mwango, F.; Danert, K.; Upton, K.; Lapworth, D.J.; Lalika, M.C.S, and Gicheruh, C. (2022) Urban Groundwater in Africa: a dialogue for resilient towns and cities. AMCOW Pan-African Groundwater Programme (APAGroP)

Design and layout by Cardiff University, United Kingdom
Printed in the United Kingdom

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Preface

Just half of the urban population in Africa has access to safely-managed water supplies. With urban populations forecast to double in the next 30 years securing access to sufficient quantities of water of suitable quality will be one of the greatest challenges we face. The challenge is all the greater when we take into account the added pressure of climate change and of economic growth.

Our groundwater is one means to address this challenge. Not only is it a readily accessible source of supply for many towns and cities it has the advantage of being less susceptible to climate change than many sources of surface waters. However, as an accessible source of water there are many pressures on our groundwater reserves. Alongside municipal water providers, domestic households often access groundwater directly for drinking and non-drinking purposes. Similarly, small-scale and larger commercial vendors may use it as a source from which to supply urban consumers. Other commercial actors include both small firms and large companies, who use groundwater as an input to their production processes. Groundwater can also provide an essential contribution to urban and peri-urban agriculture. Furthermore, groundwater sustains many of our rivers and dependant ecosystems.

Used wisely, our groundwater can provide a key input promoting the health and welfare of our urban populations and their surrounding environment. However, as a resource that is hidden from view there is a real risk that users may abstract too much water, or that the resource becomes contaminated. As we start to exploit our groundwater resources more fully, it is essential that all parties have a good understanding of this 'invisible' resource. Decisions are being made on a daily basis about how our groundwater is used, or on activities that affect our groundwater. These decisions are taken by many parties and may not always be to the benefit of our groundwater resources. Maintaining our groundwater requires a dialogue between parties.

This publication helps promote dialogue. It provides an accessible summary for those who are not technical experts. It highlights the potential that groundwater offers and reminds us why the management and protection of groundwater resources is essential for the long-term water security and resilience of urban areas across Africa. It is not a definitive guide though, but a starting point for discussion and conversation. It is for this reason that we call it a 'Dialogue'.

The African Ministers' Council on Water (AMCOW) is committed to the effective management of our continent's water resources and the provision of water supply services. Our remit promotes co-operation to achieve wider economic, social and environmental goals. Managing groundwater is a key contributor to urban water security. This 'Dialogue' provides a first step in that process, by identifying three golden rules and 13 policy principles. We are pleased with the support for this dialogue process already shown by many parties and welcome the opportunity this presents.

With this 'Dialogue', I invite others to contribute to a dialogue on managing our urban groundwater. We welcome responses, challenges, new ideas and examples of good practice. Together we can help secure our continent's groundwater resources to promote the resilience of our towns and cities.

Dr. Rashid MBAZZIRA,
Executive Secretary, AMCOW

Why focus on the groundwater in towns and cities?

Groundwater is becoming increasingly important for towns and cities across Africa. It contributes to economic growth, as well as provides the means to supply urban populations with the water they need for drinking, hygiene and general domestic use. Across Africa, the proportion of groundwater consumed by urban populations, especially through non-piped water supplies, has increased in the past 20 years.

Groundwater will play a critical role in helping African cities achieve the UN Sustainable Development Goals and the African Union's Agenda 2063. By some estimates, the amount of groundwater available across the continent of Africa is 100 times greater than the annual renewable freshwater resources. As such, in many places, it can provide a plentiful resource that is locally available and relatively cheap to access, although rates of abstraction are limited in many urban settings. Importantly, in times of drought, groundwater provides a critical resource to maintain water supplies in the face of diminishing surface water supplies caused by climate change, increasing competition, mounting water resources demands and considerable water quality threats.

Not only is groundwater an important asset for urban areas today, it looks set to be even more significant in the future. The rapid growth of cities, including slums and informal areas, across Africa will increase demand for available water supplies and groundwater provides a crucial source of supply, either on its own or in conjunction with other sources. Yet, the development of groundwater supplies can be poorly informed, resulting in possible under-exploitation or over-abstraction and contamination.

Groundwater is a 'hidden' resource that urban planners and politicians, as well as residents and firms, cannot afford to overlook. It requires improved governance and management. Governing groundwater reservoirs and groundwater use requires an understanding of a very complex subject. In this document we aim to introduce key themes of urban groundwater and help raise the visibility of this immensely important resource for urban Africa. It is hoped that it will contribute to a debate as to how to maximise its potential to deliver social, economic and environmental benefits.

If we are to maximise groundwater potential we should take a long-term, 'systems perspective' that acknowledges the part that groundwater plays in the wider whole, shaped by social, cultural, economic and political interactions as well as the physical setting of a place. At heart there are three golden rules for promoting the sustainable use of groundwater: know the resource and its uses/users; manage and protect the resource efficiently and inclusively, and integrate groundwater governance and protection in all relevant sector policies.

Three golden rules for groundwater sustainability (GWS)

What is ‘Groundwater’ and why is it important?

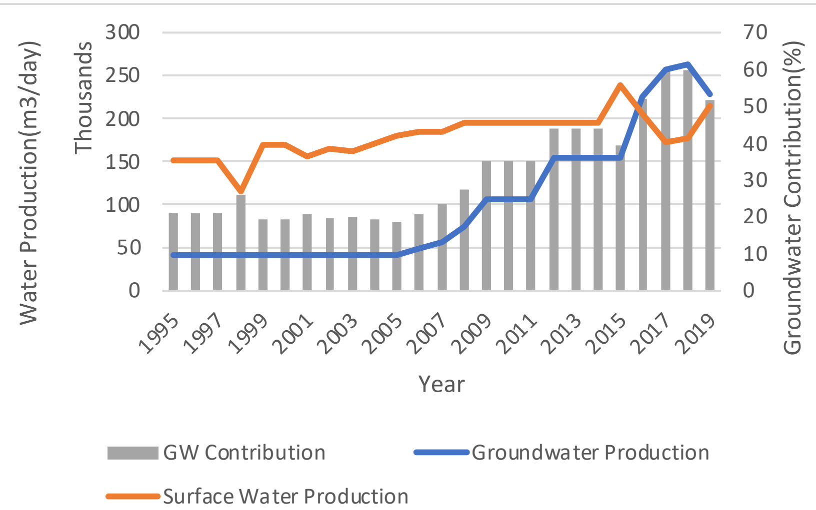
Groundwater is the water that is present in the soil and rock beneath our feet. It occurs in reservoirs referred to as ‘aquifers’. An aquifer is a saturated and permeable rock that can transmit significant quantities of water. Aquifers are important sources of water for agriculture, industry and for domestic water supplies around the world, as groundwater is used on a daily basis by municipal authorities, individual households and by businesses. For towns and cities, groundwater can provide a crucial contribution to water security and resilience.

Although the importance of groundwater for urban water in Africa is well-known, the extent to which it is used is not comprehensively reported. Similarly, estimates of the amount of groundwater available and the sustainability of the aquifers, if available, tend to be limited to the local level, or have been modelled at a large scale. This lack of information can give rise to poor management and overexploitation.

Groundwater has the advantage of being naturally protected from many sources of surface contamination and is often of a good quality. With their large storage potential, aquifers also provide a buffer in times of droughts, offering a relatively secure source of water supply. The cost of accessing groundwater tends to be relatively low, with storage more cost-efficient and localised relative to storing surface water in dams. These attributes make groundwater an attractive option for urban water supplies including for individual users. Access to groundwater is particularly attractive when piped water supplies are unavailable or unreliable. Significantly, proper access to groundwater can also help alleviate poverty and assist in delivering the goal of universal, safe and reliable access to water for all (Sustainable Development Goal 6.1).

However, some groundwater is of poor quality, containing naturally occurring contaminants from the aquifer. In urban areas, the quality of water in shallow, dug wells, springs or shallow boreholes can be affected by poor sanitation practices and waste dumping. Over-use of aquifers can also lead to falling water levels, especially where the renewal of groundwater is irregular and lower than the amount of water being abstracted. If the potential of groundwater is to be realised then it is crucial that groundwater resources are managed to maintain a sustainable supply over the long-term, especially in urban settings where abstraction rates can be high, and pollution risks are high.

The importance of groundwater for municipal water supplies in Addis Ababa (Ethiopia) has increased substantially since 2007.



With thanks to Dr. Behailu Birhanu (Addis Ababa Science Technology University)

Key groundwater concepts

Not all aquifers are the same

Aquifers come in many shapes and sizes. Sedimentary rocks, such as sandstone and limestone, and sand and gravel aquifers are amongst the most productive aquifers, providing a good source of groundwater as water flows through the pore spaces within the rocks. Hydrogeologists distinguish between sedimentary rocks that are consolidated and those that are unconsolidated. Unconsolidated aquifers are those that can be found in loose sand and gravel deposits.

Sedimentary aquifers underlie much of north Africa but are also important in certain areas of sub-Saharan Africa. Elsewhere in sub-Saharan Africa, crystalline basement rocks are the more common rock type. Here groundwater can be found in the cracks and fractures that have developed in the otherwise impervious rocks. Volcanic rocks, such as are found in Ethiopia, can also provide good groundwater stores, but can be susceptible to contamination from natural chemicals such as fluoride and arsenic.

Types of aquifer

Where an aquifer is to be found trapped between impermeable layers of rocks that stop the flow of water it is described as confined. Unconfined aquifers, which are not capped by impervious layers, tend to be closer to the surface. These often require less investment to access and may be more susceptible to changes in weather conditions than confined aquifers. Coastal aquifers are those that are located near to the sea. If seawater is mixing with the freshwater in the aquifer, it can lead to increasing levels of salt in the aquifer and make it too salty for use. Increasingly attention is also turning to offshore aquifers as potential freshwater reserves.

Four key features of aquifers

Ease of access: Some aquifers are easier to access than others. The harder the rock, or the deeper the water, the more difficult and expensive it can be to access the groundwater. Some aquifers contain ‘pockets’ of water that need advanced equipment to find. Here, the risk of drilling ‘dry wells’ is high.

Storage capacity: Some aquifers, such as the Nubian Sandstone Aquifer System in North East Africa, cover vast areas and underlie many countries. Others are smaller and more localised. Equally, some aquifers exist in just a thin band of rock whilst others are much thicker. Knowledge of the depth and thickness of an aquifer is essential for good planning but can be difficult to assess.

Water ‘flow’: How much water an aquifer can absorb and how easily the water can flow through the aquifer is determined by the size of the ‘spaces’ in the pores, cracks and fissures of the rock itself. Where groundwater flows more freely, the amount of water that can be abstracted each day from any single borehole will be higher. This is fundamental to the role of groundwater in urban settings. The ‘yield’ is the physical amount of water that can be pumped from a borehole in a given period of time.

Rate of recharge: groundwater storage in an aquifer depends on a balance between the amount of water flowing into it, from the surface or neighbouring aquifers, and the amount of water being extracted and discharging naturally e.g. via rivers. Recharge can take place over many years and so natural annual variations in groundwater levels may be expected. Some aquifers have no inflow of water and so cannot be recharged naturally; this groundwater is described as ‘fossil water’. The rate of recharge also influences the ‘sustainable yield’ of an aquifer. This refers to the level of abstraction that can be maintained indefinitely without creating unacceptable social, economic or environmental consequences.

Water Quality

A distinct benefit of groundwater is that it can often be of better quality than surface water. Percolation through rocks can remove impurities and contaminants. However, this same process can also lead groundwater to accumulate harmful but naturally occurring salts, minerals or chemicals, including arsenic, fluoride and iron, which may require special scientific tests to detect and to remove.

Groundwater is also vulnerable to human contaminants, particularly where industrial or urban waste is poorly managed and discharged directly into the surrounding environment. This is a particular risk for shallow aquifers, but deeper aquifers, and boreholes accessing deeper groundwater, can also be at risk. High levels of nitrate (generally caused by poor sanitation in urban areas and fertiliser application in rural areas) or faecal bacteria (from human and animal waste) are all signs of pollution and contamination. Pharmaceuticals, personal care products and viruses have also been found in urban groundwater in Africa. Due to slow movement of water through the ground, it can take years for pollution to be detected, and even longer to be naturally remedied.

Ideally, aquifers that are used for water supplies should be protected from contamination through the introduction of 'protection zones', which are carefully managed, although this is particularly challenging in urban settings. Understanding the direction of groundwater flow can help understand particular sources of contamination, e.g. from pit latrines and sewers, and avoid the use of potentially contaminated groundwater.

Groundwater and the environment

Humans are not the only users of groundwater. Our wider environment also depends on groundwater flows and the interconnections between aquifers, surface water bodies, and the landscape. Natural groundwater discharge, including those from spring feed directly into rivers and wetlands. This is important in maintaining flows and levels of ephemeral rivers, lakes, and water holes in the dry season. Over-abstraction of groundwater can negatively affect the wider environment, which may in turn affect towns and cities. We are also beginning to appreciate the extent to which aquifers can have their own subterranean ecosystems, which generally help keep groundwater clean and fit for human consumption and support their own unique fauna.

Reconstruction of groundwater fed municipal water infrastructure, now providing environmental and aesthetic benefits. Cape Town, South Africa.

Groundwater abstraction and use

Groundwater can be found near to the surface or at considerable depths. Where the groundwater is near to the surface, springs and shallow wells and boreholes can provide easy access. Where the groundwater is to be found at depth, boreholes are drilled to access the water. Electric pumps tend to be used to extract the water from deeper depths, while manual pumps may work for shallow groundwater. Larger boreholes can often extract more water, but the potential yield from a borehole is determined by the ease with which water flows through the aquifer. In the past, the cost of the energy required to pump water to the surface often limited the amount of water being abstracted. With the introduction of solar power, energy costs are falling, potentially opening up access to increased supplies of groundwater. However, an easier access may come with the risk that abstractions exceed the sustainable yield of the aquifer.

For municipal water supplies, a wellfield, consisting of many boreholes, will typically be established outside of the city. The groundwater is then piped into the urban area. Within an urban area, household demand can also be met by individual dug wells and boreholes supplying an overhead storage tank, a standpipe or a manual pump. In some towns and cities, business such as hotels, and households may arrange for ‘self-supply’, for instance by paying to have their own borehole drilled to secure their own water supplies, especially if municipal supplies fall short or there is intermittent supply for technical or other reasons. Wellfields should be protected to limit the potential for contamination of the groundwater. It is more difficult to protect individual boreholes, but high-quality construction, including a sanitary seal is extremely important alongside careful siting to avoid contamination from neighbouring pollution sources.

Investment in bulk groundwater supplies are financed by major international and domestic investors. The cost of drilling boreholes and supplying the necessary infrastructure to treat and supply the water can be high and tends to be the responsibility of the government or the municipal water provider, many of which are state owned in Africa. There are also costs associated with maintaining the pumping and supply infrastructures. The cost of individual shallow boreholes is much less and is often in reach of households, firms and small investors. Where the groundwater is accessed by a municipal supplier, it will tend to be treated centrally, typically by chlorination, to ensure that it is safe to drink. If the groundwater is accessed by individuals, it tends to be their responsibility to treat it, which is not always feasible or adhered to for various reasons.

Groundwater professionals play a crucial role in the quality and sustainability of groundwater supplies. It is essential that boreholes are constructed in the right place, are of the correct form and are of a high-quality. Poorly-constructed or poorly-sited boreholes enable contamination of the aquifer, and by implication the water supplied, and may also lead to low yields and the abandonment of boreholes. Good practice is for boreholes to be certified and registered as part of the implementation and following given protocols to ensure sustainable and safe water supplies.

Registration of boreholes helps when monitoring levels of groundwater abstraction and its quality, and the sustainability of aquifers. It is essential that governance authorities have knowledge of where boreholes are installed and how much water is being abstracted from the aquifers. In some cases, over-abstraction of groundwater can impact the land surface, leading to land subsidence with effects on building structures and infrastructure. Conversely, rising levels of groundwater can have a negative impact on underground infrastructures, such as underground transport, sewers and other services. Over-abstraction in coastal aquifers may also result in seawater intruding into the aquifer, resulting in groundwater tasting salty or brackish. Non-coastal aquifers can also suffer from high levels of salinity, but this tends to be from salts in the rocks themselves, or can arise due to extensive irrigation, water logging or the uncontrolled storage and discharge of waste and wastewater. Where aquifer levels are falling owing to over-abstraction, managed artificial recharge of the aquifer might be possible in some cases in order to manage the ability of the aquifer to supply water to a city.

Urban self-supply: a rising challenge for groundwater management

In many towns and cities across Africa, households and firms adopt a strategy of self-supply from local groundwater resources. This can range from the use of traditional shallow wells, to the drilling of deeper boreholes equipped with electric pumps. Remarkably, the prevalence of urban self-supply using groundwater is currently unknown in African towns and cities, but studies estimate that up to a third of households in some towns and cities may have invested in securing their own groundwater supplies. This introduces new actors involved in the exploitation and management of urban groundwater.

Alongside the benefits to individuals, the augmentation of municipal water supplies through diversified self-supply schemes assists many towns and cities to manage water shocks and water stress. In Cape Town, self-supply by households is now a formal part of the city's water strategy, whilst in Addis Ababa, commercial businesses are encouraged to invest in their own boreholes, in order to reduce demand on the municipal water supply infrastructure. Investments by individual households and firms to secure their own water supplies have proved their collective value in promoting urban water resilience, supporting economic development and fostering positive health and well-being outcomes.

However, experience also demonstrates the potential negative effects of a proliferation of wells, wellpoints and boreholes, if left unmanaged and unplanned. High levels of aggregate use can result in over-abstraction and the localised lowering of water tables. This may lead to land subsidence and environmental costs, as well as affecting the availability of groundwater for other users, particularly those with shallower boreholes/wells. Where many boreholes are located close together their operation can cause interference and there is also a risk of contamination if wells/boreholes are poorly constructed or located near to waste disposal sources. Where private boreholes are abandoned they may not be properly sealed, offering additional risks to the groundwater resource. Poor water quality can also be a concern, especially where advice, knowledge or the resources to test and treat water supplies is lacking.

Many boreholes for self-supply are manually drilled, as in this example in an urban compound.

Photo credit: A. Healy CC-BY-NC.

Critics of the urban self-supply movement also point to the loss of municipal revenue if firms or households no longer pay for municipal water supplies. This can affect the ability of municipal water suppliers to cross-subsidise water infrastructure for poorer residents and highlights the thorny question of ensuring a just distribution of access to common pool resources, such as groundwater.

A characteristic of self-supply environments is the multitude of actors involved, including the individual households and firms commissioning the boreholes or wells, through the companies drilling the boreholes, to the legislators and regulators seeking to manage the practice. One means of managing the practice is through licensing and certification. Research also stresses the importance of building awareness, understanding and dialogue amongst actors to promote positive collective actions. How to achieve this is an important theme in debates on water security and water governance. The use of urban groundwater by domestic and commercial actors to provide their own water supplies is an often over-looked aspect of urban water management, yet its significance suggests that it deserves much greater attention as an integral part of urban governance.

Know the resource and its uses

1. **Understand the physical characteristics of your local groundwater setting**

The challenge: All aquifers are different, and they are invisible to the eye. The local hydrogeology determines the amount of water that can be stored, how easy it is to access and its vulnerability to pollution. Underground geology is complex and professional advice is needed to understand the potential level of supply from groundwater, and the ability for this to be maintained over time.

> ***Why is this important?*** Understanding where your groundwater comes from underpins all other decisions on managing the groundwater resource. Without this knowledge we risk taking too much of a scarce resource or contaminating the water source. Where aquifers are easy and relatively cheap to access, demands on the resource will be much greater and may be more difficult to manage.

Groundwater settings can consist of many components

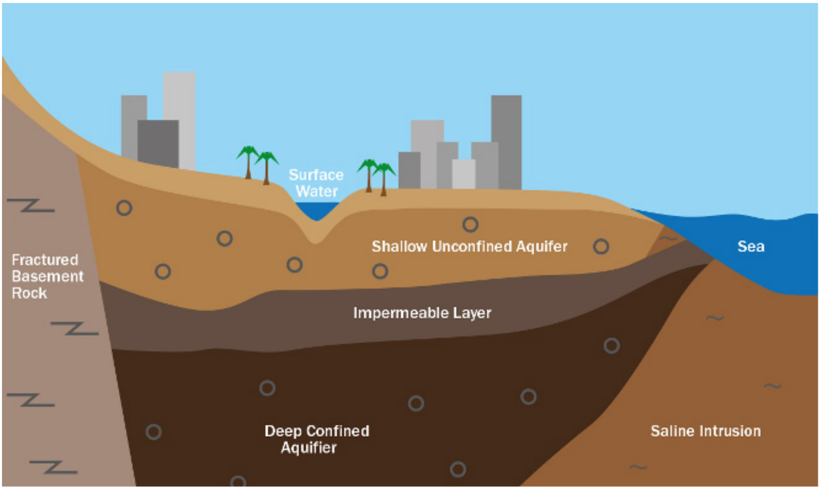


Image credit: Cardiff University CC-BY-NC

2. Understanding the water quality of your local groundwater

The Challenge: Groundwater quality may vary considerably with depth and over small spatial scales and is controlled by the local hydrogeological setting. Water quality variations for contaminants (both natural and manmade) can be costly to assess and treat, vary in time, and there may be limited options for chemical analysis locally.

Why is this important? The quality of the groundwater determines what it can be used for, the treatment that is needed for maintaining safe supply and in some cases what type of infrastructure is needed to access and distribute water. This can be a significant constraint on the availability of safe drinking water supply for example.

Knowledge of the groundwater chemistry is an essential component of securing safe water supplies.

3. **Identify who is accessing the groundwater, for what uses, and how they are doing this**

The challenge: Knowing which users (domestic, industrial, municipal and/or others) are accessing groundwater reserves and what technologies they are using is critical to our ability to manage groundwater supplies. It is also important to know what this groundwater is being used for. For example, is it being used for drinking, cleaning and hygiene purposes, or to irrigate gardens? Are users purifying the water before consumption? Some uses abstract more water but the quality of the water is less critical because it is being used for activities such as construction, whereas for other uses quality may be much more important, for example where it is used in the production of food and drinks.

Why is this important? Knowing who is using how much water and for what purposes is fundamental to our approach to advising on and regulating uses, such as through permitting schemes. It can also affect the pricing — including the need for a pro-poor policy — that can be charged for municipal piped water supplies, affecting a city's investment plans.

Groundwater is typically accessed using hand pumps or, as in this case, an electric pump. This example is a domestic borehole in Nigeria, illustrating the small footprint of an electric pump. Commercial and industrial boreholes operate at much higher capacities, as illustrated overleaf.

Photo credit: A. Healy CC-BY-NC

Municipal borehole head works for a site in the Kabwe wellfield, Zambia, situated in a dedicated compound on the outskirts of the Town

Photo credit: Dan Lapworth, BGS

4. Assess how much water is being abstracted

The challenge: Understanding how much water is being abstracted, where, and when can be challenging where there are multiple users. Levels of abstraction may also vary by season or between years depending on factors such as the wider availability of alternative water sources.

Why is this important? Knowledge of abstraction levels is crucial if we are to understand how much water is being taken from an aquifer. If more water is taken than can be replenished through the recharge of the aquifer, then the water level will fall. Not only can this increase the cost of accessing water, or cause some wells and boreholes to run dry, it can also have adverse environmental effects such as reducing groundwater flows to rivers. In some cases, over-abstraction of groundwater can lead to a permanent reduction in the storage capacity of an aquifer due to the compression of unconsolidated sediments.

Planning for the future

Like many cities across Africa, Nairobi in Kenya is experiencing rapid growth. Over the years this has led to increasing pressure on its groundwater resources. Recent research has mapped the changes in groundwater levels, highlighting areas where abstraction pressures are greatest. Areas with high abstraction levels are experiencing falls in groundwater levels. This is leading to some more-shallow boreholes drying up and the drilling of deeper boreholes. In the context of future growth projections, knowledge of where groundwater pressures are greatest can promote more sustainable urban development and prevent future failures in water supplies.

5. Assess the risks of land subsidence and seawater intrusion.

The challenge: Extracting too much groundwater carries environmental risk. As water levels fall this can lead to land subsidence at the surface, reducing surface water flows and resulting in aquifer-system deformation or, in coastal locations, incursion of saltwater into the aquifer. The local hydrogeology has an important influence on the likelihood of these risks occurring.

Why is this important? Land subsidence and saltwater intrusion can each have important economic and social impacts, as well as environmental costs. These effects can be felt many years after abstraction from an aquifer has stopped and the effects can be difficult (and costly) to reverse.

Saltwater intrusion in Dar es Salaam

Dar es Salaam, on the coast of Tanzania, is one of Africa's fastest growing urban centres. It is expected to have more than 10 million inhabitants by 2030. Piped water supply from river and deep aquifer sources reaches only around 51% of the population (2015). The remainder of the population - mostly living in informal and low-income settlements not connected to public networks - receive their water from up to 10,000 boreholes that tap the shallow aquifer under the city.

The spread of new settlements and urban infrastructure in the coastal plain reduces the infiltration of precipitation, and thus the freshwater recharge of the shallow aquifer. At the same time, abstraction from the shallow aquifer is rapidly increasing to meet the higher demand. Due to uncontrolled drilling and abstraction, intrusion of seawater occurred in the city centre close to the coast, with chloride concentrations exceeding the WHO drinking water standard of 250 mg/l. To address the problem, a systematic monitoring of groundwater quality and regulation of drilling is required to provide the basis for the conjunctive management of different water sources and the provision of affordable water services.

6. Invest in data and skills.

The challenge: Our current knowledge of the state of urban groundwater is limited, with some important exceptions. Data on the available resource is better at the continental scale, but at the local level it is sparse. There is also a recognised skills gap, with insufficient groundwater professionals in place to interpret the available data. Promoting the involvement of local residents, including women and youth, in groundwater monitoring and aquifer management is essential as we seek to meet the skills and data challenge.

Why is this important? Good groundwater management depends on having the data to understand the groundwater context, both in terms of the available resource and the demands on that resource. Acquiring good data and interpreting that data requires suitable skills and experience, but also understanding of the local context. These skills take time to develop. Developing good data and good skills requires sustained investment over long periods of time. It is also crucial that we include a variety of perspectives on the matter of groundwater management.

Students from the University of Ibadan, Nigeria developing traditional groundwater monitoring skills in Lagos, Nigeria. It is also worthwhile considering how the skills, knowledge and awareness of local residents and businesses can be mobilised and enhanced to promote good groundwater management practices.

Photo credit: A. Healy.

“In this city, it is very common to have your own borehole or well. Control of drilling is very hard as there are a lot of needs. The drillers say that water levels are dropping but people think that there is an ocean of water beneath our feet. How should we manage this, so that everybody can get the water she or he needs?”

Managing groundwater is not simple, but with a well-designed strategy cities can ensure the quantity of water remains sufficient, the quality is maintained and SDG goals can be met.

Manage and protect the resource efficiently and inclusively

7. Identify your strategy for groundwater use

The challenge: Effective management of groundwater reserves requires a strategy. How much can be taken from where and over what timescale? Is the groundwater only intended to be used for certain activities, or in certain locations? If groundwater is intended as the primary supply of water for your town or city, it will require particularly careful management.

Why is this important? Aquifers act as a store of water. It can be maintained as a strategic reserve, to be used as a buffer during times of water shortage, or it can be used as a resource for day-to-day water supplies. Some important groundwater reserves are located close to a city, others at a distance. Different management approaches will apply depending on the strategy chosen. One consideration is the extent to which the strategy promotes inclusive (and affordable) access to water for all.

Developing a comprehensive strategy for water supplies

Following the severe drought of 2018, Cape Town in South Africa has developed a new water strategy that explicitly sets out the role groundwater plays in the city's plans for future water supplies, including the role played by private boreholes and wellpoints.

8. Ensure that the amount of water remains sufficient

The challenge: Groundwater can be a sustainable resource, although the amount available may vary considerably from one location to another. It is important to monitor water levels and regulate abstractions to avoid over-abstraction and ensure that groundwater reserves can be replenished. Well-organized public institutions should care for these tasks in the interest of all users. Where natural recharge is limited, for instance due to hardened surface areas, authorities may wish to consider harvesting stormwaters and rainwater (the 'sponge city' concept) to ensure that groundwater is available when needed.

Why is this important? Climate change is exacerbating fluctuations in the volume of water available in many aquifers, and in some locations fewer but more intense rainfall events change the pattern of recharge. The integrity and health of the groundwater reservoirs must also be maintained, to avoid aquifer compaction in some places. Where users abstract too much water, this will cause water shortages to occur as the groundwater levels drop. In many parts of the world, this leads to deeper wells being constructed. Not only is this much more costly, it also risks further falls in water levels, with adverse economic, social and environmental effects, particularly on the poorest in the population. Where recharge and abstraction levels are in balance over a multi-annual period, then groundwater can be a sustainable resource for long-term urban development and contribute to equitable and universal access to water.

Managed aquifer recharge: Windhoek, Namibia

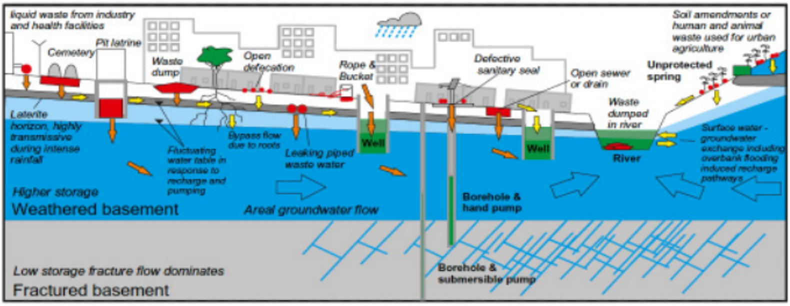
Windhoek, the capital city of Namibia, lies in a semi-arid area with limited available water supplies. Originally developed at the source of groundwater fed springs, over-abstraction of the aquifer led to the development of surface water reservoirs fed by ephemeral streams and long-distance water-transfers. Over recent decades the aquifer has been artificially recharged through the injection of water sourced from reservoirs and reclaimed water. The scheme is designed to promote water security and to provide Windhoek with a buffer in times of drought.

9. Promote awareness and management of groundwater quality

The challenge: Groundwater tends naturally to be of a good quality compared to surface water. This makes it a cost-effective source of water, as treatment can be reduced to a minimum. In some cases, naturally-occurring contaminants, such as arsenic or iron, can make groundwater unpleasant or unsafe for human consumption and other use. Urban groundwater is also susceptible to pollution from poor sanitation and poor disposal of industrial or municipal waste and wastewater. Peri-urban areas and wellfields may also be affected by encroachment and extensive agricultural use of fertilisers and pesticides. Poor groundwater quality may be very localised, affecting just one or two boreholes, or may be widespread. Poor drilling practices, borehole construction techniques and maintenance can affect the quality of the groundwater being extracted from specific boreholes, allowing the natural protection of the soil and unsaturated zone to be by-passed. Groundwater in coastal towns and cities may suffer from seawater intrusion, an issue that will be amplified by rising sea levels or more extreme storm surges due to climate change.

> ***Why is this important?*** Groundwater is a finite resource which, if it becomes contaminated, can significantly affect the health and well-being of those who use it. Reversing groundwater contamination is a costly and lengthy process that is often impractical in urban settings. Preventing the contamination of groundwater reserves at source is a more effective approach.

Multiple sources of groundwater contamination in urban settings



Source: adapted from Lapworth et al (2017)

10. Consider how promoting access to groundwater can help deliver your commitments to the Sustainable Development Goals

The challenge: Governments around the world have committed to providing universal and affordable access to a source of water that is safe, accessible and available under the UN's Sustainable Development Goals, but there is not a specific SDG covering groundwater which can obscure its importance. Groundwater offers a means to meet this commitment. Sustainable use of groundwater can also help in delivering commitments to good health and well-being, reducing inequalities and to creating more sustainable cities and communities.

Why is this important? Groundwater can provide a source of water that is relatively easy to access. This offers a real opportunity to develop an inclusive approach to promoting access to water that is often safe to drink and can be used for cooking and hygiene. Where municipal piped water supplies are unable to reach all parts of the town or city, or struggle with reliability, access to groundwater can provide the principal means of water supply. How this is delivered will determine whether the approach is inclusive, to the benefit of all, or favours some over others. The importance of access to reliable supplies of water in close proximity to the home became even more evident during the Covid-19 pandemic.

As well as helping to deliver clean water and sanitation groundwater contributes to delivering many other SDGs including: good health and well-being, gender equality, decent work and economic growth, reduced inequalities, sustainable cities and communities and life on land. How can it help deliver these goals in your town or city?

When it comes to constructing a new housing development, or to prioritize sanitation investments, how can we mobilise other sectors to protect our groundwaters?

There are many governance tools available. But the crucial first step is to recognise that managing groundwater is the responsibility of all, not just one or two government departments

Mainstream groundwater governance and protection in all relevant sectors

11. Recognise the wider environmental services/benefits of Groundwater

The challenge: Humans are not the only ones who make use of groundwater. Groundwater dependent ecosystems also rely on the availability of water from aquifers. Streamflow can be affected as groundwater levels fall, affecting biological populations. Alternatively, rising groundwater levels may lead to flooding and risk the structures of buildings. The challenge for policy makers and managers is to find the correct balance between applying a precautionary principle to the use of groundwater with the benefits of groundwater development and exploitation.

Why is this important? Development of groundwater resources can bring significant social, health and economic benefits to urban areas. Where groundwater acts as a buffer against temporary water shortages, such as droughts, it can promote the resilience of our towns and cities. Yet, policy-makers will want to also consider the wider benefits of diverse ecosystems and the role of aquifers as natural ('green') infrastructures in promoting healthy urban environments. Overlooking the benefits such ecosystem services bring, in pursuit of short-term economic gains, may prove to be short-sighted. Opportunities to create dual 'benefits' such as connecting green infrastructures, as well as waste and sanitation treatment, to managed aquifer recharge can also be considered.

Groundwater dependent eco-systems

Many natural environments rely on groundwater. If we abstract too much then levels of rivers and lakes can fall affecting the wildlife and plants that rely on these. The oases of northern Africa are some of the most famous examples of ecosystems that rely on groundwater. Across Africa there are other examples of ecosystems that depend on groundwater, many located within or near to cities. Damaging such ecosystems can have social and environmental costs.

12. Governing groundwater access and protection

The challenge: There are many ways of practically managing the exploitation of groundwater resources including policy and regulatory actions stakeholder engagement; and financing. Policy-makers must adopt those policy principles that are most appropriate to their situation and seek to influence the actions of others. Where there are many households or businesses involved in commissioning their own boreholes, the regulatory approach will be more complex than in those circumstances where there are only a few large-volume users. Similarly, where groundwater resources are shared between neighbouring areas, the governance approach will have to take this into account. Awareness-raising and advice to households on adequate treatment and water safety may be necessary. At a local level, good groundwater management requires many sectors to work together, including governing land use practices in rural areas, urban development in built up areas, the management of waste and the management of the natural environment.

Why is this important? Good governance arrangements are required to ensure that an aquifer will not be over-exploited, or contaminated. Failure to do so may lead to land subsidence, aquifer deformation and environmental costs. Declining, or contaminated ground water levels tend to disproportionately affect the poorest sections of society. Determining who has the right to access groundwater, and how much they may abstract, is as much a political process as it is economic or environmental. Maintaining the quality of groundwater also relies upon practices in many other policy fields, from urban development, waste regulation, agricultural policies, as well as those directly related to the groundwater itself, such as licensing those companies permitted to drill boreholes. In the absence of good governance, market liberalisation, technological advances and access to cheap finance can result in a free-for-all, where short-term gains are secured at the risk of long-lasting problems.

13. Appreciate that perceptions/understanding of groundwater vary

The challenge: Many of the drivers of groundwater development are the result of individual action. Where households make use of groundwater directly they may be unaware that this can be a finite resource that is susceptible to contamination. Businesses may also be unaware of the risks of over-exploitation. The fact that groundwater cannot be seen can give rise to misunderstanding and myths. Groundwater can also be seen as a 'free' resource, which makes it more susceptible to over-use.

Why is this important? Groundwater is a common resource. As our towns and cities grapple with providing enough water for all, it can be all too easy to substitute cheap groundwater for more costly municipal water supplies. Helping to raise awareness of the value of groundwater and the risks of over-exploitation can help promote the responsible use of water and so help make available water supplies go further. Education and awareness raising can also promote better groundwater quality, both through highlighting the importance of good water storage practices, and the risks of contaminating water supplies through poor waste management and poor borehole maintenance and protection. Good water and waste management results from the actions of wider society, not just technicians and engineers.

We must not use groundwater in case we damage the environment

Water levels are falling, but we can just drill deeper

Badly constructed boreholes contaminate our groundwater

There are many views of groundwater

There is a river flowing underground

A borehole provides security for my family

Adopting a 'systems' perspective to urban groundwater

Groundwater is now recognised as a crucial consideration in urban development strategies. It provides a resource to help towns and cities adapt to climate change, promotes economic and social development goals, influences the development of urban infrastructures and, fundamentally, contributes to the delivery of safe and safely-managed water supplies.

Seeing groundwater as part of a wider socio-economic and environmental system is the key to its sustainable management. Groundwater cannot be governed or managed in its own silo. It has to be seen as an interrelated, interdependent part of a broader social and ecological whole, connecting rural, coastal and (peri-) urban areas; surface and groundwater; soil, trees and landscapes; and the sea (where applicable). As such it plays a crucial role in maintaining human health and the health of our wider environment, as well as supporting the prosperity of our towns and cities.

Managing this resource sensitively for the benefit of society and the wider environment demands the attention of government across many different policy fields, at both the national and the local level. Land use management policies, transport polices, economic development strategies, agricultural policies, coastal zone management and waste management approaches are just some of the policy areas that can influence groundwater resources, as well as more traditional fields such as water supply policies and environmental planning. The role groundwater plays in promoting public health and in maintaining health and education infrastructures is also an important consideration. In the absence of an integrated management approach we risk jeopardising the very resource that our cities might otherwise rely upon for their long-term prosperity and resilience.

A core challenge for policy actors is to ensure that groundwater management lies at the heart of public finance planning and the promotion of climate change adaptation strategies. This requires raising the visibility of this 'invisible' resource. The 'systems' perspective can be challenging for governments and other authorities to implement but we cannot afford to take groundwater for granted. Groundwater professionals can provide key insights and expertise, but everyday groundwater management is a responsibility of everyone using and depending on groundwater resources. It requires inputs from a range of policy-makers as well as from households and businesses.

Managing our groundwater involves a wide range of policy spheres. Only when they work in harmony together can we be sure that our groundwater can provide a sustainable resource to the benefit of both society and the environment.

A checklist for groundwater sensitive policies

Know the resource (and its uses/users)

1. To what extent is groundwater being used for water supplies in my town or city?
2. Who is accessing this groundwater?
3. Do we know how much is used by different sectors in a year?
4. Do we know how much groundwater can safely be abstracted each year?
5. What is the groundwater quality status?

Manage the resource efficiently and sustainably

6. Do we have an agreed strategy for groundwater use?
7. Is our regulatory framework designed to safeguard groundwater supplies (by quantity and quality) and protect against wider environmental risks?
8. Do we have an appropriate monitoring arrangement to measure the health of the aquifer (quantity and quality)?
9. Do we need to consider artificial recharge of the aquifer?
10. Are we using groundwater supplies to meet agreed policy goals, such as Sustainable Development Goals and Agenda 2063?

Include groundwater governance and protection in all relevant sectors

11. Are all the relevant policy-actors engaged in managing our groundwater resource?
12. Is the public involved in discussions relating to our groundwater resource?
13. Have we included all groundwater uses and demands in our governance approach, including economic, social and environmental considerations?

In addition to national institutions, there are many resources to help those who want to understand groundwater more fully and develop the capacity to manage this.

The African Ministers Council for Water hosts a groundwater desk supported by *The AMCOW Pan-African Groundwater Programme (APAGroP)*: https://amcow-online.org/initiatives/amcow-pan-african-groundwater-program-apagrop. It also hosts the Muhktari Shehu Shagari Resource Centre (MSSRC), and a web-based open access platform (a knowledge hub of hubs): https://knowledgehub.amcow-online.org/.

The Southern Africa Development Community - Groundwater Management Institute (SADC-GMI): a regional centre of excellence for the sustainable management of groundwater. (https://sadc-gmi.org)

The African Groundwater Network: a voluntary non-profit network, open to all African countries and to external partners (http://agw-net.org)

At a local level, universities can also offer a strong knowledge resource able to provide advice and expertise on groundwater and the management of its development. International bodies, such as the International Association of Hydrogeologists and IGRAC also provide resources on specialist themes. For a valuable introduction to key concepts see: https://iah.org/education/professionals/strategic-overview-series or visit https://www.un-igrac.org

Other resources include:

- **The Africa Groundwater Atlas**: a web-based resource of data and information on groundwater across Africa.
- **The Africa Groundwater Literature Archive**: a searchable online database of literature about groundwater in Africa
- **Groundwater Solutions Initiative for Policy and Practice (GRIPP)**: a website containing open-source joint knowledge products related to groundwater management

Joining the dialogue

The material in this document draws upon a wide range of sources. We gratefully acknowledge the excellent research which lays the foundations for good groundwater policies. We have only touched the surface of such an important topic and for those who wish to engage further, a series of short thematic papers will be produced to accompany this document. These will be available at the AMCOW Knowledge Hub (https://knowledgehub.amcow-online.org/).

Developing sustainable groundwater approaches for the long-term resilience of our towns and cities is a work in progress. It is not without its challenges, and competing interests and priorities. We are convinced that it is through dialogue that we are best placed to learn from each other and to develop lasting solutions to the complex interplay of opportunities and risks facing urban groundwater development in Africa. We invite those who wish to contribute join us in this dialogue to contact AMCOW and APAGroP and so help develop a thriving community of practice.

For those who wish to read more on this subject, we include a list of publications that provide detailed, and often technical, insights into different aspects of groundwater development and management in Africa.

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ACKNOWLEDGEMENTS

We gratefully acknowledge the work of the African Ministers' Council on Waters (AMCOW)/APAGroP Urban Groundwater Action Group and other experts in compiling and editing this document. Contributions have been provided by Adrian Healy, Alusine Sesay, Behailu Birhanu, Chrysanthus Gicheruh, Dan Lapworth, Faisal Hashi, Felix Twinomucunguzi, Fred Mwango, Issoufou Ouedraogo, Jenny Grönwall, Karen G. Villholth, Kerstin Danert, Kirsty Upton, Makarius Lalika, Michael Eichholz, Micheal Ale, Moshood Tijani, Obinna Anah, Rose Alabaster, and Stéphanie Piers de Raveschoot. We thank them and the organisations for whom they work. The support of the UKRI is also acknowledged, including through the following grant: MR/S031863/1 - Water stressed cities: individual choice, access to water and pathways to resilience in sub-Saharan Africa.

To cite this document: Healy, A.; Tijani, M.; Grönwall, J.; Eichholz, M.; Villholth, K.G.; Mwango, F.; Danert, K.; Upton, K.; Lapworth, D.J.; Lalika, M.C.S, and Gicheruh, C. (2022) Urban Groundwater in Africa: a dialogue for resilient towns and cities. AMCOW Pan-African Groundwater Programme (APAGroP)

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