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South African Geographical Journal (2003) 85 (1), 42-

WATER RESOURCES IN BOTSWANA WITH PARTICULAR REFERENCE TO THE SAVANNA REGIONS

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ABSTRACT

Production and development in the savanna regions of southern Africa are primarily determined by interactions between the limitations imposed by ecological determinants (such as rainfall and soil quality) and the management strategies of the specific region. Good planning, focussing on both the short and long-term effects of water use, is needed in water management strategies. Botswana is already experiencing so-called ‘water stress’ which is related to a number of factors such as rapidly increasing population leading to a sharp increase in water demand, low and variable rainfall, high rates of evaporation, and the high cost of exploiting existing water resources. At the current rates of abstraction, the lifetime of surface and groundwater resources is limited to decades. Botswana shares four river basins with its neighbouring countries. This results in a situation where 94% of the fresh water resources which Botswana can theoretically access originates outside its borders, making water resource management highly complex. Transnational sharing and management of water resources, therefore, plays a major role in securing sustainability of this precious resource.

Introduction

Production and development in the savanna regions of southern Africa are primarily determined by interactions between the limitations imposed by ecological determinants (such as rainfall and soil quality) and the management strategies of the specific region. The former determine, to a large extent, the management policies necessary for sustainable utilisation of the natural components of savannas. This paper aims to overview the water resources in Botswana as background to discussions on the sustainable utilisation of the savanna areas. Policies on water supply and demand will be investigated in terms of the equitable distribution of the resources in relation to the areas of demand, sharing of international river basins and the agreements related to sustainable utilisation of these potential renewable water resources in Botswana, as well as the various regional factors influencing management decisions (such as the climate and population growth). Data was collected as part of a general assessment on the southern African savanna region.

Botswana is a semi-arid country in the centre of southern Africa, with a total area of 581 730 km^2. Only about 6.2 x 10^6 ha of this area (approximately 10%) is cultivable land [FAO, 1995b]. Apart from the perennial rivers and wetlands in the north and the over-utilised Limpopo and its tributaries in the east, Botswana suffers from a lack of surface water and therefore development relies heavily on groundwater. Groundwater resources can be found almost everywhere in the region and is the main source for most of Botswana’s towns and smaller settlements, the livestock industry, its power stations and many mining developments. Rural and remote towns are often entirely dependent upon groundwater except in cases such as Kasane on the lower Chobe-Zambezi River and Mohembo and Shakawe on the Okavango River (Ashton *pers. comm*., 2000).

Water is a scarce resource in Botswana that undoubtedly needs good planning which should take into consideration both the short and long-term effects of its use. Botswana, Namibia, South Africa and Zimbabwe are the four countries in southern Africa already experiencing so-called ‘water stress’, in other words the countries have freshwater resources between 1 000 and 1 700m^3 per person per year (UNEP, 1999).

One of the factors related to the scarcity of water in Botswana is the rapidly increasing population associated with a sharp increase in the demand for water. This may lead to water resource depletion if the rate of replenishment is lower than the rate of use. However, given the serious effect that HIV/AIDS is having on countries’ population growth rates in southern Africa, the earlier (outdated) estimates of population growth and accompanying water demand will be reduced significantly. According to a recent survey by the World Health Organisation (WHO), two thirds of infected adults (people aged 15 - 49 years) live in southern Africa. One in every four adults is infected in Botswana (UNAIDS, 2000).

Other factors influencing water availability and distribution in Botswana are the low and variable rainfall, high rates of evaporation and high costs of the exploitation of existing surface water resources. The semi-arid climatic conditions of the southern African region underpin the management strategies for both the groundwater and surface water resources.

Water and the environment

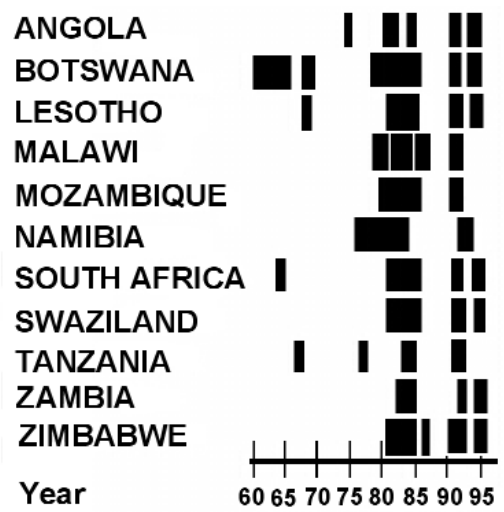
Climate

The availability of water in the environment is influenced by the climate. In southern African savannas the climate (and therefore, the water availability) sets the limit for the amount of growth and development that can take place in the region. High temperatures lead to very high evaporation rates that deplete the already low rainfall (Pallett, 1997). In Botswana, the mean daily temperatures range from a minimum of 5.5 ºC in winter to a maximum of 38 ºC in summer (Kgathi, 1999). The mean annual rainfall for Botswana is 400 mm, ranging from 250 mm in the southwest to a maximum of 650 mm.yr^{-1} in the northeast within the Kasane-Kazungula sector (Pallett, 1997). There are no major mountain chains in Botswana, therefore spatial and seasonal variations in the climate are not very complex.

Statistics such as ‘mean or average rainfall of 400 mm. yr^{-1}, tells nothing of either the seasonality or inter-annual variability in rainfall. In semi-arid regions such as Botswana the variability in the rainfall is more important than the actual rainfall itself (Pallett, 1997). Over 90% of the rainfall in Botswana occurs during the summer from November to March, mainly in the form of scattered convective thunderstorms. Hailstorms are common at the beginning and end of the rainy season [FAO, 1995b]. The variability of rainfall, in terms of the amount and timing, as well as the length of the wet season, lead to higher risks in, for example, the cultivation of crops. The temporal distribution of rainfall in Botswana is extremely variable but tends to be more reliable in the higher rainfall areas in the north of the country (Pallett, 1997).

Drought is a phenomenon that seriously influences the availability of water in the environment. Figure 1 clearly indicates that Botswana is a particularly drought prone country when compared to the rest of the southern African region in terms of the frequency and duration of drought events. The number of drought occurrences affecting the southern Africa region has been steadily increasing. In the latter half of the twentieth century, between 1988 and 1992, over 15 drought events affected this region, compared to fewer than five such events between 1963 and 1967 (Fig.1). Part of this trend can be tied to increased population growth and cultivation of marginal lands, while another part can be attributed to ENSO-related anomalies Recent work by McCarthy *et al.* (2000) has suggested very strongly that this is closely tied to a longer (80-year duration) cycle of rainfall and river flows.

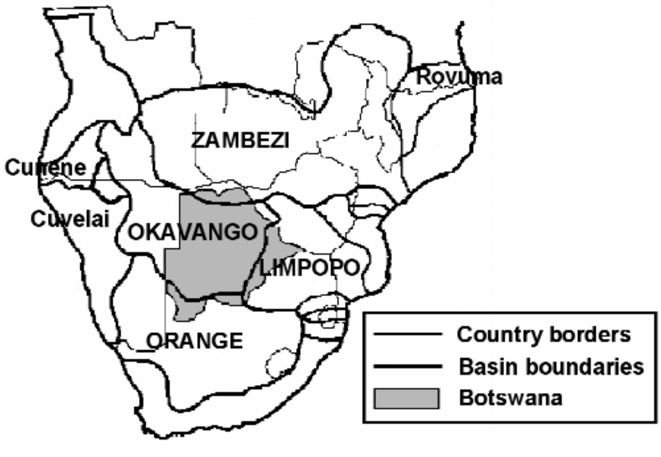
Figure 1: Recent droughts in the SADC region (from Conley, 1996).



Water resources distribution

Water resources in Botswana are generated within the basins of the four major rivers: the Limpopo, Okavango, Orange and Zambezi Rivers (Heyns, 1995) (Fig. 2). It is important to note that, apart from the Okavango River, all shared river systems flow away from Botswana and only a small area of these basins lie within the country. In contrast, the Okavango rises outside the country and much of its flow is generated external to the country. Water in Botswana is thus a common resource that must be shared between a number of the Southern African Development Community (SADC) states such as Angola, Namibia, Zambia, Zimbabwe, South Africa and Mozambique.

Figure 2: Major river basins of southern Africa (from Conley, 1996).



Tables 1 and 2 give a summary of the water balance for Botswana in terms of the availability of the resources as well as the water demand for the different sectors such as agriculture and domestic. The total mean annual surface runoff (MAR) from catchments originating within Botswana is about 1.2 x 109$m^3.yr^{-1}$ [FAO, 1995b]. Most of the surface water resources are located in the sparsely populated districts of Ngamiland and Chobe in northern and north-western Botswana where the perennial Chobe, Okavango, and Zambezi Rivers are found. In the eastern part of the country, where more than 80% of the population lives, all the rivers are ephemeral (Kgathi, 1999). Concentration of population in towns and urban villages results in an increase in the local demand for water and, therefore, development in these areas relies heavily on groundwater. Although the total renewable groundwater resource of 1.7 x $10^9 m^3.yr^{-1}$ exceeds the internal surface water resource, local exploitation can lead to mining of groundwater resources (Pallett, 1997).

Table 1: Water resources for Botswana [Sources: FAO, 1995a and FAO, 1995b].

Average precipitation	401 $mm.yr^{-1}$
Total dam capacity (1992)	400 x $10^6 m^3$
Internal renewable surface water resources	12 000 x $10^6 m^3.yr^{-1}$
Internal renewable groundwater resources	17 000 x $10^6 m^3.yr^{-1}$
Internal renewable water resources (Total)	29 000 x $10^6 m^3.yr^{-1}$
Potential renewable water resources available from outside Botswana's border	147 000 x $10^6 m^3.yr^{-1}$

Table 2: Water demand for the different economic sectors of Botswana (1995) in relation to other selected southern African countries (Source: Liasi and Chenje, 1996).

Country	Demand (x 106 $m^3.yr^{-1}$)					
	Domestic And Industry	Livestock	Mining And energy	Irrigation	Environment and tourism (including wildlife)	Total
Botswana	175	44	65	47	6	337
Mozambique	135	65	10	3 000	na	3 210
Namibia	200	70	15	248	2	535
South Africa	10 397	368	1 937	10 764	4 702	28 168
Zimbabwe	697	30	30	4 980	na	5 737
Total for Southern Africa	16 385	1 034	2 114	34 130	4 850	58 512

The development of surface water in Botswana is constrained by a number of factors such as its low and erratic run-off, lack of available dam sites, and high rates of evaporation. Approximately 35% of the total water supply is from surface water, whereas the remainder (65%) is from groundwater. Surface water, however, accounts for 90% of the total supply of water in urban areas such as Gaborone, Lobatse, Francistown and Selibe-Phikwe (Kgathi, 1999). It is estimated that approximately 19% of the MAR is already stored in a number of dams which serve these towns. Table 3 represents the dams that have been constructed on some of the rivers such as Ngotwane, Shashe, Metsemotlhabe, Motloutse and Nnywane. The Gaborone dam is the largest with full supply capacity of 144 x 10^6 m^3 (Kgathi, 1999).

Table 3: Dams constructed in Botswana (Source: Kgathi, 1999).

Name of dam	River	River Basin	Nearest town	Full supply capacity ($10^6 m^3$)
Gaborone	Ngotwane	Limpopo	Gaborone	144.0
Shashe	Shashe	Limpopo	Francistown	87.9
Bokaa	Metsemotlhabe	Limpopo	Gaborone	18.5
Nnywane	Nnywane	Limpopo	Lobatse	2.3
Letsibogo	Motloutse	Limpopo	Selibe-Phikwe	100.0
Mopipi	Boteri	Okavango	Orapa	100.0

It is evident that Botswana suffers from a lack of internal renewable resources and therefore relies heavily on surface water generated outside the country. Water transfers (as part of the potential renewable sources available to Botswana) are likely to make an increasing contribution to the country's water supply. Botswana's water resources must therefore be assessed in the context of the total resources available in the shared river basins as outlined in Table 4. The major features of these four basins as they relate to Botswana are summarised below.

Table 4: Geographic detail of the river basins shared by Botswana (Sources: Heyns, 1995; Conley, 1996, Ashton pers comm., 2000 and WRI, 2000).

River basin	Basin area (km^2)	Population density ($persons.km^{-1}$)	MAR* ($x10^6 m^3.yr^{-1}$)	MAP* $mm.yr^{-1}$
Limpopo	415 000	35	7 330	520
Okavango	721 000	3	13 339	580
Orange	973 000	12	11 860	330
Zambezi	1 332 000	18	94 000	860
**MAR - Mean annual runoff; MAP - mean annual precipitation*				

(a) The Okavango River Basin

The Okavango river basin occupies a large area of Botswana and in terms of flow volume it is the country's most significant water resource. The Cubango and Cuito Rivers flow for more than 600 km from the upper catchment in Angola in a southerly direction until they reach the west-eastern border between Angola and Namibia. From that point, the two rivers combine to form the Okavango River which then turns southwards again and ends in the inland Okavango Delta in Botswana [FAO, 1997]. The mean annual runoff of the Okavango River at Mohembo on the border between Botswana and Namibia is 10 134 x 10^6 m^3. Other small ephemeral rivers rise in north-eastern Namibia and north-western Botswana but do not contribute any flow to the Okavango River or Okavango Delta (Ashton pers. comm., 2000).

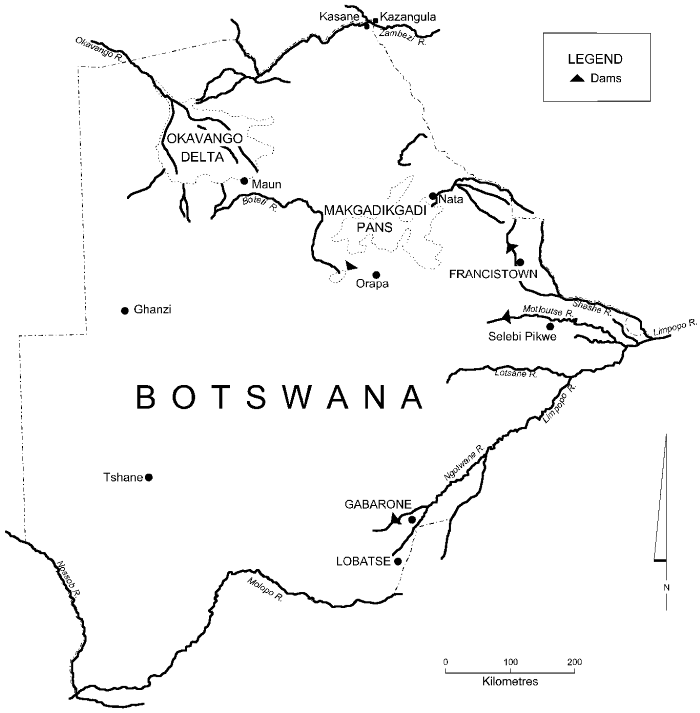
The only major development of the water resources of the Okavango River or the Delta that has taken place in Botswana is the Mopopi Dam (See Table 3) adjacent to the Boteti River (see Fig. 3). The dam was built to supply water to the Orapa diamond mine, 250 km south-east of the end of the Delta, and has a capacity of 100 x 10^6 m^3, covering 24.3 km^2 at full supply (Heyns, 1995). This water supply system, however, has largely been replaced by groundwater due to weak and erratic outflows from the Okavango Delta in recent years (Ashton pers. comm., 2000).

The institutional arrangements concerning the utilization of the Okavango Basin have been under discussion between the three basin States (Angola, Botswana and Namibia) since 1992. The existing Joint Permanent Water Commission between Botswana and Namibia was established to deal with the utilisation and management of common water resources like the Okavango. In September 1994, a Permanent Okavango River Basin Water Commission (OKACOM) was established between Angola, Botswana and Namibia to serve as an instrument for cooperation between these riparian states (Heyns, 1995). Hachileka, 2003, this issue.

(b) The Limpopo River Basin

Four countries in south-eastern Africa share the Limpopo basin: Botswana, Mozambique, South Africa and Zimbabwe (Fig. 2). This basin is extremely important to eastern Botswana as a source of surface water. Important tributaries in Botswana are the Marico River, which forms part of the border between Botswana and South Africa, and the Shashe River which originates in Botswana (Fig. 3).

Figure 3: Main sources of surface water in Botswana (after Arntzen and Kgathi, in press).



The water resources of the entire Limpopo Basin have been extensively developed. More than 40 dams each with a storage capacity greater than 12 x 10^6 m^3 have been built in the basin to supply water for cities and towns and to support industry and agriculture in the four countries encompassing the basin. The importance of the Limpopo in supplying Botswana with surface water can be seen from Table 3. These water developments include the Letsibogo Dam on the Motloutse River (a tributary of the Limpopo), presently under construction to augment the water supply to Gaborone via the proposed North-South Water Carrier Project (NSWCP). Phase I of this project involves the construction of the Letsibogo Dam near Mmadinare, about 20 km from Selibe Phikwe, and a 360 km pipeline transferring water to the greater Gaborone area (Botswana Government, 1997 and Kgathi, 1999). It is also possible to augment the supply of water to Gaborone from the Molatedi Dam on the Great Marico Tributary of the Limpopo in South Africa. This dam has a capacity to supply 9.5 x 10^6 $m^3.yr^{-1}$ to the Ngotwane River in Botswana (Heyns, 1995).

(c) The Orange River Basin

The Orange basin (Fig. 2) spreads over the four countries of Botswana, Namibia, South Africa and Lesotho (its source). The most important tributaries to the basin in Botswana are the Nossob River (which forms the border between southern Botswana and South Africa) and the ephemeral (periodically flowing) Molopo (Fig 3). Runoff from Botswana does not contribute to flows in the Orange River as the flow of water via the Molopo is blocked by the Kalahari Desert (Pallett, 1997). Irrigation potential in the Orange basin for Botswana is negligible due to a lack of renewable water resources. The average annual precipitation in the basin area for Botswana is 295 $mm.yr^{-1}$, much less than the mean annual rainfall for Botswana of approximately 400 $mm.yr^{-1}$ [FAO, 1997].

(d) The Zambezi Basin

The Zambezi River Basin is the largest of the African river systems flowing into the Indian Ocean. It is shared by eight basin states (Fig. 2) and supports a population of more than 26 million people. Water from this basin enters Botswana near Kasane where the Cuando River (which drains the highlands in Angola) links up to the Chobe River in years of exceptionally high rainfall. The objectives of the ambitious Zambezi Action Plan (ZACPLAN) include water transfers from the Zambezi to Gaborone (Botswana) and Harare (Zimbabwe) (Pallett, 1997).

Water abstraction from the Zambezi River by Botswana is being considered at a point between Kasane and Kazungula (See Fig. 3), with a subsequent pipeline southwards. Another possibility is for Namibia and Botswana to sign a joint-development agreement and construct a pipeline from Katima Mulilo in Namibia to Nata and Francistown in south-eastern Botswana (Ashton pers. comm., 2000).

Groundwater resources

Although groundwater resources contribute to 65% of the total water available in Botswana, the quantity of groundwater resources is nonetheless limited. Evidence suggests that groundwater is used at a rate higher than the rate of replenishment in many parts of Botswana (Kgathi, 1999). Recharge of aquifers ranges from over 40 mm/year in the extreme north to virtually zero in the central and western parts of the country. The average recharge is only 3 $mm.yr^{-1}$. The groundwater potential for Botswana is estimated to be 1.7×10^9 $m^3.yr^{-1}$, but the extractable volume is only about 1.0×10^9 $m^3.yr^{-1}$ and, in turn, only 1.7% of this is rechargeable (Kgathi, 1999 and FAO, 1995b). This means that the rechargeable volume of groundwater for Botswana is approximately 17×10^6 $m^3.yr^{-1}$, which is less than 0.4% of Botswana's total renewable resources (Table 1).

More recent research indicates that groundwater resources can sustain more extensive human habitation in the Kalahari as the demand is geographically spread. Recharge of groundwater is ongoing, depending on the geology, topography and weather. However, at the current rates of abstraction, resource lifetime is limited to decades, not centuries (Pallett, 1997). Careful monitoring as well as hydrogeological knowledge is needed to secure the sustainability of this valuable resource.

It is estimated that there are 15 000 boreholes in Botswana, scattered in various parts of the country (Kgathi, 1999 and FAO, 1995b). Total water abstraction in 1990 was $76 \times 10^6 m^3$ from boreholes (760% more than the recharge rate), and is forecast to rise to $140 \times 10^6 m^3$ annually by the year 2020. According to Kgathi (1999), an analysis of water samples from 2 000 boreholes by the Water Affairs Department revealed that 340 (17%) of the boreholes showed signs of nitrate pollution which indicates that the sustainability of groundwater resources in terms of the quality is threatened by pollution. This is particularly evident in areas that are densely populated, such as south-eastern Botswana (Kgathi, 1999).

Pollution of groundwater poses serious threats to users, especially those in rural areas where groundwater is the main source for domestic use and livestock watering. According to Kgathi (1999), a possible cause of nitrate water pollution in Botswana could be the organic waste from pit latrines and septic tanks, mostly in the rural areas. The Botswana Government launched a project where environmentally safer sealed pit latrines will be introduced, as a response to the concern about the pollution of groundwater by pit latrines (Kgathi, 1999). It is crucial to pinpoint the actual sources of pollution and also to prevent other water sources from becoming polluted as well. One such strategy includes a project on the use of aquifer vulnerability maps which was finished during the period 1991/92 to 1995/96 as one of the objectives of the Botswana Government's National Development Plan 7 (NDP 7) on groundwater conservation and protection (Botswana Government, 1997). Similar strategies and methods should be introduced to assure the sustainability of the quality of surface water resources as well as groundwater.

Wetlands

Despite being a dry country, Botswana has two important wetland systems, the Okavango Delta and the Makgadikgadi Pans. Wetlands are crucial for local human populations as they provide natural resources (such as reeds and wood), grazing for livestock, medicines, and boost the local economy through income generated by tourism. Wetlands also act as natural filters, trapping sediments and nutrients for life support. Although wetlands are limited to only a small portion of the total landscape, they are among the most threatened natural resources in many countries, especially arid ones such as Botswana. The Ramsar Convention Hachileka 2003, this issue, attempts to slow down the loss of wetlands and promote sustainable use for the benefit of mankind, creating a framework for development of resources in an environmentally sensitive manner, with long-lasting benefits (Pallett, 1997). In 2000 the Okavango delta became the worlds largest Ramsar site (6.8 m ha).

Rogers (1997) defines wetlands as "land where the water table is, at least periodically, at or above the land surface for long enough to promote formation of hydric (waterlogged) soils and the growth of aquatic plants". Two types of wetlands can be found in Botswana: swamps, which can be described as perennial, deep fresh-water situations (Okavango) and endorheic pans (Makgadikgadi Pans). The Makgadikgadi Pans, located in north-eastern Botswana, are ephemeral, shallow inundated depressions with no outlet, where the mean annual precipitation is less than 500mm (Rogers, 1997).

The Okavango Delta is not only the most spectacular of southern African wetlands, but it is also the world's largest inland delta. The floodplains of the Okavango River support over 1180 identified plant species and 74 species of fish (Bills pers. comm., 2001), reflecting the richness of the habitat sustaining them. This richness has been threatened in recent years, especially to the north-east and south of the Delta where population and cattle density have shown large increases. Maun is a growing urban centre at the southern end of the Delta, with many people deriving their livelihood from 'molapo' (floodplain) farming in this area (Pallett, 1997). It is also an important tourist centre. The Okavango Delta attracts many tourists to Botswana and in this way is a significant source of foreign currency.

The Department of Water Affairs (DWA) came under pressure during the droughts of the 1980s to develop water resources surrounding the Delta for domestic, agricultural and mining purposes. A feasibility study resulted in the proposal of the Southern Okavango Integrated Water Development Project (SOIWDP), which would involve dredging 42 km of the Boro River and construction of several dams on adjoining rivers to improve and regulate outflows from the swamps. The plans were put on hold in 1992, following an independent report by the World Conservation Union (IUCN) (IUCN, 1993). According to Pallett (1997), it is unfortunate from an ecological point of view that the plans have only been put on hold and not abandoned, as proposed by the IUCN, as this might lead to reconsideration of the project in the future.

The protection of wetlands should be subjected to a similar set of policies applied to other water users such as agriculture, industry and domestic water users. These include factors such as water rights, participatory approaches to involve local communities and indigenous people in the management of wetlands, education, public awareness, and legally enforceable regulations. In other words, conservation and wise use of wetlands must be an integral part of river basin management [Kinje, n.d.] and should be seen in a context of sustainable sharing of international water resources.

International context - sharing water

Water resources (both surface and groundwater) are not always confined to one private property within a single country. Where large rivers or their tributaries flow from one country to another, or form the boundaries between countries, they are referred to as international rivers or shared watercourse systems. In the case of Botswana, 94% of the fresh water originates outside its borders and this contributes to the vulnerability of the country in many ways (Van Wyk, 1998). Sharing water should imply that everyone receives an equitable (fair), beneficial and sustainably available portion.

Water must be rationed among those who have interests in it through cooperation to achieve long-term goals. This has to be done in the context of a river basin as a complete, integrated unit and it is therefore imperative that the parties understand the complexities of water in the environmental system (Heyns, 1995). One method of achieving integrated management of an international river is to establish a permanent River Basin Organization (RBO). Each state with an interest in the drainage basin should be equally represented. Such an organization should investigate the sustainable potential of the river basin, with the assistance of competent specialists, and should aim towards agreement on the equitable and beneficial use of the water resources for all parties concerned (Pallett, 1997).

The boundaries of twelve SADC states lie across fifteen major perennial and ephemeral river basins. At present there are approximately 21 agreements between different SADC countries concerning joint cooperation in various fields, including water resources of mutual interest. The commissions actively involved in the management of shared water resources in Botswana are listed below (Heyns, 1995; Pallett, 1997):

- Agreement between Botswana, Mozambique, South Africa and Zimbabwe on the establishment of the Limpopo Basin Permanent Technical Committee (**LBPTC**), 15 June 1986, Harare, Zimbabwe.
- Agreement between the Governments of Botswana and Namibia on the establishment of a Joint Permanent Water Commission (**JPWC**), 13 November 1990, Windhoek, Namibia.
- Agreement between Angola, Botswana and Namibia on the establishment of a Permanent Okavango River Basin Commission (**OKACOM**), 15 September 1994, Windhoek, Namibia.
- Agreement between Botswana and South Africa on the establishment of a Joint Permanent Technical Committee (**JPTC**), November 1983. In June l989, the **JPTC** was replaced by a Joint Permanent Technical Commission on the Limpopo Basin and this, in turn, was replaced by another Water Commission in November 1995.

Apart from the four commissions established in Botswana, the country is actively involved with two other multinational agreements on water related manners:

- Established in 1948, the Southern African Regional Commission for the Conservation and Utilisation of the Soil (**SARCCUS**) between Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa and Swaziland.
- The Declaration, Treaty and Protocol on the establishment of the Southern African Development Community (**SADC**), signed on 17 August 1992, Windhoek, Namibia.
- In August 1995, Botswana signed the **SADC Protocol on Shared Watercourse Systems** together with all but three of the SADC member states. This protocol has since been revised (in 2000) and has been ratified by all the member states except the Democratic Republic of the Congo (Ashton pers. comm., 2000).

Management

Institutional structure

The number of basins shared in the southern African region emphasises the need for international collaboration on river basin management, the equitable allocation of water and cooperation on joint infrastructure development. The development of these potential renewable water resources is complicated due to the frequent droughts and major floods. Management of Botswana's internal renewable surface and groundwater resources should be carried out in terms of their distribution within the SADC framework of shared watercourse systems.

Although a river basin should be seen as the basic unit for integrated water management, political boundaries commonly lead to its fragmentation. Aspects such as water resources planning, development and management tend to be fragmented between local communities within a country or even between countries (Heyns, 1995). Water resources are shared amongst all the components of the environment, whether humans manage these resources or not. Water is shared between areas upstream and downstream, between rural and urban locations and between the natural and human environment, and amongst all the different people within the river basin. At a country level, it is therefore only possible to assess that part of the water resource generated within the country's borders [FAO, 1997].

It is essential that water resources management should be operated within the SADC framework of sustainability, implying adherence to the principles of efficiency and equity of water use and supply. Many developing countries have institutional frameworks and agricultural policies that discriminate against the rural sector. Under-investments occur in technology development and dissemination, leading to discrimination against private sector initiatives in food marketing, and failure to maintain existing, or invest in new, rural infrastructure [Kinje, n.d]. With the assistance from the Swedish International Development Authority (SIDA), the Government of Botswana has provided reliable water supplies with reasonable access to 80% of rural villages in Botswana. The sinking of boreholes near villages and piping the water to several evenly distributed standpipes has improved overall access to water supplies (Simpson-Hebert, 1994).

A number of institutions are involved in the activities of the water sector. The Ministry of Mineral Resources and Water Affairs (MMRWA) has the overall responsibility for policies in the water sector. Groundwater protection and monitoring are the responsibilities of the Department of Water Affairs (DWA), supported by the Department of Geological Survey (DGS). The DWA is also responsible for the water supply to rural areas, for surface water development and planning, as well as protection from pollution and aquatic weeds. The Water Utilities Corporation (WUC) is responsible for the water supply to six urban/mining sectors, except the Orapa diamond mine (supplied directly by the mining company). The Ministry of Local Government, Lands and Housing (MLGLH) is responsible for the operation and maintenance of water schemes in medium and small-sized rural villages as well as waste water management (Botswana Government, 1997 and Kgathi, 1999).

According to Kgathi (1999), policies on water resources can be generally categorized as supply or demand-oriented. The former are aimed at developing water resources in order to meet the projected demand, whereas the latter are aimed at reducing the demand for water.

Supply management

"Supply management requires the development of affordable self-financing facilities for bulk water supplies, programmed to meet expected increases in requirements with an appropriate degree of assurance", (Pallett, 1997, p.102). With this is mind, it is essential that water supplies should be managed in terms of the relation between the amount of water required in various sectors of an economy, and the contribution of the respective sectors to the Gross National Product (GNP).

Management-related problems of supply systems usually include factors such as the lack of reliable information, policies and programmes to maintain and expand existing systems (Higham, 1998). As part of Botswana's NDP 8, a three-year programme for upgrading supply systems in major villages was launched in 1996. This involves aspects such as computerised operations, hand-held meters and metering procedures, computerised billing, Geographical Information Systems (GIS), Management Information Systems (MIS), and Engineering Analysis Systems (Constantinides and Kolovopoulos, 1995).

Before the system was operational, as much as 30% of the water supply was unaccounted-for (in some villages even up to 70%). A lack of reliable information makes effective management and control of supply systems very difficult. Soon after implementation, this system has already satisfied many objectives in supply management such as (Stadler, 1997):

- Improved data collection and, therefore, better data quality
- Better operational and maintenance procedures
- Better management controls
- Improved debt recovery
- Identification and monitoring of unaccounted-for water
- Effective monitoring, control and management of water supply networks.

Some 17 villages, with up to 6 000 meter connections per village, are covered by the computerised Integrated Information Systems (IIS) at DWA and this has vastly improved the efficiency of the day-to-day operations within the department as these IIS have sufficient functionality to cover most of the requirements in the maintenance, operation, management, design and planning of water supply systems. The volume of unaccounted-for water dropped from 48% to 10% (saving approximately 2 650m^3 per day) in one village alone (Stadler, 1997).

In addition to the North-South Water Carrier Project (NSWCP), an attempt will be made to construct a number of small to medium scale dams (mostly in south-eastern, hardveld Botswana) for conjunctive use with groundwater during the period of NDP 8 (1997/98 - 2002/03). In the sandveld Ghanzi and Kgalagadi Districts, where there are no suitable dam sites, attempts will be made to identify suitable aquifers for obtaining groundwater (Kgathi, 1999).

Groundwater resources will be monitored in order to ensure that extraction does not exceed the sustainability of yields. A number of measures such as the artificial recharge work that has been done near Maun (Murray and Tredoux, 1998), recycling of water and desalination should also enhance water supply. According to Kgathi (1999), the modalities of waste-water recycling at household level are still being worked out by the WUC and it is anticipated that one of the constraints may be cultural factors. In the Sandveld areas of Botswana, where groundwater sources usually become saline, the quality of water will be improved by means of desalination technology (Kgathi, 1999).

As part of agricultural water supply, irrigation is the key to the national strategy to increase food production in Botswana. Little or no land has a rainfed growing period of above 200 days [Kinje, n.d.] and food demands cannot be met from low-input rainfed farming alone. Failures of large-scale irrigation systems over the whole of southern Africa suggest a need for the implementation of small-scale irrigation as an alternative. Responsibility for planning and implementation of irrigation development rests with the Ministry of Agriculture. The Director of Water Affairs is the Registrar of the Water Apportionment Board and acts as Technical Adviser to the Board. The Water and Borehole Acts are administered by the Board and require individuals or groups to apply for a right to use irrigation water [FAO, 1995b]. Women, more than men, are often involved in small-scale irrigation development and they face a large variety of social, economic and cultural constraints to participating effectively in irrigation development and management.

Demand management

The total water demand for Botswana in terms of the different economic sectors is indicated in Table 2. These demands are generally determined by a number of factors such as population, price, incomes, level of commercial and industrial activities, and weather conditions. Projections by UNEP (1999) on water demand in the SADC region indicate a rise of at least 3% per year till 2020, a rate about equal to the region's population growth rate. However, as mentioned earlier, HIV/AIDS is having serious effects on southern African countries' population growth rates and, therefore, these estimates of population growth and accompanying water demand will be reduced significantly.

Some of the key issues in long-term water supply and demand management in Botswana include the following (Arntzen and Kgathi, in press):

- Increased water demand in the domestic, commercial and urban sectors as well as large rural settlements
- Demand increase will be highest for south-eastern Botswana (both surface and groundwater)
- Beyond 2020 water demand will equal supply and the country will have to rely on shared watercourse systems, and
- Waste water is a potential non-potable (short-term) and potable (long-term) source to meet demands.

According to Arntzen and Kgathi (in press), the nature of water management strategies may be economic (such as a pricing policy and water tariffs) or non-economic (such as population control, regulations to control water demand and the promotion of public awareness about the importance of water). The NDP 8 shows more commitment to the use of non-economic measures of water demand management than the previous plans. For example, it suggests that the use of water tariffs to reduce water demand must be complemented by educational campaigns on water conservation and the use of water saving technologies (Botswana Government, 1997). The use of pricing policy to reduce water demand is being constrained by factors such as a lack of meters and the abuse of communal standpipes by people collecting water for the purpose of watering cattle in nearby rural areas. These factors should be addressed in order to promote water conservation. According to Kgathi (1999) the urban tariffs need to be reviewed to reflect the wider social costs and should, therefore, not be based narrowly on the costs of labour and capital alone.

Conclusions and recommendations

Riparian countries sharing major river basins should not allow badly planned development and deterioration of the environment to ruin the chances of optimum utilisation of the natural resources for further generations. Serious attention should be given to using an international and holistic basin approach to regulate and manage the shared water resources. Countries therefore need to establish reliable communication channels open to discussion and the exchange of views to facilitate mutual, beneficial cooperation for better management of shared water resources. This will serve to promote the sustainable and environmentally acceptable resource development as the equitable and beneficial allocation of water for different uses will be facilitated.

It is essential to implement or introduce non-economic and conservation measures such as the use of regulations, public campaigns on water conservation, water re-use and rain water collection to water resource management in Botswana. Probably most important of all, adoption of policies on population stabilisation should be incorporated into the water management strategy, as there is a very strong correlation between population growth and water demand. The effect of HIV/AIDS on the expected population growth rates is yet to be fully recognised in southern Africa and outdated estimates of, for example the effect on water demand, should now be adjusted accordingly.

In addition, the total demand for water may further be increased if the outputs of agriculture, industry and commerce are expanded in line with the development strategy of the Botswana Government. It is evident, therefore, that a carefully worked out water management strategy in Botswana is urgently needed as environmental demands for water are bound to come into direct competition with the agriculture, household, and industrial sectors.

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