Water accounts of Botswana (1992-2003)

**Prepared by the
Department of Environmental Affairs
in association with the
Centre for Applied Research**

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Acronyms

BNWMP	Botswana National Water Master Plan
CAR	Centre for Applied Research
DC	District Council
DWA	Department of Water Affairs
DSWM	Department of Sanitation and Waste Management
DWMPC	Department of Waste Management and Pollution Control
IWRM	Integrated Water Resource Management
EIA	Environmental Impact Assessment
NAR	National Asset Registry
NDP	National Development Plan
NMPSWW	National Master Plan for Sanitation and Wastewater
NRA	Natural Resource Accounting
NSWC	North-South Water Carrier
O & M	Operation and Maintenance
P	Pula (Botswana's currency)
RBC	Rotating Biological Contractors treatment
SADC	Southern African Development Community
SEEA	System for Economic and Environmental Accounting
UAL	Un-Accounted Losses
VA	Value Added
WA	Water Authority
WAB	Water Apportionment Board
WARFSA	Water Research Fund for Southern Africa
WUC	Water Utilities Corporation
WW	WasteWater
WWTW	WasteWater Treatment Works

EXECUTIVE SUMMARY

This report discusses the state of water accounting in Botswana and the policy implications that are derived from the results. Botswana has had water accounts since 2000, which were recently further developed. Recently, wastewater accounts were constructed and this report therefore presents both water and wastewater accounts in Botswana.

Water resources were selected for account development as they are vital to the country and they are becoming increasingly scarce. At the same time, the amount of wastewater is increasing due to the construction of more wastewater treatment works (WWTW) and improved sanitation.

The complete Natural Resource Accounting framework comprises stock and use accounts as well as water quality accounts. These accounts occur in physical (e.g. kg, m^3) and monetary (e.g. Pula or $) format, physical and monetary accounts. Few countries have comprehensive accounts. Botswana currently has limited stock accounts (for dams and partial accounts for groundwater), three use accounts (by institution, economic sector and source). In addition, three wastewater accounts exist for stock, supply and use respectively. Most accounts cover the period 1990-2003. Some are shorter due to data limitations (1992-2003 and 2001-2003). The longer the time period of the accounts is the more meaningful they become for analysis and policy. All accounts are physical; monetary accounts do not exist due to data limitations.

The stock accounts show that the stock of surface water has increased in time due to the construction of new dams, but that there are significant inter annual and spatial fluctuations (Table 4.1 and Figure 4.2). Groundwater stock accounts are incomplete, but the available figures suggest that abstraction from well fields is much higher than the recharge (Table 4.2). Further investigation is necessary on the recharge of well fields and of the abstractable stock of groundwater.

The use accounts show an increase in water use from 140 Mm^3 in 1990 to 170 Mm^3 in 2003. Self providers (86 Mm^3) the main institutions supplying water followed by WUC (50 Mm^3), District Councils (22 Mm^3) and DWA (12 Mm^3). WUC water supply has grown significantly due to the North-South Water Carrier and growing urban use. The use account by source shows that the use of surface water is growing faster than that of groundwater, but groundwater continues to provide 56% of the total water use. The use account by sector shows that the agricultural sector is the largest water consumer (63 Mm^3), followed by households (57 Mm^3), mining (27 Mm^3) and government (12 Mm^3). The trend in water use by sector is, however, quite distinct. Water use of the mining sector, government and households is growing rapidly while that of agriculture is fairly stagnant (though volatile).

The wastewater supply accounts (Table A2.5) show that the supply of wastewater to treatment works more than doubled during the same period from 14 Mm^3 in 1992 to 29 Mm^3 in 2003. Urban areas generate the bulk of the wastewater (25 Mm^3 in 2003) but some 4 Mm^3 of wastewater are now available in rural areas. The supply of wastewater will further increase in future due to the construction of treatment works in large rural villages and improved living standards. The wastewater use account (Table A2.6) shows that nothing is recycled and only a fraction is re-used (3 Mm^3). Most wastewater is lost during treatment or discharged into the environment. The wastewater stock accounts are not important as only a small amount is stored in maturation ponds (less than 4 Mm^3).

Although no monetary accounts were prepared, the physical accounts have been used to estimate water use efficiency. The estimates show that the service sector and the construction industry have the highest efficiency in terms of value added/ m^3 (over P1 000/m^3). Government and the mining sector have a considerably lower value added (P 200-300/m^3), and agriculture has the lowest value added around P 5/m^3). The picture is slightly more favourable for agriculture if efficiency is measured as employment/m^3, but does not alter fundamentally. The agricultural sector is a large water user with relatively limited production outputs. From a production perspective, the rapid increase in water use by households also poses problems, as it leaves less water for productive uses. Re-use of wastewater in these sectors would benefit production and economic growth.

The water use accounts show that water consumption has increased to 170 Mm^3 in 2003. An estimated 29.2 Mm^3 of that consumption was returned to WWTW in cities, towns and major villages (16% of water consumption) with an estimated outflow from those WWTW of 14.5 Mm^3 (8.5% of water consumption). The estimated amount of re-use is 1.6 Mm^3 in 2003, representing 11% of the outflow of WWTW and less than 1% of total water consumption. The survey of small scale re-use in Gaborone indicated that 0.1 Mm^3 may be collected, currently posing no threat to large scale uses such as the new irrigation scheme in Glenn-Valley. The amount of 'new water' will increase in future because of introduction of treatment technologies with considerably lower water losses than the pond technology, construction of more WWTWs and more connections to the sewerage system of households and businesses.

Water accounts are useful for policy makers in several respects. The accounts show:

- The trend in water production and consumption that can be used to validate (and when needed improve) water demand scenarios of BNWMP;
- The most important users and their trends in water consumption. These should be priorities of water management and planning. For example, the rapid growth of water use in the mining sector needs to be addressed;
- The fast growth in wastewater supply, particularly in south-eastern Botswana. They further show the absence of recycling and very limited re-use. Both need to increase drastically to achieve the policy targets of the National Master Plan for Sanitation and Wastewater;
- The continued high loss rates (or unaccounted water) of water supply institutions, particularly at DWA. This is a waste of scarce resources, and loss reduction need to become a policy priority. Progress can be monitored through the water accounts;
- The different costs of water supply and wastewater treatment;
- The efficiency in water use by economic sector (in terms of value added and employment).

CHAPTER ONE
BACKGROUND

1.1 Introduction

The then National Conservation Strategy Coordinating Agency, now the Department of Environmental Affairs or DEA, and the Central Statistics Office (CSO) prepared the first water accounts of Botswana (NCSA/CSO, 2001). At that time, it was recognised that, with increasing resource scarcity, economic considerations needed to be systematically incorporated into resource allocation decisions. The environmental economic review of the National Conservation Strategy Action Plan (Arntzen and Fidzani, 1998) recommended that unless social or environmental reasons require otherwise, natural resources should be used for the most economically productive activities. This requires regular assessment of sectoral comparative advantages of resource use in terms of, for example, value-added or employment creation. The environmental economic review recommended the construction of NRA because they would provide the assessment of comparative advantage and could monitor trends in resource stocks and flows.

Since then the NCSA/DEA developed its environmental economic programme, and the Centre for Applied Research carried out two water accounting studies. The first study aimed at separating groundwater and surface water sources[1] in greater detail (Arntzen *et al*, 2003); the second one aimed at integrating wastewater into the water accounts (Arntzen, 2006).

This report seeks to present the current state and the major findings of water accounting in Botswana based on the above earlier work. It further presents the policy implications and 'work-to-be-done'. Below, the concept of water scarcity (section 1.2) is briefly explored for Botswana followed by a description of possible water sources: surface water, groundwater (section 1.3) and wastewater (section 1.4).

The structure of the entire report is as follows. Water policies and management strategies are discussed in chapter two. The framework for water accounting is presented in chapter three together with a discussion of the data sources. The resulting water accounts for 1990-2003 are presented in chapter four followed by a discussion of the economic aspects of water supply and use (Chapter five). Policy implications and further work are summarised in chapter six.

1.2 Water scarcity

Water scarcity may be defined from a physical and socioeconomic perspective. *Hydroclimatological water scarcity* (the physical perspective) refers to water scarcity in semi-arid and arid areas, where evaporation exceeds rainfall. Droughts are common and often cause temporary water scarcity (seasonally and annually). *Demand scarcity* (socioeconomic perspective) occurs when available water resources are unable to meet the demand of domestic and productive users. Botswana experiences both forms of scarcity but demand scarcity has been localised and limited due to the small size of the population and economy. Demand scarcity is most serious in south-eastern Botswana

Fresh water resources refer to surface and groundwater resources (mostly ephemeral rivers, dams and aquifers). Surface water is generally limited, and even absent in most of western and northern Botswana, except around the Okavango Delta and Chobe River. Ground water is also limited and

[1] This study also covered Namibia and South Africa.

recharge is generally low. Most of the perennial surface water resources are shared with neighbouring countries. Rainfall is low and highly variable and the evaporation exceeds the rainfall. Botswana thus experiences hydro-climatological water scarcity, severely restricting its agricultural potential. The spatial and temporal rainfall patterns are summarised in Figures 1.1 and 1.2. Rainfall is higher in eastern Botswana (up to 55 mm per annum) and towards the extreme north (up to 700 mm p.a.). The amount of rainfall is considerably lower in the west and north (250-400 mm p.a.) and a small dry pocket exist in the north east (less than 350 mm p.a.). Figure 1.2 shows that droughts are endemic and cyclical. When droughts occur, harvests fail and livestock mortality increases. For example, the severe drought of 1980-87 had a devastating impact on the national cattle herd (Figure 1.3). In contrast, the number of goats increased during the drought, which can be seen as an adaptation by livestock farmers as goats are more drought resistant.

Water scarcity also refers to the inadequacy of water resources to meet demands. This type of water scarcity is becoming more common due to demand growth. *Water stress* is the mildest form of scarcity and exists when water resources are short of meeting the basic consumptive and productive needs of the population (Falkenmark, 1994; Lundvist and Sandstrom, 1997). *Water stress* is said to occur when there is less than 1700 m^3 of water available per person per annum. *Absolute scarcity* is found when water cannot meet all demands. This occurs when there is less than 1000 m^3 of water per person per year. Finally, *acute water shortage* exists when there is less than 500 m^3 per person per annum available.

In some regional assessments, Botswana is not considered water scarce. For example, Ohlsson (1995) estimates the per capita water availability in Botswana at 14 107 m^3 (1990). Probably using the same data, Fruhling (1996) argues that Botswana does not experience water stress. Falkenmark and Lundvist (1997) argue that Botswana uses less than one percent of the available water resources, and is much better off than countries such as Malawi. These assessments include the large perennial resources of the Okavango and Chobe, which are shared with other countries[2]. They do not consider the spatial distribution of demand and supply with huge distances between demand and supply centres. Usually however, Botswana is recognised as one of the most water-scarce countries in southern Africa (e.g. SADC regional water strategy; SADC, 1999).

1.3 Surface and groundwater sources

Botswana relies on both groundwater and surface water sources to meet the growing demand. It is important for the water accounts to understand the resources available. Therefore, each source is briefly discussed below.

Botswana faces serious challenges with regards to fresh water resources, which could curb future welfare and economic growth if they are not addressed in time. The challenges are:

1. A growing spatial mismatch between water resources and water demand, requiring costly transfer schemes or relocation of activities;
2. High variability of annual run-off related to highly variable rainfall patterns, limiting the safe yields of dams;
3. Lack of suitable high-yielding dam sites, especially near demand centres, leading to high evaporation rates from dams;

[2] There is likely to be double counting of shared resources in the assessment of individual countries.

4 Most surface water resources are subject to the SADC Protocol on Shared water Courses, and need to be shared in a fair, equitable and sustainable way with other countries;
5 Limited groundwater resources, especially in the west, and high variations in recharge rates and saline groundwater in large parts of western and northern Botswana; and
6 Escalating domestic, urban and peri-urban water demand.

Surface water and run-off

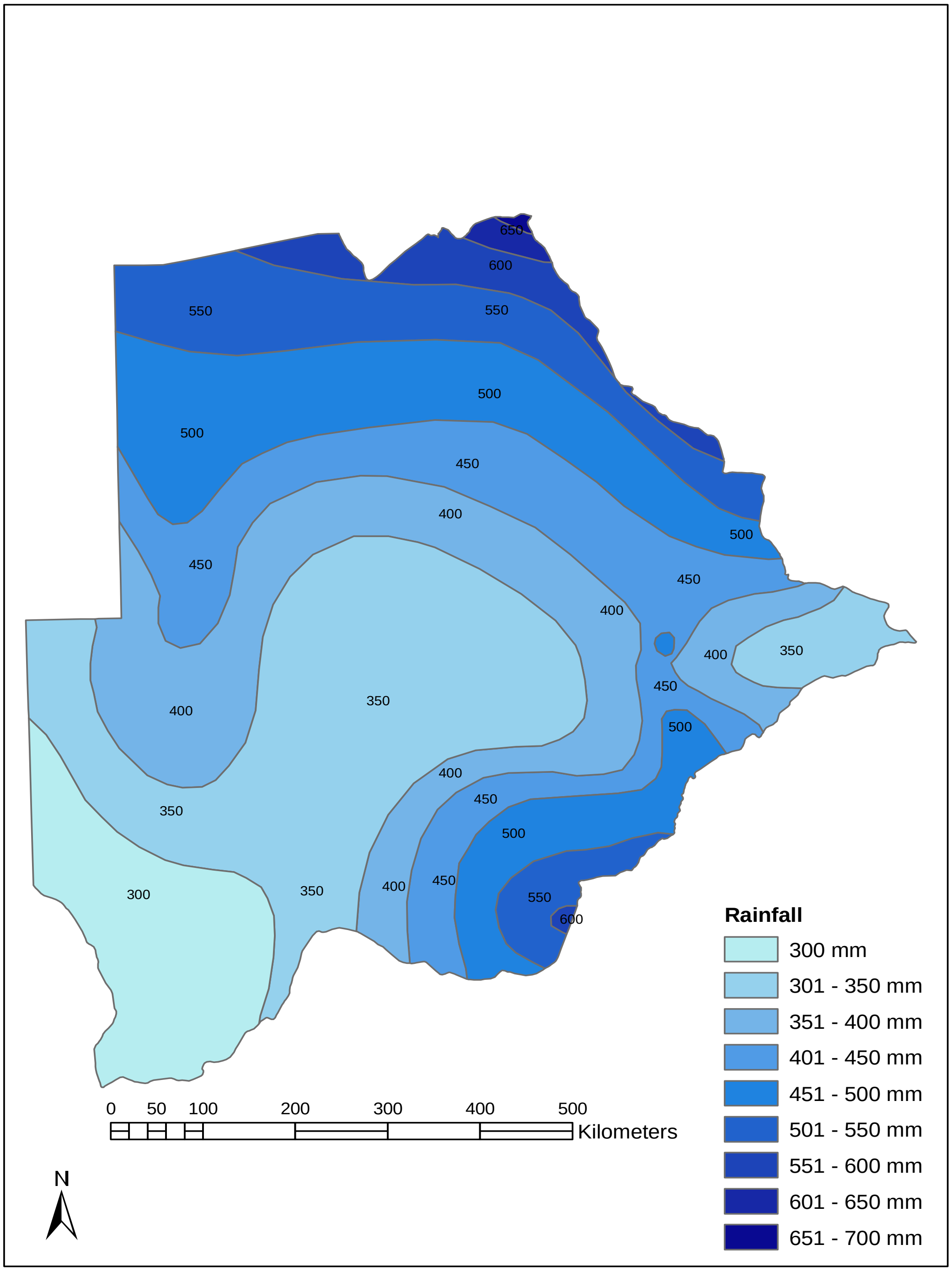
Most rivers are ephemeral with the exception of the Okavango and Chobe Rivers in the north. The average annual run-off is estimated to be 696 Mm^3 (SMEC *et al*, 1991). However, suitable dam sites are limited, and can no longer be found in the south-eastern part of the country, where most people live.

Botswana has currently over ninety-four dams, most of which are small and used in the livestock sector. The country possesses five relatively large dams for urban water supply with a total storage capacity of 354.1 Mm^3, representing over 90% of the country's estimated total storage capacity. Several medium-sized and large dams are under construction or in the planning phase (e.g. lower Shashe, Ntimbale and Thune; Government of Botswana, 2003). No significant amounts of water are abstracted from the Okavango and Chobe Rivers due to the low population density in the areas, and minimal irrigation demands.

The country has six river basins, five of which are shared with neighbouring countries (Figure 1.4):

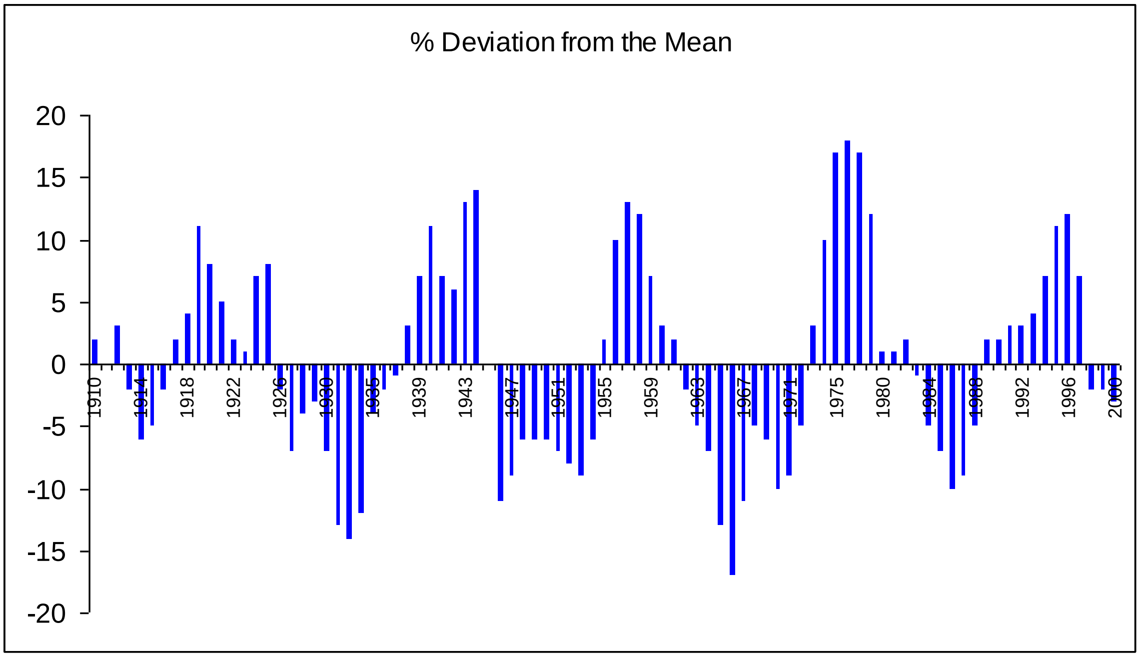
1. The *Molopo/Nossop River*, which forms the southern border between Botswana and South Africa, and flows into Orange River. However, due to the low rainfall in the basin the river has negligible flows for most of the time;
2. The *Limpopo River basin* forms the eastern border between Botswana and South Africa. Most rivers in eastern Botswana drain into the Limpopo River, including the Notwane, the Bonwapitse, the Mahalapye, the Lotsane, the Motloutse and the Shashe rivers. The basin constitutes a drainage area of some 80 000 km^2;
3. *Makgadikgadi drainage basin* to the west of the Limpopo basin. On the eastern side of the pans, the Mosope, Mosetse and the Nata Rivers all drain into the Makgadikgadi pans. The Boteti River feeds the western side of the wetland, which is part of the Okavango delta wetland system. The Nata River is the largest of the rivers draining into the Makgadikgadi pans. It drains a total area of 21 216 km^2, most of it in Zimbabwe;
4. *Kwando/Linyanti/Chobe Rivers* in the north of the country. The Kwando originates in Angola and enters Botswana after crossing through the Caprivi Strip in Namibia. In Botswana, it spreads out into the Linyanti swamps, which drains into the Savuti and Linyanti Rivers, eventually reaching the Chobe River.
5. *Okavango River drainage* and basin and Delta system in the northwest. This comprises the Okavango River, the Okavango Delta and its outlets. The Okavango system also extends down the Boteti River to the Makgadikgadi pans. The river and delta provide life sustenance for the local population and tourism in an otherwise dry sandy region (e.g. fishing and flood recession or *molapo* farming;
6. *Internal drainage system*. The remaining part of the country is the *uncoordinated* internal drainage system. All runoff is lost through evaporation and seepage. In the central Kgalagadi, some fossil river channels run in an easterly direction, but these rarely carry any significant runoff.

Figure 1.1: Average annual rainfall distribution (in mm.)



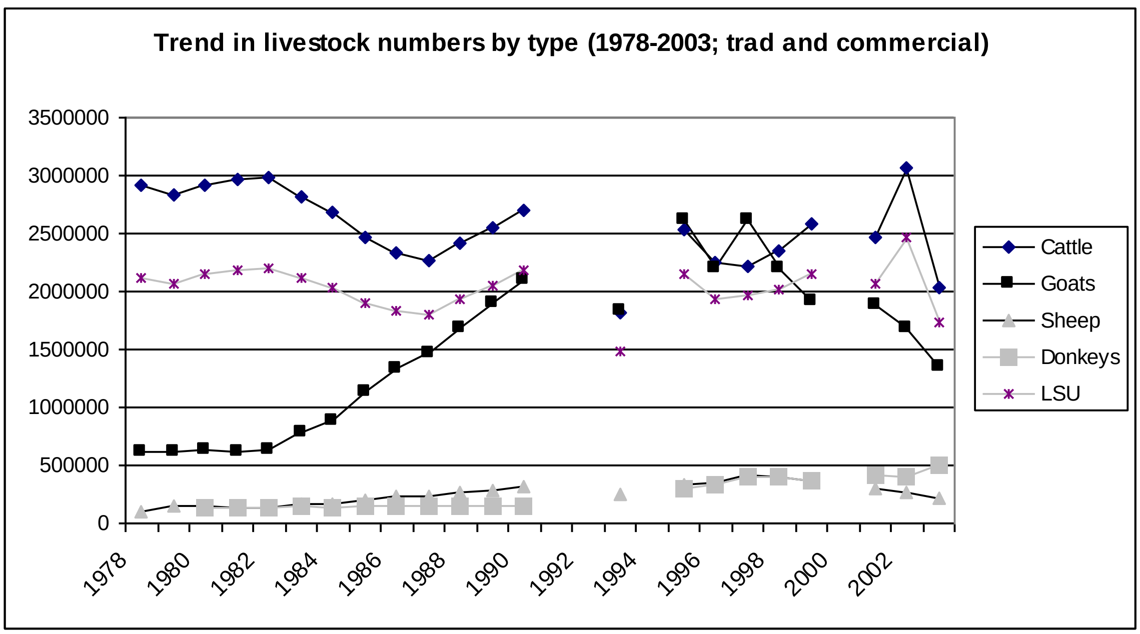
Source: Department of Surveys and Mapping, 2001.

Figure 1.2: Variations in annual rainfall (as % deviation from the mean)



Source: Tyson, 1986.

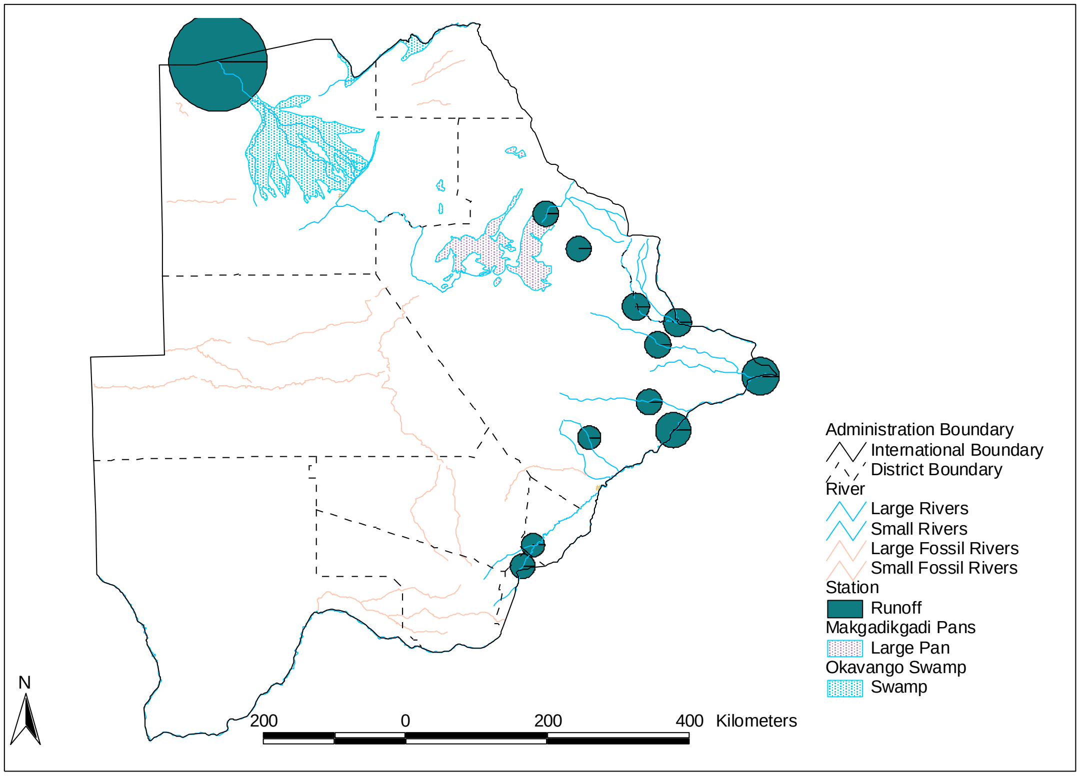
Figure 1.3:



Source: calculated from Agricultural Statistics

Figure 1.4 shows that most run-off occurs in the north (Okavango) and north-east (Shashe and other contributories to the Limpopo and Nata and other rivers into the Makgadikgadi Pans). Run-off in south eastern Botswana is very limited.

Figure 1.4: Estimated annual run-off shared rivers (Mm^3).



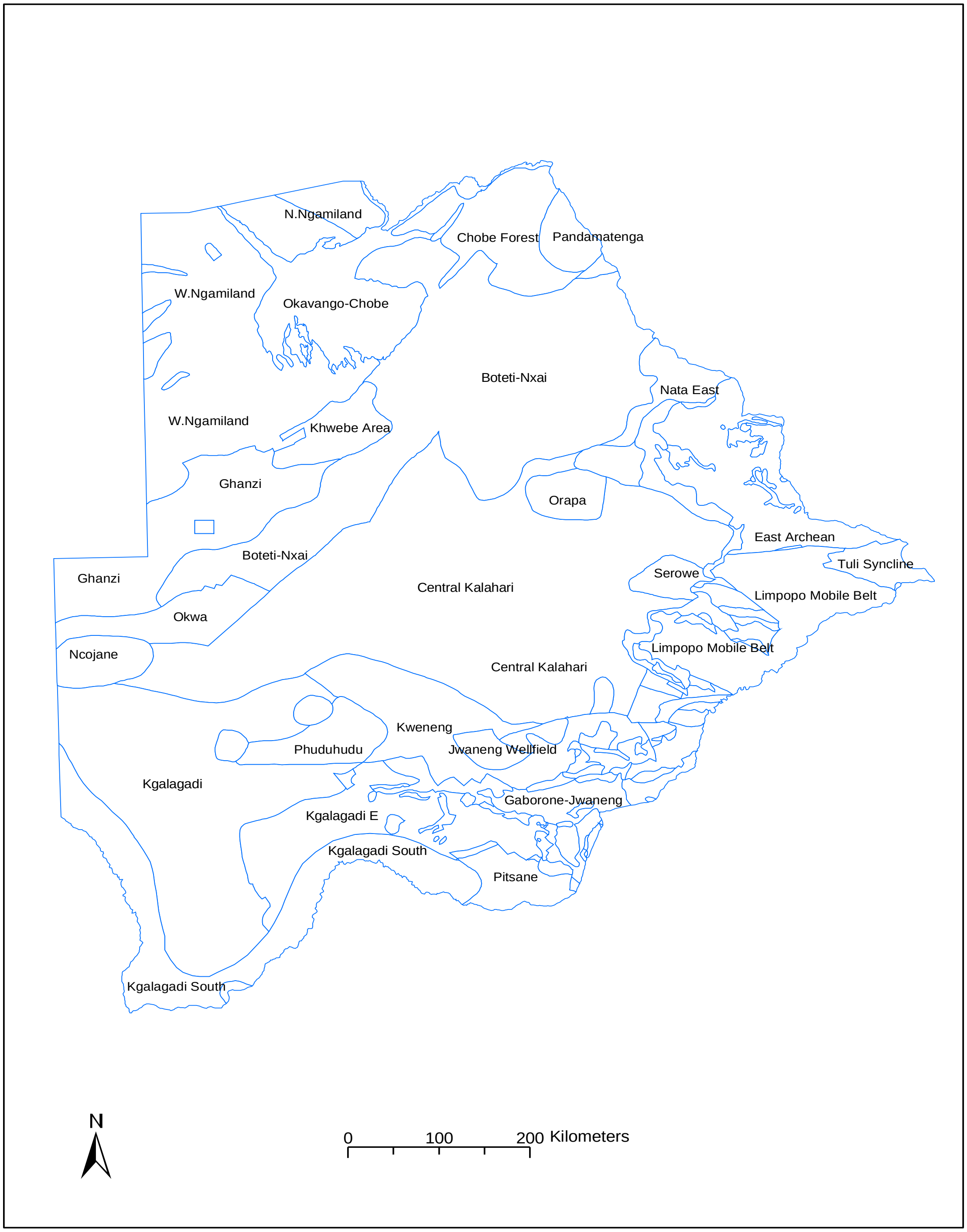
Source: Department of Surveys and Mapping, 2001.

Groundwater resources

The distribution of groundwater resources is highly uneven. Most groundwater resources are found in eastern Botswana. Renewable groundwater sources are very limited in western and northern Botswana, and often saline, where they exist (Figure 1.5). Groundwater resources supply most rural villages and the mining and livestock sectors. Concerns have been raised about groundwater depletion, especially around mines and large settlements. According to Ayoade (2001) four types of aquifers are found in Botswana:

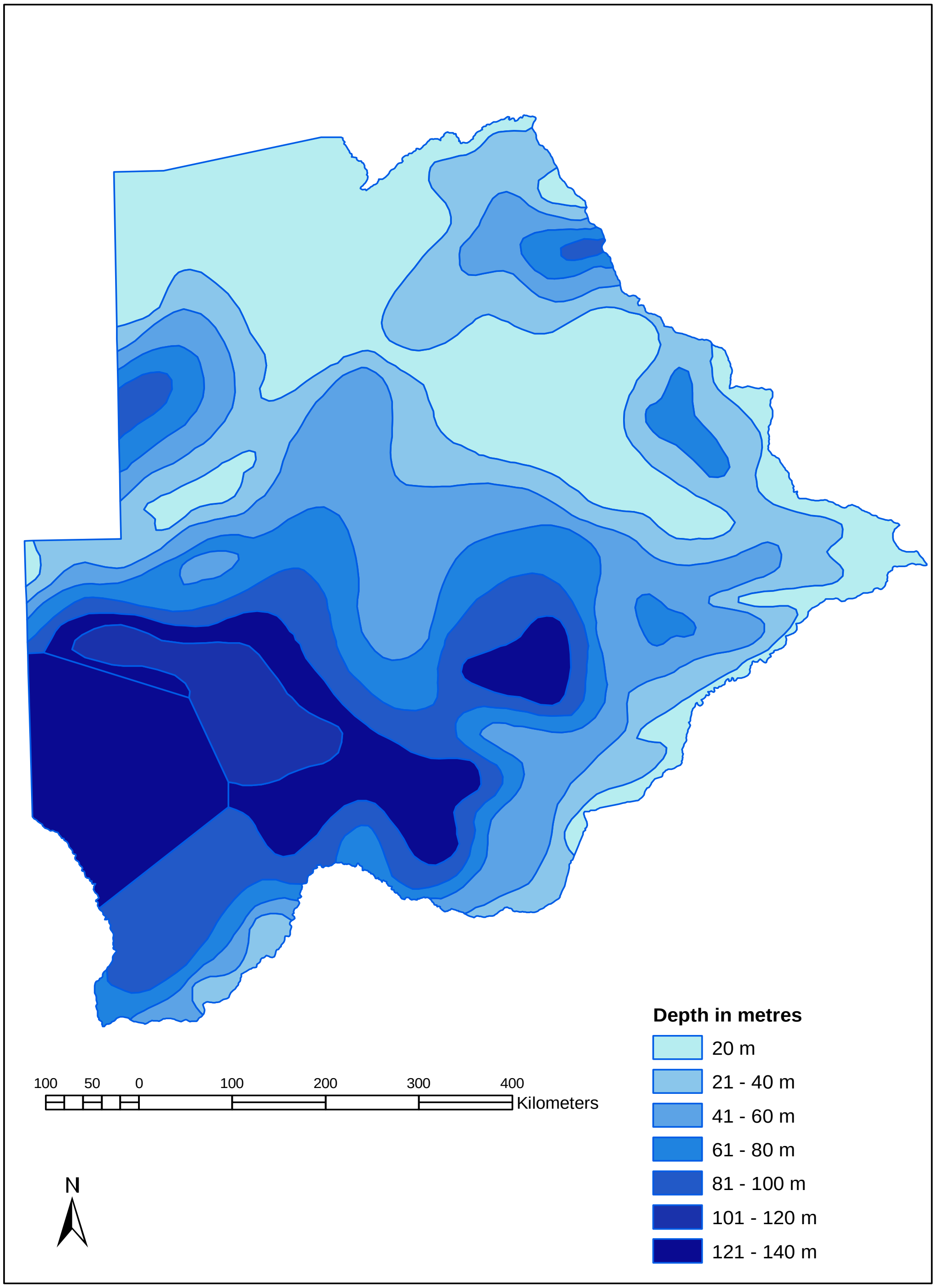
- *Fractured aquifers* cover 27% of the country and are found in the crystalline bedrocks of the Archaen Basement in the east and in the karoo basalt. These have low yields with the median yield ranging between 2 and 10 m^3 per hour;
- *Fractured porous aquifers*, which cover 37% of the country, are found in Ntane and Ecca sandstones as well as in arkoses in the karoo formation. These aquifers have the highest yields;
- *Porous aquifers*, which cover 35% of Botswana, occur in sand rivers, alluvium and the Kalahari beds. These are usually high yielding and have a yield ranging between 10 and 300 m^3 per hour; and

Figure 1.5: Major well fields



Source: Department of Surveys and Mapping, 2001.

Figure 1.6: Average depth of groundwater (metres below surface).



Source: Department of Surveys and Mapping, 2001.

- *Karstified aquifers* occur in the dolomite areas in south-western parts of Botswana as well as in other areas in Lobatse, Ramotswa and Kanye. Karstified aquifers account for only 1% of the land area of Botswana. These aquifers have a median yield of 4-20 m^3 per hour.

1.4 Wastewater resources

In 1991, the Botswana National Water Master Plan (BNWMP) recommended that a North-South Water Carrier (NSWC) be constructed to meet the water demand of south-eastern Botswana (SMEC *et al*, 1991). The 2003 National Master Plan for Sanitation and Wastewater concludes that only 20% of the outflow of wastewater treatment works (WWTW) is being re-used and that there is no recycling at all. Eighty percent of the wastewater is produced by five large WWTW located (Gaborone, Francistown, Selebi Phikwe, Lobatse and Orapa). In 2002, the inflows into all sixty four WWTW were estimated to be 24.5 Mm^3 and the outflows 12.3 Mm^3 (or 'new' water; SMEC *et al*, 2003). The projected amount of outflow produced is indicated in Table 1.1. The total outflow is significant and expected to increase six fold over the next thirty years.

Table 1.1: Estimated outflow from WWTW

Year	m^3/day	Mm^3/year
2001	33 700	12.2
2010	83 000	30.0
2020	144 000	52.4
2030	200 000	73. 0

Source; SMEC *et al*, 2003, vol.2.

CHAPTER TWO
WATER AND WASTEWATER MANAGEMENT AND PLANNING

2.1 Introduction

Management and planning of water resources is guided by the 1991 Botswana National Water Master Plan (BNWMP) and the 2003 National Master Plan for sanitation and Wastewater (NMPSWW), which act as long-term development strategies for water and wastewater respectively. The 1991 BNWMP has guided water planning and development since the 1990s. The almost completed review will strengthen and expand the scope of water management and planning. The 2003 NMPSWW has started to perform a similar function for the sanitation and wastewater sector. Unfortunately, water and wastewater planning are institutionally separate and not sufficiently integrated. In order to understand the policy implications of water accounting, it is essential that the planning and management mechanisms are understood. Therefore planning and management of water and wastewater resources are briefly discussed in section 2.2 and 2.3 respectively.

2.2 Water planning and management

The BNWMP (SMEC *et al*, 1991) and National Development Plans (NDPs; Government of Botswana, 2003) form the core of Botswana's water planning, development and management. The 1991 BNWMP forecasted a significant growth in water demand that could be met in most parts of the country by expanding water supply systems, dams and well fields. The projections indicated that the demand could not be met in south-eastern Botswana, where most people live and the country's capital Gaborone is located. Therefore, a scheme was recommended for the construction of the Letsibogo dam in northern Botswana and for the transfer of water through a 400-km pipeline to south-east Botswana. This so-called North-South Water Carrier (NSWC) became operational in 1999.

Botswana's strategy is to provide its citizens with reliable and affordable water to serve people's needs, especially the subsistence needs. Government efforts have focused on establishing water reticulation systems in cities, town and villages to ensure adequate access to water for domestic use and for productive sectors, based there. The Water Utilities Corporation (WUC), the Department of Water Affairs (DWA) and District Councils (DCs) are responsible for reticulated water supply in urban areas (WUC), seventeen large villages (DWA) and rural areas (over four hundred sixty villages; DCs).

Productive sectors that operate outside settlements are responsible for their own water supply. These so-called self providers are mostly livestock farmers and mining companies. Self providers apply for water rights from the Water Apportionment Board (WAB). Once they have been granted permission, they develop the water resources themselves with own funding. No resource charge is levied, and livestock farmers may benefit from subsidies under several agricultural subsidy schemes (eg. Livestock Water Development Programme and the programme 'Support for Livestock Owners in Communal Areas').

Two inter-related policies aim to ensure that basic water needs are met. Firstly, reticulated water supply systems are constructed, maintained and -where necessary- up-graded in all settlements with more than two hundred inhabitants. Secondly, water tariffs are set in such a way that basic water needs are affordable (see chapter five for more details).

Due to heavy investments and sound water planning most people have access to reliable and affordable water. The country is therefore well placed to meet the Millennium Development Goals regarding water and sanitation (UNDP and GoB, 2004). The comparison of the Population Census 1991 and 2001 shows that the percentage of households with access to piped or tapped drinking water has increased from 56% in 1981 to 87.7% in 2001 (Kelekwang and Gowera, 2003). Access is virtually universal in cities, towns and large villages. In smaller rural villages 73.3% of the population has access to water. Households without piped or tap water mostly rely on boreholes (5.1%), wells (1.8%), tankers (0.8%) or other water points (4.5%; Kelekwang and Gowera, 2003). Particularly boreholes are considered safe and reliable water sources. Access to water has also improved in qualitative terms. A growing proportion of households have water inside their yard and/or house, and a decreasing number of households rely on public standpipes.

2.3 Wastewater planning and management

Wastewater planning and management started in the 1990s. It is institutionally separated from fresh water management, making it more difficult to integrate water and wastewater management. The Department of Waste Management and Pollution Control is the leading institution, but local authorities are also involved (Districts and Town councils). The DWMPC coordinates and monitors sanitation and waste management and promotes effective and efficient implementation of sanitation and waste projects. Local authorities take care of off-site wastewater systems and service on-site sanitation.

The 1991 BNWMP and the 1999 Wastewater Policy provided the incentive to prepare the 2003 NMPWWS. The NMPWWS operates as the long-term strategy (up to 2030) for wastewater treatment, re-use and recycling strategy. Its overall objective is to 'evaluate the current scenario on wastewater generation and disposal, on-site facilities and their impact on the environment, and to develop planning and implementation strategies for regulating the generation, collection and disposal of wastewater in an environmentally friendly way and acceptable manner' (SMEC *et al*, 2003, p. 3).

The results from the 2001 Population Census show that access to sanitation lags behind water provision. In 2001, 39% of the population had access to acceptable sanitary services (own flush or ventilated improved pit latrines); 23% of the population, mainly in rural areas, did not have access to any sanitation facility at all. The majority of people in urban areas (53%) have access to adequate sanitation while in rural areas this figure is much lower (18%). A detailed breakdown of sanitary facilities by location is provided in Appendix 4.

The NMPSWW found that wastewater is not seen as an economic resource and that most existing wastewater treatment works (WWTW) are not properly managed. No reliable flow records are kept and personnel insufficiently aware of the importance of operational procedures for running the WWTW. Therefore, the NMPSWW recommended the establishment of a National Asset Register to record and monitor the performance of WWTW. Sewage ponds are the most common treatment technology but recently technologically more advanced methods have been used (activitated sludge, trickling filter and rotational biological filter). While the latter are more expensive, they can produce better quality of outflow and the losses of wastewater in the treatment process are considerably lower. The NMPSWW further established that recycling does not exist, and only 20% of the wastewater is re-used. The quality of outflow is not systematically monitored and tests show that it often does not meet the re-use application guidelines set by DWA. Most of the wastewater is available in south-eastern Botswana, which faces most severe shortages of water resources.

The NMPWWS plans a wide range of activities in the following areas:

- Strengthening legislation, regulations and instruments (e.g National Asset Register (NAR) which record the performance of individual WWTW and permits for commercial discharges of effluents through Trade Effluent Agreements;
- Construction of wastewater facilities in more large villages;
- Promotion of re-use of wastewater. The target for 2030 is to increase re-use from 20% to 96% of the outflow (or 48% of the inflow);
- Promotion of on-site sanitation;
- Cost recovery and affordability. The NMPWWS proposes to recover the operational costs for households.

The expansion of the sewerage network and the growth in water consumption will fuel further growth in outflows.

CHAPTER THREE
FRAMEWORK FOR WATER ACCOUNTS AND DATA SOURCES

3.1 Introduction

This section briefly discusses the accounting framework used and the sources of data used for the construction of the accounts. A detailed discussion of the framework is provided in NCSA/CSO, (2001) with additional details and up-dates in Arntzen *et al*. (2003) and Arntzen (2006). The most important points relevant to the accounting framework and data sources are framework water accounts are discussed below. Section 3.2 reviews the types of accounts that exist at present. The classification of water suppliers is outlined in section 3.3, followed by classification of water users in section 3.4. Data sources and issues are discussed in section 3.5

3.2 Type of accounts

The accounts are constructed first in physical units (m^3) and, where feasible, in economic units, as a measure of the value of water. The accounts consist of stock and use accounts for water. In addition, wastewater supply accounts exist. The structure and current state of the physical accounts is summarised below.

Account	**Sub-account**	**State**
Stock accounts	Dams	Available for 2001-2003 for WUC dams
	Groundwater	Existing incomplete accounts for operational well fields
	Rivers-lakes	No accounts; few perennial rivers and lakes
	Wastewater	Developed, but not important given the small amount of wastewater stored.
Flow accounts	Institution	Covers period 1990-2003
	Source	Covers period 1990-2003
	Economic sector	Covers period 1993-2003
Wastewater accounts	WW supply	Covers period 1990-2003
	WW use	Covers period 1990-2003

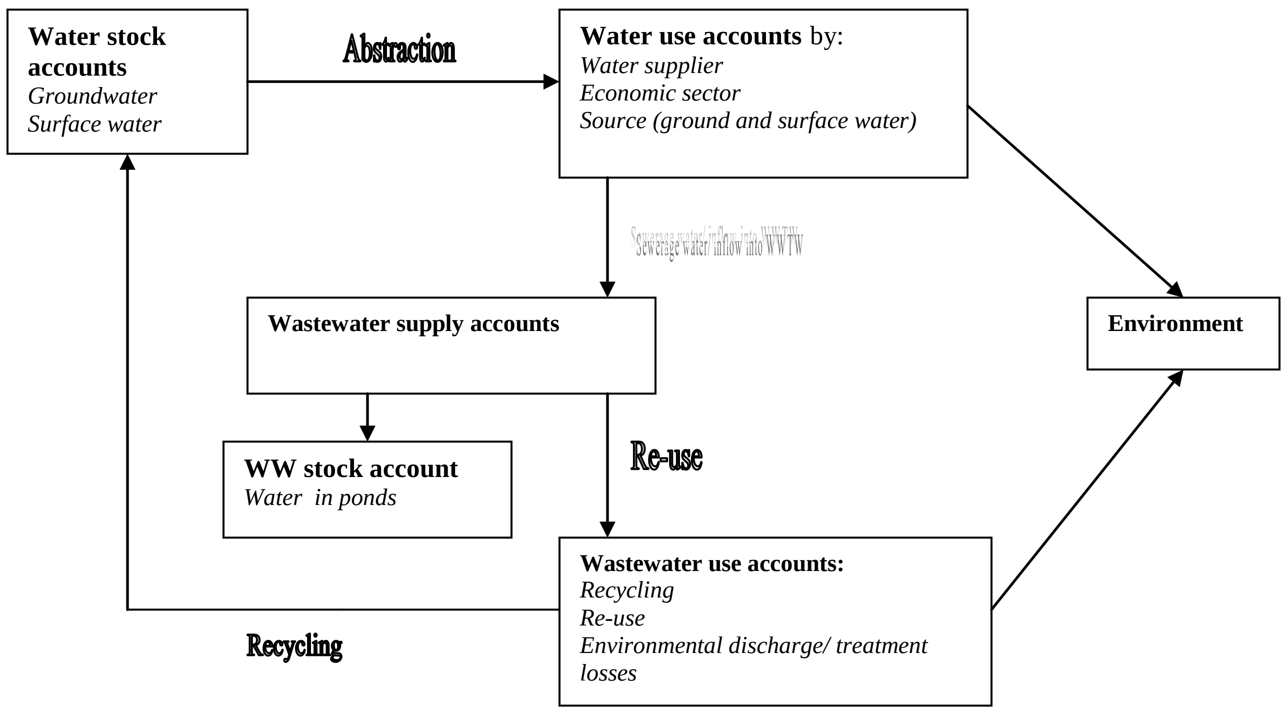
Stock accounts include information about annual quantities of water stored in dams, annual runoff to rivers, and estimated groundwater reserves, with supplemental data used as indicators such as annual rainfall. The stock accounts have not yet been developed and are not discussed here. Stock accounts also exist for wastewater but they are not important given the small amount involved.

Use accounts include the use of water for economic activities and by households according to different types of water. Different types of water are classified on the basis of natural source and institutional source. Use accounts for wastewater have been constructed to describe the use and discharge of wastewater. The physical accounts have been completed and are discussed here.

Wastewater accounts (supply, use and stock) are separate from the other accounts as the water quality is low (but not exactly known), and therefore WW accounts cannot be directly linked to the other accounts. *Wastewater stock accounts* indicate the amount of wastewater stored in WWTW. This is mostly wastewater in ponds. *Wastewater supply accounts* indicate the sources of wastewater (e.g. domestic use, business and government). The WW supply accounts are restricted to wastewater that is treated in WWTW. The accounts are constructed for individual WWTW and for the country (as an aggregate of all WWTW). The sub accounts by WWTW are area specific. The *WW use accounts* show how the wastewater is used and discharged.

The interactions between the different accounts are shown in Figure 3.1. Abstractions from stock accounts feed into the use accounts. In turn, the use accounts are linked to the wastewater supply accounts through inflows into WWTW. The WW supply account is linked to the WW use account that differentiates treatment losses, discharge, re-use and recycling.

Figure 3.1: Linkages between different water accounts.



Valuation of water is a difficult process; however, some preliminary work has been done to assess the economic benefits from water use in each sector of the economy, such as the amount of national income and employment generated by the use of water in each sector.

3.3 Classification of water supply

In order to represent both environmental and socio-economic characteristics of water, the use accounts disaggregate water into a classification based on both natural source (four categories) and institutional source (four categories). There are four sources of water supply, which vary in terms of location, renewability, quality, and reliability:

- *Groundwater*, which is found throughout the country, though varying in availability and quality. For groundwater, a distinction is necessary between fossil and renewable groundwater. However, currently we are unable to do this;
- *Dams*, which capture seasonal surface water from rainfall, which is unpredictable in location, timing, and quantity. Also, small farm dams, haffirs, and other water catchment structures are included;
- *River water*, almost all supplied from internationally-shared rivers along Botswana's boundaries such as the Limpopo and the Chobe/Linyanti systems;

- *Treated effluent for re-use or recycling.* Effluent is water that has already been used, but may be used again after treatment (so-called '*new water'*; SMEC *et al*., 2003).

A number of different institutions provide water. Some of these institutions rely on relatively large-scale, technologically sophisticated infrastructure for collection and long-distance water distribution networks, while others rely mostly on local, small-scale infrastructure such as local boreholes and small dams. The former generally institute formal systems of water metering and serve urban areas and the important mining, industrial and commercial activities whereas the latter generally serve the needs of the rural population and may not keep formal records about water use. The Botswana water supply institutions include:

- Water Utilities Corporation (WUC), which provides water to six urban areas;
- Department of Water Affairs (DWA), which provides water to seventeen major villages;
- District Councils (DC), which provide water to more than 200 small villages;
- Users, who mainly provide their own water outside the other three institutions. Such self-providers are mainly found in the mining, livestock, irrigation, and wildlife sub-sectors.

Councils are responsible for the treatment of wastewater. All water providers are included in the accounts. Transfers of water from one institution to another, for example, sales from Jwaneng mine to WUC for distribution to Jwaneng and purchases by DWA from WUC, are not traced in the water accounts. Only the institution that provides the water directly to the end-user is identified at this time.

In summary, the Water Accounts presented here are disaggregated by three types of natural sources plus wastewater and four types of institutional sources. In addition, the spatial aspect of water is important because water availability and quality varies a great deal by region. To the extent possible, use of water is also identified by administrative district so that district-level water accounts can be constructed.

3.4 Classification of water users

The purpose of environmental accounting, and water accounting in particular, is to link information about water use to economic information contained in the National Accounts (NA). This link is established by using the same classification of economic activities for both water accounts and NA. The NA has a well-established classification of economic activities, which has been used to classify water use.

Some important uses of water are not reflected in the national accounts' classification because these uses do not have a corresponding economic activity. Notable among these uses are various ecological water requirements. The ecological water requirements include direct use of water by wildlife, as well as in-stream flow requirements of rivers, and the water requirements needed to maintain a healthy ecosystem in areas like the Okavango Delta. These uses of water have not been included at this time because of lack of data, but efforts will be made to include them in future work.

3.5 Data sources and major data problems

A summary of data sources and problems is provided here in Figure 3.2, in order to guide readers in interpretation of the analysis that follows, and to focus readers' attention on the major limitations. For more details: see NCSA/CSO, 2001 and appendix 2).

WUC provides a significant amount of water, 19% (1998), but does not rely on groundwater. DWA provides a relatively small amount of total water use, 9% (1998), and accounts for 13% of groundwater used. DC provide 17% of water use, but account for a large share of groundwater, 31%. Finally, self-providers account for the largest share of water use and also the largest share of groundwater, 55% and 56%, respectively. WUC data were up-dated until 2003 based on recent annual reports and data supplied by WUC. No changes were made in the water consumption of small rural villages, as the on-going pilot project on water consumption monitoring in rural villages has not yielded new results.

The System of Environment-Economic Accounting (SEEA) recommends that only off-site wastewater that passes to another economic activity or to the environment is recorded in the wastewater accounts. The WW supply accounts are restricted to wastewater that is returned to wastewater treatment works (WWTW), as these flows can be re-used or recycled and are transferred between economic agents. The following are excluded:

1. Direct discharges of wastewater from a WW supplier into the environment. Such wastewater is usually captured in sceptic tanks, which are regularly emptied into the sewerage system[3]; and
2. Institutions that generate significant amounts of wastewater such as hospitals, prisons and schools often have an on-site WWTW. These supplies are not included in accounts, but obviously may have economic and environmental benefits.

Due to inadequate management and record keeping of WWTW and the delay in establishment of the NAR (SMEC *et al*, 2003) data on inflows, outflows, water quality and re-use/ recycling are incomplete. Some NAR data for 2001/02 have been used, together with the primary data collected for Arntzen (2006).

Figure 3.2 Summary of data sources and data problems

A. Water Utilities Corporation (WUC)

Relative importance Percentage Use in 1998 of Total water: 19% Percentage Use in 2003 of Total water: 30% Water sources: all surface water, except for Jwaneng and Sowa Town
Data Source: Unpublished data base of billing records until 1998; Unpublished data base of water use and tariffs by customer type and by tariff band until 1998; Annual reports for 1998-2003 (used to up-date in-depth WUC figures up to 1998.
Major Problems: Discrepancies between billing records and published figures for water use

B. Department of Water Affairs (DWA)

Relative importance Percentage Use in 1998 of Total water: 9% Percentage Use in 2003 of Total water: 7% Water sources: mostly groundwater. Purchases substantial amount of water from WUC for large rural villages

[3] Leakages may cause ground water pollution problems.

Data Source: For each major village, unpublished databases with the following information: Production, Consumption, and Losses; Categorized Consumption; Expenditures and Revenues;
Major Problems: Missing data for water use in many villages; Extensive missing data for Expenditures and Revenues Incomplete record of Overhead & Maintenance costs in the Expenditure database Revenues; No information about capital costs.

C. District Council Water for small villages

Relative importance Percentage Use in 1998 of Total water: 17% Percentage Use in 2003 of Total water: 13% Water sources: all groundwater
Data Source: stimated on the basis of per capita daily water use in several hundred small villages. Per capita water use derived from one month of metered water use in each village, used to derive average daily use per person. Baseline data from villages in the village water monitoring project
Major Problems: No information about how much water is used for domestic consumption, schools & clinics, offices, local government, livestock water, and other uses. No information about costs or revenues. Implementation of pilot study is delayed and no new data are available.

D. Self -Providers (mainly mining, irrigation, livestock watering industries)

Relative importance Percentage Use in 1998 of Total water: 55% Percentage Use in 2003 of Total water: 50% Water sources: mostly groundwater.
Data Source: Livestock: estimated on the basis of numbers of livestock and daily water requirements. Irrigation: using same figure as used in Water Master Plan for 1990. Diamond mining: reported use from Debswana from 1996-1998 only. Other mining: copper/nickel & soda ash from WUC records; coal from Water Master Plan.
Major Problems: No reliable livestock figures from 1991-1994. Actual livestock water use unknown. Mix of groundwater and other sources of water for livestock unknown. Actual irrigation water use unknown. Diamond mining water use before 1996 unknown. No information about costs of providing water for any users. Water consumption by wildlife sector unknown.

D. Councils dealing with wastewater treatment

Relative importance Only 20% of outflow is currently re-used
Data Source: Council expenditures on sewerage and WWTW NMPSWW 2003 Population Census 2001
Major Problems: National Asset Registry (NAR)not established No monitoring of inflows and outflows No monitoring of water quality No data on capital expenditures Incomplete data on O&M

CHAPTER FOUR
WATER RESOURCES AND USE IN THE PERIOD 1990-2003

4.1 Introduction

In this chapter the physical water accounts are discussed. In section 4.3 water use accounts are reviewed followed by wastewater supply accounts (4.4) and wastewater use accounts (4.5). Given the poor data, it is impossible at this stage to distinguish different water quality categories.

Monetary aspects of the accounts are addressed in chapter five. Stock accounts are discussed in section 4.2.

4.2 Stock accounts

The term 'stock' relates to the quantity of surface and groundwater in a territory of reference measured at a specific point in time (Eurostat and UN, 2003). Here, freshwater stock accounts show the amount of freshwater stored in dams and aquifers at the beginning and at the end of the year, and changes therein (inflows, outflows, evaporation etc.).

Surface water sub-accounts
The amount of water stored in reservoirs is limited due to shallow nature of dams, high evaporation, and low and unreliable rainfall. Individual surface water sub-accounts were constructed for each large dam or reservoirs (Gaborone, Bokaa, Nnywane, Shashe and Letsibogo) and for the aggregate of these dams. No sub-accounts have been constructed for lakes/swamps and rivers, as the former are rare and hardly used for economic activities and the latter are mostly ephemeral with the exception of the transboundary Okavango and Chobe Rivers.

WUC records the stored water volumes as well as abstraction; the inflows into the dams are not recorded. The average evaporation rate for each dam is known. Therefore, the annual evaporation was estimated as the evaporation rate for each dam[4] multiplied by the average amount of water stored. The inflow was estimated as:

Inflow = Closing volume + Abstraction + Evaporation - Opening volume

Due to data constraints, the aggregate stock accounts for the five dams could only be compiled for the period 2001-2003 (Table 4.1). The table shows that the total amount of water stored increased from 195 Mm^3 at the beginning of 2000 to 246 Mm^3 in 2003, mostly due to the filling up of the new Letsibogo dam.

Table 4.1: The surface water reservoir stock account (Mm^3)

All WUC dams	2001	2002	2003
Opening volume	289	319	235
Inflows	277	142	149
Abstraction	174	159	79
Evaporation	72	66	60
Closing volume	319	235	246

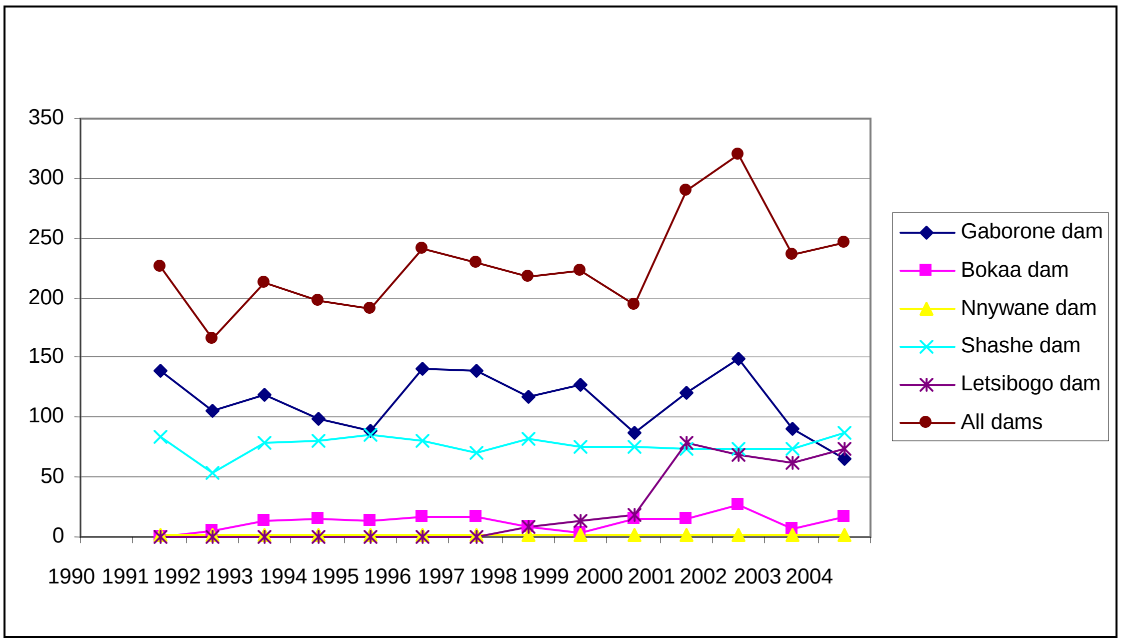
Source: calculated from WUC data.

[4] Gaborone dam: 1.6%, Letsibogo and Bokaa; 2%, Shashe dam 2.26% and Nnywane dam 2.3% (source: WUC).

The stock account shows that the volume of freshwater in Gaborone dam, supplying south-eastern Botswana, has declined persistently since 2001, leading to a severe water crisis in 2004/05. The amount of water stored in other reservoirs has increased. The Letsibogo dam has the highest growth rate as it was filling up after commissioning (314.5%). The diverging volumes stored suggest that safe yields[5] of all dams together can be increased by interlinking the major dams. In that event, failure of one dam can be compensated by increased stocks in other dams.

Figure 4.1 shows the trend in water volumes stored in the dams. Gaborone, Shashe and Letsibogo are the large dams while Bokaa and Nnywane dam are small. The total water volume in dams has increased in time due to the commissioning of Letsibogo dam. Furthermore, the Gaborone dam has performed poorly in recent years, and its water storage has dropped below the amounts stored in Shashe and Letsibogo dams, despite its larger capacity.

Figure 4.1: Opening volumes of dams by year (Mm^3)



Source: this study

Groundwater stocks

The stock accounts for groundwater are incomplete due to insufficient data (Arntzen *et al*, 2003). Stock accounts are restricted to developed groundwater resources, i.e. well fields and individual boreholes. A sub account was developed for each well field, using DWA WELLMON data and recharge estimates. The aggregate of all well fields was used on the overall groundwater stock account. This account also contained estimates for the aggregate abstraction of individual boreholes, mostly used by the livestock sector. Given the importance of groundwater for the country, the groundwater stock account is presented here even though it is incomplete (Table 4.2). The opening and closing volumes are unknown, making it impossible to estimate when well fields could run dry.

[5] Safe yields of dams are strategically more important than the dam capacity.

Table 4.2: Groundwater stock accounts (Mm^3)

		1992	1995	2001
Opening volume well fields				
	Abstraction (-)	46.3	49.8	55.7
	Recharge (+)	15.5	15.5	15.5
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume				
Opening volume individual boreholes				
	Abstraction (-)	42.1	42.6	39.7
	Recharge (+)	Likely to exceed abstraction	Likely to exceed abstraction	Likely to exceed abstraction
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume		Not known	Not known	Not known
Opening volume total developed groundwater				
	Abstraction (-)	88.4	92.4	95.4
	Recharge (+)	At least 57.6	At least 58.1	At least 55.2
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume		Not known	Not known	Not known

Notes: well field capacity assumed constant.

Source: Arntzen *et al*, 2003.

Table 4.2 shows that for well fields groundwater abstraction exceeds recharge. While the figures are estimates that require further work, this is cause for concern given the heavy reliance on groundwater of most villages and the mining sector. Due to the data gaps, the stock account for groundwater is less informative for policy-makers than the surface water account.

4.3 Water use accounts

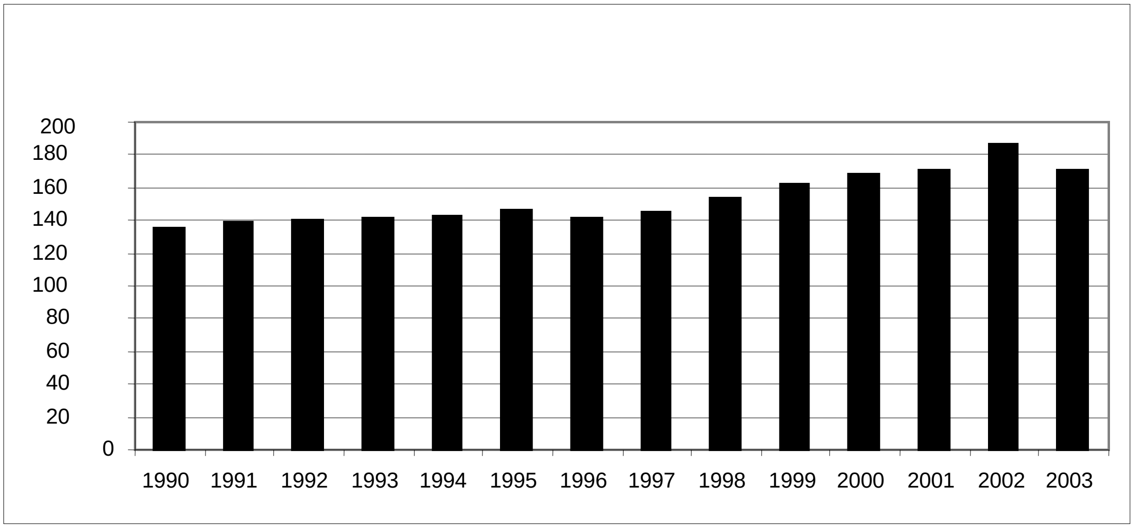
Detailed tables with the figures of the three water use accounts (institution, source and sector) are given in appendix 3. Below, the main issues and conclusions are presented.

The country's aggregate water consumption (Figure 4.2) shows an increase in water consumption from just under 140 Mm^3 in 1990 to 170 Mm^3 in 2003. The growth is lower than predicted by the BNWMP (SMEC *et al*, 1991) and is not continuous. Growth in consumption has been minimal during the first half of the 1990s and in the first half of the 2000s. Growth was rapid in the second half of the 1990s, mostly due to expansion of the mining sector (see Table 4.3).

The consumption peak in 2002 and the subsequent decrease in 2003 are entirely due to the livestock sector. It is reasonable to assume that water consumption has levelled off in the early 2000s. The number of livestock seems over-estimated in 2002[6] and 2001 and 2003 are considered to be more reliable.

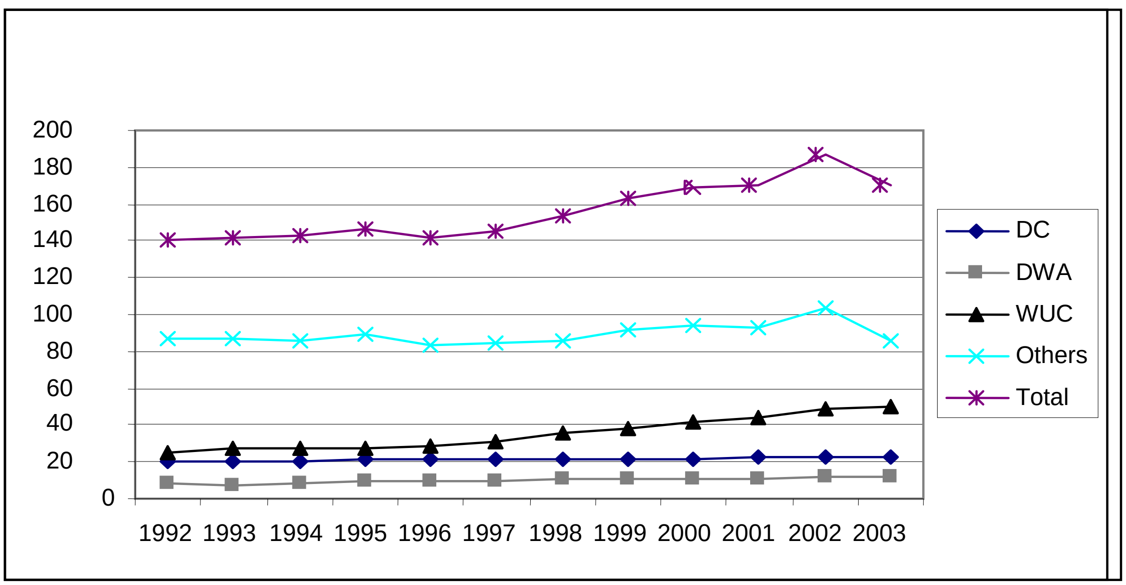
[6] The number of cattle dropped by around one million from 2002 to 2003.

Figure 4.2: Trends in overall water use (1990-2003; Mm^3)



The water use account by institution is shown in Figure 4.3. The figure shows that self providers remain the largest institutional category followed by WUC, District Councils and DWA. This is important for policy, as monitoring and control is problematic under the current institutional arrangements. The role of WUC has significantly increased due to the growth of urban water consumption, the construction of Letsibogo dam and the NSWC.

Figure 4.3: Water use account by institution (in Mm^3)



The use account by economic sector is summarised in Table 4.3 for selected years. The agricultural and household sectors (63.4 Mm^3 and 56.9 Mm^3 in 2003 respectively) are the largest water users at a distance followed by mining sector (26.8 Mm^3) and government (11.5 Mm^3).

Table 4.3: Water use by economic sector (Mm^3)

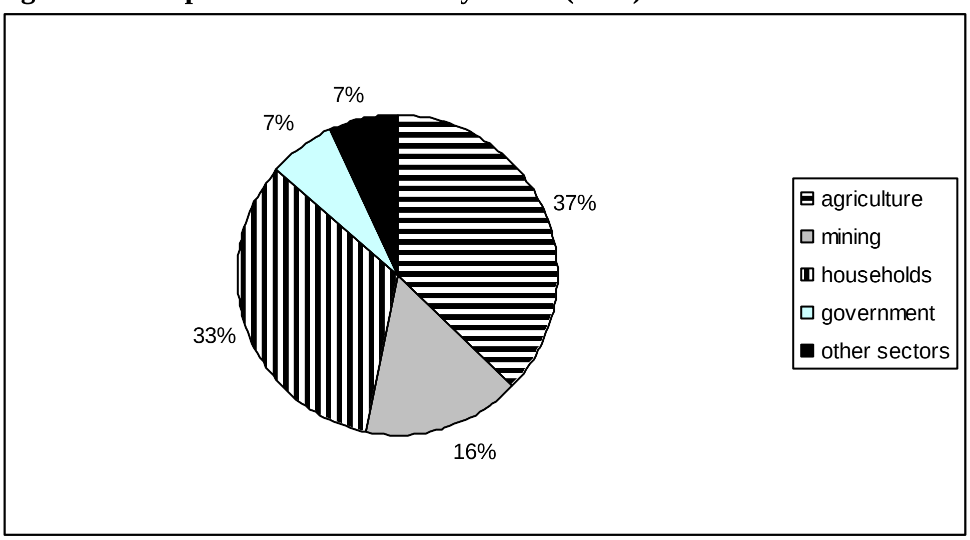
User category	1992	1996	2000	2003
Agriculture	72.9	70.6	76.0	63.4
Mining	12.8	14.4	24.1	26.8
Manufacturing	3.9	2.1	4.0	5.1
Water + electricity	0.0	0.8	0.5	0.7
Construction	0.0	0.4	0.4	0.4
Trade	0.2	0.7	1.0	1.2
Hotels and restaurants	0.2	0.5	0.8	0.8
Transport + communication	0.0	0.2	0.2	0.3
Insurance, banking, business	0.0	0.5	0.7	0.8
Social and personal services	0	1.2	1.7	2.4
Government	8.7	8.8	11.1	11.5
Household use	36.1	41.1	48.1	56.9
WUC private sector	7.7	0.0	0.0	0.0
Grand total	140.3	141.3	168.6	170.3

Note: figures for the entire period 1992-2003 are provided in Appendix 4.

The trend (Table 4.3) shows that the mining sector records the fastest growth in water consumption, followed by households and government. Agricultural water consumption fluctuates but does not show an overall increase.

Figure 4.4 shows a break-down of water consumption by sector (2003). Agriculture and households together use 70% of the water, the mining sector 17% and government 7%. All other sectors together use only 7% of the water.

Figure 4.4: Proportion of water use by sector (2003)



4.4 Wastewater accounts

Wastewater stock account

Wastewater stock accounts show the quantity of wastewater in wastewater treatment works at the beginning and the end of the year. Only small amounts of wastewater are stored, mostly in ponds, and temporarily awaiting maturation and discharge. The capacity of the Gaborone and Lobatse ponds amounted to 1.5 Mm^3. Assuming that the storage capacity of other WWTWs is similar, the total WW storage or volume could be around 3 Mm^3. This figure is very small in comparison to stocks of surface and groundwater.

WW supply account
Individual WW supply accounts have been prepared for each WWTW and these were subsequently aggregated into the WW supply account. The developed WW supply account distinguishes three major categories of suppliers, i.e.: domestic users, industry/ business, and government. Details of the method used are provided in Appendix 2.

The wastewater supply, received at the WWTW, is calculated based on the water consumption of each category and effluent generation fraction (EGF) used in the NMPWWS:

- Households: 80% of the water consumption of those connected to the sewerage system enters the sewerage system (EGF is 0.8). The assumption is that all households with water in the house are connected to the sewerage and that no effluent from households with a tap in the yard will generate effluent for the WWTW;
- Business: 55% enters the sewerage system; all businesses are connected; and
- Government: 65% enters the sewerage; all government institutions are connected.

Figure 4.5 shows the trend in wastewater supply for the period 1990-2003. The amount of available wastewater has more than doubled, and the growth in wastewater has been much faster than that of water consumption. In 1992, the total amount of wastewater received at WWTWs was 14.8 Mm^3 compared to an estimated 29.2 Mm^3 in 2003. This figure amounts to an inflow into WWTW of around seventeen percent of the total water consumption.

Figure 4.5: Wastewater supply to WWTWs (Mm^3)

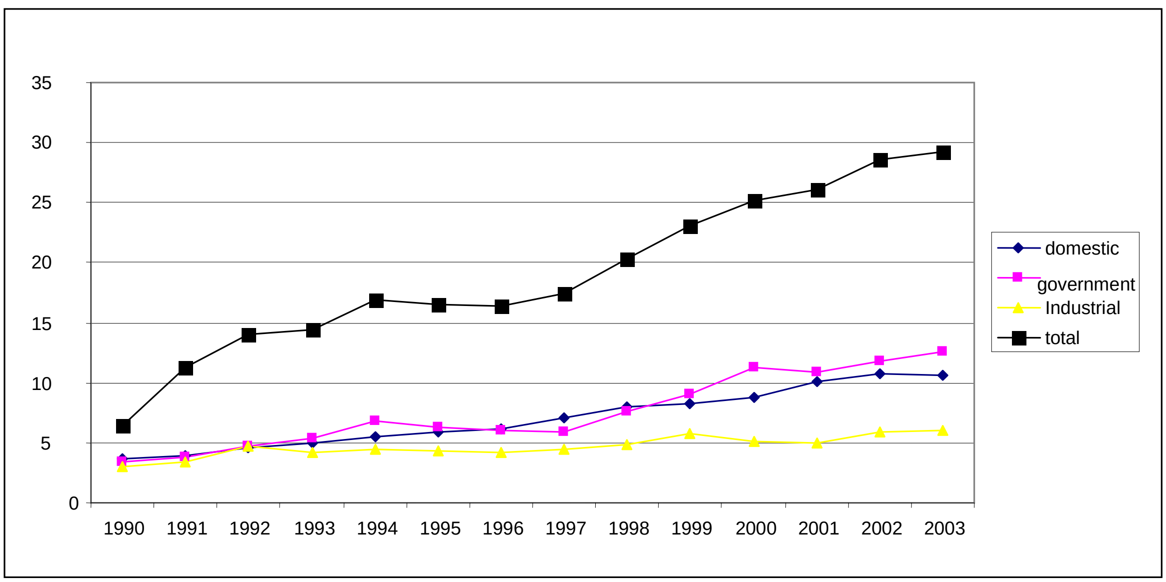
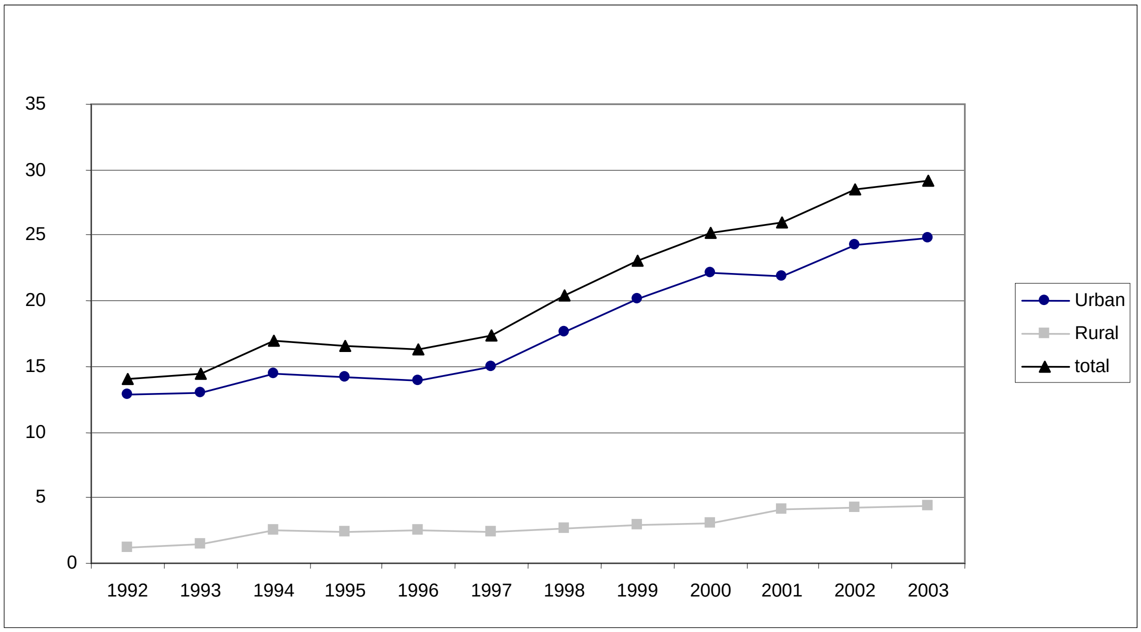


Figure 4.5 further shows that government and households are primarily responsible for the growth in WW supply with growth rates of 132.3% and 119.9% over the period 1992-2003 respectively. The large share of government reflects the dominant role of government in the economy. The large share of households reflects urbanisation and improving living standards, leading to higher water consumption and an increase in connections to the sewerage system. In comparison, the growth rate of wastewater from industry/business is only 5.7% for an entire decade, possibly

reflecting difficulties of economic diversification and the dominance of the service sector in industry/business.

Figure 4.6 shows the spatial distribution of wastewater. The bulk of wastewater is generated in urban areas. However, the growth in WW supply from large villages has been significant, and is likely to accelerate once all large villages have a sewerage and WWTW infrastructure. Currently, eight large villages contribute to the supply of wastewater[7].

Figure 4.6: Wastewater supply by urban and rural areas (Mm^3)



Source: this study.

Most wastewater is produced in urban centres, mostly in south-eastern Botswana. The WW supply accounts show that Gaborone alone supplies more than half of the urban WW supply (Table 4.4).

Table 4.4: Wastewater supply of major urban centres (1992 and 2003)

Major sources of WW	1992 supply in Mm^3	2003 supply in Mm^3	Growth as %
Gaborone	8.0	17.1	113.6
Francistown	1.9	4.1	122.0
Selebi-Phikwe	2.2	3.1	41.9
Lobatse	0.9	1.6	87.2
Jwaneng	0.7	1.1	48.7
Total	13.6	27.1	

Source: Arntzen, 2006.

Wastewater use accounts

[7] Since 1992: Kasane, Mochudi, Mogoditshane, Molepolole, Tlokweng. Others include Maun (1994), Palapye (2000), Ramotswa (2001).

WW use accounts show the possible destinations of wastewater after it enters the WWTW, i.e.: losses during the treatment process; re-use, i.e. use of the outflow by economic sectors; re-cycling, i.e. use of the outflow by water service providers such as WUC; and discharges into the environment outside the WWTW, usually in rivers.

Based on the literature, the following was assumed regarding re-use. For Gaborone, the re-use fraction was 0.064 in 2001 (NMPWWS), equally split between Botswana College of Agriculture (BCA) and the Gaborone Golf Club. The re-use fraction increases to 0.096 in 2003 due to the addition of a new re-use activity (Phakalane Golf Club). Re-use will increase drastically with the new Glenn Valley irrigation scheme. For Lobatse, 94% of the outflow is re-used and six percent is discharged into the environment. These figures are based on the NMPSWW, and slightly differ with the WWTW statement that 100% of the outflow is being re-used. In Jwaneng, fieldwork showed that 100% of the outflow is being re-used; there is no discharge into the environment. The water is re-used for landscaping and gardening. In Francistown, 95% of the outflow is discharged into the river. There is no re-use as yet but an irrigation scheme is planned. In Selebi-Phikwe, the entire outflow is discharged into the river. There is no re-use at all.

The above situation has been used to estimate the WW use accounts. The use accounts consist of sub-accounts for individual WWTW and an aggregate account. The use of WW covers re-use in economic activities, WWTW losses, recycling and discharges into the environment. The total of the WW use accounts equals that of the WW supply account.

The account is provided in tabular form in Appendix 3. The main destinations including uses, are shown in Table 4.5. It becomes clear that processing losses in WWTW and discharges into the environment, usually rivers are most important. Together these account for close to 90% of the WW supply. Recycling is zero and re-use has grown from 6.5% in 1992 to 10.8% in 2003.

Table 4.5: Main uses of wastewater (as % of total)

Wastewater destination	**1992**	**1997**	**2003**
Processing losses	43.7	43.0	42.2
Re-use	6.5	6.4	10.8
Recycling	0.0	0.0	0.0
Environmental discharge	49.8	50.6	47.0
Total use of WW	100.0	100.0	100.0

Source: this study.

Table 4.4 shows that re-use of wastewater is increasing. Re-use increased from 0.9 Mm^3 in 1992 to 1.6 Mm^3 in 2003; a growth of 83.3% in ten years. The percentage of re-use remains very low. As re-use is low, almost ninety percent of the outflow is discharged into rivers. Such discharges benefit the environment (vegetation and groundwater recharge) as well as down stream economic activities, particularly livestock and small-scale irrigation, but may pose pollution and health risk if the discharge is of poor quality. The actual amount of re-use of water discharged into rivers is unknown and could not be assessed by this study.

According to the WW use accounts, the amount of outflows or ‘new water’ reached 14.5 Mm^3 in 2003. This estimate is fairly close to that of the NMPSWW[8].

[8] Assuming a growth rate in outflow of 5% p.a., the NMPWWS estimate would be 13.5 M m^3. This is 6.9% lower than our estimate.

CHAPTER FIVE
ECONOMIC ASPECTS OF WATER SUPPLY AND USE

5.1 Introduction

As stated earlier, full monetary accounts do not exist for Botswana due to serious data limitations. Water resources and sanitation appear to be treated as public goods, for which recording of supply costs and benefits are not a priority. Therefore, this chapter focuses on economic aspects of water management. The water supply costs are revised in section 5.2. The treatment costs of wastewater are considered in section 5.3. Unaccounted water and supply losses are discussed in section 5.4. Section five explores the benefits of re-use and recycling of wastewater.

5.2 Water supply costs

Water accounts should be prepared not just in physical units but also in various types of monetary units as well such as the cost of providing water to each sector, the tariff that is paid for water use, and the subsidy, if any. Very little progress has been made here so far because information about costs of supplying water and the tariffs charged is often not available from water suppliers or is very incomplete. Some information has been collected for WUC and DWA, but the data for DWA are particularly weak. No data are currently available for water supplied by District Councils and other users. The data for WUC and DWA are discussed below.

Cost data are not only important to prepare monetary water accounts. They are also essential in the implementation of government's water pricing policy principles. In general terms, the following policy principles are applied by government and Parastatals:

- water users should pay the full costs in urban areas (capital and recurrent costs);
- in rural areas, water users should pay for the recurrent costs, and an attempt should be made to recover some of the capital costs;
- water users, who rely on standpipes, do not pay in rural areas or pay a very low flat rate in urban areas. They are subsidised by high water users in their areas**.**

As cost data are incomplete, it is impossible to ascertain whether these pricing policy principles are met in practice or are justifiable.

5.2.1 Water Utilities Corporation (WUC)

WUC has to recover its capital and operational costs. The annual WUC tariff proposals need approval from the Minister of Minerals, Energy and Water Resources (MMEWR). The current tariffs are based on full recovery of the marginal supply costs as expressed in the long run marginal costs of the North-South Water Carrier. This excludes environmental costs and foregone benefits that are part of environmental pricing. Block tariffs ensure that water is affordable for the small users, who are subsidized, by the large users, who pay much higher block tariffs. Tariff rates are the same for domestic and business customers, but, in most towns, are higher for government. Table 5.1 shows the current water tariffs for different WUC supply regions.

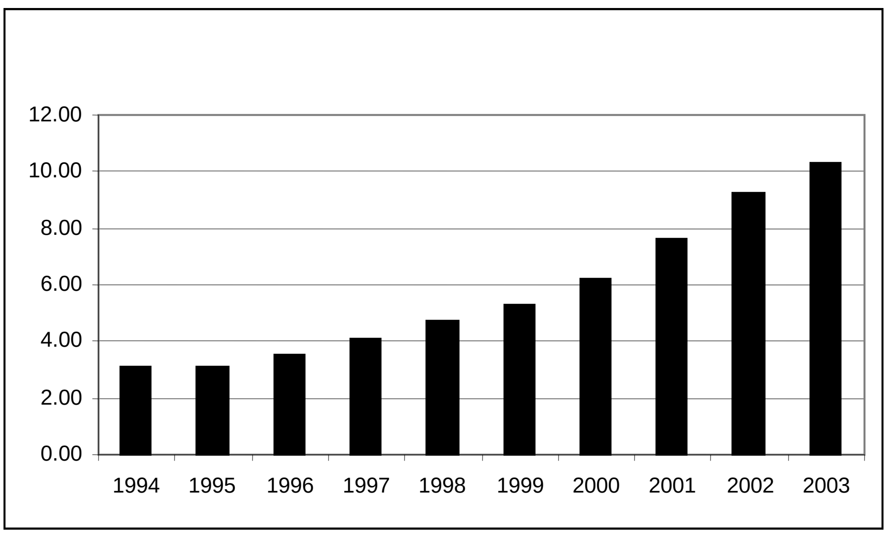
Table 5.1: Water tariffs for Gaborone and rural villages by user band (private connections for domestic users and businesses; current prices)

Use band (per month)	Gaborone	Francistown	Jwaneng	Sua Pan
0-10 m^3	2.10	2.40	1.65	1.65
11-15 m^3	6.40	5.75	3.30	3.75
16-25 m^3	8.15	8.40	4.30	5.40
26-40 m^3	11.30	9.40	4.95	6.00
over 40 m^3	11.30	9.40	4.95	6.00
average price of first 20 m^3	4.69	4.74	2.73	3.11
average price of first 40 m^3	7.60	6.94	3.76	4.48
raw water untreated	3.30	2.00	0.00	0.00

Sources: adapted from WUC data.

Figure 5.1 shows the trend in the average WUC price per m^3 in the period 1994-2003. Tariffs have increased sharply in time and the tariff rates differ considerably between cities and towns (Table 5.4). Differences in tariffs reflect the different marginal supply costs, mostly due to different transport costs. Gaborone and Lobatse have the highest water tariffs because water has to be transported by NWSC. Jwaneng town relies on local well fields operated by the mining company. Francistown and Sowa are closer to dams, hence incur lower costs.

Figure 5.1: Average selling price of WUC (P/m^3; 1994-2003)



Sources: WUC Annual reports.

Table 5.2 compares the revenues and O&M expenditures for the WUC regions for 1993/94 and 2003/04. The table shows a sharp increase in revenues and O&M expenditures due to the increased complexity of the water supply network. The difference between the revenues and O&M expenditures should cover the capital expenditures in order to achieve WUC's mandate of full cost recovery.

Table 5.2: Revenues and O&M expenditures of WUC by region.

		1993/94	2003/04
Gaborone/ Lobatse	Revenues/ m^3	3.38	12.41
	O&M expenditures/m^3	2.62	6.33
	Revenues- expenditures/m^3	0.76	6.08
Francistown	Revenues/ m^3	2.33	10.62
	O&M expenditures/m^3	2.01	9.05
	Revenues- expenditures/m^3	0.32	
Jwaneng	Revenues/ m^3	2.15	4.44
	O&M expenditures/m^3	1.32	3.95
	Revenues- expenditures/m^3	0.83	0.49
Selebi-Phikwe	Revenues/ m^3	1.95	12.08
	O&M expenditures/m^3	1.83	12.35
	Revenues- expenditures/m^3	0.12	-0.27
NSWC	Revenues/ m^3		8.72
	O&M expenditures/m^3		8.42
	Revenues- expenditures/m^3		0.30
Total	Revenues/ m^3		10.70
	O&M expenditures/m^3		6.68
	Revenues- expenditures/m^3		4.02

Source: WUC annual reports.

5.2.2 Department of Water Affairs (DWA)

Information about costs and revenues were obtained from DWA for the years 1992 to 2003. The annual figures are derived from monthly and annual reports about detailed expenditures and revenues. There are two problems with the data. The first problem is missing data indicating serious gaps in the cost and revenue data. However, the net loss or gain (revenue minus expenditure) provides fairly reliable indications of trends because, when data are missing usually both cost and revenue data were omitted. The second problem is that there are no data available on the capital costs and the reported O&M costs only cover part of the O&M costs (labour, materials to maintain and repair installations, and the costs of private connections). No and little information is provided about the purchase of water from WUC, electricity, diesel fuel, or administration costs, which are significant portions of the O&M costs.

The DWA tariffs are indicated in Table 5.3. The tariffs in villages connected to the NSWC are almost fifty percent higher, as water users have to pay part of the high supply costs of the NSWC.

Table 5.4 shows the revenues and O&M expenditures for the total of the major villages. Cost recovery improved during the period 1993-1998, but deteriorated sharply during the period 1998-2003 if the DWA purchases from WUC are included as expenditures. The net revenues per m^3 (revenues minus O&M expenditures) were slightly negative in 1993, positive in 1998 (P 0.42/m^3) and negative in 2003 (-7.47/m^3). DWA would break even if purchases from WUC would be P 36.3 million. The difference with the actual payment to WUC (P130.8 million) must be considered as a subsidy of the O&M costs.

Table 5.3: DWA tariffs in period 1990-2004

DWA tariffs for rural villages connected to the NSWC			
Monthly use band	**1990**	**2000**	**2004**
0 - 5 m^3	0.30	0.65	1.90
6-20 m^3	0.60	1.65	4.75
21-40 m^3	1.20	3.40	9.80
over 40 m^3	1.20	4.20	12.15
DWA tariffs in other rural villages			
Monthly use band	**1990**	**2000**	**2004**
0 - 5 m^3	0.30	0.65	1.25
6-20 m^3	0.60	1.65	3.20
21-40 m^3	1.20	3.40	6.60
over 40 m^3	1.20	4.20	8.15

Sources: compiled from DWA and WUC data.

Table 5.4: Expenditures and revenues for all major villages (DWA)

A. Total Expenditures, Revenues and net revenues (in Pula)	
Expenditures	
1993/94	7,7
1998/99	13.7
2003/04	53.4 and 220.5 including water purchases from WUC
Income/Revenue	
1993/94	7.7
1998/99	19.2
2003/04	89.7
Revenues minus Expenditures	
1993/94	-0.02
1998/99	5.5
2003/04	36.3 and –130.8, including water purchases from WUC
B. Water used (reported as consumed; in Mm^3)	
1993/94	9.0
1998/99	13.4
2003/04	17.5
C. Net Revenues, Pula per m^3 of water consumed	
1993/94	*-0.00*
1998/99	0.42
2003/04	2.07 and – *7.47*, including water purchases from WUC
D. Expenditures,	**Pula per m^3 consumed**
1993/94	0.86
1998/99	1.02
2003/04	3.05 and 12.6, including WUC payment

Note: expenditures only refer to O&M costs (see main text)

Sources: unpublished worksheets and annual report from DWA

5.2.3 District Councils and self-providers

No cost and revenue data are available from District Councils and self-providers. It is hoped that additional data will be identified in future work.

5.3 Wastewater treatment costs

Treatment costs of wastewater consist of operation/ maintenance costs and capital costs. Cost data are not readily available, reflecting the fact that water and sanitation are treated as public goods.

Operation and maintenance costs (O&M) were collected for five large WWTW for the period 1990-2003. O&M costs refer to the WWTW *and* the sewerage system, as it proved impossible to isolate the O&M costs for the WWTW.

Data for *capital costs* were most difficult to obtain due to poor record keeping and high turn-over rate of council staff. New WWTW were constructed in Gaborone and Francistown at estimated costs of P 118 million and P 44.5 million respectively. The WWTW of Lobatse, Jwaneng and Selebi-Phikwe were upgraded at an estimated total cost of P 44.5 million. No written sources for the capital expenditures could be traced, and therefore the reliability of the figures could not be verified. The following assumptions were made to estimate unit capital costs:

- New plants; capital costs are written off in twenty years;
- Up-grading: represent half of the capital costs. Therefore capital costs can be calculated as capital costs of upgrading divided by ten years.

The estimated treatment costs were used to calculate the treatment costs per unit of return flow (inflow into WWTW) and outflow (outflow from WWTW). The figures are indicative only. The results are summarised in Table 5.5.

Table 5.5: Treatment costs of five WWTW (2003).

	Pula/ m^3 inflow	**Pula/ m^3 outflow**
Gaborone	0.62	1.13
Lobatse	0.63	3.27
Jwaneng	2.66	7.12
Selebi Phikwe	0.96	2.44
Francistown (new plant)	3.95	1.57

The results show considerable variation in treatment costs related to the:

- Treatment technology. Pond technology is relatively cheap (Selebi-Phikwe and Lobatse) compared to trickling filter technology of Francistown, but has much higher evaporation losses;
- The Jwaneng treatment costs are much higher than the costs of other WWTW using the pond technology; and
- Size of the operation: larger operations such as in Gaborone have lower unit treatment costs.

For re-use and recycling, the costs per unit of outflow are most relevant. These costs range from P1 to 7/m^3, overlapping with the costs of raw water (P 3.65/m^3 at WUC). The unit price of treated wastewater (inflow) in Gaborone is P 0.62 and probably used as justification for the selling price of P 0.60/m^3. The price of small scale re-use of wastewater in Gaborone is on average of P 33/m^3. This price is considered excessive compared to the costs (see section 5.5). The costs of re-use are considerably lower than the price of potable water. Therefore, those end-users that do not require potable water and can efficiently organise the collection of WW would gain financially. These are typically the construction, gardening/ landscaping and irrigation sectors.

5.4 Unaccounted for water and supply losses

All providers suffer significant losses of water between the starting point of the supply system and the end user, which are called unaccounted for water. Losses occur because of leakages within the system, illegal use of water from the system, or poor monitoring and meter reading. Losses due to system leakage are not directly attributable to the use of water by any specific economic sector. Unaccounted for water due to illegal use or poor monitoring may be for an economic purpose, but there is not sufficient information to assign it to any particular sector. Although unaccounted for water cannot be attributed to specific economic activities, it is important to monitor this figure because it represents a drain on scarce resources as well as a potential source of additional supply—often at a relatively low cost.

Few institutions regularly measure and report unaccounted for water. WUC started to estimate this figure only in 1998; a figure for Gaborone is also available for 1997 (Table 5.6). After a special study of unaccounted for water in Gaborone in 1997—then estimated at about 30%—WUC undertook a programme to reduce physical leakages in the city system. The result was a dramatic reduction, from 30% to 14% in 1998 and 9% in 1999 (pers. com. WUC). DWA estimates losses annually as the difference between production of potable water and what is metered at a customer's premises. Though this figure is officially called loss, it includes both leakages and unmonitored water use, and hence conforms to the definition of unaccounted for water. To be consistent with DWA terminology, it is referred to as losses in this report.

Table 5.6: Reported losses of water (in percent)

WUC	**1993**	**1997**	**1998**	**1999**	**2003**
Gaborone	Na	30	14	9	Na
Lobatse	Na	Na	18	22	Na
Jwaneng	Na	Na	24	21	Na
F/town	Na	Na	27	29	Na
S/Phikwe	Na	Na	10	9	Na
Sowa	Na	Na	17	54	Na
DWA					
Average	**28**	**23**	**24**	**Na**	**28**
Village with highest loss	49	36	35	Na	49
Village with lowest loss	6	3	12	Na	6
DC	Na	Na	Na	Na	Na
Self-providers	Na	Na	Na	Na	Na

Note: Na = not available

Source: WUC; DWA, Annual Reports discussed in this text.

The average rate across the major villages served by DWA has remained 28%, despite a decrease to 23% in 1998. There is a also tremendous range of loss rates for the different villages supplied by DWA, and the range is not narrowing. In 1993 and 2003 the lowest reported loss rate was 6 % and the highest was 49%. District Councils and self-providers do not provide estimates of losses.

In conclusion, the loss rates are relatively high, except in Gaborone and Selebi-Phikwe. Although information about losses is only available for WUC and DWA, there is no reason to assume that loss rates are much lower for the other providers. Clearly, there is need for more comprehensive monitoring of losses by all providers, for example as part of environmental auditing.

5.5 Value added per unit of water

The combination of water consumption and the output by sector gives an indication of the efficiency of water consumption in each economic sector. Using this indicator, previous studies (NCSA/CSO, 2001; Arntzen *et al*, 2003) have shown that the value added per m^3 is highest in the service, construction and public sectors (over P $1000/m^3$). Botswana' water efficiency was higher than that of Namibia and South Africa (Lange et al, 2003). The value added per m^3 is considerably lower in the manufacturing industry, mining and government[9] (P 100 to $300/m^3$) and by far the lowest in the agricultural sector (around P $5\text{-}7/m^3$).

Using recent data from the Annual Economic Report 2005, earlier findings were up-dated to 2003 (Table 5.7). The up-date shows that water use efficiency has increased in time to an average of $P106/m^3$ in 2003 (93/94 Pula price). This implies that more economic gains are derived from each consumed water unit.

Table 5.7: Water productivity (value added per m^3 by sector; 1993/94 Pula).

User category	1993	1998	2002	2003
Agriculture	6	6	5	4
Mining	274	257	257	260
Manufacturing	194	219	144	138
Water + electricity	190	357	942	654
Construction	2,294	4,890	2,395	2,468
Trade	1,116	1,800	1,543	1,445
Hotels and restaurants	276	373	334	321
Transport + communication	2,448	3,221	2,441	2,428
Insurance, banking, business	2,421	2,884	2,577	2,666
Social and personal services	382	494	1,247	1,282
Government	236	237	270	271
Grand total	*76*	*91*	*93*	*106*

Sources: NCSA/CSO, 2001 and this study.

Water efficiency can also be measured by the number of jobs created per m^3. In 2003, an average of 2 807 paid jobs were created for each Mm^3. The service sectors create the largest number of jobs (20 to 50 000 per Mm^3) with government creating around 25 000 jobs for each Mm^3 consumed. Efficiency in terms of paid employment creation is much lower in industry (several thousands), mining (365) and agriculture (83). Most jobs in agriculture are self employment of

[9] Prices are indicated in 1993/94 Pula values.

farmers and informal employment. If those would be included, water efficiency in terms of employment would exceed 1 500 jobs per Mm^3.

Water efficiency is an important policy consideration for the destination of treated wastewater. Re-use could boost economic growth through the extra value added and employment generated by the re-used water. For example, re-use of one m^3 in the construction sector would generate value added of P 2467.54 (in 1993/94 Pula) compared with extra value added of P 121.92 in the manufacturing industry, P 271.39 in the government sector and a mere P 5.31 in the agricultural sector[10]. Recycling of wastewater would also enhance economic growth with a value added of P 660.40 in the utilities sector and additional benefits which depend on the efficiency of the sector which uses the treated wastewater.

5.6 Benefits of wastewater re-use

The literature shows that re-use and recycling may have three types of benefits:

- Postponement of investments in additional water supply schemes;
- Benefits derived from the use of the 'saved' water, i.e. additional production and economic growth and/or improved welfare through serving more households with more water; and
- Lower water tariffs, which enhances the country's competitiveness and leads to income savings for households. For example, prudent re-use and recycling of wastewater have given Windhoek a competitive advantage over Gaborone (see appendix 7).

Postponement of additional supply works is a well known benefit of re-use and recycling. According to NDP9, re-use of WW in Gaborone and south-eastern Botswana could lead to the postponement of the planned capacity expansion of the NSWC by five years. The first phase of the NSWC has been the biggest ever construction project undertaken in Botswana. The expenditures for the first phase were around P1.6 billion. If we assume that:

- The second phase would cost the same (conservative);
- Construction costs would be evenly spread over five years (i.e. 320 million per annum); and
- Opportunity costs of capital are 10% per annum.

Project deferment by five years would imply a cost saving of over P 500 million in five years. If the opportunity costs would be half (5%) there would still be a considerable saving.

Major economic benefits can also be obtained from alternative use of the fresh water that becomes available. There is a growing realisation that re-use of treated wastewater could have economic benefits, but the optimal use of wastewater is rarely considered. The implicit assumption is that irrigation is the best destination. The discussion has, however, not yet considered the questions:

- Which sectors should be targeted for re-use?; and
- What are the benefits of re-use as compared to recycling?

In order to optimise growth and welfare, a holistic strategy towards re-use and recycling is needed as part of the broader Integrated Water Resource Management (IWRM) approach. Below, we

[10] The value added of high value irrigation crops would be much higher.

explore the costs and benefits of re-use and recycling. Further work is needed to answer the questions in greater depth.

The amount of 'new water' or outflow from WWTW is around 14.5 Mm^3 in 2003. Currently, around ten percent of the outflow is re-used by agriculture, and landscaping, gardening and golf courses. The following sectors offer opportunities for re-use at the moment:

- Agriculture and irrigation (water consumption in the order of 70 to 80 Mm^3 per annum);
- Construction sector (around 1 Mm^3 per annum);
- Manufacturing (0.7 Mm^3 per annum);
- Government sector (2.4 Mm^3 per annum); and
- Domestic use (34.0 Mm^3 per annum, up to half or 17 Mm^3 could be used for gardening).

Irrigation and domestic use are the largest users, and could each absorb the entire amount of wastewater generated in the country[11]. Similarly, irrigation projects in urban and peri-urban areas could easily absorb the available wastewater. The amount of wastewater could not be fully absorbed by the construction and government sectors.

<u>If all wastewater would be used for domestic use</u>, no direct economic benefits would be generated. Instead, the benefits would depend on the destination of the 'released' fresh water. Using the average value (constant 93/94 prices) of P 105.94/ m^3, the gross economic benefits in terms of value added would be Pula 1.5 billion per annum. The extra costs of delivery and infrastructure need to be deducted in order to estimate the net benefits. This scenario is not fully realistic as many economic sectors require better quality water than the current wastewater.

<u>If all wastewater would be allocated to irrigation</u>, the gross economic benefits could amount to around P 290 million (based on an average value added of P 20/m^3, as found in Namibia (Arntzen *et al*, 2003). Once more the extra costs of delivery and infrastructure need to be deducted in order to estimate the net benefits. Clearly, exclusive re-use for irrigated agriculture does not maximise the economic benefits of re-use *unless* the value added in irrigated agriculture exceeds the country's overall average; this could only be achieved by highly efficient irrigation of high-value products.

Given the above, the wisest choice of re-use seems to be a combination of re-use destinations. An example is presented in Table 5.8 with its economic consequences. The value added excludes indirect benefits and cost savings to companies that could be associated with re-used water. The estimate gross benefits total P 925 million per annum. It is difficult to estimate the impact on employment. Using the average employment rate of 2 800 per Mm^3, employment generation could be as much as 40 000 paid jobs. The figures in Table 5.8 are indicative at best. It is clear, however, that employment creation could become a major policy consideration in the promotion and allocation of waster water for re-use.

Full recycling would require additional treatment and adjustments of the water supply systems. It also introduces health risks (given the uncertain quality of outflows), requiring expensive monitoring. The precautionary measure of Windhoek to blend one unit of treated wastewater with two units of fresh water is feasible in Gaborone. The experience of Windhoek shows that monitoring costs are significant (Appendix 7). The additional costs would be much higher than the costs of re-use, but the benefits are also expected to be higher. Recycling would be viable as

[11] Watering of gardens is a substantial part of domestic use (up to 50%).

long as the extra treatment costs do not exceed the long run marginal supply costs plus the current treatment costs.

Table 5.8: Possible direct gross economic benefits of a composite re-use scenario

Destination	Designated re-use amount Mm^3)	Value added / m^3 (93/94 P/m^3)	Directly associated value added of re-use (M Pula 93/94 prices)	Possible associated paid employment
Irrigated agriculture	8.0	20	160	50 - 500
Construction	0.2	2 468	494	7 000 - 12 000
Government	1.0	271	271	20 000- 25 000
Domestic use	5.3	0	None[12]	
Total	14.5		925	Around 40 000

Recycling would boost the water production of WUC in urban areas and of DWA for urban villages. The gross economic benefits can be calculated as follows:

- For WUC: the amount of urban wastewater multiplied by the average value added per m^3 of WUC water;
- For DWA: the amount of rural village wastewater multiplied by the average value added per m^3 of DWA water.

[12] The benefits of re-use in the domestic sector depend on the destination of the saved fresh water sources, and could be substantial.

CHAPTER SIX
POLICY IMPLICATIONS AND FURTHER WORK

The water accounts raise a wide range of policy issues, which are briefly discussed below.

The report identified the following water management challenges:
- A growing spatial mismatch between water resources (mostly in the north) and water demand (mostly in the south-east);
- High variability of annual run-off related to highly variable rainfall patterns, limiting the safe yields of dams;
- Most surface water resources are subject to the SADC Protocol on Shared water Courses, and need to be shared in a fair, equitable and sustainable way with other countries;
- Escalating costs of traditional water supplies (dams and well fields);
- Limited groundwater resources, especially in the west, and high variations in recharge rates. Poor quality of groundwater in western and northern Botswana;
- Inadequate groundwater availability and recharge data;
- Rapid growth in water demand of households, government and the mining sector; spatially rapid growth in urban and peri-urban water demand;
- Serious under-utilisation of wastewater, in part due to separation of institutional responsibilities of water and wastewater management and lack of information and education about re-use and recycling of wastewater;
- Need to link investments in water and sanitation infrastructure to increase their benefits and efficiency.

Water stocks
The dam sub-account demonstrates that the amount of surface water stored is highly variable depending on rainfall patterns, even in a relatively short period of four years. Safe yields will increase by connecting dams and optimising their use as rainfall is spatially variable and evaporation rates differ. The groundwater stock account shows that the amount of groundwater available for development is unknown. Current results suggest that well fields are overutilised, and groundwater resources are likely to decrease. Without knowledge about the amount of groundwater available, it is difficult to estimate the lifetime of well fields. This is a policy concern for water supply of villages and the mining sector.

Water use
The use accounts show an overall growth in water consumption. However, there is no continuous, linear growth. Droughts and sectoral developments, such as the expansion of the mining sector and stagnation of the livestock sector, determine the growth in particular years or periods. The growth raises the policy of water demand management, which should focus on the leading water consumers (e.g. domestic use and government), areas where water savings can most easily and efficiently be achieved (e.g. irrigation and cutting water losses) and promotion of economic sector that require little water (e.g. service sector) .

The agricultural sector and households are the leading water consumers. Examining the trend since 1990, households, government and the mining sector experience the fastest growth. Therefore water management needs to focus on these four sectors. In terms of water suppliers, self providers (i.e. mining and livestock sector) account for around half of the country's water consumption. This has helped government to focus on urban areas and villages. However, there is need to guide and monitor strategies and activities of self providers. The introduction of a resource rent charge related to the consumption level needs to be considered.

Wastewater (WW)

The WW supply account shows that the amount of wastewater has doubled since 1992 and WW supply is growing faster than water supply due to improvements in wastewater treatment and an increase in sewerage connections. Households and government are the largest suppliers of wastewater. The WW use account show that only 3Mm^3 is re-used or around 20% of the outflow. The remainder is discharged into the environment. There is need to increase re-use ((i.e. with the current water quality) and to consider recycling (i.e. further treatment to potable drinking water standards) of treated wastewater. Current plans for irrigation in Gaborone and Francistown are useful, but additional opportunities need to be considered as well as opportunities for re-use in large villages. Re-use and recycling plans should be fully integrated into the design of new WWTW. The wastewater use accounts further show that advanced technologies produce more outflow as less water evaporates in the ponds. Re-use and recycling of the outflow would increase the efficiency of investments in advanced treatment technologies. The choice of technology should therefore also be part of the feasibility studies for wastewater treatment works.

Economic aspects

Water and sanitation are mostly treated as public goods, the development of which is financed from general government revenues. Self providers and WUC is the exception. Chapter five shows that the costs of traditional water supply (WUC and DWA) have increased significantly due to the need for more advanced and complex infrastructure, lower productivity of many dams and well fields and long distance water transfers. The costs of wastewater treatment are generally less than Pula 3/m^3 of outflow, hence lower than the costs of raw and potable WUC water. Re-use leads to costs savings if the transport costs of treated wastewater can be controlled. This requires efficient distributions mechanisms (e.g. dedicated industrial site for companies that can re-use water, concentrated irrigation such as in Glenn-Valley and wastewater trade).

Windhoek has lower water tariffs than Gaborone, even though both cities use the same water pricing principle and the former receives less rainfall. More re-use and recycling has assisted the city to keep water tariffs lower.

Despite higher tariffs, government subsidises large villages connected to the NSWC for P 130 100 million (2003) as DWA only recovers a small part of its payments to WUC. DWA water purchases from WUC have adversely affected the DWA policy to recover its operation and maintenance costs. This is an important policy issue.

Water accounts proved useful in various other ways for policy makers. It shows:

- Long terms in water production and consumption that can be used to validate (and when needed improve) water demand scenarios of BNWMP;
- The most important users and their trends in water consumption. The increase in water consumption for the mining sector is clearly visible and needs to be addressed;
- The fast growth in wastewater supply and limited use;
- The continued high loss rates (or unaccounted water), particularly at DWA. Progress in reducing such wastage can be monitored through water accounts;
- The different costs of water supply and wastewater treatment;
- Efficiency in water use by economic sector (in terms of value added and employment).

Further work is needed on water accounts, which is summarised below.

	Recommendations	Tasks
1.	To reflect the growth in inter dam water transfers[13], the inflow should ideally be separated into natural inflow and inflow *from* other dams (as well as inflows from treated wastewater that is recycled).	WUC to collect disaggregated data DEA to incorporate into WA Future: measure any recycled water flows
2.	Surface water stock accounts need to distinguish between international water sources and domestic ones. The former are shared with other countries, and their use is subject to international treaties and negotiations.	Input from WUC and DWA Incorporation by DEA
3.	In-depth work is needed on the amount of groundwater stored in aquifers/ well fields and on recharge estimates for well fields. This could be linked to the existing WELLMON data base in DWA. Non-DWA well fields need to develop similar monitoring data base.	DWA and DGS to improve data on groundwater availability and recharge Incorporation by DEA
4.	Future water use accounts need to make a distinction between intermediate and final water use. This requires data about water transfers between water providers.	Detailed data from WUC, DWA and the mining sector Incorporation by DEA
5.	Economic aspects of the water accounts need to be strengthened once better data become available. Cost and revenue data from DWA and WUC are improving; better wastewater treatment data are essential.	Cost data from DWA, WUC and DCs Incorporation by DEA
6.	Water accounts need to be developed for shared river basin such as the Okavango. This could support joint management decisions.	ODMP/ DEA
7.	Water accounts should distinguish accounts with different water qualities. This can only be done with adequate data. Improving water quality data, especially on wastewater is essential.	NAR, Councils and DWMPC Incorporation by DEA

In addition to the above, there is need to study the feasibility of re-use and recycling of wastewater and water demand management from an integrated water resource management perspective. This would help to solve water shortages in south-eastern Botswana and increase the competitiveness of the area through lower water tariffs.

[13] Two inter-dam transfers occur: Gaborone dam receives water from Bokaa dam and Molatedi dam in South Africa. NSWC from Letsibogo dam destined for Gaborone does not enter Gaborone dam but reaches end-users after treatment in Mmamashia plant north of Gaborone. Part of the water transfers from Bokaa and Molatedi dams is channelled directly into the treatment plant while another part is stored in Gaborone dam. No figures were available for the size of each part.

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APPENDIX 1: DEFINITION OF TERMS

Abstraction: total volume of water withdrawn from a territory of reference in a given year.

Aquifer: a formation which may either be a consolidated or unconsolidated rock in which groundwater collects.

Discharge: release of wastewater into the environment (BOS 93: 2004).

Drinking or potable water: water that is suitable for drinking purposes.

Effluent: the final liquid waste from a processing facility or household (adapted from BOBS standard 93-2004, which is restricted to processing facility)

Evaporation: amount lost to evaporation during the accounting period.

Inflow: amount of water that enters the territory of reference, usually a WWTW.

Territory of reference: encompasses dams, rivers, lakes and aquifers.

Outflow (or 'new' water): volume of water that leaves the territory of reference, usually WWTW.

Return flows: amount of water that reaches a territory of reference, usually a WWTW, from other uses, e.g. wastewater

Wastewater: water contaminated with pollutants following its use or application in domestic industrial, commercial or institutional premises (BOS 93: 2004)

APPENDIX 2: METHODOLOGICAL DETAILS

Wastewater supply estimates

The major supply groups could be further sub-divided, but currently this is only done for households, which are grouped into those depending on standpipes, those with yard connections and those with house connections. A further sub-division of business and government can be made but it is currently not meaningful as the same effluent generation fraction (EGF) is used for all sectors.

Method and assumptions
WW supply has been estimated by multiplying the actual water consumption derived from DWA and WUC by the above EGF. Further details are given below.

For the years 1990 and 1991, WUC data for Francistown, Jwaneng and Selebi-Phikwe are not broken down into domestic use, industry/business and government. Therefore, it has been assumed that the share in water consumption of each category is the same as that of 1992 (first year with disaggregated consumption) data.

Regarding domestic use, the estimated WW supply is calculated by multiplying the domestic water consumption from standpipes yard connections and house connections by the above mentioned standard or norm factor for the return flows. It is assumed that no water from standpipes and yard connection enters the sewerage system and WWTW.

The domestic consumption data for rural villages (DWA) are subdivided into the three categories (standpipes, yards and houses), and hence readily usable. However, urban water consumption does not have this breakdown. Therefore, the urban water consumption by category was calculated as a weighted average of the population depending on three water sources (standpipes, yards and house connections) and their average water consumption, as given in the NMPWWS (SMEC *et al*, 2003):

- House connections: 165 l/d/p;
- Yard connections: 50 l/d/p; and
- Standpipes: 35 l/d/p.

The percentages of population depending with the different types of water connections were derived from the Population Census 1991 and 2001 and interpolated for the period 1991-2001 and extrapolated for the period 2002-2003. In the Population Census 1991, yard and house connection were lumped together. Therefore, the assumption was made that in the period 1991-2001 the percentage of people with a house connection in stead of a yard connection increased by 1% per annum, reflecting improved welfare and living conditions. The subsequent calculations resulted in proportions of water consumption from yards and houses for the period 1991-2003 (see Table A2.1).

Table A2.1: Estimated proportions of water consumption by type of connection for five urban centres (1991 and 2001)

	water consumption of house connections as % of total domestic use (1991)	water consumption by yard connection as % of total domestic use (1991)	consumption by house connection as % of total domestic use (2001)	water consumption by yard connection as % of total domestic use 2001	Annual growth rate in wat. cons. from house connections	Annual growth rate in wat. cons. from yards
Gaborone	56.8	14.7	78.8	13.4	7.5	3.1
F/town	36.8	15.4	66.6	18.8	7.7	3.5
Jwaneng	77.3	18.4	85.4	13.3	4.1	-0.0
S/Phikwe	46.8	22.2	67.8	22.1	3.5	-0.0
Lobatse	47.8	14.5	69.4	14.3	3.6	3.6

Regarding the government sector, WW supply has been calculated as water consumption by government multiplied by the EGF of 0.65. It is assumed that:

- All government institutions are connected to the sewerage system and WWTW;
- For the period 1998-2002, the share of the government consumption in Gaborone is the average share for the period 1990-97 (0.9153).

Regarding the industry/ business, WW supply has been calculated as the water consumption of this sector multiplied by the EGF of 0.55. It is assumed that:

- All industries and business that use water are connected to the sewerage system and WWTW;
- For the periods 1998-2002, the share of industry/business water in Gaborone is the average for the period 1990-97 (0.775);

APPENDIX 3: DETAILS OF THE WATER ACCOUNTS

Use accounts

Table A3.1: Water use account by institution (in 000m^3; 1992-2003)

Category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DC	20435	20611	20791	20973	21158	21345	21536	21734	21937	22151	22369	22591
DWA	7765	7715	8703	8961	9080	9374	10356	10723	10465	10413	11326	11805
WUC	25391	26973	27692	27672	28043	30661	35435	38438	41903	44585	49170	50343
Others	86661	86476	85584	88912	83009	84178	86042	91798	94363	93182	104060	85592
Total	140252	141775	142770	146518	141290	145558	153369	162693	168668	170331	186925	170332

Table A3.2: Water use account by source of water (in 000m^3; 1992-2003)

Category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
groundwater	86658	86903	87455	90609	87060	88624	91078	96898	99272	97761	107774	94605
Dams	43919	45203	45746	46237	44840	47462	52653	55862	59607	62597	68698	66158
Rivers	9674	9545	9569	9808	9390	9471	9638	9649	9711	9972	10453	9569
Total	140252	141651	142770	146654	141290	145558	153369	162409	168590	170331	186925	170332

Table A3.3 Water use account by economic sector (in 000m^3; 1992-2003)

User category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Agriculture	72913	74196	72912	75216	70592	69558	71559	74802	76048	75652	82086	63420
Mining	12840	14890	15197	16551	14418	17910	18361	20857	24098	22851	25357	26751
Manufacturing	390	2289	2291	2282	2069	2559	3108	3725	3994	4392	4910	5109
Water + electricity	1240	1306	1176	1152	768	738	960	735	510	467	475	710
Construction	0	320	246	240	364	304	193	365	386	397	423	430
Trade	159	660	651	618	749	760	747	932	956	1053	1067	1175
Hotels and restaurants	227	635	624	540	546	567	535	755	803	800	804	845
Transport + communication	0	172	161	169	167	171	185	222	235	241	260	265
Insurance, banking, business	11	488	446	457	517	529	583	657	692	706	771	782
Social and personal services	0	1272	1182	1247	1176	1148	1285	1587	1680	1727	2395	2435
Government	8689	7459	9017	8693	8847	8577	10101	10347	11096	11275	11053	11502
Household use	36090	38089	38866	39352	41078	42742	45752	47603	48093	50771	57224	56908
WUC private sector	7695	0	0	0	0	0	0	0	0	0	0	0
Grand total	140252	141775	142770	146518	141290	145562	153369	162588	168590	170331	186825	170332

Wastewater accounts

Table A3.4: Wastewater supply account by area and sector ($000m^3$)

Urban areas	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Gaborone	7225	7399	8418	7991	7696	8250	10102	11859	12435	12599	15055	14971
Ftown	1867	2028	2217	2216	2233	2457	2722	3237	3646	3909	3826	4145
Jwaneng	712	707	779	757	778	774	786	855	844	864	1007	1059
S/Phikwe	2167	2012	2129	2313	2294	2484	2937	2952	3884	3071	2986	3076
Lobatse	856	894	888	933	893	1072	1114	1227	1284	1480	1418	1604
Large villages												
Kasane	123	146	170	232	202	224	110	178	229	251	253	275
Maun	0	0	410	308	302	403	418	391	388	450	322	303
Mochudi	139	147	151	131	178	214	279	317	400	422	545	499
Mogoditshane	574	648	1284	1204	1321	1018	1459	1025	757	1329	1406	1446
Molepolole	150	195	166	157	167	234	90	434	265	325	292	353
Palapye	0	0	0	0	0	0	0	0	409	456	454	445
Ramotswa	0	0	0	0	0	0	0	0	0	258	285	314
Tlokweng	221	269	300	315	302	293	344	603	661	633	675	716
$000m^3$	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Urban	12828	13040	14431	14210	13895	15037	17662	20130	22092	21922	24292	24855
Rural	1206	1405	2480	2346	2473	2386	2700	2948	3110	4125	4231	4352
Total	14035	14445	16911	16556	16368	17422	20362	23078	25202	26047	28524	29207
$000m^3$	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Households	4598	4958	5560	5927	6213	7080	7965	8271	8796	10110	10768	10640
Government	4708	5354	6847	6322	6024	5879	7599	9079	11323	10937	11819	12561
business/ industry	4729	4133	4504	4307	4131	4463	4799	5729	5083	5000	5937	6006
Total	14035	14445	16911	16556	16368	17422	20362	23078	25202	26047	28524	29207

Note: Tlokweng and Mogoditshane are added to urban areas as their wastewater is treated in Gaborone.

Table A3.5: Wastewater use accounts (1990-2003; 000m^3)

	User category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
I.	Agriculture	320	335	332	349	334	401	417	459	480	554	531	600
II.	Mining	214	212	234	227	233	232	236	257	253	259	302	318
III.	Industry	0	0	0	0	0	0	0	0	0	0	0	0
IV.	Water/ Electricity	0	0	0	0	0	0	0	0	0	0	0	0
V.	Construction	0	0	0	0	0	0	0	0	0	0	0	0
V	Services	141	146	176	167	164	168	210	237	244	256	302	302
VI.	Government												
	Central govt	141	146	176	167	164	168	210	237	244	256	302	302
	Local govt	71	71	78	76	78	77	79	86	84	86	101	106
VI.	Domestic Use	0	0	0	0	0	0	0	0	0	0	0	0
VII.	Environment												
VII.1	Evaporation/ treatment losses	6127	6232	7301	7164	7055	7480	8714	9785	10540	10591	11724	11942
VII.2	Discharge in rivers	6880	7144	8362	8148	8060	8528	10093	11535	12466	13932	15126	15497
	Other outflow	34	38	42	51	47	54	38	51	60	67	65	72
VIII.	**Total use of WW**	**13929**	**14325**	**16700**	**16348**	**16135**	**17109**	**19995**	**22648**	**24372**	**26002**	**28453**	**29138**

Table A.3.6: Value added per m^3 of water (1993/94 constant prices; Pula).

User category	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Agriculture	6.50	6.43	6.67	6.73	7.05	6.37	5.53	6.07	5.91	5.41	3.71
Mining	274.44	262.04	252.18	313.36	269.56	256.93	252.12	260.45	264.69	257.08	260.22
Manufacturing	194.24	236.95	256.97	300.80	250.04	218.78	187.49	177.10	160.25	144.29	137.83
Water + electricity	190.07	222.61	228.33	366.90	409.44	357.19	500.91	796.56	895.79	942.17	653.86
Construction	2294.25	2999.12	3189.95	2269.05	2766.54	4889.56	2629.59	2565.12	2596.33	2395.36	2467.54
Trade	1116.19	1396.79	1653.76	1635.61	1631.08	1799.96	1522.98	1613.83	1570.70	1543.14	1444.62
Hotels and reastaurants	275.65	3199.90	367.99	364.84	380.04	372.69	281.75	277.32	303.24	333.64	321.38
Transport + communication	2447.82	2758.13	2649.87	2869.92	2971.32	3220.92	2739.03	2677.95	2673.90	2441.42	2428.13
Insurance, banking, business	2421.34	2821.44	3025.64	2770.76	2901.15	2883.80	2657.51	2692.61	2807.68	2577.31	2666.16
Social and personal services	381.65	435.46	436.30	497.49	511.82	494.27	415.64	1631.55	1708.88	1247.45	1281.89
Government	236.34	199.61	218.47	238.06	261.76	237.48	244.53	247.06	261.69	270.26	271.39
Grand total	75.88	90.48	80.44	90.24	92.27	91.24	91.48	98.04	98.92	93.06	105.78

APPENDIX 4: FEATURES OF CURRENT WASTEWATER TREATMENT WORKS

Name and location	**year built**	**Technology**	**Operator**	**m^3/day**	**m^3/day**	**m^3/yr**	**m^3/day**	**m^3/yr**
				capacity	**inflow**		**outflow**	
Gaborone Treatment Plant	1997	A S	GCC	40000	34000	12410000	18700	6825500
Otse Police College	2000	RBC	own	262	200	73000	200	73000
Moeding College	1998?	RBC	own	50	50	18250	50	18250
Ramotswa village	2001	Ponds		3000	400	146000	0	0
St. Joseph's College	1983	Ponds	own	100	100	36500	40	14600
Mokolodi Game Reserve	1996	wetlands	own	10	10	3650	10	3650
Tlokweng village	2002		SEDC			0		0
Tlokweng TTC	2000	wetlands	own	20	20	7300	19	6935
Lobatse Town	1982-1999	ponds	LTC	6200	3100	1131500	1240	452600
BMC abottoir Lobatse	1985	ponds + trickling filter	BMC	1700	900	328500		0
BMC tannery Lobatse	1985?	ponds	BMC	??	??	??	??	??
Molepolole village	1986 upgrade	ponds	KDC	345	400	146000	160	58400
Molepolole Prison	1995	ponds	own	50	30	10950	12	4380
Thamaga Prim. Hospital	2002	A S	own	45	25	9125	24	8760
Thamaga TL housing	1994	wetlands	own	5	5	1825	5	1825
Thamaga TL Research	1994	wetlands	own	5	5	1825	5	1825
BDF air base	upgrade 2000	ponds	own	1700	300	109500	300	109500
BDF	1991	ponds	own		700	255500		0
Moshupa SSS	1986/ 1996	ponds	own	80	80	29200	80	29200
Seepapitso SSS	upgrade 1996	ponds	own	100	50	18250	20	7300
Kanye Prison	1997	wetlands	own	25	30	10950	29	10585
Kanye Educ. Centre	2001	ponds	own	106	50	18250	0	0
Kanye hospital	?	RBC	own	20	20	7300	20	7300
Nat. Food FTEC	2000	wetlands	own	10	10	3650	10	3650
Ramatea College	1998	wetlands	own	15	15	5475	14	5110
Jwaneng Town	1980-1995	ponds	JTC	5000	3500	1277500	1400	511000
Jwaneng mine	1981	ponds	Debswana	150	150	54750	60	21900
Mochudi south	upgrade 1998	ponds	KDC	3500	350	127750	0	0

Mochudi north	upgrade 1999	ponds	KDC	1300	100	36500	0	0
Selebi Phikwe	upgrade 2002	ponds	STC	5000	5000	1825000	2000	730000
Madiba SSS	1990?	ponds	own	30	30	10950	12	4380
Mahalapye prison/ hosp.	1990?	ponds	own	200	240	87600	96	35040
Mahalapye Prison Coll	2000	ponds	own	100	30	10950	0	0
Sefhare Prim. Hospital	1998	ponds	own	40	30	10950	12	4380
Shoshong SSS	1996	ponds	own	100	50	18250	0	0
Moeng College	1983	ponds	own	100	100	36500	40	14600
Lotsane SSS	1989	ponds	own	100	150	54750	60	21900
BHC housing Palapye	1992	ponds	own	200	200	73000	80	29200
Palapye village	2000	ponds	CDC	1000	300	109500	0	0
Swaneng SSS	1985	ponds	own	300	300	109500	120	43800
Serowe new prison	?	ponds	own	75	150	54750	60	21900
Serowe TTC	?	ponds	own	150	150	54750	60	21900
Letlhakane SSS	2000	ponds	own	200	150	54750	60	21900
Letlhakane prison	1998	pond	own	50	30	10950	1	365
Letlhakane mine	1998	RBC	Debswana	60	60	21900	57	20805
Orapa township	1999	AS	??	3000	2500	912500	2375	866875
Matshekge SSS-Bobonong	upgrade 98?	ponds	own	100	70	25550	28	10220
Shashe River SSS	1989	ponds	own	100	100	36500	40	14600
Tonota CE	1987	ponds	own	100	100	36500	40	14600
Gweta Prim. Hospital	2001	ponds	own	71.3	50	18250	20	7300
Martin's drift border post	2001	wetlands	own	35	20	7300	19	6935
Mc.Connel and Tutume Health Centre	1989	ponds	own	100	100	36500	40	14600
Sowa township	1991	ponds	STC	370	400	146000	160	58400
Sowa mine	1990?	ponds	mine	20	20	7300	8	2920
Ftown old	?	ponds		6000	?	?	?	?
Ftown new	2002	TF	FTC	15000	6000	2190000	5700	2080500
Masunga village	?	ponds	NEDC	560	400	146000	160	58400
Maun village	1994	ponds	NDC	600	400	146000	140	51100
Boro Farm prison	2002	ponds	own	100	50	18250	0	0
Thuso Rehab centre	1994	wetlands	own	10	10	3650	10	3650

Hukuntsi prim. Hospital	1997	ponds	own	30	20	7300	0	0
Matsha College Kang	1999	ponds	own	200	150	54750	60	21900
Middlepits border post	1996	wetlands	own	35	25	9125	24	8760
Mc.Cathy rust border post	1996	wetlands	own	50	50	18250	38	13870
Tshane prison	2001	ponds	own	50	20	7300	0	0
Ghanzi SSS	1995	ponds	own	60	100	36500	40	14600
Kasane village	1992	ponds	CDC	580	500	182500	200	73000
						0		0
Total				**98674.3**	**62655**	**22869075**	**34158**	**12467670**

Source: adapted from SMEC *et al*, 2003.

APPENDIX 5: HOUSEHOLD ACCESS TO WATER AND SANITATION

Table A5.1: Household access to sanitation facilities (2001).

	Urban areas	Rural Villages				sub-total	Localities				sub-total	Total	Total
		less than 500	500-999	1000-4999	5000+	Villages	lands	CP	farms	others	localities	Rural	
Own													
Flush toilet	31.0	3.8	3.7	7.3	27.5	6.6	2.3	0.1	22.6	22.3	6.6	6.6	20.7
Improved	22.8	10.6	14.1	19.9	23.8	18.2	3.4	1.3	3.7	5.3	3.2	12.5	18.5
Pit	30.1	14.8	20.8	28.1	30.1	25.7	8.3	2.3	5.8	5.9	6.0	18.2	25.1
Environ-loo	0.5	1.0	0.7	0.5	1.0	0.6	1.5	0.4	2.3	1.8	1.3	0.8	0.7
total own	84.4	30.1	39.3	55.7	82.3	51.0	15.5	4.1	34.3	35.3	17.1	38.1	64.9
Shared facility													
Flush toilet	0.9	0.4	0.3	0.4	2.3	0.4	0.4	0.0	5.3	4.3	1.3	0.8	0.8
VIP	0.9	0.6	0.8	0.6	0.1	0.6	0.6	0.5	3.5	0.9	0.8	0.7	0.8
Pit	4.3	6.6	6.0	7.0	2.9	6.7	4.1	1.7	9.5	4.9	4.0	5.7	4.9
Neighbours	5.1	6.4	9.5	11.4	7.8	10.6	1.6	0.4	0.7	0.8	1.1	7.0	5.9
None	4.3	55.6	44.0	24.8	4.7	30.5	77.6	93.2	46.7	53.6	75.6	47.6	22.5
Unknown	0.1	0.3	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.1
Total shared	15.6	69.9	60.7	44.3	17.7	49.0	84.5	95.9	65.7	64.7	82.9	61.9	35.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Adapted from Population Census 2001 (Central Statistics Office)

Table A5.2: Proportion of households with access to water by type and location (2001)

% of hh	Urban areas	Rural Villages				sub-total	Localities				sub-total	Total	Total
		<500	500-999	1000-4999	5000+	Villages	lands	CP	farms	others	localities	Rural	
piped house	31.6	4.2	5.2	8.7	28.8	7.9	2.2	0.1	15.2	20.8	5.8	7.1	21.3
piped yard	37.8	10.3	16.3	24.7	38.3	22.2	6.4	0.0	23.8	8.2	6.1	16.1	28.7
Standpipe	28.7	73.9	74.6	63.1	32.1	65.8	33.4	12.3	12.5	26.4	24.7	50.2	37.7
Bowser-tank	0.1	4.4	1.4	0.4	0.2	0.9	3.3	3.2	5.6	5.9	3.9	2.1	0.9
Well	0.0	0.3	0.2	0.3	0.0	0.3	10.9	15.3	1.8	6.1	10.6	4.2	1.8
Borehole	0.1	2.3	0.4	0.3	0.0	0.4	19.3	55.9	34.3	22.6	31.3	12.2	5.1
River	0.0	3.6	0.7	0.7	0.0	0.9	11.5	7.9	1.2	5.3	8.6	3.9	1.6
dam pan	0.0	0.3	0.0	0.3	0.0	0.2	9.9	3.6	4.8	3.4	6.6	2.7	1.1
Rainwater tank	0.0	0.1	0.1	0.1	0.0	0.1	0.6	0.4	0.3	0.2	0.5	0.2	0.1
spring water	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.3	0.4	0.2	0.1
Other	1.6	0.6	0.8	1.4	0.6	1.2	1.8	1.0	0.5	0.6	1.3	1.2	1.5
not known	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: adapted from CSO, 2003

APPENDIX 6: WATER STANDARDS

Drinking water standards

The Botswana Bureau of Standards has developed countrywide standards for drinking water. Water providers, whose water falls in class 3, get a limited period of time to provide water of class 2 standards.

Variable	Unit			
Physical and aesthetic	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable)**
Colour	TCU	15	20	50
Conductivity at 25 25 o C	S/cm	700	1 500	3 100
Dissolved solids	Mg/l	450	1 000	2 000
Odour		Not objectionable	Not objectionable	Not objectionable
PH value at 25 C		6.5- 8.5	5.5- 9.5	5.0 – 10.0
Taste	N/a	Not objectionable	Not objectionable	Not objectionable
Turbidity	NTU	0.5	5	10
Chemical requirements macro determinants	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable**
Ammonia as N	mg/l	0.2	1.0	2.0
Calcium as Ca	mg/l	80	150	200
Chloride residual	mg/l	100	200	600
Fluoride as F	mg/l	0.7	1.0	1.5
Hardness as $CaCo_3$	mg/l	20	200	500
Magnesium as Mg	mg/l	30	70	100
Nitrate as NO_3	mg/l	45	45	45
Nitrate as NO_2	mg/l	3.0	3.0	3.0
Potassium as K	mg/l	25	50	100
Sodium as Na	mg/l	100	200	400
Sulfate as SO_4	mg/l	200	250	400
Zinc as Zn	mg/l	3.0	5.0	10.0
Chemical requirements- micro determinants	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable**
Aluminium as Al	μg/l	100	200	200
Antimony as Sb	μg/l	5.0	5.0	5.0
Arsenic as As	μg/l	10	10	10
Cadmium	μg/l	3.0	3.0	3.0
Chromium as Cr (total)	μg/l	50	50	50
Cobalt as co	μg/l	250	500	1000
Copper as Cu	μg/l	1000	1000	1000
Cyanide (free as CN	μg/l	70	70	70
Cyanide (recoverable) as CN	μg/l	70	70	70
Iron as Fe	μg/l	30	300	2000
Lead as Pb	μg/l	10	10	10
Manganese as Mn	μg/l	50	50	50
Mercury as hg (total)	μg/l	1.0	1.0	1.0
Nickel as Ni	μg/l	20	20	20
Selenium as Se	μg/l	10	10	10

Source: Botswana Bureau of Standards BOS 32:2000.

Wastewater standards

Determinant	Unit	Upper limit and range	Class 3 potable water	Comment
Colour	TCU	50	50	Acc
Temperature	0 C	35		NN
Total dissolved solids (TDS)	Mg/l	2000	2000	Acc
Total suspended solids (TSS)	Mg/l	25		NN
BOD_5 (max.)	Mg/l	30		NN
Faecal coliform	Counts/ 100 ml	1000		NN
COD (max)	Mg/l	75 (filtered)		
COD (max)	Mg/l	150 (unfiltered)		
Dissolved oxygen (min)	% sat.	60		
PH value at 25 C		6.0-9.0	5-10	Acc
Turbidity	NTU	30		
Chemical requirements macro determinants	**Unit**			
Free and saline ammonia as N	mg/l	10	2.0	Not acc
Calcium as Ca	mg/l	500	200	Not acc
Chloride as Cl	mg/l	600		NN
Fluoride as F	mg/l	1.5	1.5	Acc
Chlorine residual	mg/l	1.0	600	??
Magnesium as Mg	mg/l		100	NN
Nitrate as N	mg/l	22		NN
Ortho phosphate or soluble phosphate as P	mg/l	1.5		NN
Potassium as K	mg/l	100	100	Acc
Sodium as Na	mg/l	400	400	Acc
Sulphate as SO_4	mg/l	400	400	Acc
Zinc as Zn	mg/l	5.0	10.0	Acc
Chemical requirements- micro determinants	**Unit**			
Aluminium as Al	μg/l		200	NN
Antimony as Sb	μg/l		5.0	NN
Arsenic as As	μg/l	0.100	10	Acc
Boron as B	μg/l	0.50		NN
Cadmium	μg/l	0.02	3.0	Acc
Chromium VI as Cr	μg/l	0.25		NN
Chromium as Cr (total)	μg/l	0.5	50	Acc
Cobalt as co	μg/l	1.00	1000	Acc
Copper as Cu	μg/l	1.00	1000	Acc
Cyanide as CN	μg/l	0.100	70	Acc
Iron as Fe	μg/l	2.00	2000	Acc
Lead as Pb	μg/l	0.05	10	Acc
Manganese as Mn	μg/l	0.100	50	Acc
Mercury as hg (total)	μg/l	0.01	1.0	Acc
Nickel as Ni	μg/l	0.30	20	Acc
Selenium as Se	μg/l	0.02	10	Acc

Note: acc: wastewater standard is acceptable as class 3 drinking water; NN: standards are not comparable; Not acc.: wastewater does not class 3 drinking water standard.

Source: Botswana Bureau of Standards BOS 93: 2004.

Standards for discharge on perennial and ephemeral streams

By law, water resources need to be returned of a quality closest to the quality of the abstracted water. DWA has developed standards for the quality of the water discharged in streams.

Physical and aesthetic variables	Unit	Perennial	Ephemeral
Temperature	0^0C	35	35
Colour	TCU	30	50
Conductivity at 25 o C	S/cm	700	1 500
Dissolved oxygen (% sat.)		75	75
pH		6.5-9.5	6.5-9.5
BOD		20	30
COD		30	75
Free and Saline Ammonia as (N)		1.0	10
Nitrate as (N)		2.0	-
Total Phosph. as (P)		-	1.5
Total Chloroforms/100ml		5000	20000
Faecal Chloroforms/100ml		100	500
Arsenic		1.0	0.5
Boron		-	0.5
Zinc		5.0	5.0
Copper		1.0	1.0
Phenols		0.005	0.01
Lead		0.001	0.05
Cyanide		0.01	0.1
Cadmium		1.0	0.05
Mercury		0.001	0.02
Selenium		0.01	0.05
Iron		1.0	1.0
Manganese		0.1	0.5
Sulphate		400	600
Chlorides		600	1000
Sodium		400	600
Fluorides		1.5	2.5
TDS		10000	2000
Turbidity	IUTU		
Oil and Scum		Nil	Nil
Chromium		0.05	0.5

Source: Department of Water Affairs

APPENDIX 7:
THE "WINDHOEK" EXPERIENCE WITH RE-USE AND RECYCLING

The capital of Namibia is an international front runner in the re-use and recycling of treated wastewater (Van der Merwe and Haarhoff, 1999; Van der Merwe, 1999). Windhoek receives potable water from a combination of groundwater, dams and recycled wastewater. The city re-uses treated wastewater through a dual pipe system (potable and non-potable water), and reduces evaporation losses of surface water by interconnecting dams and artificial recharge. The package of water supply and demand control measures in Windhoek has kept the water tariffs at bay and below those of Gaborone (cf. Figure 2.1) even though Windhoek has lower rainfall than Gaborone and the cities use the same pricing principles. Windhoek has an average rainfall of 360 mm per annum and an average evaporation of 3400 mm per annum; corresponding figures for Gaborone are 500 and 2000 mm. Windhoek had a population of 224 500 in 1999; its main water sources are summarised in Table A7.1.

Table A7.1: Water supply sources of Windhoek

Type of water	Infrastructure	Capacity
Groundwater	Fifty boreholes	1.93 Mm^3 for a max. of four consecutive years
Surface water	Six dams (1933-1982)	Capacity of 194 Mm^3 but safe yields of 21.1 Mm^3 (only 1.48 Mm^3 if dams would operate in isolation)
Reclaimed wastewater	Reclamation plant since 1968); expansion in 2000.	Capacity of 2.9 Mm^3; expansion to 7.7 Mm^3 .

Source: Van der Merwe, 1999.

Re-use and recycling of wastewater has led to an estimated water savings of 6.7% in 1999. Several measures were taken to control costs and health risks:

- Establishment of a water use ceiling of 1.3 m^3 /m^2 /day for irrigation;
- Diversion of industrial effluent, which may be seriously polluted, from the WWTW;
- Blending of recycled and fresh water: a maximum of 35% of recycled wastewater is mixed with a minimum of 65% of fresh water;
- Stringent water quality monitoring. Water quality monitoring is expensive at 15% of the total treatment costs; and
- Location of industries and activities that re-use wastewater in a particular site that is supplied by a dual reticulation system. The pipeline with treated wastewater has a capacity of 1.2 Mm^3 per annum and serves ninety nine large consumers.

The re-use and recycling of wastewater has been very successful. The production of freshwater for Windhoek has decreased despite the rapid growth of the city. Financial savings of US$ 8.7 million per annum have been achieved associated with the postponement of new capital works and lower water production costs. There have been no negative health impacts that could be traced to re-use and recycling of wastewater. Finally, both industry and households benefited from lower increases in water tariffs than would have been necessary without re-use and recycling. The costs of water reclamation were estimated to be the same (N$ 2.40/ m^3) as the cost of bulk water supply from Namwater, which would have risen considerably without re-use and recycling of treated wastewater. For example, the costs of water abstraction from the Okavango are almost three times the costs of water reclamation (US$ 1.43 and 0.58 per m^3; van der Merwe and Haarhoff, 1995; Van der Merwe, 1999). The cost savings[14] have had significant economic and welfare benefits, which have not been quantified.

The Windhoek experience shows that:

1. Recycling and re-use of wastewater can be cheaper than building new supply systems;
2. Proper physical planning can reduce the costs of reclamation and facilitate re-use/ recycling; and

The choice between re-use and recycling must be an informed one, based on different options and their net benefits.

[14] Water demand management and artificial recharge are cheaper than reclamation (US$0.17, 0.35 and 0.58/ m^3 respectively (Van der Merwe, 1999).