

# Capacity Development

World  
Water  
Assessment  
Programme

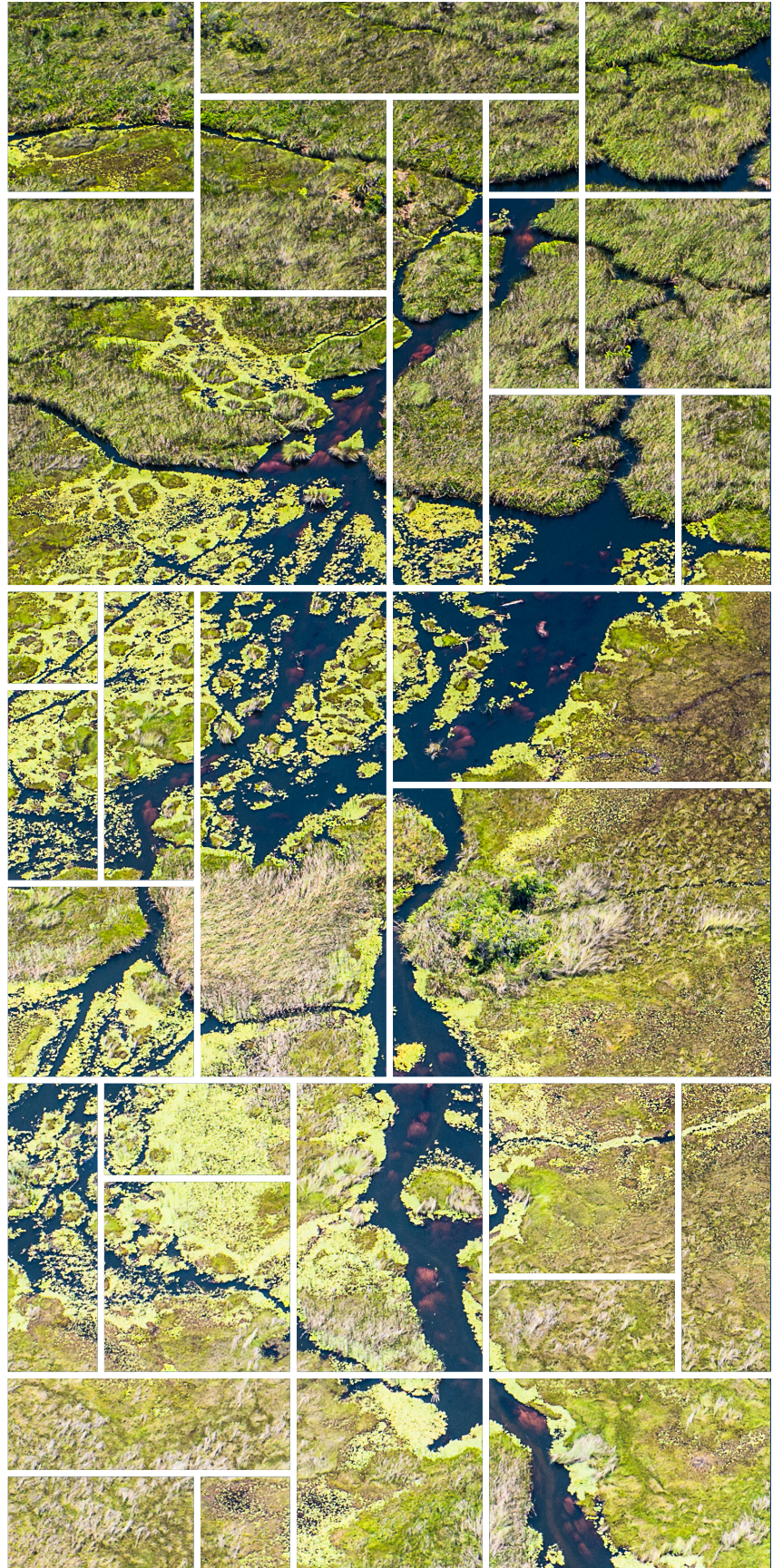


on Water and Sustainable Development



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Volume **2**  
Case studies



TRAINING WORKSHOP

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Cover photo Aerial view of the Okavango Delta  
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## FOREWORD

The first edition of the Training Workshop on Water and Sustainable Development organized by WWAP gave its participants the possibility to present their context, challenges and successful stories.

Participants from Botswana, Cabo Verde, Cote D'Ivoire, Ghana, Mozambique, Nigeria, South Sudan, Swaziland, Tanzania and Togo engaged in discussions on the central role that water plays in the development of their countries and exchanged experiences. The training explored different aspects of water and sustainable development, and took place during the year when the Sustainable Development Goals (SDGs) were approved by the United Nations General Assembly. Upon the suggestion of Professor Gerry Galloway, the stories presented during the training were collected and are currently presented in this publication, *Capacity Development Training Workshop – Volume 2 – Case Studies*.

The collection of real-life examples demonstrates the efforts that countries have made for the achievement of the Millennium Development Goals (MDGs) and aims to be a first step towards the achievement of Sustainable Development Goal (SDG) 6 on clean water and sanitation. Issues such as access to safe drinking water and adequate sanitation (SDG 6.1 and 6.2) are explored in the case studies from South Sudan, Swaziland and Mozambique, where different local solutions for water reservation are applied (e.g. hafirs, sand dams and wells). The need to recognize wastewater as a resource in tackling water scarcity (SDG 6.3) is addressed in the Botswana case study, where constructed wetlands are being used to treat and enable the use of wastewater. Two case studies presented by participants from Botswana and Nigeria address the challenges of maintaining water infrastructure and the need to improve water efficiency in agriculture (SDG 6.4), while those from Cabo Verde, Ghana and Tanzania focus on the challenge of managing water in the face of inadequate data and increase of extreme events, population and conflicts among users (SDG 6.6, 6.a).

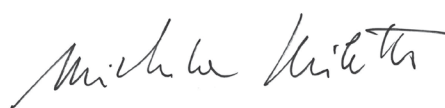
Although the case studies are country-specific, the participants during agreed the workshop that they have common issues and challenge, and it is therefore important that solutions are shared as well. Moreover, everyone had a clear understanding that the moment to take action is now.

The World Water Assessment Programme (WWAP) Secretariat is grateful to the participants who contributed to the realization of this publication by writing the case studies and sharing experiences.

WWAP is especially thankful to the Arab Gulf Program for Development (AGFUND) for providing the financial support to this project. We are confident that the case studies will be useful to other countries who face the same challenges.



**Stefan Uhlenbrook**  
WWAP Coordinator



**Michela Miletto**  
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## PREFACE

The Capacity Development of Workers in the Water Sector project is funded by the Arab Gulf Program for Development (AGFUND). This training programme focuses on 'water and sustainable development', which was addressed by the 2015 edition of the United Nations World Water Development Report. Its overall objective is to enhance the capacity of countries to deal with water issues in a complex world environment. Specifically, the training workshop aimed to provide policy-makers with tools for assessing water data, managing water resources and competing users, dealing with extreme events and with the challenge of growing urban environments, all of which are consistent with the priorities of the Agenda 2030 for Sustainable Development.

The five-day workshop was held at the WWAP premises of Villa Colombella in Perugia (Italy) from 19 to 23 October 2015, which included lectures and participative discussions. Some of the case studies produced by the participants are presented in this second volume of WWAP's Capacity Development Series.

The lectures were structured into two main parts: theoretical contents (see *Capacity Development Training Workshop on Water and Sustainable Development – Volume 1 – Coursebook*) and technical with the presentation of case studies by the training participants. The following were the topics discussed in the training modules presented by experts:

- Water and sustainable development (Angela Renata Cordeiro Ortigara)
- Information for better water management (Ricardo Martinez Lagunes)
- Competing users and uses: the water nexus (Carlo Giupponi)
- Adapting to the impacts of extreme conditions (Gerald Galloway)
- Managing water for sustainable development (Gerald Galloway)
- Planning sustainable urban water infrastructure (Franco Montalto)

The lectures were organized in a way that fostered involvement and questions from participants. During the wrap-up session, participants highlighted how they were enriched by the workshop methodology which combined lectures and case studies. The enthusiasm and meaningful engagement of both experts and participants alike reinforced the objectives of the training programme, and ensured its unqualified success.



**Angela Renata Cordeiro Ortigara**  
Programme Officer

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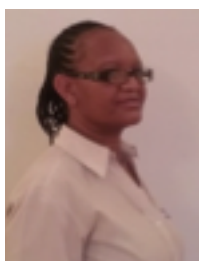
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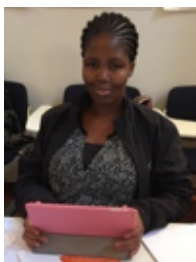
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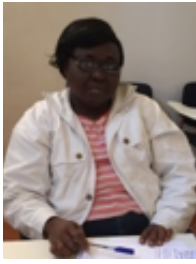
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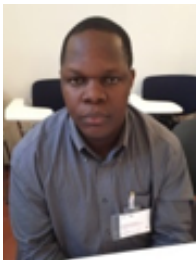
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## MAP OF AFRICA SHOWING PARTICIPANTS' COUNTRIES AND THEIR SHARED WATER RESOURCES





## SESSION 1 WATER AND SUSTAINABLE DEVELOPMENT

Overview by Angela Renata Cordeiro Ortigara

Sustainable development is a 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (UN, 1987). Embedded in this definition are two key concepts: a) the concept of needs, in particular essential needs of the world's poor, to which overriding priority should be given; and b) the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet the present and future needs' (UN, 1987).

The link between water and sustainable development was stressed by the UN Secretary General, Ban Ki-Moon: 'Water is at the core of sustainable development as it is closely linked to a number of key global challenges. We therefore reiterate the importance of integrating water into sustainable development' (UN, 2012).

The main challenges of the water sector towards the achievement of sustainable development are:

- WASH services and urbanisation: nowadays, 748 million people lack access to water; 2.5 billion people do not have access to sanitation and 65% of global population will be urban by 2050 (WHO/UNICEF, 2012).
- Food production: the current growth rates of agricultural water demand are unsustainable since food production will increase have to by 60% by 2050. It is also relevant to highlight that 75% of the world's poor are living in rural areas (WWAP, 2015).
- Energy and industry consumption: energy demand will increase by 33% by 2035 and water demand in the manufacturing industry will increase by 400% from 2000 to 2050 (OECD, 2012).
- Climate change: climatic variations affect the distribution of rainfall, the amount of snowmelt and evaporation, patterns in river flows and groundwater, and may deteriorate water quality.

In September 2015, a new set of 17 goals and 169 targets were adopted by the United Nations General Assembly and constitutes the core of the 2030 Agenda for Sustainable Development (UN, 2015). The SDGs came into effect on 1 January 2016, with the objective of guiding international development and cooperation for the next 15 years. According to the Agenda, the aspirational goals area intended to provide a reference for setting national priorities, in rich and poor countries alike.

Goal 6, namely 'Ensure availability and sustainable management of water and sanitation for all', is specifically devoted to water-related issues and encompasses a wide array of targets.<sup>1</sup>

### **Goal 6 Ensure availability and sustainable management of water and sanitation for all**

**6.1** By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

**6.2** By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

**6.3** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

<sup>1</sup> See <http://www.globalgoals.org/global-goals/clean-water-sanitation/>

- 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
- 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
- 6.6 By 2030, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- 6.7 By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
- 6.8 Support and strengthen the participation of local communities in improving water and sanitation management.

*Source: Author, based on UNGA (2015b).*

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## SESSION 2 INFORMATION FOR BETTER WATER MANAGEMENT

Overview by Ricardo Martinez Lagunes

The world usually consumes smaller quantities of resources or products that are scarce. For example, only 27 tonnes of diamonds are extracted every year, roughly 700 million tonnes of wheat are produced annually and about four billion tonnes of oil are consumed yearly. In contrast, the amount of water used yearly to supply cities in the world is around 450 billion tonnes, nearly three trillion tonnes to irrigate crops and more than 20 trillion tonnes to generate electricity.<sup>2</sup>

Water is used in very large quantities, compared to other natural resources and products. For this very reason, having water at the right place and at the right time may be as important as having it at all. Managing water requires a large infrastructure to transport it to where it is needed and to store it for when it is needed. A wide variety of data is required in order to fully understand the complex equilibrium of water supply and water demand, and the options the society has to maximize the value of its use without affecting the ecosystems that supply it or that support the complex web of life on earth.

In this context, countries need to develop robust information systems in order to better understand the multiple ramifications of the decisions that need to be made. Coordinated efforts are needed internationally, nationally, and sub-nationally in order to build these information systems. National Statistics Offices play an important role in coordinating the task at the country level. At the international level, there are several initiatives that have played an important role in developing databases for water management and policy design and evaluation, such as FAO-AQUASTAT, the surveys developed by the United Nations Statistical Division (UNSD), the United Nations Environment Programme (UNEP), as well as by the Organisation for Economic Co-operation and Development (OECD) and Eurostat. The United Nations Statistical Commission (UNSC) has also developed standards to harmonize the different data collection efforts.

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<sup>2</sup> Author's estimates based on various sources, including FAO statistics and FAO Aquastat, OECD, US Energy Information Administration, and country data.

## BOTSWANA

### Irrigation water use and implications for integrated water resources management

by Onalekutlo Kenabatho

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## 1. INTRODUCTION

### 1.1 Overview of the irrigation sector<sup>3</sup>

The irrigation potential in Botswana is estimated at about 13,000 hectares, based on land suitability and access to surface water resources. Only a small part is actually developed and used. While the exact size of land under irrigation is unknown, it is currently estimated to be between 1,500 and 3,500 hectares (cf. review of National Water Master Plan, 2006).

Based on the quarterly reports from the Ministry of Agriculture and data collected from districts through its Irrigation and Horticulture Divisions, it shows that there were 459 registered irrigation farmers with the Ministry of Agriculture (CAR/MMEWR, 2014). The two data sets provided by the same ministry differ significantly and have gaps for the period 2011–2012 and 2012–2013. Therefore, assumptions were made to estimate the hectares under irrigation and water use. Assuming that the average irrigated area for farms where the area was not known is equal to the average irrigated area by farmers with known land size, about 300 to 500 hectares are annually under irrigation in the period 2010–2012. This figure is lower than most estimates and may indicate that not all irrigation farmers are registered with the ministry. The situation is further confirmed by the fact that an estimated 2,250 farmers have acquired irrigation water rights from the Water Apportionment Board (WAB) amounting to a total of annual water abstraction rights of 142.5 Mm<sup>3</sup>.<sup>4</sup>

In terms of land use, between one third and one half of the irrigation land was irrigated: 35.6% in 2011–2012 and 53.1% in 2012–2013 (CAR/MMEWR, 2014). There is thus a potential to expand irrigation within the area serviced and equipped for irrigation. At the same time, the causes of underutilization need to be explored to develop a more productive and efficient irrigation sector for a better use of serviced land and utilization of a larger portion of the area with irrigation potential.

As mentioned earlier, the majority of the registered irrigation farmers use drip irrigation (78%), followed by sprinkler irrigation (15%), mostly near large rivers. Furrow irrigation is the least used technology, which is fortunate as it has low water-use efficiency. Apart from the technology used, other factors, such as the timing and duration of watering, influence the water-use efficiency (CAR/MMEWR, 2014).

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<sup>3</sup> Based on the Ministry of Agriculture data.

<sup>4</sup> The source of this estimation is unpublished records by the Department of Water Affairs-Water Apportionment Board (DWA-WAB).



The estimated water use by registered irrigation farmers is in the range of 2.5 Mm<sup>3</sup> to 7.5 Mm<sup>3</sup> per year, depending on the assumed of water use per hectare (World Bank, 2014). This is much lower than the estimated water use around 18 Mm<sup>3</sup> indicated by the National Water Master Plan (CAR/MMEWR, 2014). The commonly used average water use of 15,000 m<sup>3</sup> per hectare per year was used together with more water efficient figures of 10,000 (i.e. general drip irrigation) and 7,500 m<sup>3</sup> per hectare per year (carefully applied drip irrigation).

Over 68.8% of the farmers provide their own water, while 28.2% of farmers use village water supplies (mostly backyard gardens) and about 3% use government irrigation schemes because for a long time a majority of them were subsistence farmers and realised only in rainfall (CAR/MMEWR, 2014). The concept of irrigated agriculture is a relatively new concept.

Farmers that supply their own water pay the supply costs; farmers that use village water supplies have to pay regular tariffs (but often fail to pay) while farmers supplied from government schemes get free water. Lack of (effective) irrigation tariffs discourages efficient water use.

Most irrigation farmers use groundwater (60.2%), while 34% of the farmers use water from rivers and 5.8% use water provided by government (surface and treated wastewater) (CAR/MMEWR, 2014).

## **1.2 Botswana's water resources**

Botswana is located in the subtropical high pressure belt of the Southern Hemisphere in the interior of Southern Africa and away from oceanic influences, where rainfall is low, temperatures are high and water resources are scarce (Figure 1). There is therefore a high inter-annual variability of rainfall and drought is a recurring element of Botswana's climate (Government of Botswana, 2002).

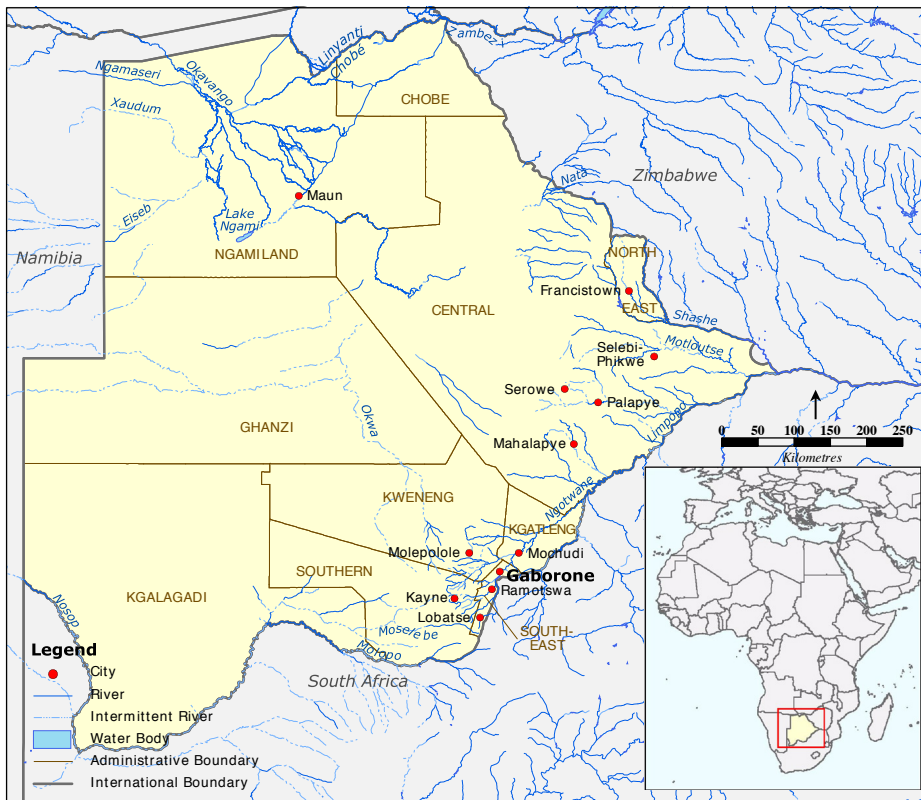
Surface water resources are limited, especially in the southern part of the country, while most of the rivers are in the north. Groundwater is therefore the major water resource and is especially important in rural areas (DEA/CAR, 2006; Lange and Hassan, 2006). There has been a rapid development over the years, which has led to the expansion of water provision services to several townships and villages, and an expansion of the end-consumers. This has exerted pressure on the available resources and as a consequence, the need to efficiently and sustainably use the available limited water resources. Water is a key resource to Botswana's development and is a basic need for human beings, ecological systems and economic growth.

Due to shortages of rainwater, the government introduced irrigated farming to improve the performance of the agricultural sector through the National Master Plan for the Arable Agriculture and Dairy Development (NAMPADD) (MoA, 2002).

## **1.3 Botswana's irrigation sector**

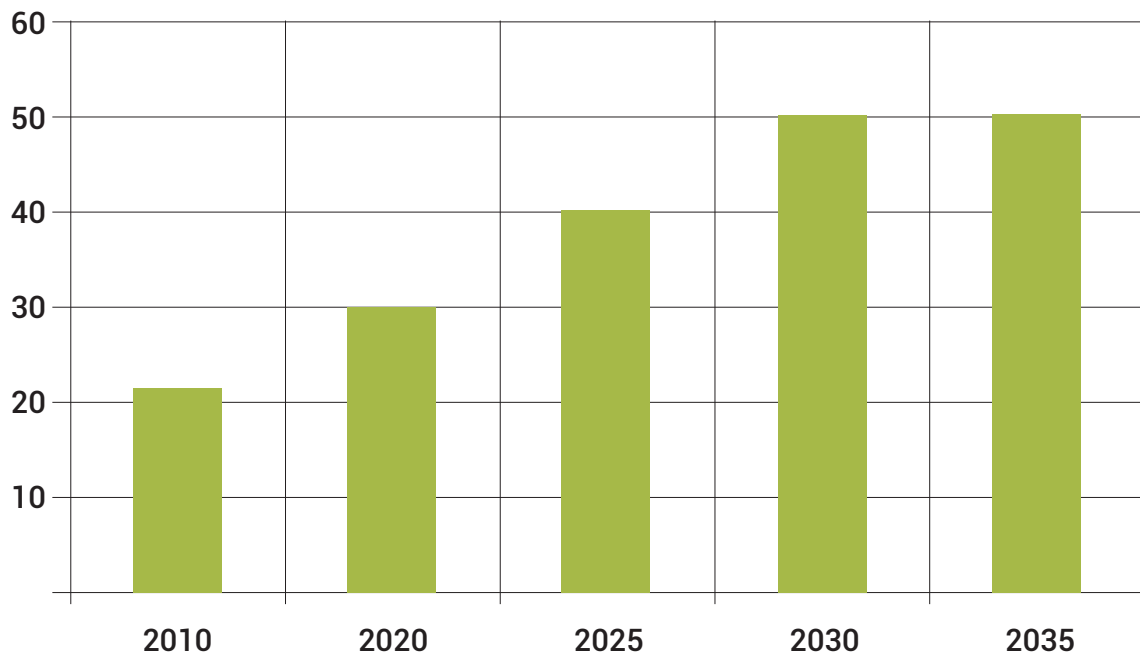
Irrigation in Botswana is predominantly used for horticulture, mostly vegetables and citrus crops for the domestic market. The exact size of land under irrigation is unknown, but it is estimated to be between 1,500 hectares and 1,800 hectares which correspond to 0.002% and 0.003% of the total area (Figure 3). The sector comprises mostly small farms as well as two government managed irrigation schemes and a few large private farms. The Ministry of Agriculture has established small holder irrigation schemes at Glenn Valley (203 hectares), using treated wastewater, and Dikabeya (60 hectares), using dam water. The sector is expected to grow significantly, if mega projects such as the Zambezi Integrated Agro-Commercial Development Project are implemented. The 2006 Review of the National Water Master Plan (NWMPR) envisages growth of water use for irrigation to around 50 Mm<sup>3</sup> (Figure 2) (CAR/MMEWR, 2014). If the Pandamatenga mega irrigation plan of over 20,000 hectares materialises (AfDB, 2008), water use for irrigation could be in the order of 300 to 400 Mm<sup>3</sup> per year.

Figure 1 – Botswana's water resources catchment areas



Source: FAO (2005, [http://www.fao.org/nr/water/aquastat/countries\\_regions/BWA/BWA-map\\_detailed.pdf](http://www.fao.org/nr/water/aquastat/countries_regions/BWA/BWA-map_detailed.pdf)).

Figure 2 – Forecasted growth of water use for irrigation (in Mm<sup>3</sup>)



Source: CAR/MMEWR (2014, Fig. 21, p. 65).

Compared to other members of the Southern African Development Community (SADC), Botswana's irrigation sector is similar in size to Lesotho and Seychelles (FAO, 2014). Like several other SADC countries, Botswana has equipped only a small portion of its irrigable land and does not use all equipped land (Table 1). SADC-wide, around three-quarters of the equipped land is actually used and only 30% of the suitable irrigation land is equipped (FAO, 2014). Namibia, South Africa and Zambia irrigate a large proportion of the equipped land, while South Africa has equipped a large proportion of potential irrigable land. On the other hand, Madagascar and Mauritius have equipped over two-thirds. In Botswana, 85% of the equipped land is utilized, but only 15% of the suitable irrigation land is equipped (Table 1) (FAO, 2014).

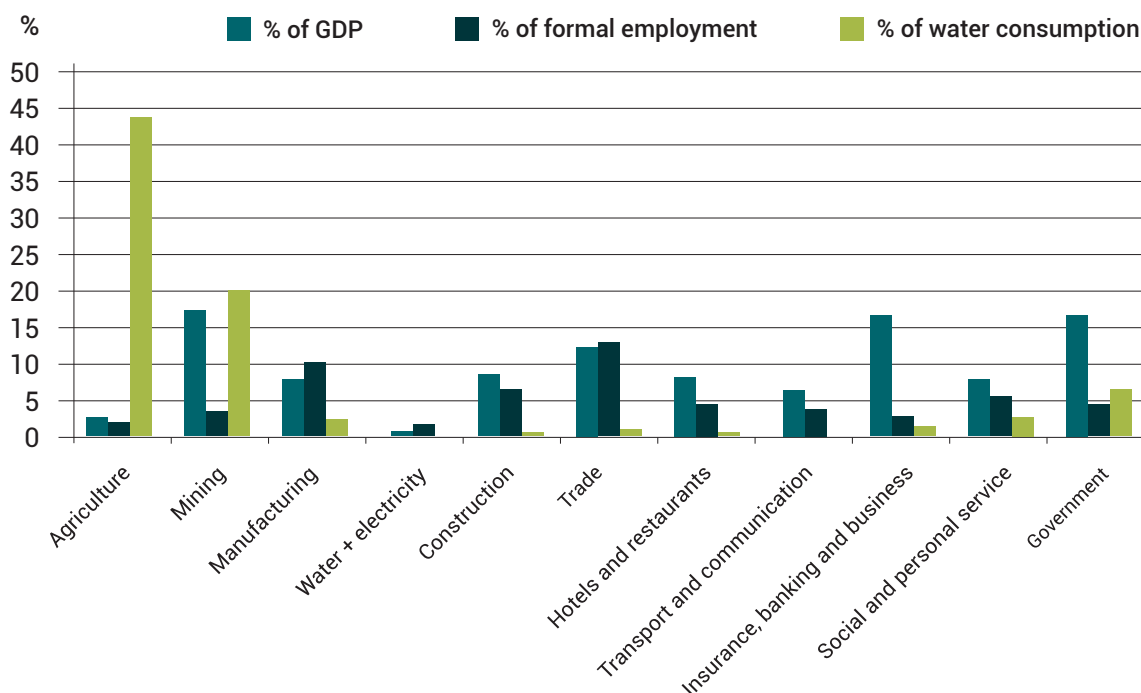
**Table 1 - Land utilization in the irrigation sector in Southern African Development Community**

Country	Irrigation			
	Potential	Total area equipped	Equipped area actually irrigated	
	Thousand ha (2012)	Thousand ha (2009)	Year (1987-2012)	% Share (1987-2012)
Angola	3 700	80	2005	13
Botswana	13	2	2002	85
Lesotho	13	3	1999	3
Madagascar	1 517	1 086	2000	51
Malawi	162	59	2002	96
Mauritius	33	22	2002	98
Mozambique	3 072	118	2001	34
Namibia	47	8	2002	100
Seychelles	1	0	2003	86
South Africa	1 500	1 498	2000	100
Swaziland	93	50	2000	90
Zambia	523	156	2002	100
Zimbabwe	366	174	1999	85

Source: Adapted from FAO (2014, Table 5, p. 24).

Although the irrigation sector in Botswana is small, it is growing but yet growing. The productivity of the sector is also very low despite irrigation being the major consumer of water in relation to other sectors of the economy (Figure 3). The sector as a whole appears to perform poorly judged by the underutilization of land available for irrigation. Water use in irrigation should be properly understood to guide critical decisions on allocations, monitoring and future expansion of the sector given the expected growth, future water demands for irrigation and the need to improve the value added by the sector (MMEWR, 2012).

Figure 3 – GDP and formal employment value added for water consumed



Source: CAR/MMEWR (2014, Fig. 4, p. 5).

## 2. PROJECT DESCRIPTION

### 2.1 Natural Capital Accounting and System of Environmental-Economic Accounting

Natural Capital Accounting (NCA) is increasingly viewed as a key tool in the pursuit of sustainable development and integrated water resources management (IWRM). NCA is a key element in the Gaborone Declaration on African Sustainability (Government of Botswana/Conservation International, 2012) signed by 10 African countries and in the Outcome Document of the United Nations Conference on Sustainable Development, The Future we Want (UNGA, 2012).

Traditional national accounts show countries' economic growth, but do not take into consideration resource depletion and degradation. Both can adversely affect the sustainability of growth and development. To correct these shortcomings, the United Nations developed the Environmental Economic Accounting Framework (UNDESA, 2012) with a SEEA-Water. This is the globally accepted template for NCA.

SEEA-Water is directly linked to the national accounts through the development of indicators such as value added per m<sup>3</sup> of water used and use of the same-sector classification. As a result, SEEA-Water provides environmental-economic indicators that can support decision-making for development planning and natural resources use and management. The SEEA-Water system captures information on water stocks (asset accounts), flows from the environment (supply accounts) and within the economy (use accounts) in physical and monetary terms.

### 2.2 Integrated water resources management (IWRM) in Botswana

Botswana has started the implementation of its 2013 IWRM Water Efficiency Plan. The overall goal of the IWRM Plan is to "improve people's livelihoods and welfare, as well as contribute to sustained economic growth, economic diversification, social justice and poverty eradication through efficient, equitable and sustainable water resources development and management" (DWA-MMEWR, 2013, p. i).



Water accounts (WA) are one of the key activities listed in the Plan, which can contribute to the plan's strategic areas,<sup>5</sup> in particular to four areas:

- i. improvement of water allocation efficiency across economic sectors, which is a major gap in current water resources management;
- ii. water supply and demand management;
- iii. integration of IWRM in development and land use planning; and
- iv. monitoring and evaluation.

Likewise, SEEA-Water becomes particularly useful when it shows trends over a longer time period.

This case study focuses on the irrigation sector in relation to two strategic areas of the 2013 IWRM Water Efficiency (IWRM-WE) Plan:<sup>6</sup> increasing the efficiency of water allocation, and water supply and demand management.

### **2.3 Increasing efficiency of water allocation**

After consideration of the basic human needs, the needs of strategic sectors and those of the environment, the allocation of water resources to most productive sectors will encourage economic growth (MMEWR, 2012). Although competition for available limited water resources among other sectors is increasing, current water abstraction allocations are done through a simple process of application for water rights with the WAB, upon which approval is granted or not. This system operates at the national level and is likely to lead to economically sub-optimal allocation of rights, and inhibit development. Therefore, increasing allocative efficiency of water resources to different sectors is a priority, and it should be done objectively to:

- Maximise the economic benefits of potable water allocations to sectors in terms of value added, employment creation and poverty alleviation;
- Ensure adequate water allocations to economic sectors that are of strategic importance to the country or contribute to sustained economic diversification; and
- Maximise the use of non-potable water for sectors that do not require fresh water resources.

### **2.4 Water supply and demand management**

The 2013 IWRM Water Efficiency Plan (DWA-MMEWR, 2013) advocates for the implementation of water demand management (WDM) strategies in order to minimize the increase in water supply costs and to prevent water shortages, which are currently affecting south-eastern Botswana. This could be achieved by enhancing the quality of treated wastewater for recycling and reuse purposes through integrated development of wastewater treatment infrastructure and reuse/recycling infrastructure. Furthermore, opportunities for WDM exist through the reduction in water losses and/or unaccounted for water. Monitoring and metering of water use remain important to effective water supply and management. For the irrigation sector, WDM would imply:

- Increased reuse and recycling of treated effluent;
- Reduced water losses and/or wastages in the sector; and
- Promotion of water-efficient irrigation technologies.

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<sup>5</sup> Efficiency of water allocation; water supply and demand management; IWRM mainstreaming in development and land use planning; establishment of an IWRM WE enabling environment; development of catchment area management approach; management of shared water resources; institutional capacity building in IWRM; stakeholder participation in IWRM; maintaining water quality and pollution control; and integration of ecological water requirements.

<sup>6</sup> According to the [Draft] National Water Policy and IWRM-WE, water allocation prioritises basic human needs and those of strategic sectors as well as the environment.

In this regard, FAO Irrigation Manual (Sava and Frenken, 2002) distinguishes three types of irrigation efficiencies, which together determine the overall efficiency of the sector:

- Conveyance efficiency (between water inlet and entry into scheme);
- Field canal efficiency (from entry point scheme to each field hydrant); and
- Field application efficiency (efficiency within the field).

For water accounts, water return flows need to be estimated in terms of return to the environment through groundwater recharge of surface water flows. In the visited schemes discussed further in this case study, no surface water runoff and ground recharge<sup>7</sup> is likely to have occurred when water use exceeded crop requirements/consumption.

### **3. METHODOLOGY**

The irrigation situation analysis conducted in the framework of the 2013 IWRM Water Efficiency Plan was countrywide, distinguishing 10 agricultural districts<sup>8</sup>, where irrigation farmers are supported by the Ministry of Agriculture. Data on water use was collected for all the registered and known farmers in each district. The analysis covered two irrigation schemes established by the government (Glenn Valley and Dikabeya), and one privately-owned scheme (Talana Farms).

The following data collection methods were used:

#### **3.1 Primary data collection**

##### **3.1.1 Irrigation data collection on the basis of a structured template**

A structured template indicating the information requirements on irrigation was designed and used for the analysis. They include: the total number of farmers in each district; the total land available for irrigation and the actual land under irrigation; the irrigation systems and technologies used; the types of crops grown; the source of water used; the water abstracted and used; and the volumes and production of water. The template was sent to the ten district agricultural offices and was self-administered because it was easy to understand. Completed templates were returned by email once completed.

##### **3.1.2 Field visits**

Visits were undertaken at the Glenn Valley and Dikabeya irrigation schemes to collect irrigation data, based on the template. The field visits were also useful because they allowed the observation of the operational activities of the systems used to irrigate and the overall management of water resources used and it created the opportunity to conduct one-on-one interviews with the farmers operating within these schemes.

#### **3.2 Secondary data collection**

##### **Review of literature and irrigation reports**

Various planning documents were reviewed to get an insight into current and future developments concerning the irrigation sector. These included amongst others: the 2006 NWMPPR, the 2013 IWRM Water Efficiency Plan, the National Master Plan for Waste Water and Sanitation (NMPWWS) and the NAMPAADD.

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<sup>7</sup> Recharge can only be estimated if the water use and water requirements are exactly known. Recharge is thus the difference between water use and water consumption.

<sup>8</sup> See DWA-MMEWR (2013, map 2, p. 36).

The quarterly horticultural reports from the District Offices received by the Irrigation and Horticulture Divisions of the Department of Crop Production of the Ministry of Agriculture Relevant information was extracted from the reports, which was used to complete the irrigation template.

The findings revealed that there are many gaps and inconsistencies between the different sources. This was attributed to the failure of regular reporting, the loss of quarterly reports and staff movements. It is also possible that the most important reason was that data are not regularly used to assess the state and performance of the irrigation sector since record-keeping has a low priority.

## **4. RESULTS AND DISCUSSION**

### **4.1 Water allocation efficiency**

Although the irrigation sector is currently small, it is expected to expand in the future given the existing plans for large-scale irrigation schemes and the need to provide sufficient food for the nation with available local resources. As such, the sector will utilize a significant amount of water (Figure 1), as is the case in other southern African countries, such as Mozambique, Namibia, South Africa and Zimbabwe (Goldblatt et al., 1999; Lange and Hassan, 2006). Thus, both water allocation and water-use efficiency in the irrigation sector are critical.

The overall water used in the irrigation sector is unknown as there is no metering and monitoring of most irrigation facilities. However, the national water accounts estimate that 18 Mm<sup>3</sup> are used, which was calculated as the average annual water use per hectare, multiplied by the total serviced irrigable land. This is probably an overestimated figure, since only around one third to one half of the land was actually used in recent years. Based on the survey and assessment of irrigation activities in the country, the results show an estimated water use of about 10 m<sup>3</sup> to 12.5 Mm<sup>3</sup> per year between 2011-2012 and 2012-2013 while another data set produced water use estimates ranging between 22 Mm<sup>3</sup> and 33 Mm<sup>3</sup>. Water use by irrigation should be linked to the value added of the sector. Unfortunately, the value added of the irrigation sector is not separately recorded in the NA.

In Botswana, although the overall highest water user in the country is the agricultural sector (43% and 44% in 2010-2011 and 2011-2012, respectively), it yields relatively minimal outputs and employment per m<sup>3</sup> of water consumed (Figure 4). This poses a water management challenge, where agriculture competes for water with other sectors. However, this is generally not the case for the livestock sector as boreholes are spread throughout the country with limited competing uses. Competing water uses exist for the irrigation sector, and need to be carefully considered. Continued neglect of allocative efficiency will carry high costs when water scarcity is increasing and the perils of climate change accelerate.

Efficiency of the irrigation sector is also affected by the irrigation technology used. There are two main irrigation systems used in the country: drip and sprinkler irrigation systems. Technically, the drip irrigation system is more efficient than the sprinkler system. The drip irrigation system also allows precise application of water-soluble fertilizers and other agricultural chemicals (AFED, 2014; Savva and Frenken, 2002). Evidently, the drip irrigation system is more common and widely used by more than three quarters of the farmers, which shows that farmers have a water-efficient infrastructure in place.

Allocation of water should take into consideration treated wastewater estimated at 27.1 Mm<sup>3</sup> (DEA/CAR, 2006). Treated wastewater is highly unutilized and generated close to population centres. It is therefore a valuable resource for irrigation and other potential users such as the

construction sector. The government-operated Glen Valley irrigation scheme utilizes treated effluent. However, this scheme is inefficient and less productive because:

- farmers do not pay for the water, so there is no incentive for water conservation;
- for all farms, there is no metering of inflow into the scheme and into individual farms; and
- land available for irrigation is not fully utilized and the irrigation system has been designed in such a way that it irrigates all the land in the scheme, regardless of whether it is cultivated or not.

There is a potential to increase productivity of the irrigation scheme if WDM is fully implemented. The government plans to invest in more irrigation schemes that utilize treated wastewater and therefore the use of treated effluent are expected to grow and increase potable water use.

### 4.3 Irrigation schemes<sup>9</sup>

Field visits were undertaken to two government operated schemes, i.e. Glenn Valley and Dikabeya irrigation schemes, to collect irrigation data based on a structured data template

#### 4.3.1 Glenn Valley irrigation scheme

The Glenn Valley irrigation scheme is operated by the government since 2006 and is located in the north-eastern part of Gaborone, close to the Gaborone Wastewater Treatment Works (GWWTW). It covers a total land area of 203 hectares, of which 124 hectares were cultivated in 2011-2012, and 135 hectares in 2012-2013. There are around 40 active farmers cultivating less than 60% of the land while the rest of the allocated land area remains unutilized. One reason for the non-development of the land is the low land rental of BWP<sup>10</sup> 3,500 per hectare and per year. The scheme produces mainly maize, tomatoes, green pepper, butternut, cabbage, flowers, green mealies, rape, lettuce, sweet potatoes, spinach and Swiss chard. There are different productivity figures for the farms (for 2011-2012: 1,642 metric tonnes and 530 metric tonnes) and therefore the productivity of the farms is uncertain. Production may be in the range of a low of 4.3 metric tonnes (high cultivated area and low production figures) to a high of 23 metric tonnes per hectare and per year (low cultivated area and high production figures).

The scheme uses treated wastewater from the GWWTW. Water rights for the entire scheme have been obtained from the WAB for a maximum of 3,000 m<sup>3</sup> per day and these are currently fully utilized and farmers use this water for free. However, there is water use inefficiency because of underutilization of the land and the free water. At full cultivation, 5,000 m<sup>3</sup> per hectare is available, unless water rights are expanded.

Plans are underway for the privatization of the scheme. Farmers would then run and pay for the water infrastructure (electricity, water and land). Their responsibilities and costs will increase, but will hopefully also offer expansion opportunities for serious farmers and enhance productive land and water use.

#### 4.3.2 Dikabeya irrigation scheme

The Dikabeya irrigation scheme, also operated by the government, started in 2005 and is located in the small village of Dikabeya in central Botswana. The scheme uses water from the Dikabeya Dam, which was constructed initially for the purpose of livestock watering. The dam's design capacity is 1.85 m<sup>3</sup>. The scheme covers a total area of 60 hectares with only an average of 4.1 hectares being cultivated. A variety of vegetables are produced including mealies, legumes, root crops and leafy vegetables such as lettuce and rape. Depending on the cultivated area and production figures used, productivity varies from 0.2 to 21 metric tonne per hectare. In 2011-

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<sup>9</sup> See World Bank (2014).

<sup>10</sup> Botswana Pula – currency of Botswana



2012, production stood at 9.2 tonnes (while another figure provides 26 tonnes. The following year, a total production of 204 tonnes was attained. Productivity is generally low but increasing, mostly due to the impact of one of the farmers. For example, in 2011-2012, it was reported that one farmer produced 120 metric tonnes of tomatoes from four hectares in a week, employing 40 workers a day to harvest the produce.

The irrigation scheme does not appear to have a water abstraction right from the WAB and it is not measured. Abstraction is estimated to be 1,069 m<sup>3</sup> per day based on nine hours of pumping per day, or 390,258 m<sup>3</sup> per year. This implies a high water use of 18,600 m<sup>3</sup> per hectare for 21 ha of irrigation. The current abstraction should be sufficient for the entire scheme (8,130 m<sup>3</sup> per hectare for 48 ha). The farmers are not charged for water but they pay for electricity to pump water from the sumps, while the electricity bill for the pump house is paid by the ministry. Each farmer pays an annual land rental of BWP 2,500 per hectare. The farmers use drip irrigation and are responsible for the on-farm drip pipeline network.

## 5. OVERALL SECTOR ASSESSMENT AND RECOMMENDATIONS

The irrigation sector is anticipated to grow in the future, both in terms of land allocated and volumes of water required. Its growth is expected to put more pressure on and increase competition for the limited water resources. Therefore, there is a greater need to improve the allocative efficiency of water to various competing sectors on the basis of the value added by each sector. Other strategic objectives, such as food security and poverty reduction, will also need to be considered. In addition, irrigation will have to account for water and prove its benefits as compared to other competing economic sectors.

The analysis showed that, at present, the irrigation cannot prove its benefits as data are fragmented and incomplete. There is considerable scope for improvements in the sector and lessons need to be learned for new irrigation projects.

Serviced irrigation land is underutilized and it should be a policy priority to fully utilize the equipped irrigation land. For example, unused land could be reallocated to productive farmers and land rentals should be increased to discourage land idling.

While most farmers use the water efficient drip irrigation technology, there is scope for improved water-use efficiency, such as improved design of irrigation schemes with water metering and the option to not supply water to unused irrigation farms. Sometimes, privatisation of government-led irrigation schemes will lead to a better appreciation of the costs of irrigation and the need to conserve water. In irrigation farms, metering should be introduced to monitor the amounts of water abstracted and used for irrigation. This would allow for more accurate water-use estimates that could be used to inform planning and decision-making for the management and development of the sector and the wider economy.

The use of treated wastewater in the irrigation sector is still low, but this is expected to improve in the future with the implementation of the 2013 National IWRM Water Efficiency plan and the provisions of the 2003 NMPWWS (SMEC and Shand, 2003). The potential use of treated wastewater will also depend on its quality (to avoid health risks) and effective wastewater treatment, quality monitoring and adherence to effluent discharge standards. Similar to the case of potable water, the use of treated effluent should be based on economic merits (e.g. value added, employment and food security). Irrigable land should be reserved in the vicinity of wastewater treatment works to encourage reuse for irrigation (where it is the preferred option).

Finally, there is a need to improve the collection and processing of specific irrigation data in order to assess and significantly improve the performance of the sector. Ideally, the irrigation sector should become a sub-sector for which data are collected in the annual agricultural statistics. Improved data would allow better irrigation water use estimates in the water accounts and improve performance assessment. This calls for greater collaboration between departments within the Ministry of Agriculture in the collection, processing and analysis of data and information on irrigation, as well as greater collaboration with the Ministry of Water Affairs, whose Water Accounting Unit is responsible for annual water accounts.

## 6. CONCLUSIONS

This case study attempted to assess the performance of the irrigation sector in terms of water efficiency and productivity and overall contribution to Botswana's economic development. The results are insufficient, because of fragmented data and lack of monitoring of the sector. Different and inconsistent data sets were provided and could not allow for a proper and informed assessment. It is therefore imperative that further work be undertaken to improve the information on the sector. A national survey of government-owned and private irrigation farms, in both the traditional and commercial sectors should be carried out. This survey should mainly assess the size of land available for irrigation and how much is actually cultivated and irrigated, as well as water abstraction for irrigation, water use, production and returns, irrigation systems used, and the expenditures associated with the farms.

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## SESSION 3

# WATER USES AND CONFLICTS THROUGH THE LENSES OF THE WATER, ENERGY AND FOOD NEXUS

Overview by Carlo Giupponi

Water covers about three-quarters of the earth's surface and is a necessary element for life. However, globally, approximately 97% of water is salt water and only 3% is freshwater, of which two thirds is frozen in glaciers and polar ice caps. The remaining third is unfrozen freshwater found mainly as groundwater and only less than 1% is surface freshwater. This means that all human activities utilizing freshwater from rivers and lakes should compete for the 0.013% of water available on the Planet, for all the possible services those ecosystems may provide us, such as provisioning irrigation, domestic water, power, transport, as well as recreation, scenic values, maintenance of fisheries and biodiversity, and ecosystem functions (Aylward et al., 2005). Therefore, it is evident that the stock of resources is limited and unbalances between needs (demand) and available resources (supply) give rise to competitions and conflicts.

Statistics show that agriculture uses 70% of water at the global level, giving politicians decision-makers the immediate perception that agriculture is the sector that needs to be reorganized. Moreover, the food supply chain utilises about 30% of the energy consumed globally (FAO, 2013) and at the same time water is required to produce and deliver any form of energy, and approximately 15% of the global water uses are dedicated to energy production (IEA, 2013). Energy and food compete for water and other resources, but they can also substitute each other in the case of energy crop and biofuels, with evident side effects on water. Bioenergy could be substantially more water intensive than energy generated with fossil fuels. Bioenergy crops compete with food production, for both land and water (with different conflicts, depending on which water is used: green or blue).

The competition for water resources creates conflicts which involve not only different sectors and economic agents, but also the environment, within the same socio-ecosystem. An efficient allocation of water resources could help avoid conflicts. The tools that humans have to manage and to solve water problems can be of different nature: engineering, nature based solutions, economic instruments, awareness raising, etc. Concerning Economic Policy Instruments (EPI), in case of scarcity, water pricing can be used to facilitate matching of water supply and demand and move towards efficient allocation of resources. Water trading (exchange of water rights) can increase economic efficiency and payments for ecosystem services (PES) with beneficiaries paying service providers to adopt an optimal management of water resources, with mutual benefit.

Economics is usually not enough, management of natural resources involve legal, environmental, technological, financial and political considerations associated often with sizable transaction costs. This combination of approaches is necessary to find efficiency, and optimal solutions should be found locally through the involvement of all stakeholders, whether environmental, economic or social. A combination of several factors (e.g. the nexus approach, proper management systems, economics implications, etc.) is helpful to solve critical challenges and conflicts. In Africa, there is a huge potential for development: the vast majority of the resources are yet to be exploited. However, a robust governance system is strongly required to reach an optimal and fair exploitation.

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## UNITED REPUBLIC OF TANZANIA

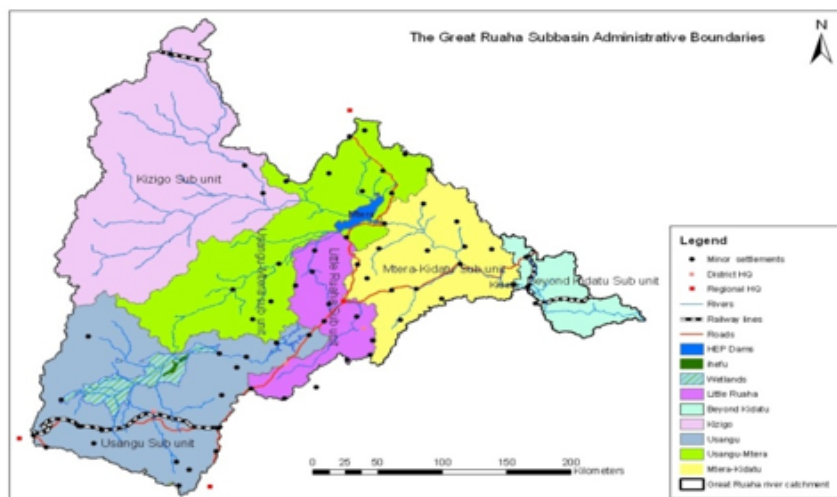
### Competing water uses and conflicts in the Great Ruaha River catchment

by David Munkhya

#### 1. CONTEXT

The National Water Policy of 2002 (MWLD, 2002) and the 2009 Water Resources Management Act (Government of the United Republic of Tanzania, 2009), stipulates that water resources in Tanzania are divided according to hydrological units, called basins, which are managed by the Directorate of Water Resources of the Ministry of Water. There are nine basins in the country and the Rufiji Basin is the largest, covering an area of 183,791 km<sup>2</sup> (about 20% of Tanzania). The Rufiji River drains into the Indian Ocean and is divided into four sub-basins, namely, Great Ruaha, Kilombero, Luwegu and Lower Rufiji (Figure 1) (MWI, n.d.).

Figure 1 - The Great Ruaha River catchment



Source: RBWB (2013).

The Great Ruaha River catchment is the upper catchment of the Rufiji Basin. It covers an area of 85,554 km<sup>2</sup> which is equivalent to 46.5% of the whole Rufiji Basin. The annual rainfall ranges from 400 mm to 1200 mm per year and the annual average flow is 3.3 billion m<sup>3</sup> per year (Table 1).

Table 1 – Sub-basin of Rujiri River Basin

Sub basin	Drainage area (km <sup>2</sup> )	% of total	Annual average rainfall (mm)	Annual average flow (billion m <sup>3</sup> per year)	% of total
Great Ruaha	85 554	46.5	400 – 1 200	3.3	14.9
Kilombero	40 330	21.9	1 000 – 2 000	13.8	62.2
Luwegu	25 288	13.8	800 – 1 000	4.0	18.0
Lower Rufiji	32 619	17.7	650 -1 000	1.1	5.0
Total	183 791	100.0		22.2	100.0

Source: RBWB (2013).

The Great Ruaha River catchment has several water users that practice intensive irrigation at the upper part of the river, where more than 45,000 ha per year are used. Downstream the irrigation area, the Ihefu wetland is not only home to different species of wildlife, but is also the natural regulator for the water flowing down through the Ruaha National Park, which is the largest national park in Africa. However, the Great Ruaha River, previously a perennial river, is drying up for about two months in a year since the 1990s, which is a disaster to the ecological sustainability of the national park, as the Great Ruaha River is its only perennial source of water.

After the national park, the Great Ruaha River flows down to the Mtera Dam, a reservoir for hydropower generation at the Mtera and Kidatu power plants, with a total capacity of 284 MW. The river flows further to the Kilombero Sugar Company which uses water for irrigation and industrial activities. After the sugar company, the river flows to the Selous Game Reserve, one of the largest game reserves in Africa and from there to the Indian Ocean through the Rufiji delta.

The scenario of heterogeneous water uses has caused the Great Ruaha River catchment to be very complex in terms of its management and has accelerated conflicts among different water users.

## **2. TYPE OF CONFLICTS IN THE CATCHMENT**

There are several water use conflicts in the basin which have arisen from the competing use of scarce water resources, especially during the dry season. According to RBWB Water Users Conflicts Register (2010–2015), Conflicts that have been reported can be categorized as follows:

- Conflicts between large scale irrigators against small scale ones. Small scale farmers have accused the large scale farmers that they are using too much water and cause water shortages. Larger scale farmers claim that poor irrigation infrastructures owned by small scale farmers cause water shortages.
- Conflicts between the national park authorities and irrigators. The National Park Authority blames the upstream irrigators, both small and large scale farmers, that they are the reason for water shortages in the national park.
- Conflicts between the Hydropower Authority and irrigators. The Hydropower Authority is blaming upstream irrigators that they are causing water shortages in reservoirs as they consume much water from the rivers.
- Conflicts between industrial companies and the Hydropower Authority. For example, the Kilombero Sugar Company, located downstream, has reported water shortages for its irrigation and industrial activities due to upstream abstractions, including those for the operation of the hydropower plant.

## **3. POSSIBLE CAUSES OF CONFLICT**

According to the Ministry of Water and Irrigation (2010) and WREM International (2015a), the main causes of conflict are:

- Water scarcity in the basin, especially during dry periods. This phenomenon has been caused by climate change and variability;
- Inadequate water user associations (WUAs) to monitor proper use of local water resources. The WUAs are grassroots institutions responsible for water resources management. The lack of financial resources for the constitution of these institutions explains why there are some areas in the catchment where WUAs have not been formed, which has affected the management process of water resources;

- Illegal water abstractions and non-compliance with conditions set out by water permits. The 2009 Water Resources Management Act restricts abstraction of water resources without 'Water Use Permits' (Government of the United Republic of Tanzania, 2009). Water abstractions carried out without these permits have jeopardized efforts made for a proper water resources management;
- Lack of village land use plans to guide the orderly use of local land and water resources. These plans are very crucial in water resources management. Unfortunately, some of the villages have not yet developed these plans;
- Water source degradation due to anthropogenic activities, including bottom valley cultivation, deforestation, uncontrolled movement of pastoralists and bush fire have been one of the major causes of water scarcity;
- Availability of inadequate data for making substantiated decisions. Data is a powerful tool in a decision-making process, especially with regard to water allocation. Due to the large area of the basin, it is difficult to have monitoring networks in all streams, which has created challenges in water allocation and water resources management; and
- Political interference in water resources management. Any water resources intervention requires political commitment, which has been a challenge for some politicians and has jeopardized the effort of ensuring sustainable water resources management.

#### **4. POTENTIAL IMPACTS**

All these conflicts reduce agricultural productivity as communities spend much of their time fighting for water resources rather than concentrating on farming. The absence of a clear understanding between farmers, who in their majority are located upstream, and the Hydropower Authority, located downstream of the catchment, results in high water abstraction upstream, leaving a minimum amount of water for hydropower generation and as a consequence electric power shortages in the country (WREM International, 2015b).

As mentioned earlier, the Great Ruaha River is now dry for about two to three months during the dry season. The situation has been a disaster for the ecological sustainability of the Ruaha National Park as it causes wildlife deaths and migration due to lack of water and grazing resources. Water scarcity and lack of alternative livelihood have been a source for encroachment of water resources through bottom valley cultivation, which has accelerated the destruction of water resources and reduced water flows in most of the rivers (WREM International, 2015b).

Water use conflict is a source of tension among people. Women and girls are more vulnerable when they are likely to compete with men for water use. Furthermore, if the catchment is water stressed, women and girls have to walk long distances searching for domestic water, which make them even more vulnerable (WREM International, 2015b).

#### **5. CHALLENGES**

The following challenges to water use and water resources management have been identified as follows (WREM International, 2015b):

- defragmented plans among the different sectors involved;
- financial restrictions faced by resources management institutions, in particular the WUAs hindering their ability to perform their duties and responsibilities;
- inconsistencies in existing hydrological data, affecting the decision-making process for water allocation; and
- climate change-related impacts, such as an increase in evapotranspiration in the catchment, which reduce the flow of most of rivers and, hence, lead to water-use related conflicts.

## 6. OPPORTUNITIES

Some of the opportunities identified that help enhance water management in the area are (MWI, 2010):

- The formation of WUAs, the community based institutions responsible for water resources management. There are 28 WUAs in the Great Ruaha River catchment which have played a crucial role in conflict resolution, water allocation and enforcement of the Water Resources Management Act, 2009.
- The development of an IWRM and Development Plan. One of the challenges facing water resources management is the fragmented plans among different sectors. The Ministry of Water is in the final stages of preparing an IWRM and Development Plan, a tool for sustainable water resources management.
- The promotion of the PES principle through the National Water Policy. This encourages the downstream water users to allocate some resources (financial) for upstream water users as an appreciation of the efforts dedicated for management and sustainable utilization of water resources.
- The promotion of the possibility of utilizing groundwater resources to augment the surface water flows especially in the agricultural sector. In water stressed areas, the declaration of a moratorium on new irrigation permits until the irrigation efficiency target is achieved has been promoted.

## 7. CONCLUSION

Generally, population growth and economic development have been one of the major reasons for increased water demand and consequently water conflicts in many areas. However, the IWRMDP for Rufiji basin which is recently developed is anticipated to be an appropriate intervention toward water-related challenges, including water use conflicts. IWRMDP is an important tool in water allocation and demand management as it provides trade-offs between different water users and sectors.

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Since the country gained independence from the Sudan on 9 July 2011, and became a Member State of the United Nations on 14 July 2011, it has been faced with enormous responsibilities of providing the required services for its people. The long and protracted civil war, which lasted over five decades, caused the destruction of property, skilled and unskilled human resources, livelihoods and the underdevelopment of the region.

In spite of the vast freshwater reserves, many rural communities suffer from severe flooding during the rainy season and drought during the dry season. During the drought, many of the cattle-keeping Nilotic communities travel long distances with their livestock in search of water and grazing areas, thus exposing them to attacks by cattle raiders. In addition, their migratory routes may fall along areas inhabited by sedentary crop farming communities. Cattle normally destroy crops along their migratory routes, leading to conflicts between the Nilotic and sedentary farming communities.

Field crop farming is not performing well in the country. Rainfed agricultural crop farming, with poor yields, and livestock productivity characterize the rural economy of South Sudan. There are many factors leading to this situation, among which are: a) lack of a water resources master plan; b) lack of an irrigated agricultural master plan; c) dependence on rainfed agriculture; d) lack of zero-grazing for animal farming; and e) militarization of rural communities (especially the Nilotic cattle-keeping communities). The fishery industry is not doing well either. It is said that the fish in this country 'die of old age' (South Sudanese myth).

The Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) decided to embark on the construction of water storage facilities, called *haffirs*<sup>12</sup> in Arabic, in most of the areas where there are conflicts due to the utilization of scarce water resources (FAO/UNEP/PBSO, 2015a). Although it is said that the level of violence within certain communities has been declining, the effectiveness of the haffirs remains questionable. Therefore, FAO and the United Nations Environment Programme (UNEP), in collaboration with the UN Peacebuilding Commission, decided to carry out an assessment in partnership with MEDIWR to establish the effectiveness of the haffirs. Section 2 describes the approach, findings and recommendations (FAO/UNEP/PBSO, 2015a).

## 2. PROJECT DESCRIPTION AND FINDINGS

The objectives of the assessment of water harvesting structures for sustainable livelihoods and peacebuilding in South Sudan were to:

- generate lessons from haffir construction in the various states of South Sudan, in order to support a long-term, cost-effective, socially acceptable and environmentally sound development of the water harvesting facilities for the provision of water for animals; so that such initiatives will effectively contribute towards peacebuilding and conflict reduction among communities, especially during the dry season; and
- develop environmental and socioeconomic assessments (ESEA) for similar interventions in the future in order to maximize impacts of such forthcoming initiatives on conflict reduction and peace building.
- The assessment was designed to come up with four strategic outputs:
- Assessment and analysis of water harvesting structures, including an inventory of water harvesting and storage facilities;

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<sup>12</sup> *Haffirs* are man-made ground reservoirs in the earth at suitable locations to store water for drinking purposes for both human and livestock uses. The concept involves water running in natural streams during the rainy season and diverted at certain suitable locations (*haffirs*).

- Guidelines for effective water harvesting project design and management;
- Effective capacity building strategy to enhance planning and implementation of water harvesting interventions; and
- Enhanced knowledge sharing on water harvesting and best practices and lessons learned.

### **3. GENDER MAINSTREAMING**

According to the FAO, water harvesting structures mainly concentrate on the technical aspects of the design and implementation of water storage. Similarly, livestock herders, or pastoralists, normally do not involve women and certain age groups in the discussion of matters pertaining to livestock welfare. Based on assessment's findings, FAO came up with guidelines where gender mainstreaming issues are addressed explicitly from the pre- and until the post-construction phases.

In the pre-construction phase, the guidelines strongly employ the concepts of gender mainstreaming in IWRM, where water harvesting interventions should be taken as one priority area of the livelihoods of the people being served. In the post-construction phase, it recommends that a gender-sensitive monitoring and evaluation system be set up to consider holistically issues such as the impact of water harvesting structures (WHS) on the time and workload of the different groups, on their operating and maintenance responsibilities, and the gender disparities in the allocation of roles and related conflict management mechanisms (FAO/UNEP/PBSO, 2015b).

### **4. CHALLENGES**

In all the areas covered by the field assessment, the biophysical environmental conditions of the existing structures, along with the various human induced dynamics, have exerted substantial influences on the levels of effectiveness and sustainability of the water harvesting structures. Field observations showed that performance of haffir projects are challenged by the environmental conditions characterized by highly variable rainfall patterns both in quantity and timing. In concrete terms, some of the adverse effects of the haffir projects on the biophysical and socioeconomic environment include (FAO/UNEP/PBSO, 2015a):

- Depletion of freshwater resources by both domestic and wildlife;
- Bacteriological, chemical and physical degradation of the stored water quality in haffirs where environmental protection is not sufficient;
- Land and ecosystem degradation, which endangers sustainability of biosphere;
- Human safety and health hazards, undesirable adverse implications of pastoralists' youths prolonged idle time affecting peace building initiatives; and
- Reduction in the service life of haffirs due to sedimentation and increased water demand as a result of overuse of haffirs.

While some of the haffirs do not meet the required standard design criteria, there is room for effective improvement of the design of future projects.

### **5. OPPORTUNITIES**

Nearly all the areas targeted for haffir construction initiatives are situated in arid to semiarid areas. The positioning of water harvesting structures gives rural communities the opportunities to improve their livelihoods. At the same time, the haffirs are located in conflict-prone areas

among predominantly pastoralist states. Therefore, it was found out that the haffirs have impacted the communities by:

- reducing conflicts;
- improving livelihoods;
- improving/increasing the attendance rate of community participation in other development initiatives, such as schools, health care centres, etc.;
- increasing food security, nutritional and health statuses among the pastoralists, as the livestock travel less in search of food and water, and milk and meat productivity; and
- spreading the use of the haffirs built in different parts of the country to not only livestock but also for use by humans, regardless of the water quality.

## 6. CONCLUSION AND RECOMMENDATIONS

According to the findings of the assessment (FAO/UNEP/PBSO, 2015a), the development of water harvesting facilities should give adequate consideration to several issues pertaining to the environment and socioeconomic aspects. In general terms, the current socioeconomic situation and subsequent developments in South Sudan show the importance of water development as a major intervention for the country's large livestock population as a means to reduce conflicts between the different communities over access to water sources during dry periods. However, without a comprehensive Water Resources Master Plan, allocation of water resources by competing users may lead to undesired socioeconomic and environmental hazards.

Regarding future water harvesting, interventions must be preceded by ESEA as a major component of the feasibility study in order to determine the likely effects (short- and long- term) on the communities. Adequate design storage capacity for water harvesting needs to be ensured through carefully estimated demand levels and water losses in addition to unforeseen variations in seasonal rainfall patterns. In addition, the selection process of a site for the implementation of water infrastructures need to take into consideration the principles of equity and optimal inter-spacing with other related facilities, bearing in mind that also their environmental and socioeconomic effects should play a vital role in the planning process for the location of the service. Moreover, the development of a Water Resources Master Plan is paramount to effective water resources management in South Sudan (FAO/UNEP/PBSO, 2015c and 2015d).

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**Recommended websites for further information:**

FAO/UNEP/PBSO (Food and Agriculture Organization of the United Nations/United Nations Environment Programme/United Nations Peacebuilding Support Office). 2015. Water Harvesting and Natural Resource Management in South Sudan: Technical Guidelines. Rome, FAO. <http://www.fao.org/resilience/resources/resources-detail/en/c/317319/>

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## SESSION 4 ADAPTING TO THE IMPACTS OF EXTREME CONDITIONS

Overview by Gerry Galloway

Water-related natural disasters such as floods, storms, droughts, cyclones and several others continue to increase, with its social and economic consequences. Risks associated with natural hazards and catastrophes are a function of hazard,<sup>13</sup> vulnerability<sup>14</sup> and consequence.<sup>15</sup> Consequences of a hazard are economic, socio-cultural and environmental, and can be mitigated by selected actions by the potentially affected parties.

While it is not possible to eliminate risks, it is conceivable to minimize vulnerability through breakwaters, levees, dams, floodwalls, evacuation, flood-proofing, codes, policies, etc., and mitigate the impact after the hazard has occurred. There are several risk reduction tools which aim at increasing resilience and reducing risk, such as zoning building codes, risk communication, evacuation plans, insurance, warning systems, education and structural measures such as shock systems shelters.

Policies and strategies, as well as risk analysis and long-term planning, are equally needed to manage risks. Although there is always a certain amount of uncertainty that the risk which will occur in the future, all of these techniques are crucial. Therefore, it is necessary to develop alternative strategies to reduce risks, and analyse each strategy against a number of potential scenarios.

For decades, the principal tools in development of flood frequency analyses have relied on the concept that the future of flooding can be predicted by looking at the past. This reliance on past trends is defined as 'stationarity'. However, the past is not a good mirror of what will occur in the future. In today's context, another risk to be taken into account is the risk of drought, which is a period of below-average precipitation. This particular risk is driven by the probabilities of occurrence of a meteorological drought, the vulnerability of the environment to arid conditions and ultimately, the consequences that result. In many countries, where drought is perceived as a normal circumstance, mitigation strategies are sometimes lacking and the responses are much less accentuated than the response to floods. It is therefore necessary to enhance awareness of climate change and disaster management by mainstreaming these issues in the public's conscience and incorporating them in all social and economic planning.

According to the 2012 report of Global Facility for Disaster Reduction and Recovery (GFDRR), only 3.6% of the US\$91.2 billion allocated for international disasters is dedicated to disaster prevention and preparedness; 24.8% are dedicated to reconstruction and rehabilitation, and 69.9% to emergency response (GFDRR, 2012). These amounts indicate that it is crucial to increase prevention and preparedness strategies to avoid the occurrence of natural disasters.

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<sup>13</sup> *Hazard* is the naturally occurring threat.

<sup>14</sup> *Vulnerability* is the susceptibility to withstand the hazard, e.g. the strength of a levee system, as well as the exposure to the hazard.

<sup>15</sup> *Consequence* refers to the outcome, usually adverse, of the combination of hazard and vulnerability.



## MOZAMBIQUE

### Feasibility study for the adaptation of low-cost desalination technologies for boreholes from Chigubo, Gaza Province

by Roda Nuvunga Luis

## 1. INTRODUCTION

The management of water resources has become an object of study, discussion and formulation of proposals to contribute to food security, socio-economic development and the improvement of quality of life. It is related to the impact of climate change on water resources and the occurrence of extreme hydrological events is one of the main challenges of the twenty-first century. In this regard, Africa is one of the most vulnerable continents to climate change, a situation that is aggravated by the interaction of multiple stressors, which occur at various levels, and low adaptive capacity (IPCC, 2012).

Thus, there arises a need to conduct studies that bring solutions in the following areas: a) hydrological extreme events, such as severe droughts, landslides, floods; and b) water contamination aggravated by salinization.

In Mozambique, drought and flood cycles cause damage on the economy, infrastructure and environment, and are directly responsible for public health problems. Most semi-arid regions, such as in some districts of the Gaza Province, particularly in the Chigubo, Chicualacuala and Massagena districts, are plagued by prolonged droughts, brought about mainly by the lack of rainfall, which is normal in the region due to its geographical location. The responsibility to perform, promote and create conditions for conducting scientific research that responds to the main challenges of the water sector rests on the National Water Research Institute (IIA)<sup>16</sup>, a public institution under the Ministry of Science and Technology, Higher, Technical and Professional Education. The IIA initiated a preliminary study, entitled designated "Feasibility Study for Desalination of Water Hole", in Chigubo district, Gaza Province, undertaken by technicians of IIA and researchers from Eduardo Mondlane University. This paper presents a brief analysis of the study.

## 2. DESCRIPTION OF THE STUDY

### 2.1 Background

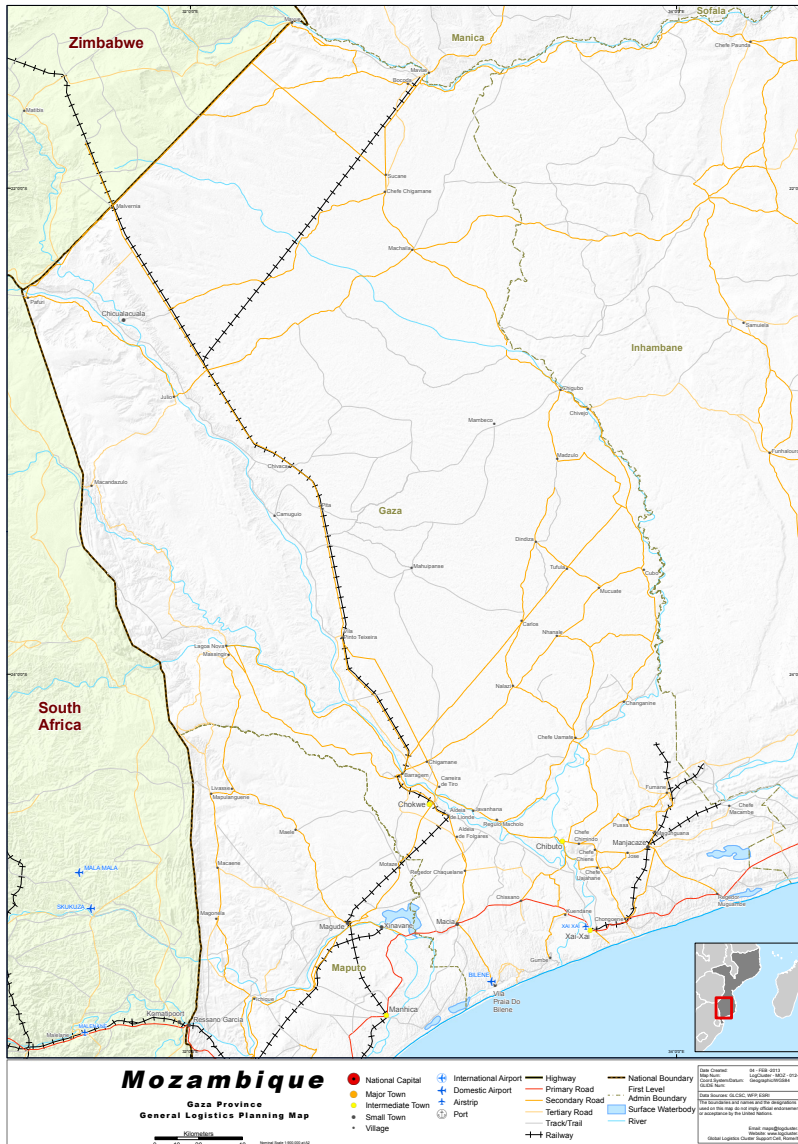
#### Geographical location and socio-economic context

The study was conducted in the Chigubo district, located in the north of the Gaza Province (southern part of Mozambique) (Figure 1). It covers a total area of 14,864 km<sup>2</sup>, with a population of 13,405, 47% of whom are below 15 years of age, and the majority of whom are women. Illiteracy rate is 82%, mostly women, and approximately 30% of farmers are children under 10 years of age (MAE, 2005).

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<sup>16</sup> The IIA is a public institution that conducts and promotes the realization of water research, consistent with the strategies of the government of Mozambique for the management of water resources.

Figure 1 – Gaza Province



Source: GLCSC-WFP (2013, <http://reliefweb.int/map/mozambique/mozambique-gaza-province-general-logistics-planning-map>)

### Climatic and topographical conditions

The climate of the district is arid with an average annual rainfall of less than 500 mm per year and a reference evapotranspiration of more than 1500 mm per year. Most of the region has an average temperature exceeding 24°C (MAE, 2005).

The soils are generally thin, with sandy areas, a characteristic of Mananga<sup>17</sup> deposits. Alluvial soils can be found along the Changane River plain, although limited due to the presence of excess salts (MAE, 2005). The salinity in the soil causes destructuring, increased bulk density and water retention, thus reducing the infiltration of water and reduced fertility (Gheyi et al., 2010).

<sup>17</sup> These materials are of ancient seabed sediments with a sandy coverage of variable thickness. The development of the B horizon massive, extremely hard which hinders the penetration of plant roots is very common.

### **Water resources and agricultural activities**

According to the report on water supply and rural sanitation in the Chigubo district, prepared by the National Water Directorate, there are 35 water committees and half of whom are women (NWD, 2012). In water collection points, mainly women and children undertake the subsequent performance of the water-related activities.

Agriculture is a risky activity in the region due to irregular rainfall and lack of skills for irrigation systems.

In terms of agriculture, the harvest is not sufficient to cover the basic needs of the population, and the additional sources of income are scarce. During periods of food scarcity, families resort to the '*food for work*'<sup>18</sup> programme collecting wild fruits, and seeking food in the neighbouring region, especially in the Chókwè district.

### **2.2 Objectives of the study**

The study aims to describe the quality of water for human consumption, which is available in some locations of the Chigubo district, in order to provide the mapping of the regions covered by the study and the results of the analysis of the water from wells and boreholes. This assessment will be useful for the implementation of water desalination and water supply systems to local communities.

### **2.3 Sampling sites**

Following the serious water scarcity crisis in the northern districts of Gaza province, and focusing on the Chigubo district, the team selected sampling sites and conducted informal interviews on-site, collected water samples and carried out physical and chemical analyses.

The water wells in the region were located, and critical areas<sup>19</sup> were selected, particularly in the localities of Ndlopfu and Nhanale and in the village of Dindiza. The collection of water samples was performed in nine water wells and four boreholes, and samples were collected only once during the study.

The physicochemical parameters (pH, conductivity, deposit, colour, turbidity, temperature) were analysed on-site using portable temperature metres, pH and conductivity, while other analyses (nitrates, ammoniac, chlorides, total hardness) were performed at the National Laboratory of Water and Food Hygiene. Analyses of samples from each location were conducted.

## **3. CHALLENGES**

The information collected on-site indicated that climate variability in the region may increase, more severe droughts may occur, and consequently, water availability will be affected. Most of the population living in the Chigubo district is going through a very difficult period of water shortage for human consumption, livestock drinking and agricultural activities, due to prolonged drought.

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<sup>18</sup> "Food for work" was introduced by the International Labour Organization (ILO) through the World Food Programme (WFP). See [http://www.ilo.org/dyn/ilossi/ssimain.viewScheme?p\\_lang=en&p\\_geoaid=508&p\\_scheme\\_id=1544](http://www.ilo.org/dyn/ilossi/ssimain.viewScheme?p_lang=en&p_geoaid=508&p_scheme_id=1544)

<sup>19</sup> Regions where the available water has high salinity levels.

The water from wells and boreholes supplying the local population is brackish, making its salinity above the normal limits and unfit for human consumption. This situation is endangering the health of the communities, food security and increases poverty levels – leading to school abandonment by young people and children, which is a great concern.

#### 4. METHODOLOGY

Following the serious water scarcity crisis (Fews Net, 2009) in the northern districts of Gaza province, especially in the Chigubo district, putting most families in a cyclical vulnerability, the IIA and the Eduardo Mondlane University (UEM), in a joint effort to mitigate the impact of the lack of water for human consumption, prepared a study for the implementation of a water desalination project and the establishment of small systems for water purification for the local communities in the affected regions.

This study consisted of visiting the affected areas. An assessment and mapping of favourable sites for the implementation of water desalination systems was done, and water samples were collected.

The methodology used in the study, including description of location, climate and topography, were based on the literature review of existing sources in Mozambique and other countries.

Quantitative methods were used for the evaluation of physical and chemical parameters in the field and in the laboratory for the analysis of water.

In addition, qualitative techniques were used to gain a better understanding of the environmental and socio-cultural issues, through interviews with key stakeholders. These methods were used to interpret the data.



Depth measurement of the wells in Maguandzuane Community

*Photo: Author/IIA.*



Feature wells in Nhanale

*Photo: Author/IIA.*

#### 5. RESULTS

The results of pertinent water quality parameters, such as ammonia, nitrites, total hardness and chlorides, are presented in Tables 1 and 2.

The pH values of water samples from wells and boreholes in the study are within the range recommended by the National Institute of Standards and Quality, and the Ministry of Health,

whose degree of restriction is in the range of 6.5 to 8.5 (MISAU, 2004). While the concentration of chloride exceeds four times the maximum permissible limit, the amounts of nitrite and nitrate are below the recommended values. Ammoniac nitrogen values exceed the permissible limit and constitute a health risk because nitrogen is a component that can be present naturally in groundwater as a result of the decomposition of organic matter in an advanced state, such as for example, animal urine.

According to the results obtained in the present study, the water quality of most of the wells and boreholes is above the permissible limit patterns. The wells and boreholes have a higher concentration of salts since the levels of chlorides and carbonates are high.

**Table 1 – Results of the analysis of water from wells on-site (Unglopfu)**

Analytical parameter	Method	Results			Permissible limit		Unit
		Well 1	Well 2	Well 3	Minimum	Maximum	
pH	Potentiometric MI B05	6,6	6,6	6,7	6,5	8,5	-
Conductivity	Conductivity MI B02	3 900	7 700	6 200	50	2 000	µS/cm
Deposit	Visual	present	present	present	-	absent	-
Colour	Visual MI B04	ruddy	Ruddy	ruddy	-	colorless	-
Turbidity	MI B12	*	*	*	-	5	NTU
Nitrites	Molecular absorption MI C06	*	0,070	0,041	-	3	mg/l NO3
Ammonia	Molecular absorption MI C06	*	1,324	1,00	-	1,5	mg/l NH4+
Chlorides	Volumétrico MI C17	744.4	2 623.3	2 375,1	-	250	mg/l Cl-
Total Hardness	Volumétrico MI C14	1 034.5	6 467.5	7 164	-	500	mg/l CaCO <sub>3</sub>
		<b>depths* (m)</b>					
		9,0	7,0	8,0			

Source: IIA (2015).

**Table 2 – Results of the analysis of water from borehole (Que-Que)**

Parameter	Method	Borehole Depth** (m)	Results***				Permissible limit		Units
			S3	S4	S5	S6	Min	Min	
Ph	Potentiometric	120	7.6	7.8	7.0	7.2	6.5	8.5	
Conductivity	Conductivity		10.4	10.0	30.7	30.3	0.05	2.0	mS/cm
Turbidity	Visual		6.5	5.0	5.0	5.0	-	5.0	NTU
Chlorides	Volumetric		3 545.0	3 551.3	14 180.0	16 484.0	-	250.0	mg/l Cl-
Total Hardness	Volumetric		1 373.1	935.3	4 776.0	4 925.2	-	500.0	mg/l CaCO <sub>3</sub>

\* These tables were elaborated in 2015 during the study.

\*\* Information on borehole depth was obtained locally from the owner.

\*\*\* From samples S3, S4, S5 and S6.

Source: IIA (2015).



## 7. CONCLUSIONS

The conduct of the study allowed the IIA to observe that the population needs to be supported for the availability of water for household activities and agriculture.

The findings reveal that low water levels in most of the locations described are due to drought. Agricultural practices and cultivation were lost. In particular, the socio-economic conditions of communities degraded. In order to survive, the local population sold firewood, charcoal, traditionally distilled liquor, craft products and other goods, and started to consuming wild foods. Most families, especially those living in the southern part, receive remittances from family members working in South Africa and other places. The poorest households started exchanging casual manual labour in exchange for food in the surrounding areas, although these sources are also likely to be limited.

The majority of the population living outside the central district does not have water supply systems (boreholes). For domestic consumption and livestock drinking, they dig wells in lowland areas where the water table is not deep (between 7 and 14 m).

It is recommended to introduce low-cost technologies for the purification of water for the local communities, such as: i) the construction of water boreholes with insulation for salty aquifers; and ii) the choice of a sustainable infrastructure and adapting it to climate change in the region. In this context, the water sector institutions should intervene and install water supply and treatment systems in key locations in order to provide the population and livestock. In these regions due to water scarcity, many cattle are dying, and local communities are taking their cattle to the wells and boreholes to have water. Due to sanitary issues, we propose the construction of community sites for livestock drinking water.

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## SWAZILAND

### The sand dams technology as a means of adapting to the impacts of extreme conditions

by Sindy Nkosisphile Mthimkhulu

#### 1. INTRODUCTION

Climate change is now a reality as evidenced by global warming, with a greater frequency and intensity of droughts as well as floods. In Swaziland, the negative impacts on the agricultural and water sectors are already felt to a large extent. The impacts of climate change on water resources are increasingly threatening water availability for domestic purposes and agricultural production, while many small rivers are drying up and others are fast becoming seasonal streams (Matondo, 2014).

Vulnerability assessments carried out over the last ten years indicate that increasing population, rising per capita domestic water use, degrading catchments and expanding agriculture are leading to water demand outstripping available water resources. Findings show that climate change is an additional factor in increasing water scarcity, and adaptations must be made to reduce water consumption (SWECO, 2005).

The main findings of the modelling report<sup>20</sup> on three major river basins in Swaziland – the Komati, Mbuluzi and Usuthu River basins – already show a deficit when considering all legitimate water use. The report further indicates that the deficits will become even more pronounced in the future as demand grows and rainfall patterns change. The modelling results also show that most of the pressure on water resources will come from an increase in water demand, which could be up to 28% by 2050, while climate change will have significant negative impacts, making an already bad situation worse. The report suggests that increased water storage in the Komati and Usuthu River basins might mitigate the effects of climate change on water supply.

The negative impacts of climate change in Swaziland are among other factors exacerbated by baseline conditions of widespread poverty (63% of the population), high unemployment (40%), a high prevalence of HIV (26% of adults), and widespread land degradation as a result of deforestation, alien plant invasions and overstocking of livestock (Government of Swaziland, 2014).

These conditions called for the exploration of alternative means of availing water. A project, entitled 'Adapting national and transboundary water resource management in Swaziland to manage the expected impacts of climate change', was initiated under the Department of Water Affairs, with financial support from UNDP and the Global Environment Facility (GEF) (UNDP, n.d.). The project has supported grassroots-level adaptation projects such as the construction of sand dams in five ephemeral streams in very arid rural areas of the country (Figure 1).

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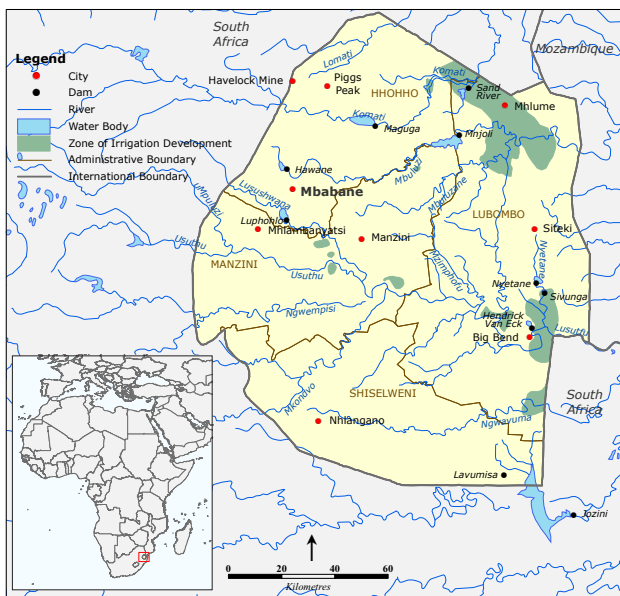
<sup>20</sup> Prepared by Optimal Solutions in 2015 under the Climate Change Adaptation Project for the water sector in Swaziland.



A mature sand dam (of Swaziland)

Photo: Department of Water Affairs (2015).

Figure 1 – Map of Swaziland, including water resources and zones of irrigation development



Source: FAO (2005, [http://www.fao.org/nr/water/aquastat/countries\\_regions/SWZ/SWZ-map\\_detailed.pdf](http://www.fao.org/nr/water/aquastat/countries_regions/SWZ/SWZ-map_detailed.pdf)).

## 2. BRIEF DESCRIPTION OF A SAND DAM TECHNOLOGY

The innovative concept of sand dams was first introduced in Swaziland by a consultancy company, Excellent Development, who was hired through the Climate Change Adaptation project. The company is a pioneer in the development of sand dam technology in arid East African countries such as Kenya.

A sand dam is a small dam built above ground and into the riverbed of a seasonal sandy river. It comprises of a concrete embankment built across an ephemeral stream. The wall harvests sand during the rainy season, where 20-40% of its total volume is water. These dams are suitable for rural areas with a semi-arid climate in order to store the only available seasonal water to be used in dry periods for livestock, minor irrigation and domestic use. They can be built with locally available material and labour. Nevertheless, their building still requires a financial investment because it is labour intensive and specific expertise is required. It is also important to involve the community in order to create a feeling of ownership, which has proven to be the key factor in the successful construction and maintenance of the dams.

The construction of a sand dam can take four weeks or more, depending on manpower availability and site feasibility. Construction is normally undertaken during winter when there is little or no stream flow, and involves marking, trenching and drilling of holes in the bedrock to insert reinforcements. Once measurements are marked, formwork is constructed using timber and filled with a mixture of mortar and rocks to make the structure solid and strong.



Construction of a sand dam (Swaziland)  
*Photo: Department of Water Affairs (2014).*

During construction, an infiltration gallery is installed to drain out the water from the sand once it has rained and filled up. The infiltration gallery is composed of pipes with slots and these pipes are covered with stones and sand, and then held firmly in place by concrete.



Putting the infiltration gallery in place (Swaziland)  
*Photo: Department of Water Affairs (2014).*

Once the dam is complete, rain will bring floods with sediments and silt. The heavier sand sediments settle at the bottom and the silt on top. At the beginning, the dam only collects water and matures with time. As it continues to rain, silt is washed over the dam wall while more and more sand sinks. The filling of the dam is determined by the amount of floods and the sand sediments they carry. This process can take two or three rainy seasons (Excellent Development, 2012).

The filtration gallery drains clean water from sand into a sump, where it is then pumped into a chamber connected with a submersible or hand pump. The well needs to be covered to prevent water contamination.



Pumping water out of a sand dam (Swaziland)  
*Photo: Department of Water Affairs (2015).*

## 2. CHALLENGES

In these arid areas, the demand for water is high for both domestic use as well as livestock drinking. Drinking troughs and laundry facilities also need to be built. It is important to note that the designs must ensure that the overflow of water is channelled away from the natural flow to prevent downstream contamination for other users (see photo below).



A sand dam with a properly built cattle trough downstream (Swaziland)  
*Photo: Department of Water Affairs (2015).*

Since the construction of sand dams is labour intensive and requires high community involvement, community engagement and education about the benefits of sand dams are required to ensure the community's participation. Education is an important factor which ensures that the water collected by sand dams is properly used for the intended purposes. Prior to maturity, sand dams collect water that becomes stagnant for long periods of time, creating breeding ponds for mosquitoes and other waterborne hazards. In this regard, raising awareness on the proper use of such water is essential.





Community involvement in sand dam construction (Swaziland).

*Photo: Department of Water Affairs (2014).*



Stagnant water at a maturing sand dam (Swaziland)

*Photo: Department of Water Affairs (2014).*

There are other methods used to draw out the water from sand dams, such as traditional scoop holes - where water is accessed by digging holes from the sand upstream of the dam wall. The first water to emerge is scooped out at first, and the water that refills the scoop hole is then abstracted. This method is, however, susceptible to pollution, especially by livestock.

### 3. OPPORTUNITIES

The sand dam technology presents a lot of opportunities in a time of extreme changes to water availability due to climate change. Some of the benefits associated with these dams are its low costs and the use of local materials (rocks and sand) that are normally collected by the community. The dams are constructed on otherwise non-flowing streams, and utilize the once-off flows and therefore extend their benefits over a longer period of time. Moreover, as the water infiltrates, sand filtration offers natural purification of the water. The sand cover also reduces water loss through evaporation and keeps the water where it is needed, reducing the time required to collect the water. Storing the water under the sand also raises the groundwater table around; and the positive impacts of the sand dams increase as they mature. Sand dams also help in the reclamation of eroded land.

According to the Swaziland Poverty Reduction Strategy and Action Plan (Government of Swaziland, 2007), access to water remains a basic necessity for all Swazi people and water has been identified as key for domestic consumption and a driver for sustaining agricultural production. Water has been used for downstream development projects, which have complimented the country's efforts toward food security, while diversifying income revenue streams mainly for rural communities.

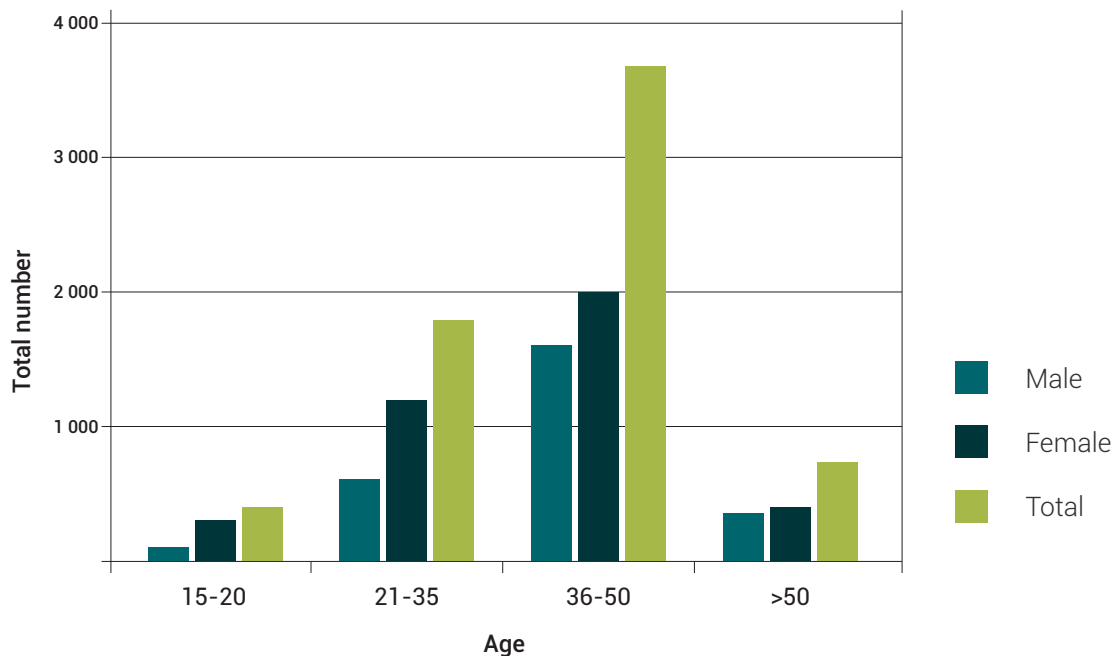
It is envisaged therefore that any predicted water stresses will negatively impact on all the initiatives for economic development and sustainable livelihoods. As a result, all efforts geared towards water harvesting even through non-traditional means, such as using underground sources are highly encouraged through the National Water Policy of 2009 (NWA, 2009) as well as the Integrated Water Resources Master Plan of 2011 (MNRE-DWA, 2011) .

#### **Gender issues**

In Swaziland, mainly women collect, carry and manage water for domestic use. Generally, in water resource management, women play a substantial role through their productive activities in subsistence and cash crop production. As custodians of family health and hygiene, and providers of domestic water and food, women are the primary stakeholders in household water and sanitation. Accordingly, there is a need to address gender inequalities in terms of access to,

and control over, water development resources. Through the Project Impact Review, conducted by LCC Capital in 2015, a gender perspective has been meaningfully applied to the sand dams' projects (LCC Capital, 2015) (Figure 4).

**Figure 2 – The age and sex profile of the participants of the sand dams' projects**



Source: Author, based on data from L.C.C. Capital (2015).

#### 4. RESULTS

According to the UNDP Climate Change Project Impact Review, 2015, the sand dams' project involved 6,711 participants from 1,005 homesteads of which 56% fell within the 36-50 age bracket. This shows direct involvement of the middle-aged group, who are invariably heads of families and breadwinners, and generates confidence that the project has a high likelihood of survival and sustainability (UNDP, 2015).

Targeted analyses of the projects have revealed the following issues:

- The interviews conducted concluded that from the commissioning of the projects, women were generally more concerned with development initiatives of the areas than men. The most contributing factor to that was the transient residency of men at their homes. In these rural and poverty stricken areas, a lot of men leave their homes and travel to towns in search for jobs;
- Most of the households are headed by women since men migrate to look for work;
- The participation of women in the construction of the sand dams was more pronounced as they anticipated easy access to water for domestic purposes, including backyard gardens that contribute to food security and micro-income realized from the sale of excess vegetables harvested;
- During the period of conducting interviews with beneficiaries, while the sand dams were still maturing, more men were found within the vicinity of the project sites. This was because they are cattle herders depending directly of available water near the sand dams for sustenance.
- The sand dam initiative has benefitted the communities in that herders do not have to hike far to find water for their livestock. Previously, herds would have to be driven long distances along the dry river beds to sandy areas where watering pits would be dug for the livestock to drink.

## 5. CONCLUSION

Depending on the structural integrity, sand dams do not need much maintenance (Excellent Development, 2012). Maintenance would be required only on the abstraction and distribution system, such as the repairing of the abstraction pumps and distribution pipes. In addition to providing drinkable water, sand dam water can be used for various purposes that ensure food security. Through this intervention, development projects can be established in previously arid areas for livestock watering, vegetable irrigation, growing of fruit trees and nursery establishment.

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## SESSION 5 GETTING THE MOST OF THE WATER RESOURCES

Overview by Gerry Galloway

International Water Resources Management (IWRM) has been defined by the Global Water Partnership (GWP) as 'a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP, 2013). The participants to the course proposed to define IWRM as 'a global look at how water should be managed to provide adequate living for all on the globe without polluting or depleting the resources for future generations'. Another definition was also retained considering IWRM 'an integrated participatory decision-making process that takes account of the ecosystem and future generations'. IWRM provides decision-makers and water managers a framework for dealing with the challenges they must face in an ever more uncertain environment.

The allocation of water is a fundamental issue, should take into consideration the following principles: a) Equity: allocating water in a way that is fair and equitable; b) Environmental protection: allocating water in a way that recognizes the needs of freshwater dependent ecosystems and protects key ecosystem services; c) Development priorities: allocating water in a way that supports and promotes economic and social development; and d) Efficient use of water: allocating water in a way that promotes its most efficient use.

However, access to water is a human right, and therefore equitable and inclusive allocation is fundamental. One participant to the course noted that 'there has been a paradigm shift; everyone now accepts that you should pay for water but the question is how much'. Striking the balance between creating realistic tariffs for managing water consumption and the equitable provision of water services can be particularly difficult in some contexts, but the current use of pro-poor tariffs and ensures water availability for those who would otherwise not have access.

In order to make more water available, managers must integrate the conjunctive use of water with current methods for the development of water resources. A careful management of the appropriate combination of ground and surface waters over time and space can significantly improve the availability of water resources in water-short areas, but may, however, require changes in existing governance structures.

Another challenge is the management of water resources in transboundary contexts. Although the issues of national sovereignty may have a fundamental impact on international agreements, it is necessary to harmonize the legal framework and technical structures of water resources management (WRM) among the countries concerned, and to share data and information about water resources in the transboundary basins. It is also important to recognize that national security interests and development goals will differ among the countries involved to that national interests may vary depending on the size of the basins of each country.

An effective and efficient development and management of transboundary, national and local water resources will require that water professionals fully appreciate the vulnerability of the water resources; the value of broad participation in IWRM; the essential role of women in management and decision-making; and the need for equitable, efficient and sustainable use of water.

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## BOTSWANA

### Effluent utilization through a constructed wetland system at the Department of Water Affairs Headquarters (DWA HQ)

by Kene Carol Dick

#### 1. INTRODUCTION

Botswana is faced with water shortages due to its limited water resources. The situation is exacerbated by low rainfalls, high evaporation rates, poor water quality that is caused by the salinity of underground water; and water wastages, especially in institutions such as schools. The country has reached its full potential in terms of its surface water development (construction of dams) (DWA-MMEWR, 2006). All of Botswana's perennial rivers are shared with neighbouring countries. The shared rivers are Okavango, Zambezi, Orange-Senqu and Shashe-Limpopo (UNDP, 2012). As a developing nation, the country requires water for economic growth. The current water demand for the entire country is estimated at around 250 Mm<sup>3</sup> (MMEWR, 2012). Botswana requires water for economic growth in domestic, energy, agriculture, tourism and the mining sectors. According to Zhou and Masundire (1998), the projected water demand for Botswana by 2020 is estimated at 336 Mm<sup>3</sup>.

As the demand for water is increasing, the 2006 National Water Master Plan Review (NWMPR) has identified wastewater as a resource. Its recuperation and reuse will assume equity with other water resources, hence becoming an increasingly important component of national water resources management (WRM) (DWA-MMEWR, 2006). The Tenth National Development Plan (NDP 10) 2009-2016 identified four strategies to meet Botswana's water challenges: institutional restructuring, water infrastructure development, water conservation and demand management (WC and DM), and capacity building (MFDP, 2009).

Institutional restructuring was recommended by the NWMP to strengthen the WRM function and to improve the water service delivery. According to the NWMP, separating the resource management functions (policy-making, implementation and monitoring) from the service delivery activities was found to be essential for Botswana to meet its current and future water challenges as well as align planning and operations with international practices.

Water infrastructure development is required to relieve pressure on the existing infrastructure, which is due to increased economic activities and moderate population growth. In order to facilitate a private sector-driven economy, Botswana needs to develop a robust water infrastructure to enable effective management of scarce water resources (MFDP, 2009). This strategy is always coupled with WC and DM to curb water wastage and explore on the alternative water sources.

According to the NWMP, WC and DM should be given primary consideration in water resources planning, because of their effectiveness compared to the development of new resources. WC and DM promote water efficiency and the exploration of alternative water sources, such as greywater recycling, rainwater harvesting, stormwater collection, saline water and wastewater utilization.

Capacity building entails the development of new skills to cope with the changes in the water sector. The move to a stewardship role requires the development of skills for the assessment and protection of water resources. The skills required should include adequate knowledge and abilities to perform a strong stewardship role, knowledge of policy development to educate and build awareness on the merits of water use, and adequate knowledge and expertise for an effective participation in the activities of regional commissions.

## 2. DESCRIPTION OF THE PROJECT

The project for the rehabilitation of a constructed wetland system at the Department of Water Affairs Headquarters (DWA HQ) at Old Naledi, a suburb of the capital Gaborone, aims to promote the application of the WC and DM principles by the various stakeholders and also to demonstrate the various reuse options of water.

The constructed wetland consists of four cells with a vertical flow (Figures 1 and 2). The cells are filled with sand of 600 mm, sloping eastwards and increasing the depth of the sand to 700 mm. The size of each cell is 25 m x 5 m, with a total surface area of 125 m<sup>2</sup> each. The constructed wetland receives sewage from the DWA HQ and the Old Naledi settlement. Sewage from the surrounding Old Naledi is from both toilets and kitchens, while from the DWA HQ offices mainly come from toilets.

Wastewater discharged from the DWA HQ and Old Naledi is diverted from the main sewer into the constructed wetland ecosystem for treatment. This wastewater is taken through a physical treatment to remove the solids from the wastewater through the use of septic tanks and grit removers. After the separation of the solids from the liquid, the water is passed through a reed bed system that consists of four beds running in parallel and receiving the same load. Three beds contain three different types of reeds to remove the nutrients such as phosphates (PO<sub>4</sub>) and nitrates (NO<sub>3</sub>) while the fourth bed contains only sand. This bed is used as a control.

After the biological treatment through the reed bed system, the effluent passes through the four distinct cells to the collection chamber. At the collection chamber, a chemical dosage of a bio-safe disinfectant called (Huwa-San TR 50, which contains silver (Ag) and Hydrogen Peroxide (H<sub>2</sub>O<sub>2</sub>) as the active ingredients, is administered to kill the microorganisms. After the chemical treatment, the water is stored and it is ready for irrigation of the DWA HQ landscape, horticulture and orchard. The constructed wetland ecosystem is coupled with a mini reverse osmosis plant that further treats wastewater to meet the drinking water quality requirements (Figures 2 and 2).

### 2.1 Effluent quality assessment

The wastewater quality from the wetland is assessed in accordance with the national standards for water quality. These are:

- drinking water specifications (BOS 32:2009) for human drinking purposes;
- wastewater discharge requirements (BOS 93:2012) for the discharge on the open environment, river systems and sewer line; and
- water quality for irrigation (BOS 463:2011) for the irrigation of the landscape, the orchard and the vegetables.

The drinking water quality standard measures compliance with microbiological, physical, inorganic and chemical requirements. The wastewater discharge standard measures compliance with physical, microbiological and chemical requirements, while the water quality for irrigation standard measures compliance with physical, chemical organic, biological and microbiological determinants.

## 3. Challenges and opportunities

The operation and maintenance of the constructed wetland system is a challenge for the DWA HQ because they have to cope with the shortage of funds and skilled manpower. There are challenges on the operational and maintenance levels which have resulted in the blockage of the pumps due to the lack of preventive maintenance. The reeds were also observed to overgrow



their discrete cells and some foreign weeds were also found to have developed in the reed beds. These problems have affected the performance of the constructed wetland and resulted in low water flows.

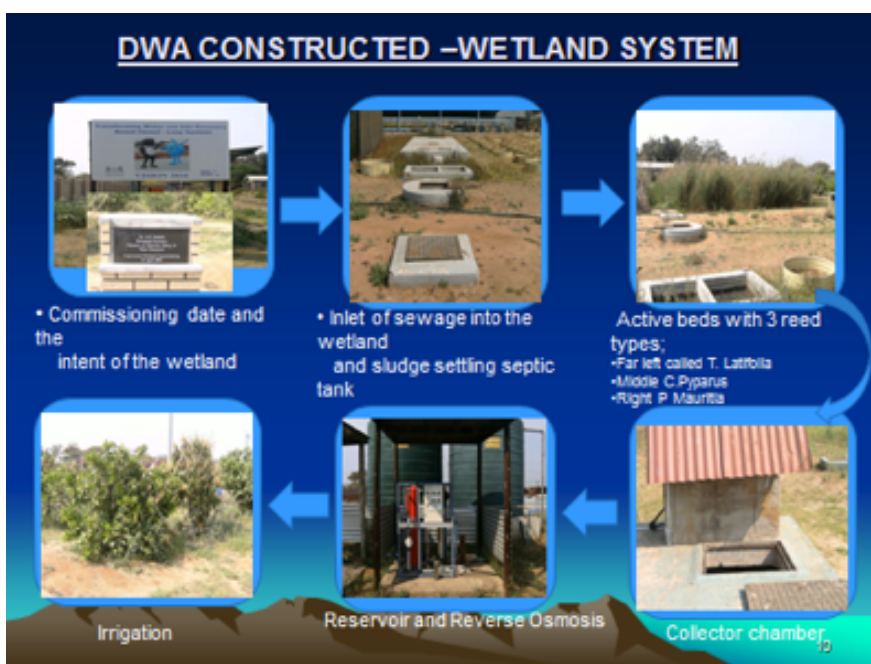
Staff movements and transfers that were implemented between 2008 and 2013 by the Water Sector Reforms (WSR) also contributed to the poor maintenance and operational dysfunctions at the constructed wetland system. They also affected its daily operations such as the routine wastewater sampling for water quality monitoring. In addition, one should bear in mind that treating wastewater for drinking purposes is a challenge given the local beliefs about treating sewage into drinking water.

However, the WSR has given the DWA a new mandate for WRM, which recognizes wastewater as a water resource. The WSR has devolved the WRM function to the DWA, while the water service delivery was transferred to the Water Utilities Cooperation (WUC). Therefore, DWA's mandate is to manage all the water resources in the country, including wastewater, which is given the same equity as groundwater and surface water (DWA-MMEWR, 2006). This new mandate provides the opportunity to recruit personnel with appropriate skills.

In general, public education and awareness on wastewater reuse is a leverage to improve on the buy-in of wastewater utilization by the various stakeholders and will also enhance public knowledge on safety and hygiene on handling wastewater.

In addition, the implementation of the Integrated Water Resources Management Water Efficiency Plan of 2013 (IWRM WE Plan 2013)<sup>21</sup> is an opportunity to facilitate wastewater utilization and greywater recycling. The plan has identified water supply and demand management as one of the strategic areas in bridging the water scarcity gap in Botswana, where wastewater utilization and greywater recycling are the drivers. Stakeholder participation and community involvement in WRM is also part of the IWRM WE Plan 2013 (DWA-MMEWR, 2013).

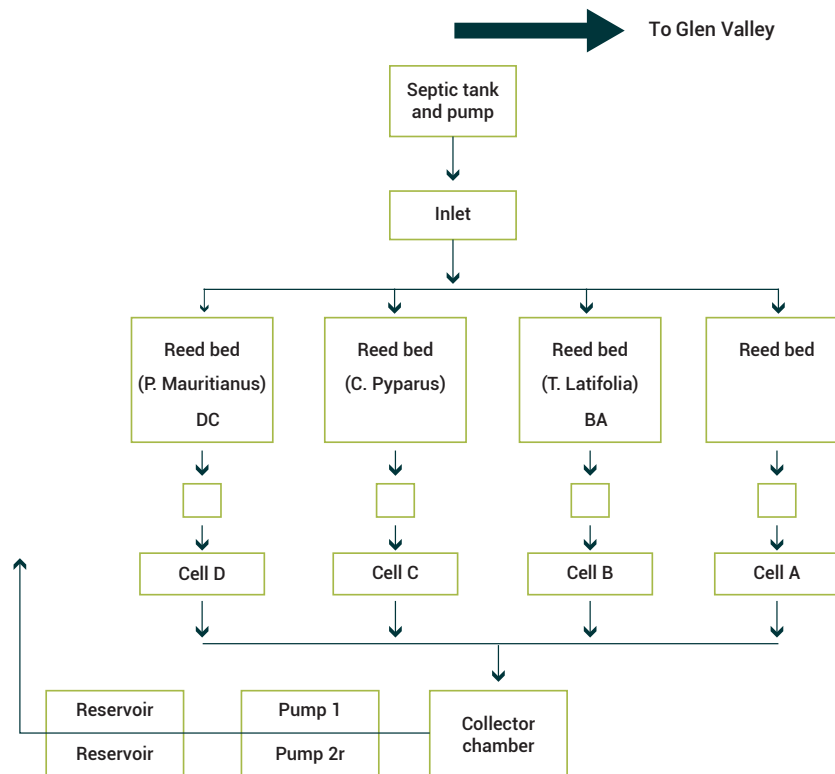
Figure 1 – A pictorial flow diagram of the DWA constructed wetland system



Source: Author, DWA Water Quality and Conservation Division (2012).

<sup>21</sup> For a detailed analysis of the IRWM WE Plan 2013, please refer to Session 2, Case Study on Botswana.

Figure 2 – A schematic flow diagramme of the constructed wetland at DWA HQ



Source: Author.

Finally, there is a potential for further research on the wastewater treatment technologies which can improve its quality for the intended use, as well as on the consequences of cumulative pollution over extended use of endocrine disrupting substances; nutrients recovery from wastewater; and reeds species suitability and effectiveness. Building partnerships with research institutes, such as the University of Botswana, the Botswana Innovation Technology and Research Institute (BITRI), the Botswana Agricultural College (BCA) and the Botswana International University of Science and Technology (BIUST), can assist in finding solutions regarding wastewater utilization and management. Resources are available within the government and the academic world to conduct demand-driven research.

#### 4. CONCLUSIONS

Improving the operations and maintenance of the constructed wetland at the DWA HQ will ensure an efficient and effective system that delivers water of acceptable quality for the various reuse options, such as for irrigation, dust suppression, construction and drinking. However, reuse for drinkable water will require further investigation and studies to ensure safety on human health over a prolonged use. Reusing for non-potable purposes, such as irrigation, construction and dust suppression will increase the efficiency of water use in Botswana. When operational wastewater from the DWA HQ constructed wetland system was used largely for the irrigation of the landscape, it experienced a 30% reduction in its monthly water consumption and water bills.

Providing a proper financing for the maintenance of the wetland system will improve and reduce the blockages and ensure the proper maintenance of the reed bed system. Intensive public education and awareness campaigns on the promotion of WC and DM principles, particularly on wastewater utilization and water quality, will enhance acceptance by the various stakeholders. Furthermore, the accreditation of testing methods in the testing facilities will build confidence on

the stakeholders with regard to the use of recycled water and improve the social acceptability on using such water.

The implementation of the IWRM WE Plan 2013 will also assist in increasing the uptake of the WC and DM principles. The plan is promoting increased Water Demand Management (WDM), rainwater harvesting, improved water saving technologies and accelerated reuse and recycling of treated wastewater.

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## CABO VERDE

### Vulnerability and pollution risks of groundwater on the island of Santiago<sup>22</sup>

by António Pedro Said Aly de Pina

#### 1. INTRODUCTION

Water resources management (WRM), in its various forms, has evolved quickly to respond to the worsening challenges, such as the increasing demand for the protection and enhancement of water resources, the increasing uncertainty and vulnerability of systems and the need to incorporate a set of environmental, economic and social interactions into the decision-making process of a country.

Cabo Verde is a small island country covering an area of about 4,000 km<sup>2</sup>, and its surface and groundwater are among the most important natural resources. The increasing use of groundwater is considered strategic since the volume of drinking water is diminishing and the demand for the settlement of dump sites, the salinization and contamination of coastal aquifers is increasing.

In Santiago, one of the islands of the archipelago, groundwater has been progressively overexploited to supply the various water needs of the municipalities and communities, as well as of the residential autonomous systems, industries, services, and for irrigation and recreation. The exploited volume of groundwater is quite significant when compared to the potential of its renewable resources. Despite its significant contribution to the socio-economic development of the island and its ecological role in maintaining the basic flow of water bodies, the management of groundwater remains embryonic and does not reflect its current and strategic relevance.

The use of the 'vulnerability index' is a first step in the elaboration of a development plan and the management of an aquifer system. This is an important tool for the study of the potential pollution of groundwater, both related to the mechanisms and natural hydrogeological characteristics and the activities of anthropogenic pollutants. However, in order to maintain compliance with a given continued demand, and ensure the quality, detailed research, it is necessary to put in place the proper management of water resources.

In this context, assessing the degree of vulnerability of aquifers to contamination is a useful tool in decision-making and land use planning. In this regard, this assessment can be used for defining the strategic areas of protection and aquifer recharge levels (the most permeable and with the greatest impact on quality groundwater).

The mapping of the natural vulnerability to pollution at the local level is relevant in that the base flow – a polluting source stemmed from the aquifer or higher areas – may become an environmental hazard for the entire domain, a watershed, thus affecting the entire supply source and the dynamic equilibrium of the system. Studies on natural vulnerability of groundwater contaminations are based upon the principle that the physical environment may contribute to a certain degree of protection from contaminants, considering that the geological materials can act as natural filters. However, this natural protection varies depending on the location of for different locations.

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<sup>22</sup> This case study is a translation of some sections of the author's thesis with the same title (Pina, 2014). See complete references at the end of the case study.



The adoption of vulnerability indexes has the advantage, in principle, to eliminate or minimize the subjectivity inherent in evaluation processes (Figure 2).

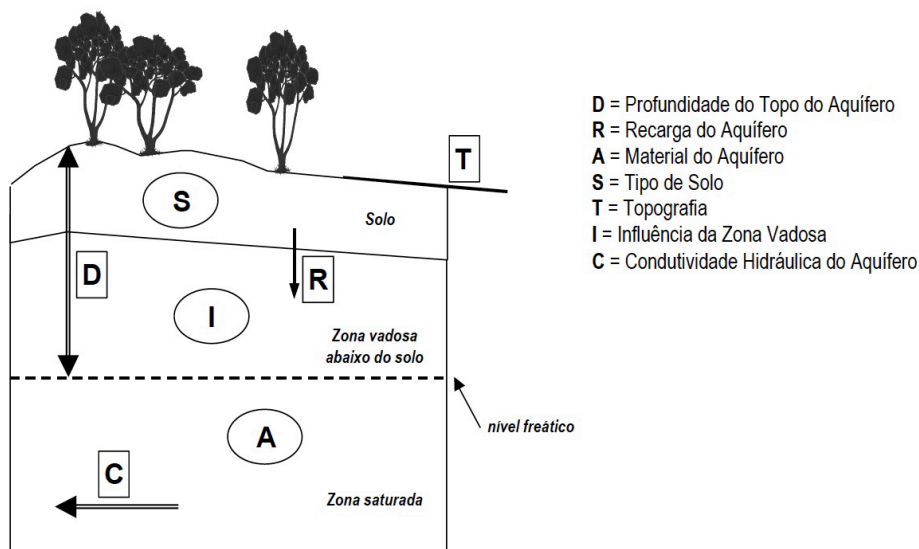
The DRASTIC method was developed based on the following assumptions (Aller et al., 1987):

- The contaminant is added to the ground surface;
- The contaminant is transported vertically to the aquifer by water infiltration;
- The contaminant has the mobility of water; and
- The minimum area evaluated by DRASTIC is 0.4 km<sup>2</sup> (100 acres).

The DRASTIC index represents the weighted average of 7 values, corresponding to the following hydrogeological parameters or indicators (Aller et al., 1987; p. 6):

- D - Depth to groundwater;
- R - Recharge;
- A - Aquifer media;
- S - Soil media;
- T - Topography;
- I - Impact of the unsaturated (vadose) zone;
- C - Hydraulic Conductivity.

Figure 2 – Hydrogeological parameters incorporated in the DRASTIC model



Source: Pina (2014, from Lobo-Ferreira (1986)).

Each parameter has a predetermined weight that reflects their relative importance in the measurement of vulnerability and range from 1 to 5 (Table 1).

Table 1 – Relative weight of each parameter in the DRASTIC index

PARAMETER	D	R	A	S	T	I	C
WEIGHT	5	4	3	2	1	5	3

Source: Pina (2014, table 4.1.6 – 1.1, p. 95).



These weights, called DRASTIC weighting factors, are related to each other by Equation 1, applied to each geographical unit. Each of the seven DRASTIC parameters was divided either in scale or in types of significant kind of condition the potential for pollution and is attributed to each of the divisions an index ranging from 1 to 10 and whose value is directly related to the potential for pollution (Albinet and Margat, 1970).

The DRASTIC vulnerability index is obtained by Equation 1:

$$\text{DRASTIC} = D_p \times D_i + R_p \times R_i + A_p \times A_i + S_p \times S_i + T_p \times T_i + I_p \times I_i + C_p \times C_i.$$

where i is the index assigned to the element concerned and p its weight.

The most common DRASTIC index values are between 50 and 200 (Aller et al., 1987, Lobo-Ferreira and Oliveira, 1993). They were adapted by Pina (2014, p. 96) as classes or vulnerability intervals (Table 2).

**Table 2 – Values related to the intervals of the DRASTIC index**

DRASTIC index	Level of vulnerability
> 199	Very high vulnerability
Between 160 and 199	High vulnerability
Between 120 and 159	Intermediate vulnerability
< 120	Low vulnerability

Source: Pina (2014, table 4.1.6 – 1.2, p. 96).

The value for each parameter of the DRASTIC index was defined according to pre-existing data obtained from a set of water points monitored by INGRH.<sup>23</sup> In areas where there are no water points, consideration was given to the data extracted from geological and topographic maps, and on-site visits in order to identify drainage networks and allow a better interpretation of the medium. The vulnerability arises, therefore, as a concept that allows integrating various parameters characterizing the underground environment and its specificity. The procedures used for the characterization of each of the parameters of the DRASTIC method are described below. The realization of the spatial location operations was made using the geographic information system ArcInfo Workstation for Windows, version 8.1.

### 3.1 Depth to groundwater – D

The depth of the aquifer is defined as the vertical distance that a certain pollutant has to travel to reach the aquifer. The greater the distance covered by the pollutant, the greater are its chances to be purified by the soil. In order to elaborate a mapping of the depth of the water table it was necessary to establish the altitude of the river system based on its spatial location in two dimensions using the digital terrain elevation model. The same digital terrain elevation model was used to determine the altitude of the water level at a number of observation points which made it possible to calculate the difference between the altitude of the terrain and the depth of the water table. Unlike the digital terrain elevation model for the elevation of the surface of the water table allowed us to determine the depth of the water table values - D parameter - whose values are represented in Figure 3a).

<sup>23</sup> Instituto Nacional de Gestão dos Recursos Hídricos. See: <http://www.ingrh.cv/>

### 3.2 Recharge – R

The climatic water balance, developed by Thornthwaite and Mather (1955) is one of the several methods of estimating the average groundwater storage over time. The water balance method can serve both to estimate specific refills at local level and at larger scales, such as river basins. Due to the great heterogeneity of the distribution of rainfall on the island of Santiago, three major bioclimatic zones according to their altitude were considered for the calculation of the water balance according to the Thornthwaite and Mather method (1955).

The recharge hypsometry is the change in elevation of the area that is above or below a certain altitude. In Santiago, the potential areas for recharge are located in the central part of the island, relatively far from the coast. It is associated with the formation of the Antonia peak where the terrain provides the orographic precipitation and fogs and the geological formations are favourable to infiltration and water storage (Figure 3-b).

### 3.3 Aquifer media – A

There are five classes of geological formations on the island of Santiago: basalt, sandstone, alluvial sand, limestone and "calciaro carstificado". Descriptions of floods, often referred to as sandy, could point to a higher rate than the index 4 assigned to them (Figure 3-c).

### 3.4 Soil media – S

The soil of the archipelago is derived from volcanic or igneous rocks, being essentially characterized by shallow horizons. The map of the parameter S is made based on the characterization of soil profiles for texture and thickness. After soils with thin stony or phase is automatically assigned the index 10 (Figure 3-d).

### 3.5 Topography – T

The T parameter was developed using as background information the levels on the military maps at 1: 25,000, A digital elevation model of land with 25 m aside and calculated to the slopes, which is presently classified according to the parameter T DRASTIC method in the Figure 3-e.

### 3.6 Impact of the unsaturated (vadose) zone – I

On the island of Santiago, the conceptual model of flow is a free regime with shallow groundwater levels. In free aquifers the lithologic formation is generally the same as the saturated zone, depending on the dominant material, it will influence the dopant contact time, favouring the occurrence of various processes such as biodegradation, mechanical filtration, chemical reactions, volatilization and scattering. Once the characterization of the index tables A and I for the present materials are similar, the values to be assigned to parameters A and I are the same because they incorporate the two characteristics on the depth of the water level and permeability. The I parameter map is depicted in Figure 3f.

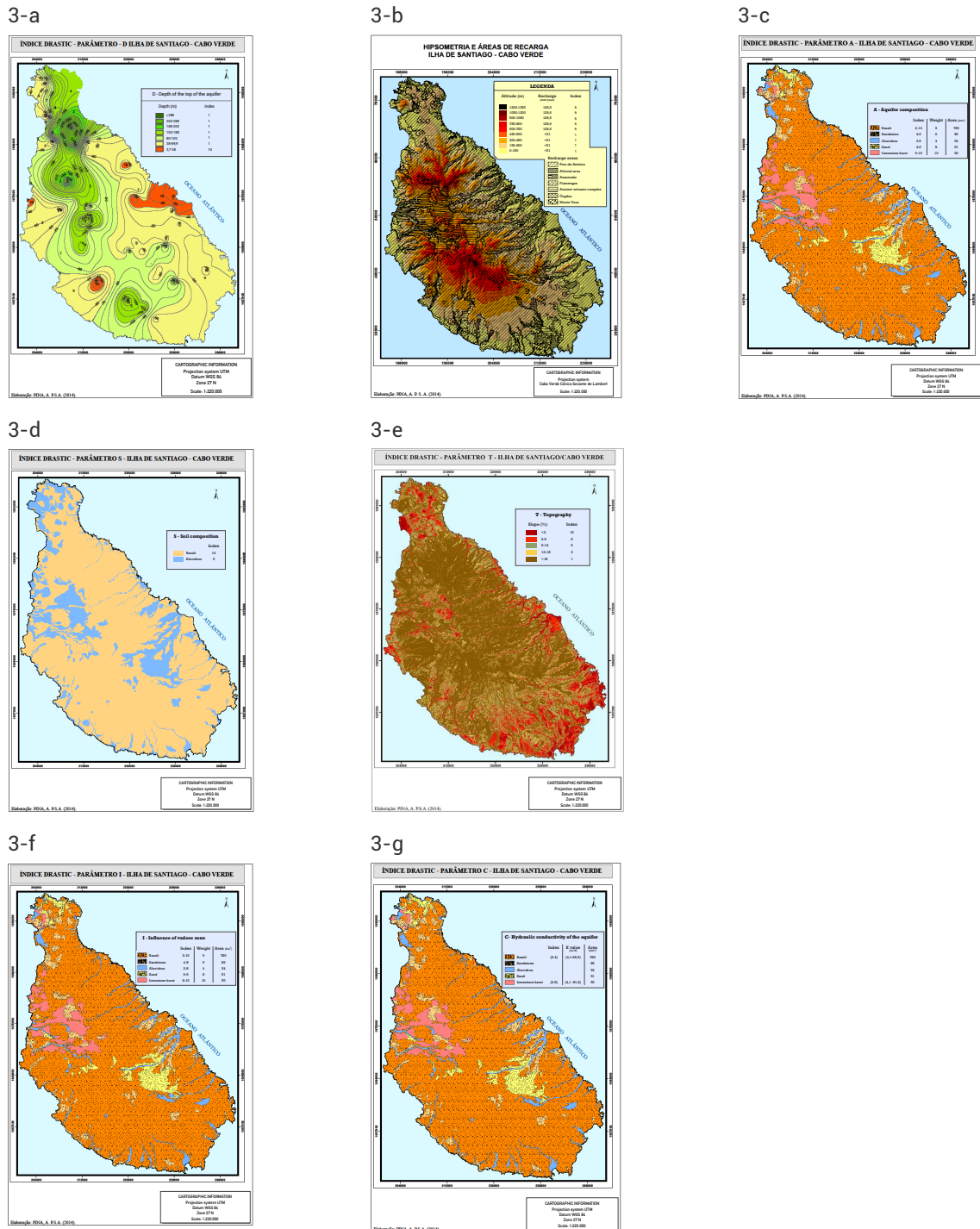
### 3.7 Hydraulic conductivity – C

On the island of Santiago, there is no information available on values of hydraulic conductivity and saturated thickness. Only transmissivity values ( $m^2$  per day) for the different geological formations are available. A good approximation of the hydraulic conductivity of the geological formations that occur at shallow depths would divide the transmissivity by the saturated thickness, if there was information. As there is no published information, tables or the abacus method should be used, that relate to the hydraulic conductivity for the characterization of the lithology parameter C. According to the abacus method, the fractured igneous and metamorphic formations represent values of hydraulic conductivity of 0.001 m per day to 28.5 m per day.

However, since formations of this kind also occur in association with unconsolidated formations with hydraulic conductivities up to 80 m per day (index 8), the option is to assign an intermediate index (index 2).

Finally, for unconsolidated detrital formations (sands, gravels) characteristic values shall be given that cut across all classes, and index 4 is assigned to these formations (Figure 3-g).

Figure 3 (a-g) – Characterization and ARCTIC mapping on Santiago Island - Cabo Verde



Source: Pina (2014, Figures 5.6-1 – 5.6.7-1, pp. 178-196).

## 4. METHODOLOGY

### 4.1 The concept of vulnerability

The concept of the vulnerability to pollution of groundwater has been defined according to the conclusions of the international conference on 'Vulnerability of Soil and Groundwater to Pollutants' of 1987: 'the sensitivity of groundwater quality to a pollution load is a function only of the intrinsic characteristics of the aquifer' (Duijvenbooden and Waegeningh, 1987).

Defined in this way, vulnerability is different than risk of pollution. The risk of pollution does not depend only on vulnerability, but also on the existence of significant pollutant loads that can enter the underground environment. Aquifers with a high vulnerability index may exist, but without a risk of pollution since there are no significant pollution loads, or, an aquifer can have a high risk of pollution despite a low vulnerability index. It is important to clarify the difference between vulnerability and risk of pollution. The risk is not only caused by the intrinsic characteristics of aquifers, which are very stable, but also due to the presence of polluting activities, a dynamic factor, which, in principle, can be controlled (Foster, 1987).

Severe episodes of pollution of groundwater and its consequences on environmental quality or the degree of disturbance of public supplies are not deliberately considered in the definition of vulnerability.

When defining the concept of vulnerability, it is also important to recognize that the vulnerability of an aquifer also depends on the type of potential pollutant. For example, the quality of groundwater can be very vulnerable to nitrate loads, caused by incorrect agricultural practices, which is however, less vulnerable to pathogenic loads. Taking this into account, vulnerability need to be assessed in specific cases of pollution, such as nutrients, organic pollution, heavy metals, etc., and therefore the creation of a concept of particular vulnerability is needed (Lobo-Ferreira and Cabral, 1991).

Preparing a specific vulnerability mapping is more consistent from a scientific point of view; however, in general, the available data are insufficient to prepare such a specific mapping. It became therefore necessary to develop concepts that are more suitable for the use of available data.

### 4.2 Vulnerability to pollution of groundwater – DRASTIC index

The DRASTIC index method was chosen for the assessment of the intrinsic vulnerability of groundwater pollution on the island of Santiago, which is based on a set of procedures integrating various parameters characterizing the underground environment and its specificities, the information available, the assessment of the achievements and results validation.

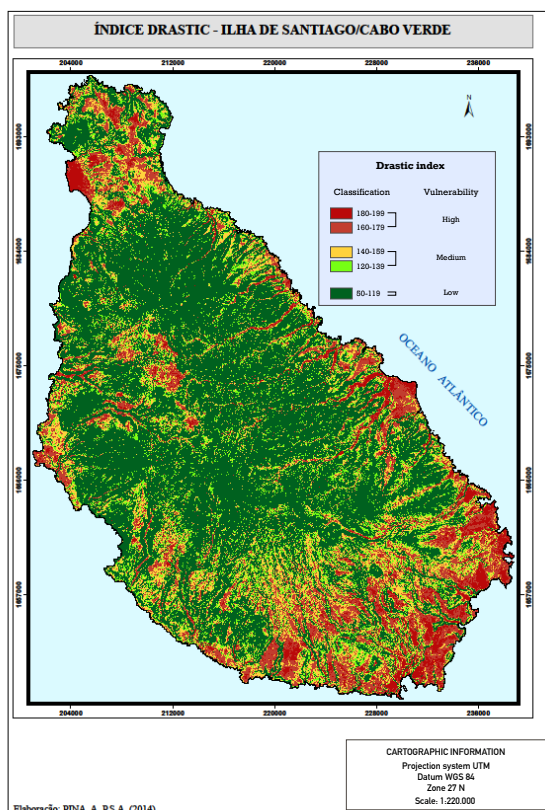
The DRASTIC vulnerability index was obtained by the weighted sum of the product of the index assigned to each parameter by the weight of this parameter. The DRASTIC index of Santiago Island is shown in Figure 4.

According to the DRASTIC index method, the higher the index, the greater is the vulnerability to groundwater pollution. A better understanding of the final index values in qualitative terms of vulnerability can be illustrated as follows:

DRASTIC index	Level of vulnerability
> 199	Very high vulnerability
Between 160 and 199	High vulnerability
Between 120 and 159	Intermediate vulnerability
< 120	Low vulnerability

The calculated DRASTIC index for Santiago Island ranges between 65 (low vulnerability) and 208 (very high vulnerability) to a possible range of 23 to 226. The calculated average value is 137 (intermediate vulnerability).

Figure 4 – DRASTIC index vulnerability to groundwater pollution on the island of Santiago



Source: Pina (2014, Fig. 5.7-1, p. 198).

## 5. CONCLUSIONS AND RECOMMENDATIONS

The degree of dependence of ecosystems to groundwater should be evaluated based on several hydrogeological attributes, such as the flow rate of groundwater flows, the water levels and hydrochemical descriptors.

The ecosystem responds in many ways but when its threshold is reached, it can collapse. Within this framework, it is possible to identify various degrees of dependence in a range that goes from ecosystems wholly dependent on groundwater to those who use groundwater occasionally for their survival. In order to understand the extent to which terrestrial ecosystems are dependent on groundwater, it is essential to use the holistic approach, which consists of applying either conventional techniques, such as water balance, or more sophisticated techniques, such as isotopic analysis, and hydrological and hydrogeological modelling. The result leads to the application of a multidisciplinary approach which assesses the vulnerability and the risk of ecosystems to threats that are anthropogenic of nature.

The solution to the current risk on the east coast of the island of Santiago, as well as to prevent future occurrences, depends on a change in the planning paradigm and management of these territories which has to address issues work with a certain degree of uncertainty and complexity.

The island's vulnerability to groundwater pollution was evaluated using the DRASTIC index method. The values obtained show that DRASTIC indexes vary between 65 and 208. These indexes show that there are hydrogeological conditions that correspond to a very high vulnerability.

Although the mapping used has been at the scale of 1:220,000, there are uncertainties in the definition of some parameters. It is therefore recommended to use the scale of 1:100,000. The natural vulnerability of each aquifer in a given location is dependent on the degree of reliability of the resolution of the working range.

In mapping the DRASTIC index, there are spots with areas below the minimum area required (0.4 km<sup>2</sup>), according to the assumptions presented. This means that the ratio obtained in a given location has an equivalent in the index to an area of 0.4 km<sup>2</sup>. It also means that at a given point, the index could indicate a different value other than the one it is actually presenting. If the index value is not readily available, it is preferable to undertake a comparative analysis using values from the most vulnerable areas (higher levels) and from less vulnerable zones (lower levels). The final values obtained should be interpreted according to the hydrogeological functioning of the study area. Thus, knowledge of the hydrological dynamics was an important factor in the assessment of the degree of sustainability of the water system of the island of Santiago and in the identification of potential sources of pollution.

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## NIGERIA

### Inspection of service reservoirs at the Federal Capital Territory, Abuja

by Timothy Olatunji

## 1. INTRODUCTION

In August 2013, the National Water Resources Institute (NWRI) of Nigeria, in collaboration with the Water Board of the Federal Capital Territory (FCT), Abuja, where the capital of Nigeria is located, developed a water safety plan<sup>24</sup> (WSP) for the FCT.

According to the WHO and IWA (Bertram et al., 2009, p.1), the development and implementation of the WSP approach for each drinking water supply organization is as follows:

- Set up a team and decide a methodology by which a WSP will be developed;
- Identify all the hazards and hazardous events that can affect the safety of a water supply from the catchment, through treatment and distribution to the consumers' point of use;
- Assess the risk presented by each hazard and hazardous event;
- Consider if controls or barriers are in place for each significant risk and if these are effective;
- Validate the effectiveness of controls and barriers;
- Implement an improvement plan where necessary;
- Demonstrate that the system is consistently safe;
- Regularly review the hazards, risks and controls;
- Keep adequate records for transparency and justification of outcomes.

## 2. PROJECT DESCRIPTION: FCT WATER TREATMENT PLANTS AT LOWER USAMA DAM

### 2.1 Background information

The relocation of all ministries, government agencies and diplomatic representatives to the FCT triggered a major growth in Abuja City. Abuja is the capital city of Nigeria, located in the centre of Nigeria with a population of 776,298 (2006) (NPC, 2010). While the state population indicates an average annual growth rate of 3.2%, Abuja FCT enjoys an annual growth rate of 9.3% (NPC, 2007).

The rate and the projected rise of the population require the rapid development of infrastructures and services, and increased water demand has thus become a priority issue.

The urban water demand of Abuja and its satellite towns is 210,000 m<sup>3</sup> per day. The Lower Usuma Dam, located 20 km north of Abuja was built in 1984 with a reservoir capacity of 100 million m<sup>3</sup>.

The Lower Usuma Dam Water Treatment Plant (LUDWTP) has four treatment plants with a total combined capacity of 30,000 m<sup>3</sup> per hour. It is located in Abuja and owned by Federal Capital Territory Water Board (FCTWB). Two of the four treatment plants were constructed by Biwater in November 2011, and has the capacity to process 240 million litres of water a day. The four plants have a combined capacity to provide 720 million litres of clean drinking water per day to Abuja and its neighbouring areas.<sup>25</sup>

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<sup>24</sup> A WSP is a systematic assessment of every aspect of the provision of safe drinking water. It is an effective means of risk management through which risks from catchments to consumers are identified and mitigated.

<sup>25</sup> See <http://www.water-technology.net/projects/lower-usuma-dam-water-treatment-plant-expansion-abuja/>

In December 2005, the Federal Ministry of Water Resources launched the Gurara Dam Water Project,<sup>26</sup> a multipurpose project which is intended, in part, to supplement supply of raw water to the FCT to meet the demand for the next 50 years and/or until the anticipated ultimate development of the FCT is achieved.

The Gurara dam spillway is designed to discharge a maximum of 2,715 m<sup>3</sup> per second; a routed estimate from design flood and return period of 10,000 years. Located on the left bank of the Gurara River, the spillway comprises a 307 meter-long concrete ogee weir, un-gated at the normal water level (NWL) (El.624.9). The weir supports a bridge across and prolonging the dam crest.



Gurara Dam spillway  
Source: NWRI (2013).

There has been an improvement in water supply in the Federal Capital Territory (FCT) with the commissioning of the Inter-Basin Water Transfer Project from Gurara Dam in Kaduna State to the Lower Usuma Dam, in Abuja through a three-meter diameter pipe covering about 75 kilometres, according to the FCT Minister, Muhammad Musa Bello.

The Minister made the assertion recently at the opening ceremony of the 23<sup>rd</sup> Regular Meeting of the National Council on Water Resources (NCWR) held at International Conference Centre (ICC), Abuja.<sup>27</sup>

He said that the two additional water treatment plants of 10,000 m<sup>3</sup> per hour production capacity each have been constructed to improve water supply in the FCT.

He also recalled that the FCT Millennium Development Goals (MDGs) in the course of its work provided 400 communities and schools with (Boreholes) portable water, which is today being maintained by the FCT.

## **2.2 Inspection of the FCT service tanks in the framework of the elaboration of a WSP Plan for the FCT**

The inspection of the water distribution system (WDS) was carried out by a WSP Team to determine the capability of the distribution system to provide a safe, reliable, and adequate supply of drinking water to the customers.

The inspection by the WSP team started at the treatment plant clearwater well, where drinkable

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<sup>26</sup> The Lower Usuma Dam, constructed in 1984, has a reservoir capacity of 100 million m<sup>3</sup>. The Gurara dam, which has 850 million m<sup>3</sup> reservoir capacity, provides additional raw water transfer into Lower Usuma dam. The maximum water transfer rate is 12m<sup>3</sup>/s - 43,200 m<sup>3</sup> per hour (Tractebel Engineering, n.d.).

<sup>27</sup> See <https://www.today.ng/news/national/133699/water-supply-improving-abuja-bello>



Inspection team at Maitama Tank 3 main (Nigeria)

Source: NWRI (2013).

water is fed by gravity into ground service tanks at higher locations around the FCT. The 'Maitama Tank 3', has the highest storage capacity of 48,000 m<sup>3</sup>. The receiving service reservoirs at FCT in turn feed the end users by gravity. Some of these receiving reservoirs also have pump units attached (where necessary) to lift water to other designated service reservoirs supplying various areas of the FCT. Table 1 lists the 12 service reservoirs that were inspected.

The service reservoirs are washed twice a year and disinfected. The inspection of the water tanks revealed that:

- Distribution maps and records are kept at the Water Board Headquarters (WBH);
- The maps show existing network indicating pipe sizes and location of service reservoirs;
- Site inspection shows existence of fire hydrants, valves, and other accessories;
- Interactions with the operational staff confirm that field sampling was generally practiced to determine residual chlorine and bacteriological testing across the distribution network;
- Maintenance records (repairs, flushing or new connections) are kept at the WBH;
- Residual chlorine was tested for by the WSP team to assess recontamination, if any, across the distribution network.



Water sampling by WSP Team (Nigeria)

Source: NWRI (2013).

However, maximum and minimum pressures at the high and low points in the WDS were not measured due to the absence of pressure gauges on the pipelines.

**Table 1 – Characteristics and distribution network of reservoir tanks**

S/N	Name/Location	Capacity (m <sup>3</sup> )	Shape and material	Area of service
1	Tank 3 Main (Maitama)	48 000	Twin rectangular reinforced concrete tanks of 24 000 m <sup>3</sup> each	<ul style="list-style-type: none"> <li>• Garki (part)</li> <li>• Wuse I (part)</li> <li>• Wuse II</li> <li>• Asokoro</li> </ul>
2	Tank 3-1 (Mpape)	5 400	Rectangular reinforced concrete tank	<ul style="list-style-type: none"> <li>• Maitama (A 6)</li> </ul>
3	Tank 2 (Katanpe Hill)	45 000	Rectangular reinforced concrete	<ul style="list-style-type: none"> <li>• Life Camp</li> <li>• Jabi</li> <li>• Utako</li> <li>• Gwarimpa</li> </ul>
4	Tank 3-2 (Yar'adua Barrack)	5 400	Rectangular reinforced concrete tank	<ul style="list-style-type: none"> <li>• Yar'adua Barrack</li> </ul>
5	Tank 4 Main (Asokoro)	12 000	Rectangular reinforced concrete tank	<ul style="list-style-type: none"> <li>• Garki</li> <li>• Asokoro</li> <li>• Central Area</li> <li>• Gudu</li> <li>• Tank 4 Extension</li> </ul>
6	Tank 4 Extension	12 000	Rectangular reinforced concrete tank	<ul style="list-style-type: none"> <li>• Garki</li> <li>• Nyanya</li> <li>• Karu</li> <li>• Asokoro (part)</li> <li>• Central Area (Part)</li> </ul>
7	Tank 5 (Apo)	40 000	Rectangular, reinforced concrete	Phase II (not in use)
8	Tank 4-1 extension (Mogadishu Barrack)	12 000	Rectangular, reinforced concrete	<ul style="list-style-type: none"> <li>• Abacha Barrack</li> </ul>
9	Gwagwalada Tank (Gwako)	20 000	Rectangular, reinforced concrete	<ul style="list-style-type: none"> <li>• Gwagwalada</li> </ul>
10	Kubwa Tank (Kubwa)	12 000	Rectangular, reinforced concrete	<ul style="list-style-type: none"> <li>• Kubwa Town</li> </ul>
11	Bwari Tank (Bwari)	12 500	Rectangular, reinforced concrete	<ul style="list-style-type: none"> <li>• Bwari</li> </ul>
12	Airport Tank (Airport)	12 000	Rectangular, reinforced concrete	<ul style="list-style-type: none"> <li>• Airport</li> <li>• Airforce Base</li> <li>• Prison headquarters</li> <li>• Immigration village</li> <li>• University</li> <li>• Permanent site</li> </ul>

Source: NWRI (2013).

The field staff is experienced professionals holding national diplomas and higher degree certifications and proficiency tests (trade tests). A customer care unit exists at the headquarters dealing mainly with matters related to maintenance, repairs and billing. In addition, customer care units at the districts receive and attend to leakage complaints, etc. from customers. There are no procedures/schedules of maintenance but corrective maintenances are conducted across the WDS. During the field activities of the WSP team, the water hydrant on Nasarawa Street, off Kano road and a washout on J.S. Tarka Street were tested to verify functionality and service ability (NWRI, 2013).

### 3. CHALLENGES ENCOUNTERED

The LUD WTP and distribution system are providing an accurate service. However, the following challenges remain:

- Environmental sanitation around the service reservoirs requires attention;
- Noticeable cracks on the walls of two reservoirs provoked water leakages and could lead to possible contamination in reservoirs;
- The storage reservoirs are not secured;
- Motor mechanics operations within the Mpape tank should be checked;
- The basketball court located on the access route to the Karu tank is inappropriate;
- Tank tops should be cleared of grasses to safeguard water quality;
- Monitoring programmes for the reticulation system or at point of use is absent;
- Some parts of Abuja, i.e. Lugbe and Kubwa, lack potable water supply leaving residents to rely on boreholes and water vendors; and
- Low pressure is experienced in some places in Abuja.

All risks should be documented in the WSP and be subject to regular review even when the likelihood is rare and the risk rating is low. This avoids risks being forgotten or overlooked and provides the water utility with a record of due diligence should incidents occur (Bertram et al., 2009, p. 32).

According to the semi-quantitative risk matrix approach (Deere et al., 2001), the WSP team determined the likelihood/frequency<sup>28</sup> and the severity/consequence<sup>29</sup> rating on a scale of 1–5 for each hazardous event (risk) identified. The risk score is the product of likelihood/frequency of the risk and severity/consequence of the risk occurring. The risk score ranges from 1–25. The risk rating depends on the risk score and can be low (<6), medium (6-9), high (10-15) and very high (>15). The findings of the inspection of the 12 tanks, conducted by the WSP Team according to the risk assessment matrix, are listed in Table 2.

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<sup>28</sup> The likelihood/frequency rating considered is: Almost certain/Once a day (5); Likely/Once a week (4); Moderate/Once a month (3); Unlikely/Once a year (2); and Rare/Once every five years (1).

<sup>29</sup> The severity/consequence rating considered is: Insignificant or no impact (1); Minor compliance impact (2); Moderate aesthetic impact (3); Major regulatory impact (4); and Catastrophic public health impact (5).

**Table 2 – Distribution system of water safety plan (WSP) risk assessment**

Sub-process steps	Hazardous events	Associated hazards and issues to consider	Risk analysis			
			Likelihood	Severity	Risk score	Risk ratings
Distribution maps and records	Out-of-date map of the WDS*: Inadequate mapping of distribution systems facilities	Technical hazards: Inability to locate appurtenances, prolonged faults diagnostic time, repairs and plant closure period in the event of system breakdown	2	3	6	Medium
Field samplings and measurements	Pressure at high and low points of the WDS not measured due to lack of pressure monitoring devices	High or low pressure; ingress of contamination	3	4	12	High
	U-metered supply in and out of the WDS	Unascertained level of service	5	3	15	High
		Under supply of water	3	3	9	Medium
		Loss of revenue	5	3	15	High
DS design and Maintenance: design/ material	The use of asbestos cement and ductile iron pipes in the distribution system	Contamination (chemical, microbial and cancerous conditions) due to usage of different pipe materials of water in the pipe line	4	2	8	Medium
Maintenance procedures: No inspection programme	Inoperable fire hydrant due to irregular inspection	No water supply in the event of fire	2	4	8	Medium
	No regular flushing of the mains	Microbial contamination	4	4	16	Very high
		Customer complaints	2	3	6	Medium
	Inoperable valves due to irregular inspection	No water supply	4	4	16	Very high
		Microbial due to stale water	4	5	20	Very high
Water loss elimination	Water loss not calculated causing ingress of contaminants and deposition of particles and rust materials due to low pressure and pipes carrying capacity	Loss of revenue and lack of planning data leading to systems inefficiency.	5	2	10	Medium
		Microbial	5	5	25	Very high
Storage type	Air and roof vents without screen causing direct entry of insects, lizards, bats and rodents into clear water tanks	Contamination	4	4	16	Very high
Storage location	Potential sanitary hazards near the storage tanks	Contamination	5	3	15	High



Storage tank minimum design components	Non-functional Water level measuring device; No alarm device for high or low water level	System inefficiency	5	1	5	Low
Storage tank cleaning and maintenance	No water supply to users during maintenance causing people to look for alternative source of water leading to outbreak of diseases.	Microbial	5	4	20	Very high
	Ingress of microorganisms and other contaminants due to cracks on the tank wall	Microbial	5	5	25	Very high
	Tank roofs overgrown with vegetation may cause contamination from worms, insects and rodents falling into the reservoir.	Microbial	5	5	25	Very high
	Water tank aerators without and torn screens causing contamination from worms, insects, and birds.	Microbial	5	5	25	Very high
	Rainwater accumulation and vegetal growth on reservoirs' roof causing contamination of water	Microbial	4	3	12	High
Site security	Tank sites cannot prohibit un-authorized access due to lack of and inefficient fencing, CCTV devices, and bushy surroundings.	Sabotage and vandalization of clear water tanks	3	3	9	Medium
		Microbial	3	5	15	High
		Loss of service	3	3	9	Medium
Pumping station location	Pump house at Tank 3 subject to flooding.	Contamination	3	4	12	High
	Inadequate lighting for security and maintenance impair visibility for security and safety.	Endangers operators, loss of service	5	3	15	High
	Water accumulation on the floor of the pump house. Inadequate ventilation in the pump house. Pumps and accessories not tagged	Poor environment and slippery floors	5	4	20	Very high
	Inadequate ventilation in the pump house.	Non-conductive working environment to operate and to make repairs	5	3	15	High

\* Water distribution system

Source: Sanitary Inspection Form I: the Distribution System, data collected and compiled by WSP team (NWRI).

#### 4. CONCLUSION

The FCT Water Board service within Abuja and surroundings is impressive. However, there is room for further improvement if the Water Board addresses the challenges and opportunities identified. It is the responsibility of the Water Board to implement the measures suggested to address the hazardous events identified during inspection. These hazardous events are risks of various impacts which together undermine a consistent safe water supply practice.

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## SESSION 6 PLANNING SUSTAINABLE URBAN WATER INFRASTRUCTURE

Overview by Franco Montalto

The world's fastest growing cities are in Africa and Asia. By 2050, more than half of global population growth will occur in Africa and more than half its population will be urban. For example, the population of Dar es Salaam, the capital of the United Republic of Tanzania, has increased by more than five million over the last 100 years. Due to its high growth rate, approximately 70% of its residents currently live in unplanned settlements; infrastructure and services are no longer able to meet their needs; wastewater management is very poor, and many informally developed areas are regularly flooded, as disaster risk management is inadequate.

While the older generations of water infrastructure in cities need to be upgraded, the world's newest cities represent an opportunity to realize new models for urban water infrastructure sustainability. Historical water infrastructure systems were planned for particular purposes, with the oldest systems designed principally for storm drainage. Next came drinking water systems, then wastewater disposal systems, followed by wastewater treatment systems, and much more recently, plans that focused on limiting total pollution loads and restoring specific ecosystems within the developed landscapes. Today, the focus has shifted to sustainable urban water infrastructure systems that equitably and cost-effectively provide drinking water, wastewater, and flood control services to users while minimizing negative impacts on ecosystems. In order to effectively address human needs, the design and layout of these critical infrastructure systems is tailored to reflect local customs and preferences. All three sets of considerations – economic, ecological, and social – should be simultaneously considered in the planning, design, and operation of sustainable water systems for cities.

As summarized by Wolff and Gleick (2002), there are two different paradigms for addressing water-related needs: The so-called 'hard path', which relies more on centralized decisions and infrastructure (such as pipelines, dams, reservoirs, water departments, agencies, etc.). The second, 'soft path', emphasizes on the research for innovative ways to meet a range of water needs, rather than focusing on merely supplying bulk water. Although water infrastructure decisions can be made solely based on 'expert knowledge', the 'soft path' involves intensive stakeholder input. Indeed, experts have much to learn from local stakeholders whose experiences, knowledge, and aspirations can help to identify locally appropriate (i.e. decentralized) solutions to water resource challenges. Local stakeholder support is also a key determinant in the successful operation and maintenance of urban water systems. Sustainable urban water management is thus conceived as a shift in management perspective that focuses less on mitigating threats, and more on identifying local opportunities.

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## GHANA

### The challenges of potable water provision in the context of rapid urbanization: The case of Accra

by Kwabena Asare Gyasi-Duku

#### 1. INTRODUCTION

An increasing number of people are moving into urban areas and cities in search of job opportunities and better living conditions. This process is usually referred to as urbanization. It is expected that between 2009 and 2050, the world population will increase by 2.3 billion, from 6.8 to 9.1 billion. At the same time, urban population is projected to increase by 2.9 billion, from 3.4 billion in 2009 to 6.3 billion in 2050 (WWAP, 2012).

Population growth is therefore becoming largely an urban phenomenon concentrated in the developing world. Rapid urbanization poses a serious challenge to most developing countries, including African countries. Most African cities are not able to provide basic amenities for the increased population. The exploding urban population growth leads to the development of slums that churn out a unique set of unprecedented challenges, among which provision for water and sanitation have been the most pressing and painfully felt when lacking (WWAP, 2012).

In Ghana, the rural–urban migration is rising continuously. According to the 2010 Population Housing and Census, the proportion of urban population rose from 43.8% in 2000 to 50.9% in 2010, with the capital Accra recording the highest percentage increase (GSS, 2013). The inter-censal growth rate for the region was estimated as 3.1% and population increment was estimated at 38% which exceeded the national average of 30.4% (GSS, 2013).

#### 2. ACCRA'S CONTEXT

Accra is the capital and largest city of Ghana, with an estimated urban population of 2.07 million (GSS, 2013). The city is not only the economic nerve centre of the Greater Accra Region, but also of the whole country and attracts many migrant workers looking for better jobs and opportunities. The majority of economically active population are engaged in the primary, secondary and tertiary sectors. They work in occupations or jobs such as trading, construction, fishing, farming, services, and manufacturing, among others. The indigenous peoples were, until recently, mostly engaged in fishing and farming (GSS, 2013).

During the last 20 years, Accra has sprawled beyond its boundaries as a result of the constant increase in population.

Potable water supply to the city of Accra and its surrounding area consists of piped water from the Weija dam on the Densu River, the Kpong treatment plant on the Volta River and the newly installed seawater desalination plant, at Teshie (Adank et al., 2014). These systems are managed by the Ghana Water Company Limited (GWCL).<sup>30</sup> There are also a number of small town water supply systems that have been established with the support of the Community Water and Sanitation Agency (CWSA)<sup>31</sup> that are being community managed.

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<sup>30</sup> Ghana Water Company Limited is a 100% state-owned company who responsible for the provision of water to urban areas and operates 86 systems nationwide.

<sup>31</sup> Community Water and Sanitation Agency is a government agency that facilitates the provision of safe water and related sanitation services to rural communities and small towns.

The estimated water coverage as at December 2012, based on the production capacities of the facilities mentioned above was 63% (Government of Ghana, n.d.),<sup>32</sup> thereby leaving a supply shortfall of almost 37%.

The continuous exponential increase in population growth has enormous consequences on human health and well-being, safety, the environment, economic growth and development. It exerts a lot of pressure on the already stretched infrastructure, particularly housing, water supply and environmental sanitation.

The lack of adequate water and sanitation facilities is at the origin of diseases, such as diarrhoea, malaria and cholera. The cholera outbreak in Accra in June 2014, the worst since the early eighties, can be attributed to a lack of inadequate access to WASH facilities and services (WHO, 2015).

This case study aims to briefly examine some of the challenges affecting the provision of WASH facilities within Ghana and what can be done to address them in order not to worsen the supply and demand gap as the urban population continues to increase.

### **3. CHALLENGES FACING THE PROVISION OF POTABLE WATER IN ACCRA**

#### **3.1 Financial challenges**

##### **3.1.1 Inadequate funding**

Water supply projects are generally capital intensive and in many cases, acquiring funding has proven to be a difficult task for most African countries, including Ghana. Historical data show that sanitation and drinkable water projects received more than 8% of the total Official Development Assistance (ODA) to developing countries in 1997. At that time, other social infrastructure sectors, such as health, education, population and reproductive health, received lower proportions of aid compared with sanitation and drinking water. However, between 1997 and 2008, the proportion of development aid allocated to sanitation and drinking water fell from 8% to 5%, while development aid allocated to health increased from 7% to 12%, and that for education remained steady at around 7% (WHO, 2010).

In the urban water sector of Ghana, a Water Sector Strategic Development Plan (WSSDP) has been prepared to allow for the systematic development of all urban water supply systems in the country. It is estimated in the WSSDP that about US\$3.8 billion will have to be invested if current urban coverage is to be increased to 100% country-wide by 2025 (MWRWH, 2014). Analysis indicate that if the desired coverage levels are to be achieved over time, then about US\$270 million should be invested annually in the urban water sector infrastructure development. However, the average amount of investments over the past years cover only 53% of the investments needed (MOFEP/MLGRD/MWRWH, 2010).

##### **3.1.2 Low capital cost recovery**

Most utility companies in Africa lack the financial resources to expand their infrastructure to meet the ever growing demand, and also to address the major challenge of consumers' failure to pay for their water consumption. Until recently, most countries and donor agencies treated water supply and sanitation as a public good, and pricing was not dictated by market forces. This means that the pricing of water by the regulatory bodies does not cover a full cost recovery since they consider water as a social good rather than an economic good (Okonkwo, 2010).

The inappropriate allocation of government subsidies has also affected government plans for increasing access to water and sanitation, as subsidies did not reach those who needed them.

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<sup>32</sup> Water coverage figure computed is based on the capacities of the systems and per capita water demand according to GWCL and CWSA Standards and Guidelines.

In Ghana, water tariffs are set by the Public Utilities Regulatory Commission (PURC). The set water tariff should address issues of cross-subsidy and the needs of the poor. Table 1 provides an overview of the current water tariffs of the PURC.

**Table 1 - Gazetted tariffs for water consumption\***

Consumption categories (m <sup>3</sup> )	Monthly consumption per 1 000 litres m <sup>3</sup>	Rate (in GHS**) Approved rate	Rate (in US\$) Approved rate
Metered domestic	0-20 (Life line)	1 783	0.557
	21 and above	2 673	0.835
Public institutions/Government departments	Flat	3 429	1.072
Unmetered premises – Flat rate per house per month		11 607	3.627
Premises without connection (public stand pipes per 1 000 litres)		1 763	0.551
Special commercial per 1 000 litres		10 806	3.377
Commercial/Industrial	Flat	3 800	1.188

NB: Special commercial refers to bulk customers who use Ghana Water Company Limited treated water as the main raw material for bottling water for resale.

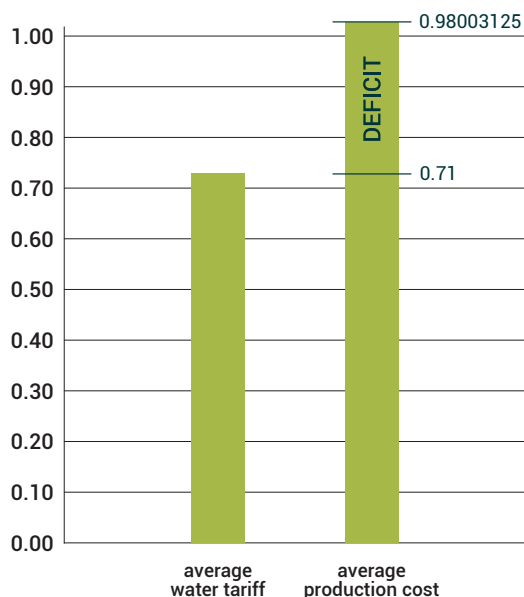
\* Effective July 2015 billing cycle.

\*\* Ghana Pesewas

Source: Adapted from PURC (2015).

The average tariff per m<sup>3</sup> of water is GHS 2.27 (US\$0.71). However, the average cost of producing a cubic meter of water by the Ghana Water Company Limited is GHS 2.453.1361 (US\$0.7798). The pricing therefore makes it difficult for the company to breakeven. The situation becomes worse when physical and commercial losses are also considered. Figure 1 explains the disparity between the cost of production and tariffs.

**Figure 1 – Average production cost versus average tariff for one cubic meter of water**



Exchange rate US\$1 = GHS 3.2 (July 2015)

Source: Author, based on PURC (2013).



## 3.2 Technical challenges

### 3.2.1 Non-revenue water and overage infrastructures

Centralized water supply networks are very cost intensive in terms of construction, operation and maintenance. Insufficiently maintained networks deteriorate and leakages appear over time leading to water losses within the system. These losses result in irregular water supplies and low revenue collection for the utilities. Most African cities suffer from chronic water shortages due to water losses within their systems, which sometimes reach up to 60% of the volume of water supplied (UNESCO/Veolia Water/Programme Solidarité-Eau, 2004).

In Ghana, non-revenue water losses – both physical and commercial – account for almost 46.37% of the volume of water produced (PURC, 2013). Even though the trend seems to be slowing down in the last five years, significant efforts should be done to bring the levels within international benchmarks.

### 3.2.2 Spatial planning – sprawling slums and shanty settlements

The consequence of a lack of a proper urban planning in developing countries is that they have no clearly defined boundaries. The development of sprawling peri-urban communities (slums or shanty settlements) is characteristic of many African urban cities, such as Accra, Kampala and Lagos. These settlements are informal and not guided by urban planning and development, and render the provision of water supply to its residents cumbersome, difficult and capital intensive.

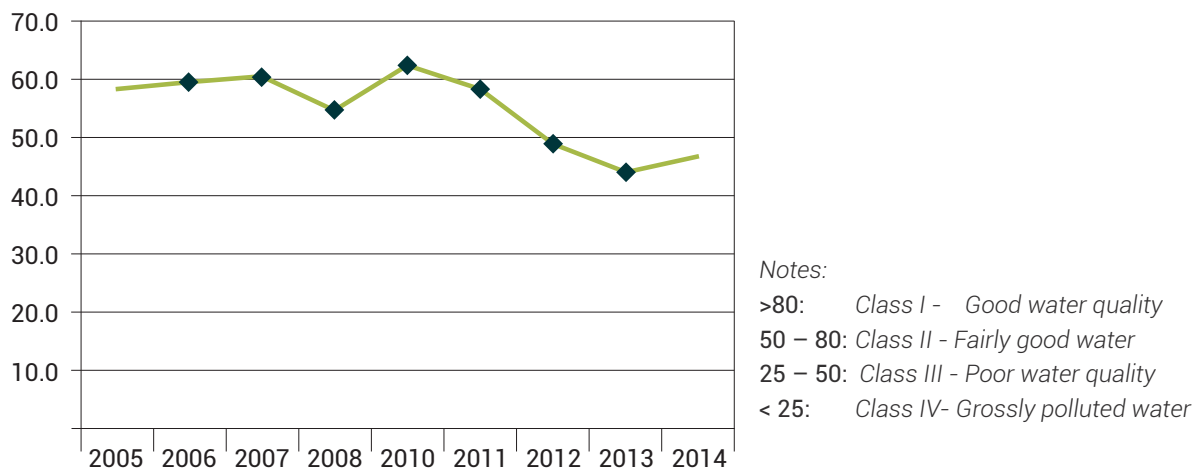
In Accra, it is estimated that 43% of the population live in slums (Next City, n.d.). These low-income neighbourhoods are characterized by a high population density, poor infrastructures, including low housing quality, informal businesses, and an irregular development without any planning and built with limited scope for expansion.

### 3.2.3 Pollution of water resources

Inadequate supply of water is not the only water problem facing African countries, but also the pollution of water bodies, which severely impacts the quality of raw water. It is common knowledge that industrial pollutants are disposed of into lakes, rivers and other surface water bodies despite the legislation banning this practice. The increase in solid waste and wastewater generated by urban areas will place further pressure on water quality and on urban drainage, further complicating efforts to secure an adequate supply of clean water to a thirsty population. In fact, "it is estimated that more than 90% of sewage in the developing world is discharged directly into rivers, lakes and coastal waters without treatment of any kind" (Luethi et al., 2009, p. 453).

In Ghana, studies and reports emanating from the Water Resources Commission indicate that the quality of freshwater bodies is gradually deteriorating (Figure 2). This is due to the increased encroachment and human activities within water bodies, such as illegal and small-scale mining. The activities of illegal miners are located within and along surface water bodies. Mercury and other harmful chemicals are dumped into the water bodies and deteriorate the quality of water and making it expensive to treat for consumption.

Figure 2 – Average water quality index of 38 major river basins



Source: Author, adapted from WRC (2015).

### Box 1. Adapted Water Quality Index

The adapted Water Quality Index (WQI) is used as a tool to classify the overall ambient water quality of freshwater bodies in Ghana. The index classified water quality into one of four categories:

- I – Good (Class I, >80)
- II – Fairly good (Class II, 50 - 80)
- III – Poor (Class III, 25 - 50)
- IV – Grossly polluted (Class IV, <25)

Ten water quality parameters are used to determine the water quality index (WQI): Dissolved Oxygen (DO % Saturation), Biochemical Oxygen Demand (BOD), Ammonium Nitrogen (NH<sub>4</sub>-N), Faecal Coliform (FC), pH, Nitrate as Nitrogen (NO<sub>3</sub>-N), Phosphate as Phosphorus (PO<sub>4</sub>-P), Total Suspended Solids (TSS), Conductivity and Temperature.

Source: Author, adapted from WRC (2015).

### 3.3 Climatic changes and decrease in rainfall

As water demand grows, water resources become scarcer. More than 40% of Africans live in arid, semi-arid and dry sub-humid areas. The amount of water available per person in Africa is far below the global average and is even declining with an annual per capita availability of 4,000 m<sup>3</sup> compared to a global average of 6,500 m<sup>3</sup>. Drought is endemic to many regions and repeated drought cycles kill thousands of people each year. In addition, the groundwater table is being lowered and rainfall is declining in many regions (Jacobsen et al., 2012).

In Ghana, climatic conditions over the last decade or more have been aggravated by the changing weather patterns in the form of erratic rainfalls and extreme droughts conditions, or both. An assessment of rainfall departure plots over the last 50 years shows that there has been a decline in rainfall and an extension of the dry season (Nkrumah et al., 2014). This situation may affect the volumes of both surface and groundwater in time.

## 4. RECOMMENDATIONS

### 4.1 Decentralized water supply systems

Decentralized water supply systems offer increased opportunities for local stakeholder participation in planning and decision-making. These systems can be community managed and may not require enormous financial investments. They are also easier to operate and maintain since they are manageable in terms of size. The 'Small Town Water Supply System' concept implemented by the CWSA is a good example of decentralised water supply systems. According to the concept, communities and towns are prepared to manage their water supply systems in an efficient and sustainable manner. As of December 2014, 327 small town pipe water schemes have been developed (CWSA, 2014).

### 4.2 Private sector participation

Public service providers, more particularly in developing countries, are often unable to keep up with the urban population growth as they face a double challenge of maintaining on one hand, the existing and often deteriorated networks, and on the other, extending the services to the rapidly growing settlements on the periphery of the cities. One of the solutions to improve service delivery is the engagement of the private sector. For example, in Ghana, the construction of water facilities, as well as the provision of spare parts for water supply systems, is mainly carried out by the private sector. In most cases, they have been engaged to manage water supply systems on behalf of small towns and communities. Most of the thriving small towns in the country, such as Bekwai and Atebubu, have their water supply systems managed by the private sector (Tuffuor, 2010).

### 4.3 Financial sustainability

If water supply and sanitation solutions are to be sustainable, they need to remain operative over time. This requires, among others, sufficiently high investments in the water sector and sound financial planning. Even though funding is difficult, there is the need for governments and development partners to continue to invest in water supply projects since their economic and social benefits are quite high.

### 4.4 Public private partnerships

A stronger partnership between the private sector and governments is needed in the field of the delivery of water supply projects or interventions. Governments should provide the conditions that will make countries investment friendly and also create an environment to gain the confidence of the private sector to become partners with the government in water supply projects.

Implementing projects on Private Placement Platforms (PPP), releases the burden of funding from the government and also fosters collaboration with the private sector in the delivery of water services to the public. To enhance the PPP concept, the government has established a Public Investment Division at the Ministry of Finance to guide public investment decisions and to facilitate PPP projects within the country. The 13 million gallons per day desalination water treatment plant at Teshie is an example of a PPP project (Government of Ghana, n.d.).

## 5. CONCLUSION

Population growth and urbanisation is inevitable. It therefore behoves on all stakeholders to find pragmatic ways to address its impact on water supply services.

The government alone cannot continue to bear the burden of the cost of investments as well as the operation and maintenance of the water infrastructure. Alternative sources of funding, such

as PPP and the active engagement of the private sector, can harness resources and potential to overcome the challenges associated with urban water supply in cities such as including Accra.

Additionally, appropriate service delivery models, such as decentralised water systems and community managed water schemes, could be explored to enhance the efficient and effective management of water schemes.

Moreover, utility companies should make an effort to reduce the volume of non-revenue water, the savings of which could be used to maintain and expand the existing infrastructure.

All these options will yield the necessary results, if there is a conducive environment and a tariff structure that will allow utility companies to recover their production costs.

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## Annex 1 - Synoptic table of challenges and policy responses

Country	Subject	Area description	Challenges	Policy responses (implemented/suggested)
Botswana	The irrigation sector: increasing efficiency of water allocation, water supply and demand management.	Botswana is located in the sub-tropical high pressure belt of the Southern Hemisphere in the interior of Southern Africa and away from oceanic influences. The country is characterized by scarce water resources and high temperatures. Rainfall is around 400 mm on an average year; the dry period lasts from May to October, while the temperatures go from 26.5°C during the warmest period to 15°C in the coldest month. There is, therefore high inter-annual variability of rainfall and drought is a recurring element of its climate.	<ul style="list-style-type: none"> <li>• Low efficiency of the irrigation sector due to the technology used (drip or sprinkler systems) and lack of effective tariffs which encourages an efficient use of water resources particularly in agriculture.</li> <li>• Water allocation need to improve among competing sectors on the basis of the value added (agriculture uses almost 45% of the total water consumption, mining around 20% and manufacturing about 2%).</li> <li>• Alternative water sources such as wastewater need to be explored to face water scarcity.</li> <li>• Lack of data on irrigation (i.e.: water consumption, irrigation system used and size of available land).</li> <li>• Improve collaboration between departments within the Ministry of Agriculture as well as greater collaboration with the department of Water Affairs.</li> </ul>	<ul style="list-style-type: none"> <li>• In 2003, the National Master Plan for Sanitation and Wastewater, entered into force. In 2013, the government created the National IWRM - Water Efficiency Plan. Both aim at increasing the use of treated wastewater.</li> <li>• More investments by the Government for irrigation schemes using wastewater are needed; thus the use of treated effluent would grow and reduce the pressure on potable water.</li> <li>• Improved data would improve irrigation and allow performance assessments, therefore it is imperative that further work is undertaken to improve the data collection and information in agriculture.</li> <li>• A national survey on irrigation farms (government owned and private) in both the traditional and commercial sectors should be carried out to quantify the following: the dimension of land available for irrigation, water abstraction for irrigation, water use, production and returns, how much is actually cultivated and irrigated, the applied irrigation systems and the expenditures associated with the farms.</li> </ul>

Contributed by Ilaria Marini and Angela Renata Cordeiro Ortigara (WWAP).



<p><b>Tanzania</b></p>	<p>Competing water uses and conflicts in Great Ruaha Catchment.</p>	<p>Tanzania is located in Southern – East Africa, bordered on the East, by the Indian Ocean. Rainfall occurs mainly during the wet period (from December to April). The average temperature goes from 20°C, during the coldest period, to slightly more than 24°C in the warmest period.</p> <p>The Great Ruaha catchment is the upper catchment of Rufiji basin and it covers an area of 85,554 km<sup>2</sup>. The annual rainfall ranges from 400 to 1 200 mm/yr.</p>	<ul style="list-style-type: none"> <li>• Defragmentation of water resources management plans among different sectors is leading to conflicts between different water users.</li> <li>• Financial constraints for water resources management institutions especially water user associations (WUAs) hinders accountability (the ability to accomplish duties and responsibility) also leading to conflicts.</li> <li>• The inconsistency of hydrological data hinders water allocation.</li> <li>• Climate change is causing an increase of evapotranspiration which reduces the flow of most of the rivers leading to water use related conflicts.</li> </ul>	<ul style="list-style-type: none"> <li>• In 2009 the Water Resources Management Act No. 11 entered into force, aiming to restrict abstraction of water resources without water use permit. However, few villages adopted the Land Use Plans which would guide the local use of land and water resources.</li> <li>• In the Great Ruaha catchment, there are 28 water user associations (WUAs) who have a key role in resolution of conflicts among users and they have helped the enforcement of the Water Resources Management Act.</li> <li>• IWRM and Development Plan are on the final stages of preparation under the Ministry of Water; they aim to function as a tool for sustainable water resources management.</li> <li>• The Payment for Ecosystem Services (PES) will encourage downstream water users to allocate some financial resources for upstream users, explore new water sources (such as groundwater) and implement policy tools, such as the declaration of a moratorium on new irrigation permits in water stressed areas, has been promoted until irrigation efficiency target is achieved.</li> </ul>
<p><b>Mozambique</b></p>	<p>Preliminary study about desalination of boreholes in Chigubo district, located in Gaza Province.</p>	<p>Mozambique is a country located in Southern- East Africa, lying on the Indian Ocean coasts. It is affected by drought and flood cycles. Temperatures are quite constant throughout the year: from 20°C in July, the coldest month, to 26°C in December, the warmest. Rainy seasons last from December to March, during which the average rainfall exceeds 700 mm. The District of Chigubo is located in the Northern area of Gaza Province. The climate of the district is arid with an average annual rainfall less than 500 mm/yr and evapotranspiration of more than 1 500 mm/yr. Most of the region has average temperatures exceeding 24°C.</p>	<p>Prolonged drought in the northern region of Gaza Province:</p> <ul style="list-style-type: none"> <li>• Most of Chigubo District has been characterized lately by a critical period of water shortage for human consumption, livestock drinking and agriculture practice;</li> <li>• Wells and boreholes supplying drinking water for the local population are brackish, contains salinity which exceeds normal limits for human consumption (e.g. salts, chlorides and carbonates), endangering the health of the communities, food security and increasing poverty levels.</li> </ul>	<ul style="list-style-type: none"> <li>• Research has been done to assess the quality of drinking water. Analyses underlined the need for future interventions;</li> <li>• The Water Research Institute, in collaboration with the Eduardo Mondlane University, promoted a study for the implementation of a water desalination project and the establishment of small systems for water purification in local communities. Further plans could focus on the installation of water supply and treatment systems in key locations in order to provide the population safe drinking water for consumption;</li> <li>• Employment of low-cost technologies for water purification in communities would contribute in the improvement of the quality of water, such as constructing of boreholes with insulation of salty aquifers and adoption of sustainable infrastructure.</li> </ul>

<p><b>South Sudan</b></p>	<p>Water harvesting structures for sustainable livelihoods and peace building in South Sudan.</p>	<p>South Sudan is a country located in the heart of Africa, with no direct access to the sea. It has a climate characterized by a rainy season which goes from June to September, with an average rainfall of 300 mm. The rest of the year can be considered as a wet period. Temperatures do not vary much during the year; during the coldest period (from December to February), they are above 20°C. During the rest of the year they exceed 25°C, reaching more than 30°C in May and June.</p>	<ul style="list-style-type: none"> <li>• Many rural communities suffer from water scarcity, droughts and floods despite the vast water reserves of the Nile basin.</li> <li>• In South Sudan, water-harvesting structures are sensitive to environment conditions. Therefore, highly variable rainfalls patterns, both in terms of quantity and intensity influence the performance of water – harvesting structures.</li> <li>• Deficient management of existing haffirs<sup>33</sup> present impacts on the environment including: depletion of fresh water resources by both domestic and wildlife; bacteriological, chemical and physical degradation of the quality of stored water ; land and ecosystem degradation and endangered sustainability of the biosphere.</li> <li>• Existing haffirs can affect human safety, cause health hazards and increase undesirable adverse implications for youth pastoralists.</li> <li>• Reduction of life span of haffirs from sedimentation and increased water demand resulting from positive or over use of the service.</li> <li>• The water sector is very important in South Sudan; in fact, improving the management of water resources could help mitigate conflicts among different communities.</li> </ul>	<ul style="list-style-type: none"> <li>• The Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) decided to construct water storage facilities (haffirs) in most of the areas where conflicts due to utilization of scarce water resources are predominant.</li> <li>• In order to develop future water harvesting interventions, the European Sustainable Energy Innovation Alliance (ESEIA) will perform a feasibility study. This aims to determining the likely effects (short and long term) on the communities. Furthermore, it would analyse and estimate demand levels, water losses, effects of seasonal rainfall patterns and ensure an adequate design and storage capacity.</li> <li>• The Development of Water Resources Master Plan is needed to promote effective Water Resources Management in South Sudan.</li> </ul>
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<sup>33</sup> Haffirs are man-made ground reservoirs from water diverted during the rainy season at in the earth at suitable locations to store water for drinking purposes for both human and livestock uses. The concept is that water running in natural streams during rainy season is diverted at certain suitable locations into these haffirs.

<p><b>Swaziland</b></p>	<p>The sand dams technology as a means of adapting to the impacts of extreme conditions.</p>	<p>Swaziland lies in Southern Africa and it has no direct access to the Indian Ocean. Its annual rainfall is around 800 mm per year. The average temperature goes from 15°C in winter (June and July are the coldest months) to 24°C, in summer, January and February are the warmest months.</p> <p>Swaziland has several rivers flow through the country, such as the Great Usutu River, the Lubombo, the Ngwavuma, the Usutu and the Mbuluzi River.</p>	<ul style="list-style-type: none"> <li>• The water demand has increased in the last decade due to population growth, higher domestic water use, decrease conditions of catchments, expanding agriculture and climate change effects;</li> <li>• In arid areas, there is a lack of water abstraction facilities and water demand is high, both for domestic use as well as for livestock.</li> </ul>	<ul style="list-style-type: none"> <li>• A project entitled 'Adapting national and trans-boundary water resource management in Swaziland to manage the expected impacts of climate change' has supported grass root level adaptation projects amongst which was the construction of sand dams in five ephemeral streams in very arid rural areas of the country. This project was promoted by the Department of Water Affairs with the financial support of the United Nations Development Programme (UNDP) and the Global Environmental Facility (GEF).</li> <li>• Communities involvement has proven to be the key factor in successful construction and maintenance of these dams.</li> <li>• Water has been identified as key for domestic consumption, and a driver for sustainable agricultural production. It has been used for downstream development projects which have complemented the country's efforts toward food security while diversifying income revenue streams mainly for rural communities.</li> </ul>
<p><b>Botswana</b></p>	<p>Effluent utilization through a constructed wetland system at Department of Water Affairs (DWA) Headquarters.</p>	<p>Botswana is located in the sub-tropical high pressure belt of the Southern Hemisphere in the interior of Southern Africa and away from oceanic influences. The country is characterized by scarce water resources and high temperatures. Rainfall is around 400 mm on an average year, the dry period lasts from May to October, while the temperatures go from 26.5°C during the warmest period to 15°C in the coldest month. There is, therefore high inter-annual variability of rainfall and drought is a recurring element of its climate</p>	<p>The wastewater from DWA HQ toilets and the neighbouring settlement is treated physically through the use of septic tanks and grit removers and after separation, it passes through a reed bed system (constructed wetlands, or CW). After the biological treatment the effluent goes to the collection chamber where disinfection takes place. Then, the water is stored and used for irrigation of the DWA landscape, horticulture and the orchard. The CW system is coupled to a mini reverse osmosis plant that provides further treatment of the wastewater to the drinking water quality requirements. The main challenges facing in the operation are:</p> <ul style="list-style-type: none"> <li>• Shortage of funds and skilled manpower challenges the Department of Water Affairs (DWA) in the operation and maintenance of the constructed wetland system (e.g. pumps clogging, plants overgrow);</li> <li>• Treating this effluent for drinking purposes is a challenge due to the low social acceptability by the general public.</li> </ul>	<ul style="list-style-type: none"> <li>• The implementation of the Integrated Water Resources Management/Water Efficiency (IWRM/WE) plan will assist in increasing the uptake of Water Conservation and Demand Management (WC&amp;DM) principles. The plan is advocating for increased Water Demand Management (WDM), rainwater harvesting, improved water saving technologies and accelerated reuse and recycling of treated effluent.</li> <li>• Increase the budget allocated for the maintenance of the wetland system to improve the operations and ensure the maintenance of the reed bed system.</li> <li>• Intensive public education and awareness campaigns promoting WC&amp;DM principles, effluent utilization and water quality, will enhance uptake by the stakeholders; Improving the existing laboratories and facilities would help to build stakeholders' confidence on the use of recycled water.</li> </ul>

<p><b>Tanzania</b></p>	<p>Managing water resources.</p>	<p>Tanzania is located in Southern – East Africa; and on the East, it is bordered by the Indian Ocean. Rainfall occurs mainly during the wet period (from December to April). The average temperature goes from 20°C, during the coldest period, to slightly more than 24°C in the warmest period. Tanzania is characterized by nine water basins.</p>	<p>This study has highlighted the following challenges in the management of water resources in Tanzania:</p> <ul style="list-style-type: none"> <li>• Inadequate human resources in terms of both amount and required skills/professions;</li> <li>• Lack of adequate funding and lack of planning for its allocation;</li> <li>• Lack of proper data management framework from data collection to data analysis and implementation of the observed results;</li> <li>• Poor understanding of the society about water resources management principles and values;</li> <li>• Inadequate awareness on water resources management among different societies;</li> <li>• Poor legal enforcement.</li> </ul>	<p>Suggested future actions:</p> <ul style="list-style-type: none"> <li>• Human resources recruitment and development should be done periodically as needs arise;</li> <li>• Awareness raising and legal enforcement should be given priority by each of the Basin Water Boards in order to protect water sources from deterioration caused by human activities;</li> <li>• Effective monitoring is needed to detect and assess the hydrologic alterations of climate change;</li> <li>• Development of adaptation strategies to climate change effects.</li> </ul>
<p><b>Cabo Verde</b></p>	<p>Vulnerability and pollution risks of underground waters on the Island of Santiago.</p>	<p>Cabo Verde has 10 islands lying in the Atlantic Ocean in front of the African coasts. The main island is Santiago; it is mountainous, although slightly flatter in the southeast. The wetter climate of the interior and the eastern coast contrasts with the drier one in the south/southwest coast. Yearly average rainfall exceeds 350 mm and the temperature goes from 20°C during the coldest month to 26°C in September, the warmest month.</p>	<ul style="list-style-type: none"> <li>• The limited availability of surface water, combined with low and irregular rainfall, explains the heavy reliance of the inhabitants on groundwater.</li> <li>• The increasing use of groundwater is considered strategic since there is a reduction of the volume of drinking water and consequent demand of dumps settlement, and the salinization and contamination of coastal aquifers.</li> <li>• Groundwater on the island of Santiago has been progressively overexploited supplying the various water needs in the several municipalities and communities as well as in residential autonomous systems, industries, services, irrigation and recreation.</li> </ul>	<ul style="list-style-type: none"> <li>• Different methodologies /models can be used to access the vulnerability of surface and groundwater resources.</li> <li>• In this case, DRASTIC index was used taking into consideration seven hydrogeological parameters or indicators: D - Depth to groundwater; R - Recharge; A – Aquifer media; S - Soil media; T – Topography; I – Impact of the unsaturated zone; C - Hydraulic Conductivity.</li> <li>• The reliability and consistency of data is very important for the use of any model. In Cabo Verde, water data are collected by the National Water and Sanitation Agency (previous National Institute for Water Resources Management - INGRH).</li> </ul>
<p><b>Nigeria</b></p>	<p>Inspection of Service Reservoirs at Federal Capital Territory (FCT), Abuja.</p>	<p>Nigeria is characterized by a very warm period; temperatures can exceed 30°C in April, the warmest month. Just after, a wet period follows, it lasts from June to October (the average rainfall for these months is 900 mm) with temperature around 27°C.</p>	<p>The Lower Usuma Dam Water Treatment Plants and distribution system are providing good service, however, some challenges remain:</p> <ul style="list-style-type: none"> <li>• Environmental sanitation around the service reservoirs requires attention;</li> <li>• Lack of maintenance in water reservoirs promotes water leakages and can lead to possible contamination;</li> <li>• Lack of a monitoring program for the reticulation system and for at point of use is absent;</li> <li>• Systems do not reach some parts of Abuja: residents living in these areas have to rely on boreholes and water vendors;</li> <li>• Low water pressure is experienced in some places in Abuja.</li> </ul>	<ul style="list-style-type: none"> <li>• Inspections of the Water Distribution System (WDS) are carried out to determine capability of the distribution system to provide a safe, reliable and adequate supply of drinking water to the customers.</li> <li>• Federal Capital Territory (FCT) Water Board is responsible for the implementation of the measures suggested by the inspections: i.e. to address the hazardous events identified.</li> </ul>



This book – the second of three volumes – contains a collection of case studies from nine African countries selected during the Training Workshop on Capacity Development on Water and Sustainable Development, organized by UN WWAP UNESCO in October 2015. This activity was realized under the project “Capacity Development of Workers in the Water Sector” funded by the Arab Gulf Development Fund (AGFUND).

The training programme was aimed at providing water professionals with tools for: identifying, maintaining and assessing data that may improve water management; managing water resources in a way that ensures a rational allocation of water among competing users; preserving ecosystems; mitigating the effects of extreme events such as floods and droughts on water supply and treatment; and facing the challenges associated with the achievement of an efficient, effective and equitable water resources management, transboundary water management and growing urban environments.

Each case study covers a different aspect of the path that will lead to sustainable management of water resources, highlighting challenges and solutions adopted by the country. The discussions that ensued were enriching for both participants and professors alike, which demonstrated the importance of exchanging information and comparing the challenges in diverse realities.