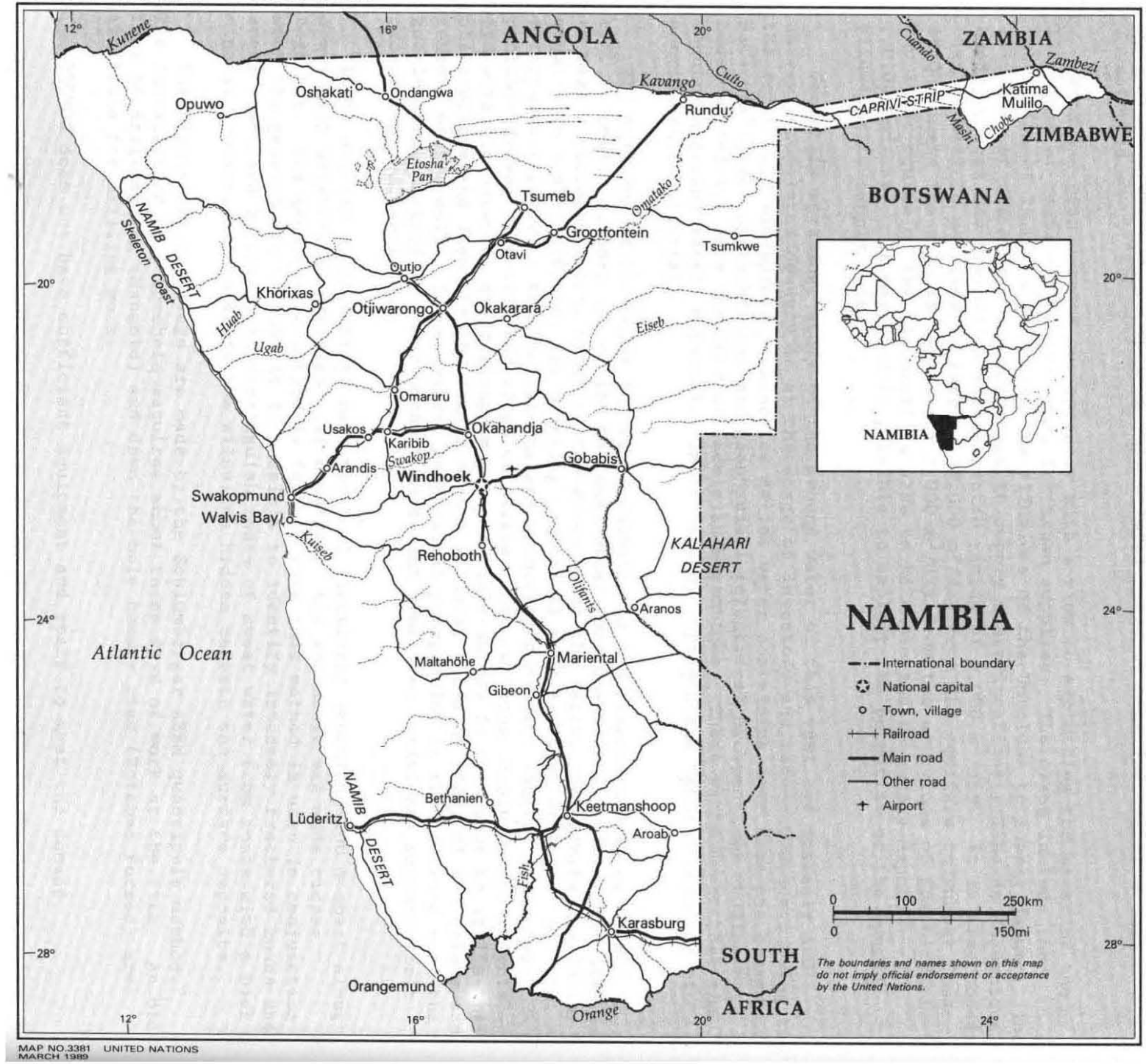
MAP 20. NAMIBIA — GENERAL MAP



NAMIBIA

(Administered by the Republic of South Africa; the United Nations Council for Namibia is working to achieve the country's independence)

Area: 824,235 km^2
Population: 1.5 million (United Nations estimate, 1983)

I. BACKGROUND

Namibia has 1,500 km of coastline on the South Atlantic. The country is divided into three large natural regions: the coastal Namib Desert, the mountains and central plateaus of the Great Escarpment, and the interior basin of the Kalahari.

The Namib Desert, which gave the country its name, consists of an almost continuous stretch of sand from the Orange River in the south to the Kunene River in the north. It stretches eastward to the foot of the Great Escarpment for a distance of 80 to 140 km, at altitudes ranging from 200-300 m to 3,000 m. The Desert has several types of dune formation. Along the coast are found small or medium-sized dunes, probably Recent, running northwards. Towards the interior the dunes are large and resemble those of Arabia. These are probably Ancient dunes (by reason of their darker colour) and they are relatively stable. Towards the Great Escarpment the dunes are less developed. The sand was produced by erosion of the Great Escarpment. It was transported either by the wind or by the watercourses. The Namib Desert is virtually uninhabited except in some small areas around the few towns, which are from south to north: Orangemund, Lüderitz, Walvis Bay, Swakopmund, Wlotzaka's Baken, Hentiasbaai and Kappkruis. These are mainly mining centres and fishing ports. In the north the Namib is called the "skeleton coast" owing to its extreme aridity. The country has only two permanent watercourses and they form international frontiers: the Kunene in the north - the frontier with Angola; and the Orange in the south - the frontier with the Republic of South Africa. Mention must also be made of the intermittent watercourses rising on the Great Escarpment which peter out in the west in the sands of the Namib but whose underflow represents an important water resource for the coastal towns, although in many cases this water is too saline to be used.

The Great Escarpment is one of the most important physiographic units of Africa; it extends almost without interruption from the Zambezi in Zimbabwe down into the south of the continent and then climbs northwards to the Kunene River and beyond it into Angola.

The Escarpment takes up about 35 % of Namibia's area from the Orange River in the south to the Kunene in the north, between the Namib Desert in the west and the Kalahari in the east. This part of the country has several mountain ranges, vast plateaus and wide V-shaped valleys. The highest point is Mt. Brandberg (2,573 m). The main highlands of the Escarpment are, from south to north: the Huib-Hoch plateau, the Tsarisberge, the Noukloufberge, the Hakos mountains, the Khomas highlands, the Gobabis range, the Waterberg mountains, the Damara plateau, the Otavi range and the Kaokoveld plateaus. All the country's watercourses rise on the Escarpment, except for the Orange, Molopo and Kunene Rivers and the watercourses in the Caprivi Strip. Most of the mining is concentrated on the Escarpment, except for diamonds, which are mined in the south of the coastal desert, and salt, which is extracted in the Etosha depression.

The Kalahari basin covers the central part of the Southern African plateau. It was produced by orogeny in the Mesozoic period. It is a vast closed depression in which several watercourses reach their end in swamps or salt pans.

The Kalahari is covered with sand, under which are found continental Cretaceous formations, themselves deposed on the Ancient Gondwana erosion surface. It has three hydrographic basins: the Etosha in the north-west, the Okavango in the north and centre, and the Molopo-Nossop in the south, which once flowed towards the Orange River.

Climate

The country is arid because of its geographical position: the cold Benguela current causes the ocean cloud systems to discharge their moisture over the sea before reaching the land.

In general terms, the south of the continent is the site of an anticyclone, mainly in winter. This anticyclone produces high temperatures and dry air and can continue for 14 days in succession. At the end of winter and spring, an influx of cold air can cause squally weather near the coasts in the south. In the interior the air is dry and the climate fairly pleasant. Masses of wet equatorial air can also come down from the north and north-west and deliver heavy rains, but this phenomenon lasts hardly more than two or three days.

The amount of rainfall increases from almost zero on the west coast (Swakopmund - 8 mm) to 500 mm in the north-east (Tsumeb), with 300-400 mm on the Escarpment (Windhoek - 362 mm). There are wide interannual variation (Port Nolloth: 15 mm in 1985 et 158 mm in 1925) which decline from 80 % on the west coast to 25 % in the north-east, where the maximum rainfall occurs.

The rain falls mainly during the southern-hemisphere summer (October-March). Only in a small area of the south-west does the rain fall in winter (May-August) and the summer there is dry. The number of days of rain increases from 10 on the west coast to 100 in the north-east.

The country is subject to lengthy droughts, which can last up to 69 days without rain.

The maximum daily rainfall seems to be 100 mm in the south-west and 125 mm in the north-west.

The temperatures are fairly cool, especially in the western slopes of the high ground of the Escarpment; the hottest areas are those bordering the Kalahari.

The hottest place is Goodhouse (203 m) in the lower valley of the Orange, where the temperature ranges from 1 °C to 48 °C.

In the Kalahari the temperature ranges from 1 °C to 22 °C in winter and from 15 °C to 35 °C in summer. The lowest temperatures occur in July throughout the country. The relative humidity is 70 to 80 % at the coast. Wet mists occur in the Namib Desert during the night and in the early morning. Animals and plants can condense this moisture and live off it. The interior is dry, with 30 % humidity in the Kalahari. The potential evapotranspiration is highest in the south-east (4,000 mm). It is lowest at the coast (2,000-2,250 mm).

II. SURFACE WATER

Surface water is scarce and extremely irregular. A distinction must be made between flows arriving from neighbouring countries, i.e. the Rivers Kunene, Cuvelai, Okavango, Quinto, Zambezi and Orange, and those originating in Namibia; at least 1,200 mm of rainfall is necessary to maintain permanent flows.

The country does not have any permanent watercourses of its own. The main watercourses are:

Watercourse	Measuring Season	Basin	Area (km^2)	Length (km)
Fish	Hardap	Fish	12,700	170
	Gibeon	(Orange)	13,815	245
	Neckartal		41,615	487
	Orange		62,780	735
Konkiep	Bethamie	Fish	3,900	124
	Confluence	(Orange)	18,300	298
Löwen	Confluence	Fish	9,846	180
Black Nossob	Confluence	White Nossob	8,640	302
Seeis	Confluence	Elephant	3,049	78
Schaf	Hatsamas		1,020	36
	Dorbabis		1,370	42
	Confluence	Usob	3,900	116
Omatako	Kano-Viei	Okavango	19,990	460
Ugab			15,450	450
Omaruru	Omaruru	Atlantic	2,940	85
	Mouth	Mouth	14,050	296
Swakop	Okahandja	Atlantic	2,700	85
	Khan Mouth		21,970	340
	Mouth		31,000	380
Khan	Confluence	Swakop	8,570	280
Kuiseb	Namib Desert	Atlantic	4,230	178
	Rooibank		6,230	375

The main flow of the country's various basins is as follows:

Basin	Area (km^2)	Average rainfall (mm)	Assumed flow (mm/year)	Rainfall (10^6 m^3/year)	Flow (10^6 m^3/year)	Flow coefficient
Kunene	12,783	232	5.3	2,961	68	2.2
Atlantic 1	13,365	53	3.0	703	40	5.7
Atlantic 2	47,696	89	3.0	4,255	143	3.3
Endorheic Atlantic	178,222	206	5.3	36,785	945	2.6
Orange a/	127,771	138	15.2	17,594	1,942	11.0
South Kalahari	114,918	245	6.1	28,155	701	2.4
Middle Kalahari	89,303	421	6.1	35,944	545	1.4
Okavango a/	140,291	464	15.2	65,123	2,132	3.2
Etosha	99,947	460	15.2	45,926	1,519	3.3
Total	824,296	288 (average)	9.7 (average)	237,445	8,035	

a/ Only the part of the basin located in Namibia.

The following table presents an inventory of the country's dams. Almost all the potential dam sites have been developed. Some dams contribute to the recharge of aquifers.

Name of dam	Watercourse	Basin	Built in	Basin (km^2)	Volume (10^6 m^3)	Type
Voigtsgrund	Tsub	Fish	1914	330	6.8	Earth
Avis	Avis	Swakop	1933	104	3.5	Earth
Omatjenne	Otjitasu	Ugab	-	200	0.4	Earth
Van Rhyn	Auob	Fish	1952	312	2.6	Earth
Bondels	Homs	Orange	1960	265	1.3	Earth/concrete spillway

Name of dam	Watercourse	Basin	Built in	Basin (km^2)	Volume (10^6 m^3)	Type
Daan Viljoen	Gobabis	Gobabis	1956	5,200	0.3	Concrete
Goreangab	Gammans	Swakop	1959	135	4.7	Concrete
Neudam	Seeis	-	1957	156	0.4	Earth and concrete
Hardap	Fish	Fish	1962	1,360	252.0	Rock-fill, asphalt, concrete spillway
Swakop (proposed)	Swakop	Swakop	?	2,700	60	Rock-fill, asphalt, concrete spillway
Okatana	Cuvelai	Canal from Cuvelai	1957	37,200	3.3	Earth

International rivers. Namibia shares international rivers with:

- South Africa and Botswana (Orange);
- Angola (Kunene, Cuvelai and Okavango);
- Angola and Zambia (Kwando and Zambezi).

The mean annual flows are as follows:

The Kunene at Erikson Drift: 5 billion m^3;

(There is an international agreement between Angola and Namibia concerning this water; Namibia is entitled to 50 % of the flow.) The maximum instantaneous flow is 6,000 m^3/s.

The Cuvelai: low flow;

The Okavango at Runta: mean flow of about 5 million m^3 a year;

The Kwanda: 10 billion m^3;

The Zambezi: 38 billion m^3;

The Orange: 7 billion m^3.

III. GEOLOGY

The geological history of Namibia covers four main periods:

- From the Vaal to the Upper Mokolian (about 2.1 to 1.5 million years ago);
- The Upper Mokolian (1.5 to 1 million years ago);

- The Damarian orogeny (from 0.9 to 450 million years ago); from the Carboniferous to the Lower Cretaceous (345 to 120 million years ago);

- From the Tertiary to the Recent (from 65 million years ago).

The country can be divided into three parts according to the distribution of the Pretertiary rocks:

- The northern half with the Damarian sequence;

- The south-west with rocks more than 600 million years old;

- The south-east, which includes the Nama group and the Karroo sequence; the oldest rocks outcrop in the extreme south.

The Tertiary deposits of the Kalahari cover large areas in the east and north of the country. Most of the coastal zone is covered with sand of marine detritic origin and fluviatile deposits of the Namib Desert.

Vaal and Lower Mokolian formations

These formations belong to several metamorphic complexes, of which the most Ancient is the Epupa in the north-west, with intrusions of the Kunene complex.

Other similar formations are found west of Outjo in the Tsumeb-Grootfontein area between Okahandja and Svakopmund and also south and south-west of Windhoek. These complexes include intensely deformed granitic paragneiss and orthogneiss, with in places large amounts of hornblende gneiss, amphibolites, marbles, quartzites and schists.

The Orange River group along the southern frontier consists mainly of calc-alkalic, basic, neutral or acid volcanic rocks, with sedimentary pockets in some places. It is traversed by the Vioolsdriff calc-alkalic subvolcanic intrusive system, which consists mainly of granodioritic and porphyritic rocks.

The Khoabendus group north-west of Kamanhab consists in its lower part mainly of volcanic rocks and in its upper part mainly of sedimentary rocks with intrusions of Fransfontein granites. The metamorphism is not well developed. The folds run north, north-east and north-west.

The Elim formation in the Rehoboth area contains inclusions of sedimentary rocks and slightly metamorphized basic lavas.

Middle and Upper Mokolian formation

The Rehoboth sequence is confined to the area along the southern limit of the Damarian orogeny. It contains three formations: the first consists of quartzites, phyllites, basic lavas, amygdaloids, and acid volcanic rocks (the Marienhof formation); the second consists of quartzites and phyllites with many beds of basic lavas and some porphyritic quartz (Billstein formation); and the third consists of brown quartzites, phyllites, brown limestone conglomerates, and many beds of acid and basic lavas (Gaub valley formation). Intrusions of gabbros, pyroxenites, serpentinites, diorites and granodiorites are found in these formations. They have been dated at 1.7 to 1.4 million years old.

The Namaqualand metamorphic complex is found in the south of the country. It consists mainly of:

(i) Pre-tectonic gneiss and metasedimentary rocks;

(ii) Charnockites, gabbros and serpentines;

(iii) Syntectonic granitic rocks;

(iv) Post-tectonic granitic rocks.

The Sinclair sequence was formed in the Helmeringhausen-Solitaire area during three main cycles of volcanism, plutonism and sedimentation between 1.3 and 1 million years ago.

In the Rehoboth-Witvlei area are found several formations of volcanic and sedimentary rocks equivalent to the Sinclair formation, with large amounts of granites dating from 1,100 to 950 million years ago.

Damara sequence

The Damara sequence occupies most of the centre and north of the country. At the base is found the Nosib group, consisting mainly of arenites dating from 850 to 700 million years ago. Next comes the Swakop group, consisting of carbonated rocks with intercalations of mica, graphites and quartzites. This group is overlain by thick layers of schist (Kuiseb formation) and a narrow strip of green rocks 350 km long. These formations were deformed by a collision of continents 650 million years ago, with the deposition of arenites and pelites of the Mulden group and the Otavi carbonates, and intrusion of serpentinites and graphites. The Garieb group at the south-west coast consists mainly of arenites in the east and basic lavas in the west. This group has undergone little metamorphism but it is intensely deformed.

The Nama group in the south-east is a series of shallow marine deposits on a stable platform. The white quartzite at the base is covered successively by black limestones, schists and green sandstones, with at the second level black argillaceous limestones and red sandstones and argillaceous schists.

Karroo, associated intrusions and Cretaceous rocks

The Karroo covers vast areas of the country. The rocks of glacial origin of the Dwyka formation are overlain by argillaceous schists, sandstones and coal-bearing schists of the Ecca group. Next come red deposits and eolian sandstones, followed by basalts dating from 180 to 120 million years ago. The volcanic rocks are traversed by large dykes.

The Karroo formation is of definite economic interest owing to the presence of coal seams, secondary mineralization, uranium in the sandstones, and clays suitable for brick-making.

There are two lines of intrusions formed during and after the Karroo period running north-east from the coast, one south of Lüderitz, the other north of Swakopmund. The southern line consists mainly of syenites and the northern line of rhyolites, tufas, granites, gabbros, pyroxenites and cabonatites. These intrusions are of economic importance owing to the presence of fluorides, iron ore and apatites.

Kalahari sequence and associated deposits

These Tertiary to Recent deposits of continental origin cover a large area in the east and north of the country. At the base are found sandstones and conglomerates with limestone cement overlain by partly calcareous white sandy clays. At the top, unconsolidated eolian sands are found throughout the Kalahari sequence, with stretches of stable dunes in the east. The sandy expanses of the Namib Desert contain Tertiary and Recent dunes.

Most of the beds of the big westward-running watercourses contain Tertiary to Recent fill consisting of coarse or fine fluviatile sediments and thick layers of sandstones and conglomerates with limestone cement. Deposits of gypsum are found to the west. Several of these watercourses end in vast deltas containing saline and sandy strata with gypsum cement.

At the coast there are raised Quaternary terraces/beaches: from 2 to 10 m, 12 to 25 m, 30 to 35 m at Oranjemund, and 5, 10, 16 and 23 m in the area north of the Ugab River.

IV. GROUND WATER

The following are the main aquifer systems:

- Archean basement: ground water in the fractures and altered zones;
- proterozoic Damara facies and Otavi series: mostly fractured rocks with a good proportion of limestones and dolomites;
- Cambrian Nama facies: originally porous rocks but now mostly cemented;
- Postcambrian formations: porous rocks;
- Unconsolidated formations with good primary porosity.

The country's hydrogeological network emerges clearly on the geological map. There is a central chain, with slopes facing towards the Atlantic and towards the interior, i.e. towards the Kalahari. The mountain slopes and their immediate foothill areas consist of fractured hard rocks where there is little infiltration and abundant runoff. In the east the chain is flanked by Kalahari sediments, and in the west by the sands and alluvial fans of the Namib Desert. These formations are porous and can absorb the surface flows and transmit them underground towards the areas where they find their outlets, for example in the Kalahari towards Mkghadikghadi and through the Namib towards the coast. The ground-water aquifers are unconfined in the areas of recharge and discharge, and artesian in the intermediate areas of ground-water flow. In these areas pumping causes large drawdowns.

The country's hydrogeological network thus consists basically of a central mass of fractured rock running north-south with low capacity and artesian conditions, although the peripheral porous rocks have high capacity and unconfined aquifers.

These recharge zones constitute the upstream part of porous artesian aquifers with large capacity.

Downstream are found the discharge zones, also with porous unconfined aquifers of large capacity.

In the artesian zones with heavy drawdown, irrigation is ruled out by the high cost of raising the water from great depths, but the water can be used for livestock. The water in the unconfined aquifers is generally close to the surface and irrigation is possible, especially if the water has to be raised from a depth of only 5 to 10 m.

The forms of relief also play an important role where ground water is concerned. The Southern African plateau is situated at a fairly high altitude and erosion in intense. The soils and alteration zones are not very thick. The flow coefficients are high, and the beds of the watercourses are narrow and sandy; the alluviums are not very well developed and deep gorges are found in the upper basin. The evolution of the chemical composition of the ground water is generally as follows:

(1)	Recharge (upstream):	Calcium bicarbonate and magnesium bicarbonate water with little mineral content;
(2)	Underflow:	Sodium bicarbonate water, with dry residue up to 2,000 ppm;
(3)	Discharge zones (downstream of the aquifer):	Sodium chloride/calcium sulphate water, with a high dry residue of up to 200,000 ppm.

From (2) to (3) the water deposits siliceous ferrous materials.

Thus in Namibia:

- The recharge zones at the edges of the Namib and Kalahari basins contain bicarbonated water of good quality, as do the zones immediately downstream;
- The outlet zones contain deposits of extremely saline water which can be used for industrial purposes;
- The zones of hard rocks contain small isolated ground-water basins, in which the water quality varies from place to place. However, if the alteration zone is thin, the water is usually sweet.

Water with very high mineral content of up to 80,000 ppm is found close to the surface in the Kalahari sediments.

Mountain region and high plateaus in the centre of the country

This is the upstream part of the hydrographic basins which lie above the Kalahari in the east, the Etosha in the north and the Namib in the west; it is deeply scored by the beds of the watercourses. The surface has been worn away by erosion which has left the rocks practically bare.

The Kaokoveld area in the north-west is arid and generally inhospitable, with poor grazing and a fragile ecology. Only nomadic herdsmen live here. The formations consist mainly of granites, intrusive basic rocks and strata of Otavi facies, rich in calcium and magnesium. Water is taken mainly from springs, and most of the population lives in the northern part, along the Kunene River. The Otavi limestone and dolomitic series are probably water-bearing but there are no data on them. Water may also be contained in the intrusive rocks close to the watercourses or in the upstream parts, i.e. in the recharge zones. However, the soil and the ecology do not seem suitable for agricultural development in the Kaokoveld. Any future hydrogeological studies in this area will probably be connected with mining development.

The Otavi limestone and dolomitic series extend from the Tsumeb-Grootfontein area westwards to the southern limit of the Etosha basin and into the southern part of the Kaokoveld. To the east, around Tsumeb, they are karstic and known as "Karstveld". Karstic water is Namibia's most important ground-water resource. The Karstveld aquifer slopes down towards the Etosha. The boreholes drilled in other parts of Otavi have produced uneven results. Large yields have been obtained from dolomites in the north.

The Damara region in the centre and centre-north of the country consists mainly of intensely metamorphized gneiss and schists. There are fairly extensive areas of granites but they are of little interest from the standpoint of ground water. The country's best grazing land is found here and many boreholes have been drilled.

Many faults and dykes have been identified by aerial photography. The ground-water potential should be fairly large, for this is an intensely tectonized and faulted area with fairly high rainfall. Since the region is deeply scored by the hydrographic network, the aquifer must lie fairly deep below the surface.

The rocks of the crystalline basement from south of Windhoek to Lüderitz are mainly granitic. They are mostly covered with Namib sands in the coastal zone. Most of this territory is mountainous, of difficult access and poor; but it is also the area which receives the rainfall and transmits it to the recharge zones situated downstream.

Lastly, there are the Nama sediments of Cambrian age in the centre-south of the country; this is perhaps the series of hard rocks of greatest interest from the standpoint of ground water, although the pores in the rocks are mostly cemented. Ground water is found here in aquifers of local size and in perched aquifers.

To sum up, the fractured rocks in Namibia contain outcrops of the parent rock which itself has been worn away by erosion of its soil and alteration strata. Accordingly, there is little infiltration and the surface flow coefficients are very high. The water-bearing strata lie deep below the surface on the plateau, where the watercourses have cut steep-sided channels. The aquifers are of small capacity and subject to artesianism. These initially difficult conditions can be overcome if the sitting of the boreholes is based on careful studies. Satisfactory yields may be obtained from such boreholes for appropriate uses in the country.

Zone of porous rocks

These zones are the basins of the Etosha and Kalahari, with two sub-basins, and the sands of the beds of watercourses and the coastal sands.

The Etosha basin is the outlet from the Cuvelai slopes. It was formed by faulting probably associated with the Rift and by subsidence of the northern areas of Otavi facies. Deposits of natron, gypsum and rock salt are found here - an indication of artesian pressure since this situation is the result of evaporation of bicarbonated artesian water raised by drainage; this water then evolves towards the chloride and suphate type. Most of the boreholes have produced saline water. The sediments are of the fine grain deltaic type and there is little circulation of ground water, for it is generally trapped in isolated lenses of sand.

The bicarbonated water is of little interest unless the evaporites contain phosphates or uranium. The hydrogeological study of these formations has therefore been abandoned and the efforts are being focused on the surface water of the Cuvelai

and on securing additional supplies from the Kunene basin. The present state of knowledge indicates that the Etosha basin is probably not a potential source of ground water. It is an endorheic basin in which the ground water will be saline no matter what its depth below the surface.

Kalahari basin

This is a vast structure running north-east to south-east towards Botswana and covered with Karroo sediments, including the Dwyka, Ecca, Stormberg and Kalahari strata. The Stormberg stratum is represented by vast basaltic effusions divided by dykes and sills into water-bearing compartments. The Stormberg and Dwyka sandstones are also noteworthy aquifers.

In Namibia the Kalahari is divided into two sub-basins separated by the raised threshold of the Gobabis-Ghanzi.

The southern part is known as the "salt block" and its artesian aquifers underlie 15,000 km^2 of grazing land. It consists of Auob and Nossob sandstones and Dwyka series which slope down towards the east and are covered with Kalahari sediments: sands, clays, argillaceous schists, calcareous concretions and laterites, the thickness of which increases from 50 m in the west to 400 m at the Botswana frontier. The recharge zones of these artesian aquifers outcrop in the form of a vast arc of Karroo sediments in the Mariental-Keetmanshoop area.

As already pointed out, the water of the Kalahari sediments may have mineral concentrations of up to 80,000 ppm. It should be noted that the tubing of the deep boreholes tapping the Auob and Nossob aquifers in the "salt block" is subject to intense corrosion by the sulfated water acting on the cementation. There are therefore two possibilities: either the hydraulic head of the Kalahari is the stronger, causing invasion of the deep aquifers by salt water from shallow depths; or the sweet artesian water rises from great depths and is dissipated in the saline Kalahari strata.

Given this problem, either the wells are repaired by cementing of the upper sections, or they are abandoned and new wells installed. This is a costly operation in either case.

The sandy beds of the watercourses usually contain ground water close to the surface which is extensively exploited, especially in the national parks. The aquifers of this southern region are sufficiently productive to meet requirements compatible with the preservation of the ecology.

Little is known about the resources of the northern region. Some boreholes have been drilled in the areas of lava and coal along the Botswana frontier. The existence of closed depressions with deposits of bicarbonate of soda seems to indicate that the sub-basin is compartmentalized. Ground water is present at depth, but the exact depth is not known.

The Department of Water Affairs has made studies of the recharge zones of the northern Kalahari but the results have not been published.

The Namib Desert

This is a sandy coastal desert, essentially an area of crystalline basement rock and hard rocks covered by sands. The formations are thickest at the foot of the

central mountainous zone and end in a wedge in the coastal zone in the west, with a continuous line of mainly gypsum and halite evaporites.

As this is a desert area of sand dunes, the water requirements do not receive high priority unless for the purpose of establishing villages or bourgs in the coastal zone and along the central mountainous zone, where there is fertile soil and good grazing. Similar areas have been brought under cultivation in Oman, Iran and Saudi Arabia. Ground water might also be found by drilling in the alluvial cones.

The evaporites indicate the end of the ground-water flow. There is therefore virtually no chance of finding ground water in the coastal zone, except in the sandy beds of the watercourses close to their mouths, as in the case of the lower reaches of the Kuiseb and the Omaruru, which are intensely exploited: they contain sequences of sands, silts and clays. Up to 90,000 m^3/day has been extracted and this would seem to be the extreme limit of the safe yield (beyond it, saline invasion occurs).

The ground water of the coastal zone has been explored only in Walvis Bay, in the Swakopmund zone. The coastal zone might contain a number of fossil beds containing sweet water which it would be worth researching.

Lastly, ground-water resources might be found in the coastal zone if new needs arise.

Water balance

Some estimates indicate an annual recharge of the aquifers of 5 mm over 20 % of the country (i.e. the recharge zones of the foothill areas), making a total of a little under 1 billion m^3. The Department of Water Affairs estimates the water resources at 500 million m^3, including 300 million of ground water, i.e. infiltration of 3.6 mm.

This infiltration value is highest than the value for Saudi Arabia (1.6 mm). It is therefore probable that the figures of 20 % and 5 mm are underestimates. There should therefore be 1 billion m^3 of ground water to be developed. Such development would promote a better distribution of population throughout the country.

V. INSTITUTIONAL FRAMEWORK AND EXPLOITATION OF THE GROUND WATER

The Department of Water Affairs, which replaced the Division of Water Affairs on 1 July 1980, has a number of services concerned mainly with urban and rural water supplies and supplies for industry and mining. The Department employs 3,500 persons, including 450 middle and senior management staff.

The largest amounts of water are consumed by the municipalities of Windhoek, Walvis Bay and Swakopmund and the Rossing mining complex. The water is extracted from the sand aquifers in the beds of the Kuiseb and Omaruru Rivers. The systematic study and exploration of ground water began in 1959 and was continued up to 1977 by a specialized section of the Geological Service; since then this work has been the responsibility of the Department of Water Affairs, which can carry out drilling works for private individuals. The scientific studies are carried out in co-operation with the Council for Scientific and Industrial Research (CSIR).

The water resources are exploited at a rate which is increasing by 3 to 3.5 % every year; it seems that most of the known potential will be developed by 1990. Further prospecting must therefore be carried out in order to discover additional resources.

VI. REFERENCES

Most of the material for this paper was taken from an unpublished United Nations report (June 1984) prepared under a project of the Department of Technical Co-operation for Development implemented on behalf of the United Nations Council for Namibia and entitled "Survey of water resources and requirements". This report was prepared from data collected by two consultants in Lusaka, London, Paris, Geneva and Rome. Some material was taken from the reports on a UNDP/FAO project (NAM/78/004) entitled "Assessment of potential land suitability" (FAO, Rome, 1987).