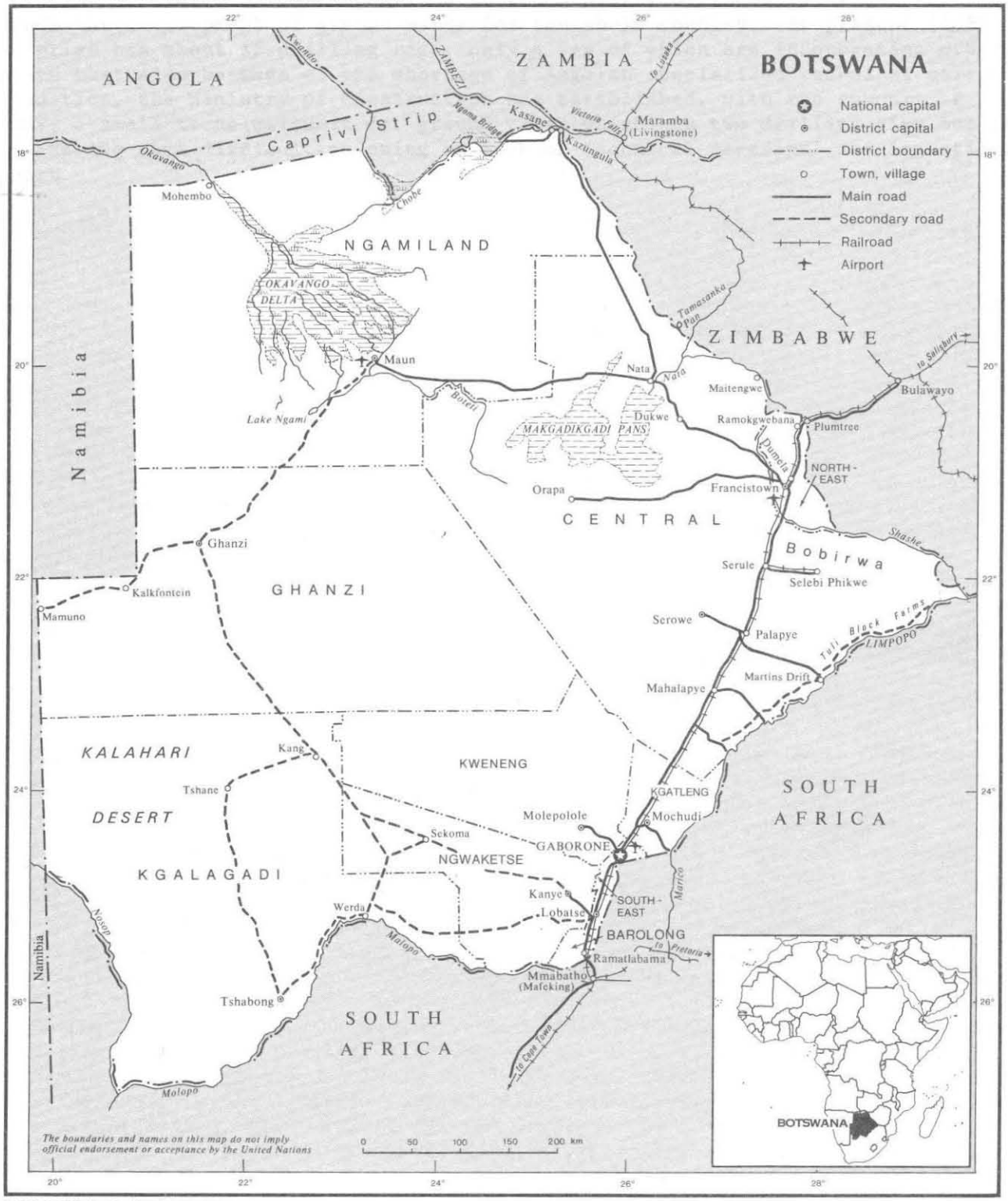
MAP 2. BOTSWANA — GENERAL MAP



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BOTSWANA

Area: 570,000 km^2
Population: 1,000,000 (United Nations estimate, 1983)

I. BACKGROUND

The Republic of Botswana occupies a vast desert plateau with an average altitude of 1,100 m. A narrow strip of higher ground consisting of hard rocks covered with dense thorn-steppe vegetation runs along the eastern frontier. Most of the population in found here, for it is the part of the country least harshly treated by nature. The population is concentrated in three areas:

- The area of the capital, Gaborone, as far as Lobatse in the south;
- The area of Serowe-Palapye-Mahalapye, in the centre;
- The area of Francistown in the north, with Selebi-Phikwe.

To the west stretch vast desert steppes declining towards the Kalahari depression which is covered with red sands.

The north-west of the country has a tropical climate. Here is found the vast interior marshy delta of the Okavango, the destination of several rivers which rise in the Angolan plateau. The Okavango's overflow spreads over the vast salt depression of Marikari, situated downstream. In the south, the country's frontiers follow the courses of two important rivers, the Limpopo and the Molopo.

Botswana is relatively rich in mineral resources, with three diamond mines and one nickel-copper mine. It also has substantial reserves of coal.

Climatology and hydrology

Botswana is one of the driest countries in the world, and over most of the territory the rainfall amounts to less than 250 mm per year. The driest regions of the Kalahari receive less than 100 mm per year.

The potential evaporation is over 2 m a year. The most favoured, eastern region, receives an annual average of 400 mm of rainfall, with a maximum of 600 mm.

Moreover, these rains are very irregularly distributed over time, with periods of drought which can last several years. The conformation of the hydrographic system encourages most of the water to run out of the country. This system includes:

- The Shashe, part of whose course forms the frontier with Zimbabwe and whose resources available for Botswana are very modest;

- The Chobe, a tributary of the Zambezi in the north of the country, whose average annual flow is 32 m^3/s. However, this resource is located very far from the areas in which it could be used either for the towns, mining or irrigation;

- The Okavango delta, a huge area of flood plain and marshes in the north-west, where evaporation and infiltration are intense; it has 200 to 400 m^3/s of surface runoff and less than 12 m^3/s flows out of the area in the Boteti River. The ecological environment of the Okavango has been the subject of many studies and is extremely vulnerable, so that even modest exploitation of its water resources is unadvisable. Nevertheless, the peripheral zones of the delta could be used for the irrigated cultivation of grains;

- The Molopo, which forms the frontier in the south, has little hydraulic potential;

- The Limpopo, which also forms the frontier with the Republic of South Africa.

Under the Helsinki Convention on international rivers, Botswana could count on exploiting barely 1 m^3/s at minimum flow. At present the waters of the Limpopo are used by Botswana for irrigation at a rate of 3.6 m^3/s under an agreement with the Republic of South Africa.

A total of 17 sites for dams have been identified in the country.

II. GEOLOGY

Two physiographic and geological provinces can be distinguished in Botswana: the region of the eastern Bushveld and the Kalahari, both part of a clearly defined ridge running north-north-east and passing through Serowe.

This ridge forms the watershed between the Limpopo system which flows eastwards and the endorheic and fossil drainage system of the Kalahari. This system includes the Molopo and its tributaries in the south.

The eastern Bushveld is a flat region with some inselbergs and ranges of hills consisting of quartz and dolerites, such as the Shoshong Hills, Otse-Lobatse Hills and Tswapong Hills.

The main geological formations are listed in the table below.

The tectonics of the eastern part of the country have been studied in some detail, for they determine the presence of ground water in the hard rocks of this region. The geological maps of the country show various tectonic features such as faults, fracture zone and veins, which usually run north-east/south-west and east, north-west/south-east, north-east/south-west and east-west; the rock masses have been broken up into fairly regular blocks which appear on the Landsat images in the areas which are not covered by the Kalahari formations.

In the Molepole area, for example, the open fractures or faults run 60° North, 80° West.

Kalahari		Sands, sandstones, conglomerates, marls, up to 40 m thick
Karroo system	Stormberg group	Basalt, sandstone, sedimentary schists, marls
	Ecca group	Argillaceous schists, sands, conglomerates, limestones, lavas
	Dwyka group	Tillites, argillaceous schists, sandstones
Waterberg system		Sedimentary schists, sandstones, conglomerates, limestones, lavas
Transvaal system	Pretoria series	Sedimentary schists, hard sandstones, conglomerates, limestones, andesites
	Dolomitic series	Dolomite, cherts, quartzites, sedimentary schists
	Black Reef series	Quartzites, sedimentary schists
Ventersdorp system		Tufas, imbrignite, quartz and feldspath porphyry, sedimentary schists, conglomerates, andesites
Kanye volcanic rocks		Felsites
Crystalline basement rock		Metamorphic rocks, various amphibolites, quartzites, marbles, conglomerates, granitoid rocks, metamorphic schists
Intrusive rocks:		
Post-Karroo to Karroo		Dolerites
Post-Waterberg and Pre-Karroo		Syenites, diorites, diabases
Post-Transvaal		Granite, syenite
Kanye and Pre-Ventersdorp Post-volcanic		Granite, Gaborone type
Pre-Gaborone granite		Gabbro, Modope type

III. HYDROGEOLOGY

The geological formations of Botswana can be classified into different types of aquifer, as follows:

Fractured aquifers:	Crystalline basement rock Kanye volcanic rocks Ventersdorp system Waterberg quartzites Karroo: tillites, hardened argillaceous sandstones, silty sandstones, argillaceous schists
Fractured and porous aquifers:	Karroo: sandstones, basalts
Porous aquifers:	Kalahari sands and gravels, recent sandy alluviums, ancient alluviums
Karstic aquifers:	Dolomites of the Transvaal system

Some areas, in particular the whole of the Karroo, contain stratified aquifers separated by impermeable or semi-permeable layers. The impermeability is never total, for the vertical faults allow communication between the different aquifers. The best aquifers are those which have both a high storage capacity and high transmissivity. This is particularly true of the intensely fractured porous "Ecca" and "Cave" sandstones. The transmissivity and storage capacity of the various aquifers are compared in the following table.

	T_{50} m^2/day	T_{20} m^2/day	S %
Sandstone (Cave)	8	17	2.4 to 3.6
Sandstone (Ecca) (excluding Jwaneng)	8	-	n.a.
Sandstone (Waterberg)	13	28	5
Lava (Stormberg)	25	220	2
Dolomite	250	550	1/10 to 6
Jwaneng Ecca	350	950	2

T_{50} = 50 % probability of J higher than T_{50} m^2/day

T_{20} = 20 % probability of J higher than T_{20} m^2/day

S = Storage coefficient.

These results show that the dolomites are good aquifers and that the Stormberg lavas have a good potential.

The S data are limited in number. The hydraulic properties of the main aquifers can be summed up as follows:

Sandstone (Ecca):	Aquifers consisting mainly of fractures with some porous zones. T high locally but S rather low owing to artesianism.
Dolomites:	The drilling sites must be determined with great accuracy. High yields can be expected from the positive boreholes. Dolomites cover a very large area of the country.
Basalts and sandstone (Cave):	Aquifers consisting of fractures and pores in the upper (Cave) sandstones and in contact with basalt and sandstone. J is rather low but S is high for the unconfined aquifer. A high success rate can be expected, with fairly small yields but little risk of barren wells.
Waterberg:	Fractured aquifer; S low and yields fairly small except in cavities in the sandstones.
Crystalline basement rock, Kanye volcanic rocks, and granites:	Fractured aquifers with low S and small yields, with occasional large yields, especially in the quartzites.

Estimates of the recharge of the aquifers vary from 0 to 100 mm a year. Recharge is thought to be very small or nil in the areas covered by the Kalahari formations, but better in the areas where the older rocks outcrop.

IV. WATER RESOURCES

The available yield per borehole is about 2.5 l/s for the Cave sandstones and basalts in the Serowe sector (5,000 km^2), with a total productivity of 400 l/s at safe yield, to be exploited by about 200 boreholes. The resources are estimated at 800 l/s in the Mmamabula zone, which consists of the same formations, together with Stormberg lavas (5,000 km^2), 500 to 700 l/s at Molepole-Letlhakeng (Ecca formation), 100 l/s at Kanye Ramotswa-Otse (dolomites), 250 l/s at Mochudi-Molepole (Waterberg quartzite sandstones), and 300 l/s in the lavas and (Cave) sandstones of the Tuli syncline.

The sandy alluviums constitute a major source of supply for the rural and pastoral population, for the water is easily accessible at shallow depths. As a rule, each of the valleys and beds of any appreciable importance, such as those of the rivers Shashe, Motloutse and Mahalapshwe, can deliver 100 to 200 l/s.

It is estimated that in 2010 the demand for water will be 3 to 5 m^3/s in the three densely populated areas where at least 60 % of the country's population will then be concentrated. The available water resources will therefore be sufficient for the needs of the people, mining and industry, but they will not always be exploitable close to the areas to be supplied; this means that with the passage of time it will be necessary to build systems to carry water over rather large distances. Fairly high production and exploitation costs should in any event be envisaged.

Moreover, these resources are not sufficient for the irrigation of the land identified as suitable for irrigation, the total area of which is in the order of 50,000 hectares, distributed mainly between the north-east, Pandamatenga, the Okavango and the Chobe River. The area to be irrigated in the Limpopo valley is about 5,000 to 10,000 hectares.

In the Okavango 2,000 to 4,000 hectares are at present irrigated by flood waters. It is thought that no more than 800 to 1,000 hectares could be irrigated with ground water.

An outline plan for the integrated development of water resources has been drafted; it calls for various hydrological and hydrogeological studies.

V. STUDY AND EXPLOITATION OF GROUND WATER

The governmental body responsible for water resources in Botswana is the Ministry of Mineral Resources and Water Affairs (MMRWA), which includes the Department of Water Affairs (DWA) and the Department of Geological Survey (GS).

The study and development of ground water in Botswana has made considerable progress since 1929, the year in which the Government had the first water borehole drilled. Some 10,000 boreholes have been drilled since then, about half of them since 1959 by the Government's drilling rigs and the other half by private companies using their own equipment.

Over two-thirds of the needs of the urban and rural populations, industry and livestock are met with ground water. The consumption of water per inhabitant in rural areas has increased up to the present from an essential minimum of about 5 l/day to 20-30 l/day and it is tending to increase still further as housing improves.

The yields of the installations are generally fairly modest owing to the poor hydraulicity of this arid country and the modest extent of the geological formations with the best potential. Thus, fewer than 20 % of the boreholes yield over 8 m^3/h, and 30 % yield under 2 m^3/h. Boreholes yielding less than 10 m^3/day are considered barren. Careful installation based on study of aerial photographs and geophysical prospecting would produce a success rate of over 70 %.

Problems

Ground-water exploitation in Botswana is beset with the following difficulties:

- Low recharge owing to enormous losses through evaporation and surface runoff, especially in the Kalahari;
- Vast barren zones in the crystalline basement rock;
- Poor recharge in the sectors where the best potential aquifers are located (2 to 8 mm of effective infiltration per year);
- Ecological hazards in the Okavango.

The total potential of exploitable ground water is estimated at about 2 m^3/s in the east of the country where most of the population is concentrated; this is in addition to the potential of the sandy alluviums (0.4 m^3/s) and the available surface water (3.6 m^3/s); this produces an overall total of about 6 m^3/s.

It is also estimated that in periods of drought the extraction of ground water could be increased to 4 m^3/s.

VI. REFERENCES

The information used in the drafting of this brief paper is taken from a report prepared for the Government of Botswana (Department of Water Affairs) by a Swedish firm of consultants (VIAK) entitled: Eastern Botswana - Regional Water Study. Report 1984-06-06.