5

THE RIVER

Meandering across the Kalahari

Convoluted meanders and horseshoe lakes on the Cutato River.

WATER COLLECTS in a large catchment area of about 111,000 square kilometres (km²), then flows hundreds of kilometres with no further inflow before finally dispersing in an alluvial fan that now covers up to 40,000 km². This is the essence of the Okavango, and very few rivers in the world work like this! The active catchment area lies wholly in Angola and is thus distinctly separated from the alluvial fan in Botswana, called the Okavango Delta.

The network of Okavango rivers sits squarely in the centre of southern Africa, where it is surrounded by other river systems that drain away east to the Indian Ocean or west to the Atlantic Ocean. The Okavango – and the Kwando just to the east – are unusual as they are the only major perennial rivers south of the equator that do not drain into the sea. Both rivers come to an end in the centre of the Kalahari Basin, a vast shallow depression of sand stretching across much of the centre of southern Africa (Figure 18).

Several other features make the waters of the Okavango special. First, the Delta is the largest wetland in southern Africa, and being in the centre of a vast arid area in the Kalahari gives it extra significance, rather like the value of a huge oasis. Secondly, the Delta is regarded as one of the most pristine wetlands in the world because it has been so little affected by humans. Few chemicals pollute its water, damming or channeling do not change the flow of water to any extent, and natural vegetation in the Delta is largely intact. In fact, many of the rivers in its catchment area in Angola are equally pristine. Thirdly, the river water is particularly clean and pure because most of the catchment areas drain Kalahari sands (see page 33) and the tributaries filter through vast areas of floodplains and marshes in Angola.

The Okavango Basin area on which we focus here is limited to the active catchment area from which water drains and the zone immediately around the flowing rivers and Delta. Some people choose to define the Basin as covering a much larger area (Figure 19) to include the fossil drainage lines in Namibia, Botswana and Zimbabwe, and also the Makgadikgadi Pans as an area into which Okavango water flowed during much wetter periods. In Angola, the catchment is made up of the western Cubango sub-Basin, consisting of the Cubango, Cutato, Cuchi, Cacuchi, Cuelei, Cuebe, Cueio and Cuatir Rivers. These join to form the Cubango in Angola, later called the Okavango in Namibia and Botswana. The eastern or Cuito sub-Basin consists of the Luassinga, Longa, Cuiriri, Cuito and Cuanavale Rivers – all of which feed the Cuito before its junction with the Okavango on the Angola/Namibia border. Water is distributed across the alluvial fan or Okavango Delta along three main channels: the Thaoge, Jao and Nqoga.

Much the largest part of the active Basin is in Angola, and the whole Basin extends across almost nine degrees of latitude between 12 and 21ºS. The main river after which the Basin is named (first as the Cubango in Angola, then as the Okavango and finally through the Delta to Maun) covers a straight-line distance of about 1,900 kilometres. This is just a rough indication of the river system's length because most of the rivers spend more time meandering than flowing directly to the south. Their waterways therefore cover many thousands of kilometres. Figure 20 and the table on page 74 show the areas covered by the catchment areas of all the major rivers in Angola, and the remaining zones in and around the river system in Kavango and Ngamiland.

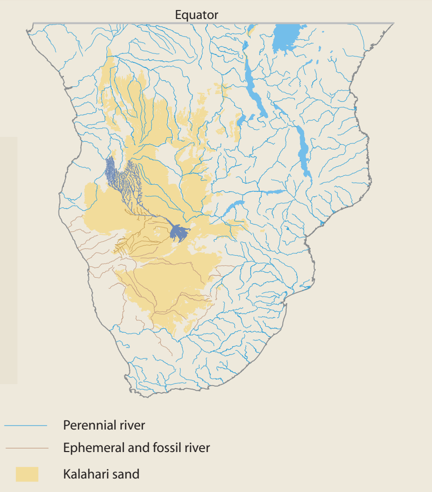
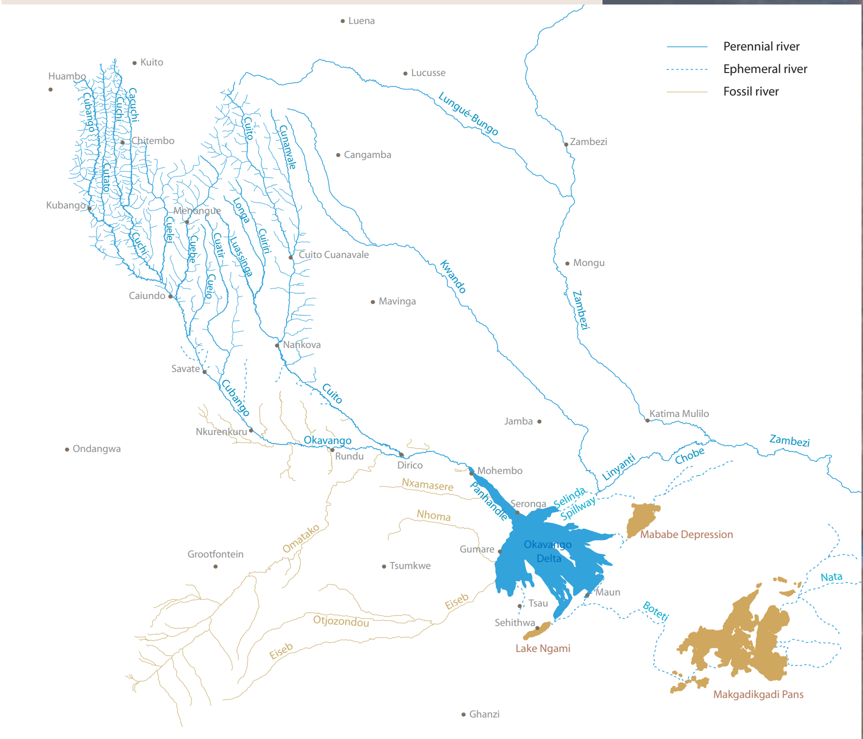
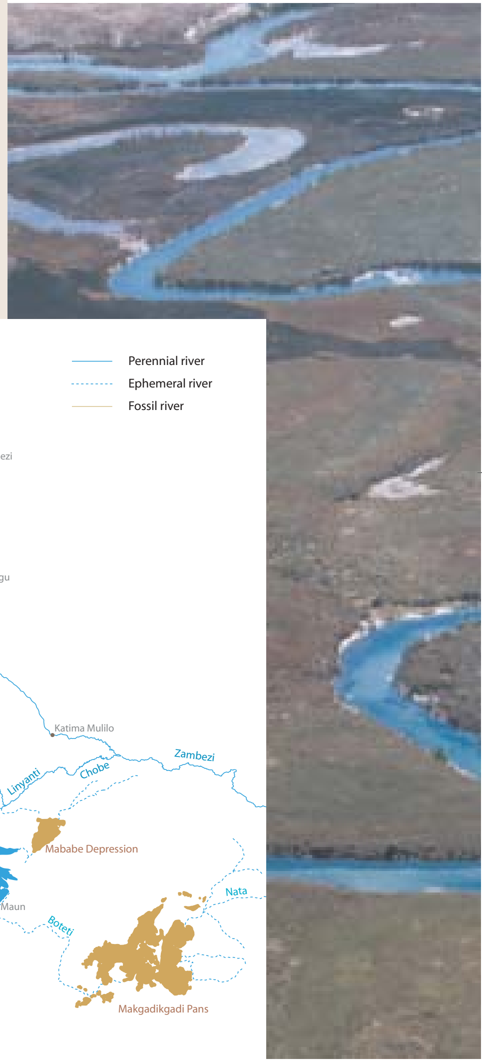


Figure 18
The Okavango and Kwando rivers drain into the central Kalahari Basin whereas all other perennial rivers flow to the coast of the African continent.

Figure 19
The Okavango Basin forms part of a large drainage area in the central Kalahari. Much of that area is now dry but a great deal of water flowed there during wetter periods long ago (see page 67). Some water still flows along ephemeral rivers after heavy rains, but the fossil rivers have not flowed into the Okavango in living memory. Many of the rivers were also connected during wetter times when Okavango water could flow into the Kwando, Chobe and then the Zambezi, and also to the Makgadikgadi Pans. The Zambezi River drained into eastern Botswana and, together with the Okavango and Kwando, produced a lake covering about 60,000 km² in and around the Makgadikgadi Pans. This is five times bigger than the largest area flooded in the Delta in recent decades. Later on, probably within the last two million years, the upper Zambezi was captured and diverted along its present course to the Mozambique coast.[1]



Crystal clear, pristine waters of the Cuebe River upstream of Menongue.



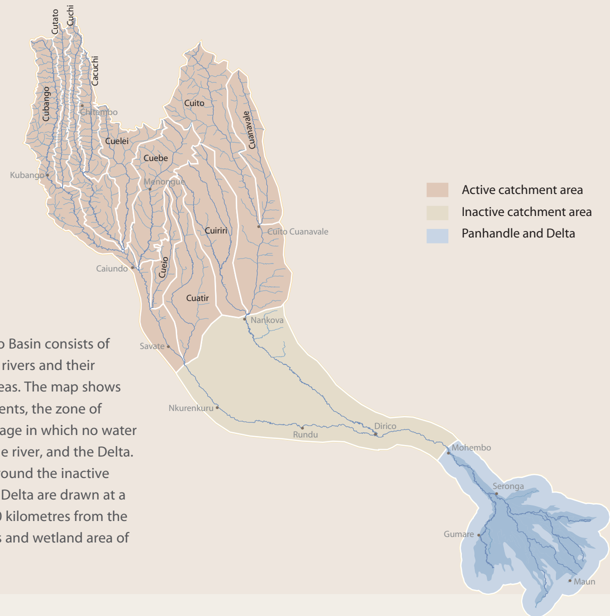


Figure 20

The Okavango Basin consists of several major rivers and their catchment areas. The map shows these catchments, the zone of inactive drainage in which no water is added to the river, and the Delta. Boundaries around the inactive drainage and Delta are drawn at a distance of 20 kilometres from the river channels and wetland area of the Delta.

The size, average rainfall and approximate run-off in the catchment area of the major rivers.[2]

River or zone	Area (square (kilometres)	Average rainfall (millimetres)	Average run off (cubic kilometres)	Percentage of total input
Cubango[a]	14,400	1,064	1.290	15%
Cutato	4,200	1,166	0.420	6%
Cuchi[b]	8,900	1,071	0.820	10%
Cacuchi	4,800	1,150	0.470	5%
Cuelei	7,500	1,065	0.690	6%
Cuebe	11,200	992	0.960	10%
Cuatir	11,600	750	0.750	5%
Cueio	3,700	829	0.260	3%
Cuiriri[c]	12,900	876	0.980	10%
Cuito[d]	24,300	975	2.060	22%
Cuanavale	7,750	1,018	0.680	7%
Total active catchment	**111,250**	**978**	**9.380**	**100%**
Inactive drainage area[e]	45,000	571	0	0
Delta	35,300	469	0	0

a Includes its own catchment area and areas downstream of the junctions of the Cutato, Cuchi, Cacuchi, Cuelei, Cuebe and Cueio rivers.
b Includes its own catchment and the area downstream of the junction of the Cacuchi.
c The Cuiriri includes the Luassinga and Longa rivers.
d Includes its own catchment and the area downstream of the junction of the Cuanavale.
e The area from which there is no active drainage surrounding the rivers in southern Angola and Namibia.

The Cuito meanders sideways as much as flowing south to its confluence with the Cubango/Okavango.

The Nxamasere or Khaudum fossil drainage course (left) *runs from Kavango east to the Delta, while the Selinda Spillway* (right) *connects the Delta with the mini-delta formed as the Kwando River runs up against the Linyanti Fault. Depending on water levels during very wet periods, water can flow from the Kwando to the Delta – or vice versa.*

The largest separate river catchments are those of the Cuito, Cuiriri and Cuatir, while the Cutato, Cubango and Cuchi catchments have the highest rainfalls. The active catchment areas of the Cubango and Cuito, together with their major river tributaries, cover areas of 66,300 and 44,950 km^2, respectively. Turning to the fossil and ephemeral river courses **(Figure 19)**, the Boteti River still carries overflow from the Delta from time to time. For example, it had substantial flows during the 1950s, 1960s and 1970s when rainfall was generally higher than in the drier 1980s and 1990s. The Nata River sometimes flows from south-western Zimbabwe into Sua Pan in the Makgadikgadi. The longest of the fossil drainages are the Omatako (635 kilometres from its source near the Omatako Hills to its confluence at Ndonga), the Eiseb and Nxamasere (also called the Khaudum). Many shorter fossil rivers or omurambas drain from the south or north into the Okavango where it forms the Angola/Namibia border. None of these river courses has flowed any distance in recorded history.

Tributaries and distributaries

The broad pattern of water flow in the Okavango should be clear: water collects in the catchment, flows down the Cubango, Okavango and Cuito for several hundred kilometres, and is then distributed across the Delta. An important point is that all water flowing into Botswana comes originally from Angola, and the river simply flows through Namibia – rather like a canal. But what are the details of where the water assembles in Angola and how it disperses in Botswana?

Inflows are fairly evenly spread across the catchment from east to west. As a percentage of all water entering the Delta, the greatest flows are provided by the Cuito (22%), Cubango (14%), Cuebe (10%) and Cuiriri (10%).[3] Although the Cutato, Cuchi, Cacuchi and Cuanavale also drain high rainfall areas, their catchments are smaller, while the Cuelei, Cueio and Cuatir have smaller catchments in rather drier areas. From these figures and water flow measurements at Rundu (before the Cuito) and Mohembo (after the confluence), about 55% of all water flowing into the Delta comes down the Cubango/Okavango while the Cuito and its tributaries provides 45%. Water flow is thus at a maximum between the confluence of the Cuito and Mohembo, a distance of about 140 kilometres.

Dispersal of the river begins at the top of the Panhandle, and an estimated 40% of the total volume of water leaks into the surrounding swamps by the time the river leaves the Panhandle. The remaining 60% flows into the head of the alluvial fan from where it is distributed down three main channels. The Nqoga channel takes 63% of water entering the fan, the Jao 21% and the Thaoge 16%. Much more water thus flows east along the Nqoga from where water leaks and disperses further along the Maunachira, Mboroga and Santantidibe distributary channels. In years of high flow, floodwaters may reach the Kunyere and Thamalakane rivers in the far south-east. And when levels are really high, the two rivers flow south-westwards bringing water to Lake Ngami and the Boteti River.

The average volume of river water coming into the Delta each year is about 9.4 cubic kilometres, and to this is added about another 3.2 cubic kilometres of rain water that falls directly on the Delta each year.[4] The total input of water to the Delta is thus about 12.6 cubic kilometres, a volume that would cover an area of 100 by 126 kilometres in one metre of water.

An estimated 96% of all water entering the Delta as river water and direct rainfall is lost by evapotranspiration. This includes evaporation of water directly into the atmosphere and indirectly through transpiration by plants. Water loss through transpiration probably exceeds evaporation, especially during the summer growing season and in the permanent swamps. About another 2.5% of all water in the Delta seeps away into groundwater aquifers, while the remaining 1.5% flows out of the system along the Boteti River. The 1.5% is an average, however, comprising many years in which there is no outflow and others when substantial volumes make their way down the Boteti.[5]

Changing rivers

Along its course, the river system has many different forms: as cascading flows, sluggish meanders, or seepage through expansive floodplains, dense reed beds and swamplands. These are the forms seen today. But it is important to recall that the structures of the rivers, especially the valleys and floodplains through which they flow, evolved over periods of hundreds of thousands or millions of years. Moreover, many of the formations developed during periods of much higher rainfall (see page 67) when the rivers carried several times more water than they do today. These effects would have been substantial because of the shallow gradient of most rivers. For example, along stretches now characterized by floodplains, the river water would have spread across much bigger areas for longer periods, rather than draining away rapidly as would happen along a steep river gradient. The mantle of Kalahari sand would also have been stripped away more rapidly during periods of high rainfall. It was doubtless those large flows that formed the broad river valleys that are now several kilometres wide in Angola and Kavango. Similarly, many other rivers would have flowed during the wetter periods. The remains of some of these are clearly visible today as fossil rivers while others have been covered up by wind-blown sand during recent arid periods.

For stretches and areas of active flow, six different formations are recognized and described here: Incised Valleys, Valley Marshlands, Floodplain Valleys, the Panhandle, Permanent Swamps, and Seasonal Swamps **(Figure 21)**. These are described and illustrated on the following pages. The first three formations encompass areas of active river flow in Angola and Namibia. Most Incised Valleys and all the Valley Marshlands are in the western highlands of the catchment where they cut through and across various bedrock formations (see page 33). Their main courses run parallel and due south, and are fed by dense networks of hundreds of tiny tributaries. Run-off from the rivers is relatively rapid and much more variable than in the Floodplain Valleys that characterize the eastern areas of the Angolan catchment. These eastern valleys sweep across large areas of Kalahari sand, and the only relatively dense network of tributaries is in the headwaters of the Cuito. Over most of the remaining areas between the Floodplain Valleys the landscape is very even, and there are vast areas in which there are no active drainage lines.

The remaining three formations are in the Delta. The first is the Panhandle with a gradient of 1:5,000, while the other two (Permanent Swamps and Seasonal Swamps) are in the slightly steeper alluvial fan with a gradient of 1:3,300. Floodplains, swamps and tongues of sandy ground separate the three main channels: the Thaoge, Jao and the Nqoga. The exact margins of the whole Delta are difficult to define because the extent of flooding varies from year to year, and some outlying areas are only inundated in exceptional flood years.

Incised Valleys

Most of the tributaries in the north-western catchment flow along clearly defined V-shaped valleys, although the valleys are all shallow. While there are broad meanders in places, the meander is usually along a single channel. Incised Valleys predominate in areas where bedrock is exposed or the mantle of Kalahari sand is shallow. There are many short rapids or waterfalls along certain stretches, and the gradients are steeper than anywhere else in the whole Basin (see page 40). Vegetation in the valleys varies considerably: woodland extends right down to the river in many areas whereas elsewhere the rivers are surrounded by margins of grassland. In some places there is riparian forest or patches of floodplains or grasses, sedges or reeds. The Cubango/Okavango runs as an Incised Valley for most of its length and it is only west of Musese in Kavango that the river changes into a Floodplain Valley. Almost all tributaries of the Cubango, Cutato, Cuchi, Cacuchi, Cuelei and many of those flowing into the Cuebe are Incised Valleys. The bottoms of the great majority of these tributary valleys consist of permanently wet grassland, or bog, on either side of small streams. This is true of even the smallest valleys and so these wet grasslands provide seepage of water into the rivers throughout the year.

Valley Marshlands

These swampy areas are restricted to the north-western catchment and are especially common along the Cutato, Cuchi and Cacuchi rivers. It appears that the bottoms of Incised Valleys have been so filled with sediments that the gradient of the rivers has become much shallower. The rivers thus snake their way downstream through dense, tall *Phragmites* reed beds. Hundreds of ox-bow lakes and convoluted meanders characterize each stretch. The marshes are often several hundred metres in width and, cumulatively, they cover an area of several hundred square kilometres. One important effect of the reed beds is that they filter out nutrients, sediments and pollutants from upstream. The marshes also stabilize the flow of water by slowing surges of floodwater, but then also gradually releasing water from the inundated reed beds during drier times.

Floodplain Valleys

Most of these valleys are in the north-eastern areas of the Angolan catchment, although sections of the Okavango along the Angola/Namibia border share this structure. The valleys are extremely shallow and are generally several kilometres wide. River channels in the centre of the valleys follow broad meanders, in some places now cut off as ox-bow lakes. The channels are lined with expanses of sedges and other grasses that form a distinct floodplain of short vegetation. Beyond the floodplains is another wide area of short, dry grassland that extends up to the sharp edges of the flanking woodland. Few trees or other woody plants grow within the Floodplain Valleys, and it is their openness, short grasses and distinct margins of woodland that characterize them best.

The Panhandle

This is the beginning of the Delta. Although most people consider the Panhandle as starting at Mohembo, the feature really begins upstream in the Mahango Game Reserve from where it extends south to the Gumare Fault. Most of the water flow is along a single meandering channel surrounded by a broad area of marshes dominated by papyrus and reeds. Relative to the adjacent floodplains, the water level of the river becomes progressively elevated down the Panhandle, rising to about 60 centimetres higher than the surrounding swamps at the end of the Panhandle. This is because sediments deposited on the floor of the channel raise the waterway, but the dense growth of papyrus along its margins acts as a barrier through which water can only seep away slowly.

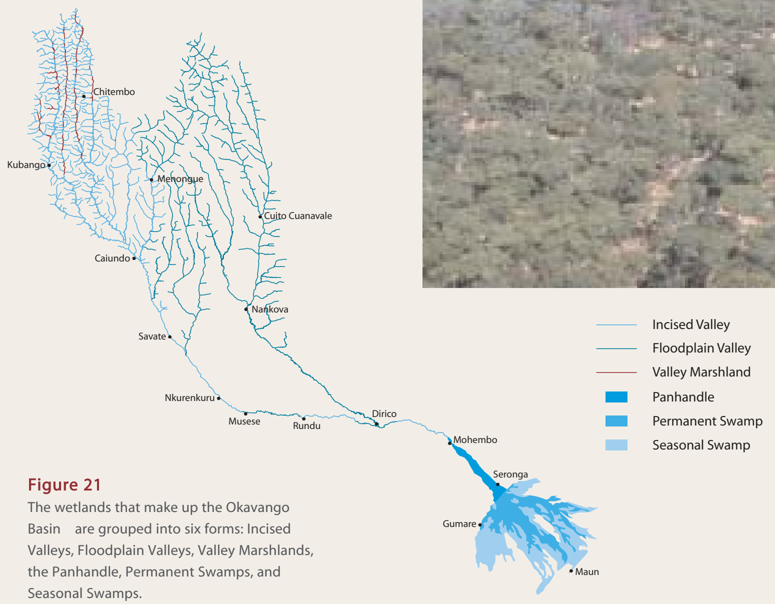


Figure 21
The wetlands that make up the Okavango Basin are grouped into six forms: Incised Valleys, Floodplain Valleys, Valley Marshlands, the Panhandle, Permanent Swamps, and Seasonal Swamps.

An Incised Valley on the Cubango River between Kubango and Caiundo (left) *and a Valley Marshland along the Cutato River* (below).

Permanent Swamps

The Permanent Swamps form the core of the alluvial fan and surround the three main channels (Nqoga, Jao and Thaoge) that distribute water across the fan. The swamps cover much of the upper northern and central areas of the Delta, where they extend over an area of 2,000 to 3,000 km². Seasonal Swamps cover the remaining southern, western and eastern areas. Many lakes (mostly ancient ox-bows) are dotted across the Permanent Swamps. Water flow is largely along channels from where the waters slowly leak through dense margins of plants into large expanses of papyrus, reeds and sedges. There are distinct zones of less dense vegetation away from the main channels because plants near the larger channels are first to absorb incoming nutrients and therefore grow best. Fewer nutrients remain available to plants growing further away, by contrast. Water levels in the Permanent Swamps are rather constant, unlike fluctuations of up to two metres during the year in the Panhandle.

A typical Floodplain Valley on the upper reaches of the Cuanavale River (left) *and a broad view across the Panhandle* (below).

Seasonal Swamps

Most floodwaters enter the Seasonal Swamps after filtering through the Permanent Swamps. The expanse of Seasonal Swamps varies greatly from year to year between 4,000 and 8,000 km², depending largely on the inflow from the Angolan catchment and local rainfall over the Delta. Unlike flows along channels in the Permanent Swamps, most water in the Seasonal Swamps flows as sheet flooding, the water spreading slowly across the gently undulating landscape. The water is usually less than half a metre deep, and many areas of higher ground therefore remain stranded as temporary islands during the floods. Plant communities are more diverse than elsewhere in the Delta because the Seasonal Swamps are subject to such a variety of flooding patterns, with different plant species favouring patches that vary according to the duration and depth of flooding.

Together with the Panhandle, the Permanent Swamps (top) *and Seasonal Swamps* (below) *form the largest RAMSAR wetland site in the world.*

Variable flows

Almost all river water originates as rain falling during the summer months (see page 66).[6] Peak flows are in March for rivers feeding the Cubango sub-Basin, while the highest flows only reach the lower Cuito in May (Figure 22). The earlier March peak is due to rainwater draining quickly off basement rocks or the thin mantle of Kalahari sand and then flowing down relatively steep gradients in the west. The whole Cuito sub-Basin, by contrast, is characterized by much more stable, regular flows of water slowly seeping through the sands and flowing gradually along its meanders and filtering through the extensive floodplains that surround its rivers.

Although little water eventually finds its way to Maun, flows that turn the Thamalakane into an actual river usually peak in August. This is four months after the highest wave of water has entered the Panhandle. Water that has covered close to 1,000 kilometres from the headwaters of the Cubango to Mohembo in a month or two thus spends another four months creeping down to Maun 250 kilometres away. The slow passage of the flood across the Delta is due to several factors: the shallow gradient, seepage into the ground, water having to filter its way through vegetation, and the uneven landscape which means that upstream depressions first have to fill before the water moves on.

As another reflection of the more variable supply of water down the Cubango sub-Basin, the highest rate of flow ever recorded for the Okavango (962 cubic metres per second (m^3/s)) is roughly 90 times greater than the lowest rate ever recorded (11 m^3/s). The same figures for the Cuito vary by a factor of less than 10: from a high of between 550 and 600 m^3/s to the lowest of 64 m^3/s. The Cubango/Okavango also flows much more rapidly than the Cuito during annual floods: average rates of flow at Rundu in April are 401 m^3/s, more than double average flow (175 m^3/s) in the peak month of May on the Cuito at Dirico. In the summer months between January and May, total volumes carried by the Cubango/Okavango are greater than those in the Cuito, while the Cuito provides more water during the other seven months of the year (Figure 22).

Flows along the Cubango/Okavango and Cuito subside each year to a fairly stable rate of discharge (Figure 23). Thus, while flows in April fluctuate greatly from year to year as a result of differences in rainfall and runoff, there is relatively little annual variation in October volumes. The only significant change is the lower flows in recent years due to lower rainfall (see page 88).

Annual flows (in cubic kilometres) per season at Rundu above the Cuito's confluence, below the Cuito at Mohembo and at Maun.[8]

Place and years of data	Average	Minimum (year)	Maximum (year)
Rundu (1945–2001)	5.207	2.260 (1971/72)	9.810 (1962/63)
Mohembo (1933–2001)	9.384	5.313 (1995/96)	15.977 (1967/68)
Maun (1951–1999)	0.271	0 (1995–1997)	1.174 (1954/55)

The differences between maximum and minimum volumes in the table are substantial – about four times at Rundu, three times at Mohembo, and hundreds of times at Maun – all largely reflecting how widely flows vary between high and low years, as shown by the year-to-year changes in Figure 25. However, several other factors play a role in determining levels

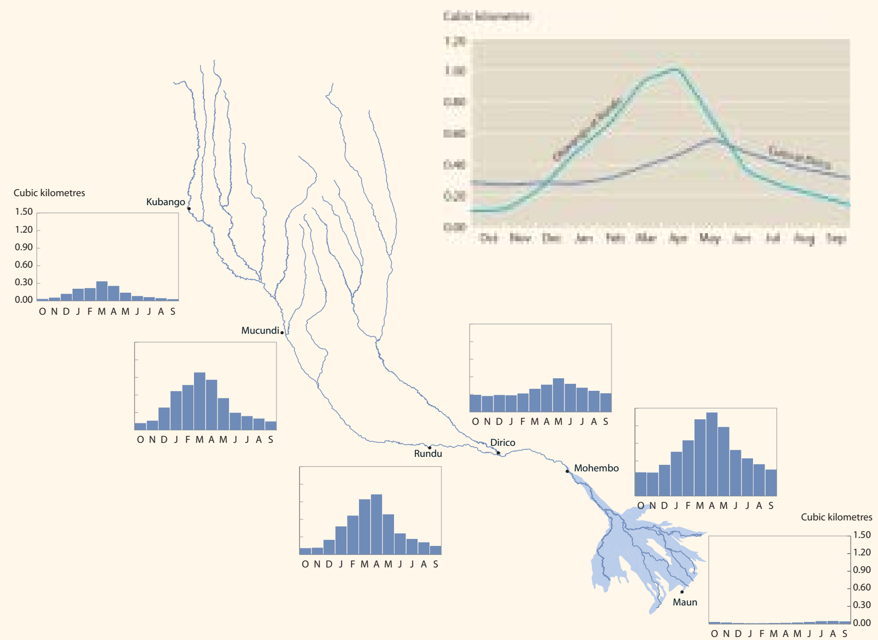


Figure 22

Most runoff in Angola is in March in the western Cubango sub-Basin and during May in the east along the lower Cuito. The time taken for Okavango water to flow from Rundu to Mohembo plus the effects of the later input from the Cuito means that peak flows enter Botswana in April. From there the waters take about four months to permeate through to Maun, where the highest flows are recorded in August. The inset graph also shows how the volume of water carried by the Okavango at Rundu is greater than that of the Cuito between January and May, but the Cuito provides more water during the rest of the year.[7]

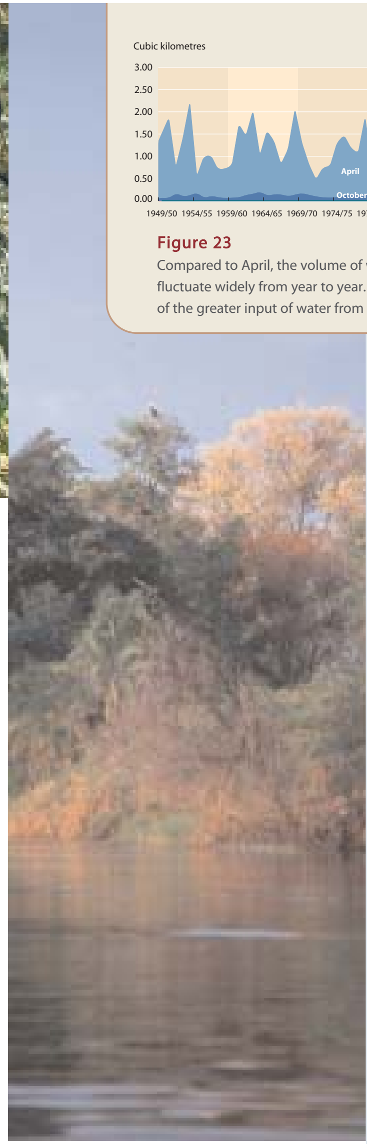
The Thamalakane near Maun is usually dry but it becomes a substantial waterway in those years when lots of water flows into the Delta.

The confluence of the Cuito and Okavango in October and April when flows are generally lowest and highest, respectively. The curved patterns are scroll bars of sand deposits left as the rivers have meandered from side to side (above). *A fish eagle overlooks the Panhandle, where biological production (and thus fish stocks) is highest because this is where most nutrients carried into the Delta are trapped* (right).

of water flow reaching Maun and this is why there is a weak correlation between river levels at Maun and those upstream at Mohembo and Rundu.

Levels of water flow along the rivers naturally have a great impact on the size of areas flooded in the Delta. Examples of the extent of flooding in two years are given in Figure 26, one for 1995 (a dry year) and 2001 (a much wetter year). The examples are limited to years for which satellite images could be obtained to map areas of flooding. While 1995 had one of the lowest flows on record, the flow in 2001 was very much lower than many of those in the 1960s (Figure 25). The largest extent of actual floodwater measured over the past three decades was 11,400 km² in June 1979. This was roughly double a maximum flood area of 5,100 km² in 1996, the driest recent year on record. The 11,400 km² of water was also about four times bigger than the smallest area of surface water recorded during the dry months: 2,450 km² in February 1996.[9]

Levels of flooding obviously depend on volumes of water inflow from Angola, but three more factors determine the degree of inundation in the Delta.[10] The first is local rainfall since an average of 25% of water in the Delta comes from rain falling directly on the area. The percentage is higher in years with good local rainfall but low inflow, but then less when good inflows dominate the effect of rain on the Delta. However, rain is often very local and so heavy falls may flood certain areas while others stay dry. Rain falling on dry ground adds to the saturation of the soil, raises groundwater levels and allows floodwaters to proceed more rapidly. This introduces a second influence on the extent of flooding: the effect of flooding during the previous year on the degree of soil saturation and height of the water table. If the ground is already saturated and the water table high from good flows in the previous year, new floodwaters move along quickly, more water remains on the surface and bigger areas are flooded. The third factor is evaporation, with floodwaters remaining longer during times when rates of water loss are low. Total evaporation amounts to over 2,800 mm of water each year, but it is during the hot, often windy spring months of September and October that water is lost most rapidly (see page 69). Up to 10 mm may then evaporate every day, an effect that does much to dry up the Delta rapidly before the coming of the next year's flood.



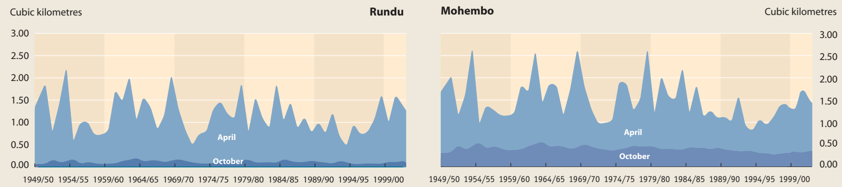


Figure 23

Compared to April, the volume of water carried in October is much lower but also much more stable than in April when flows fluctuate widely from year to year. The river also carries much more water at Mohembo during October than at Rundu because of the greater input of water from the Cuito during the drier months.[11]

Figure 24

The annual flood slowly spreads across the Delta, areas of open water increasing month by month from March. On average, August is the month in which the extent of floodwaters is greatest. The maps show the average frequency of flooding each month. Dark blue areas are inundated more often than pale blue ones.[12]

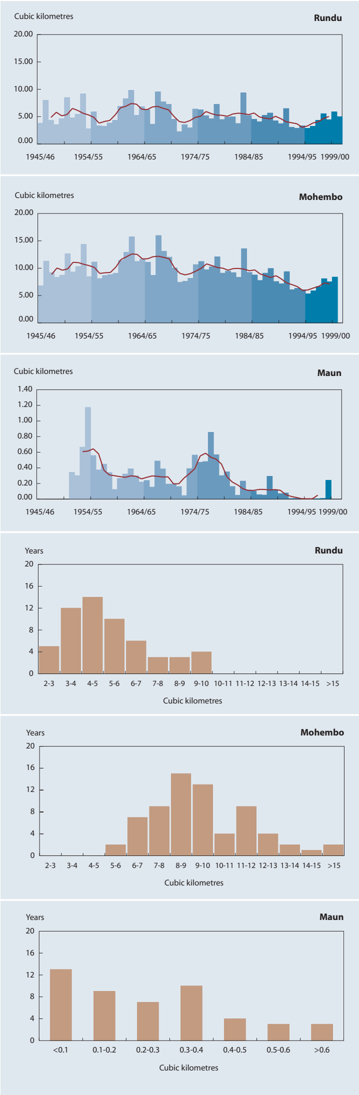


Figure 25

Volumes of water passing Rundu and Mohembo fluctuate greatly from year to year, but don't vary anything like as much as flows at Maun. Only in years with high flows and/or good rainfall over the Delta can Maun expect to see much water in the Thamalakane River. The columns show the actual values while the red lines are moving averages over five years to reflect longer-term changes, especially the lower flows in the 1980s and 1990s due to lower rainfall. The three histograms below show the number of years in which different flows were recorded.

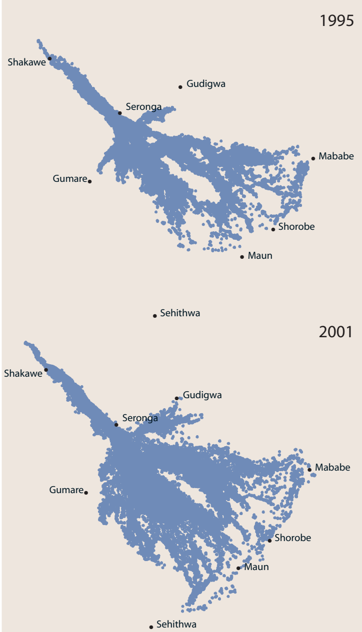


Figure 26

Differences in the extent of flooding have a great impact on life in the Delta, for example on the distribution and size of areas available for mammals to graze or fish to breed. The two maps show maximum flood areas during a dry year (1995) and a much wetter one (2001).

The dynamic Delta

Two circumstances are required for the formation of alluvial fans. The first is a landscape with a very shallow gradient, the kind of surface perhaps created in the rift valley between the Gumare and the Thamalakane faults (see page 35). The second is that river valley walls no longer confine the flow of water. Given these conditions, a river begins depositing sediments at the point where it starts flowing across a shallow surface. Water levels are raised by the accumulation of sediments and this forces the flow of water further outwards to lower-lying areas.

Although the biggest area covered by floodwater in the last 30 years was 11,400 km², sediments deposited by the river over thousands of years formed a larger alluvial fan that covers some 40,000 km² (see page 35). Much of this larger area was flooded during wetter periods when inflows were considerably greater. But the larger area of old sediments also reflects a fundamental feature of the Delta: that of continuing change in the distribution of water. Channels come and go, flowing here and then there as their current slows and then speeds off in new directions down new passages. As recently as 120 years ago, most water flowed to the southwestern areas along the Thaoge channel, and Lake Ngami was regularly filled by the Thaoge. Flows into the Thaoge largely dried up in about 1880, and the Thaoge is now a relative trickle that disperses far to the north of Ngami. The swamps that previously surrounded the Thaoge became vast areas of peat that burnt away over the years, turning the whole area into extensive grasslands.

Smoke from a smouldering peat fire that may burn over months, even years.

Okavango River

Such changes in the spread of water lead to another fundamental characteristic of the Delta: the enormous diversity of habitats produced by the changing presence and depth of water across this oasis. And from that variety of habitats follows the wealth of plants, animals and scenic beauty that give the Delta such great value. None of this would, of course, be possible without the ingredients that come flowing down the river from Angola: the water and the nutrients and sediments that it carries.

Water levels fluctuate by up to two metres between the highest and lowest flows at the top of the Panhandle, where the height, volume and speed of water flow entering the Delta is greatest. The water then disperses and fluctuations in level diminish as floodwaters percolate into the permanent swamps before spreading into the seasonal swamps. Larger areas are flooded and water remains longer in the seasonal swamps following good inflows. Moreover, plant growth is better and the underground water table rises in such ‘good’ years (see page 102).

Nutrients and sediments are the other main ingredients brought into the Delta, and it is these that have indeed built the whole alluvial fan. Salts make up a high proportion of the many different compounds carried down the Okavango, but water in the Delta is exceptionally clean and free of salts. This is remarkable because salts become concentrated in most wetlands in hot and arid areas, resulting in the formation of crusts of salty and infertile ground. Southern Africa has good examples of this in the Etosha and Makgadikgadi Pans.Why should the Delta water be so free of salts? The answer lies in the action of the rich plant life. Unlike saltpans, where water

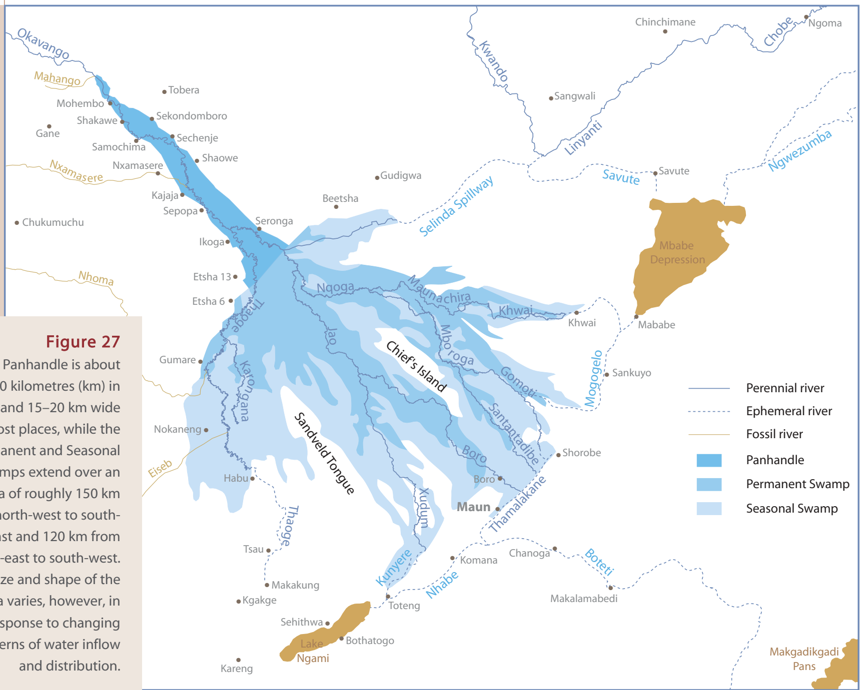


Figure 27

The Panhandle is about 120 kilometres (km) in length and 15–20 km wide in most places, while the Permanent and Seasonal Swamps extend over an area of roughly 150 km from north-west to south-east and 120 km from north-east to south-west. The size and shape of the Delta varies, however, in response to changing patterns of water inflow and distribution.

A channel, now choked with plant growth and abandoned, was raised above the surrounding floodwaters by the steady accumulation of sand on its bottom.

simply evaporates leaving behind any salt it carried, most water in the Delta does not evaporate. Rather, most is lost through the leaves of growing plants, a process called transpiration. As the plants draw up water through their roots, some salts are absorbed into the plant body while others remain in the ground. From here, the salts permeate into the groundwater below the Delta or become concentrated in the soils beneath the many islands. Indeed, the islands play a particularly important role in concentrating salts because trees growing on the islands draw water in towards them from the surrounding swamps. Salts carried by the water thus collect in the basal soils of the islands. The highest concentrations are in the island centres where so much salt aggregates that the soils eventually become too poisonous for plant growth.

Trees growing on islands transpire great quantities of water into the atmosphere, with the result that salts are concentrated on islands and thus removed from the Delta's waters. White centres to these islands mark patches of soils that are now so salty that no plants grow there (left). *Zones of vegetation around channels in the Delta reflect the access that plants have to nutrients. Thus, plant growth is tallest close to the main channels because nutrients are more abundant than further away* (below).

Each year, an estimated 170,000 tonnes of sand is carried down from the Angolan catchment into the Delta where it settles on the bottoms or beds of channels. This simple process of deposition is the main reason why flows switch from one direction or channel to another. The sand is largely rolled along the channel floors as so-called bed-load, and then settles once the speed of water flow is too slow to carry it further. The accumulating sand raises the levels of the channels, further reducing rates of flow and allowing more sand to settle. Papyrus growth also encroaches on the channels as water speeds drop, bringing the flow of water to a stop and eventually blocking the channels completely.

The diversity of habitats in the Delta is remarkably high, a quality that results in part from the presence of termites and hippos. There may be as many as 150,000 islands, particularly in the southern and eastern seasonal swamp areas, and perhaps 70% of all islands developed on original termite mounds (right).[13] *Water seepage into swamp areas away from the main channels is accelerated by hippo trails* (below). *Once the bed of a main channel rises and water flow slows as a result of sand deposition, the main flow may switch down a hippo trail. The now fast flowing water can erode and widen the trail to form a completely new channel.*

Rates of sand accumulation are substantial, perhaps as much as five centimetres per year or half a metre in 10 years. The channel margins of peat become increasingly dense and impenetrable. Water in a blocked channel can rise only so much before finally breaking through the sides of the channel to form new waterways. The breaks are often along paths worn down by hippos, and the water then rapidly flows down along the newfound courses into the surrounding, lower-lying floodplains. Large channels are thus diverted into new ones, and the diversions may radically change the pattern and distribution of flow in the Delta.[14]

Clean waters

One feature characterizes the waters of the Okavango more than any other: its overall purity and clarity. Few other large rivers in the world boast such cleanliness, but the good quality of Okavango water is both an asset and a constraint. On the plus side, the water is so clean because there are few sources of pollution or contamination. Soils in its catchment and along its riverbanks also do not erode easily and the water is thus free of the muddiness that colours most other rivers during the rainy season. Unlike lake water in most hot and arid parts of the world, water in the Delta is surprisingly free of salts, an aspect described on page 90. All of this means that rural people can drink and wash in the water with less risk of picking up diseases than in dirtier rivers.

Most river beds are lined with Kalahari sand, the sand usually forming a rather even carpet. In some places, however, the sand is shaped into underwater dunes called mega-ripples (left). *The waters of the Okavango are very clean, such as here in the Cuebe River* (right).

The purity of Okavango water also means that it is extremely deficient in nutrients, and this places a limit on life in the river. There would be more fish, birds and plant life in the river if there were more nitrogen, phosphorous and other minerals. During aerial surveys of the Angolan rivers in May 2003, we were struck by the almost complete absence of water birds. Many people assume that much of the wildlife was killed during the last few decades of hostilities in Angola. That may be true of large mammals and many birds, but it is hard to escape the conclusion that some other factor must be responsible for the absence of ducks, egrets and herons, for example. Most of the wetlands surveyed from the air were far from any human habitation and possible disturbance, and we conclude that many of those wetlands are simply deficient in nutrients.

If nutrients are so scarce in the waters of the Basin, why should there be such an abundance of life in the Delta? Several explanations help answer the question. First, and most importantly, the low levels of nutrients upstream become concentrated in the Delta where the river comes to an end. An estimated 490,000 tonnes of dissolved material washes down the river each year. This is not much in relation to the volume of river water and most of the chemicals are toxic salts and other solutes of little value to plants. But there are also substantial quantities of nutrients that are trapped in the Delta, year after year. In essence, the Delta is a nutrient sink.

Second, large quantities of nutrients are released from accumulations of peat when it burns, an effect that has immediate benefit for grasslands that grow on burnt areas. Third, considerable amounts of nitrogen and phosphorous are deposited from the atmosphere, especially during anti-cyclonic weather conditions in winter. For example, about 250,000 tonnes of atmospheric deposits may land on the Delta each year, including about four kilograms of nitrogen per hectare.[15] Finally, limited quantities of nutrients are transported from the surrounding woodlands into the water in the form of dung, especially that of hippos.

In addition to dissolved chemicals now concentrated in the Delta, two other kinds of sediment inputs have helped build the fan of alluvial deposits. The first consists of the fine sand particles that settle and raise the level of the Delta's channels. Most sand is carried down from the catchment during the late summer floods when water flow is fast enough to move sand grains along. At other times, much of the sand remains trapped on the riverbed, often forming spectacular underwater dunes or mega-ripples. The second kind of sediment is suspended mud, mostly fine silt and tiny particles of plant material. However, the roughly 30,000 tonnes of these sediments that make their way down the river each year is so little that the Okavango's waters remain clear.

Key points

- The Okavango Delta is the largest wetland in southern Africa, and one of the most pristine wetlands in the world.
- The Okavango and its many tributaries arise in Angola. All water flowing down to the Delta thus comes from the Angolan catchment.
- Of all water flowing into the Delta, 45% comes down the Cuito and 55% along the Cubango/Okavango River. The Cuito delivers more water between June and December than the Cubango/Okavango.
- Much of the north-western drainage consists of rivers that flow quite rapidly along a single channel with a moderately steep gradient. Rivers in the eastern catchment, by contrast, meander along very shallow, broad valleys.
- Frequent changes to the distribution of water and habitats in the Delta are due to the deposition of sand in the channels and resulting switches in the direction of water flow.
- The river and Delta water is exceptionally clean and clear because few minerals or clay particles are released from the Kalahari sands and because floodplain and marshes along the rivers filter out nutrients and mud particles.
- Mineral nutrients and sediments that do make their way down the river eventually collect in the Delta, making the Delta biologically productive.
- Total volumes of water flowing into the Delta average 9.4 cubic kilometres per year, but there are wide year-to-year fluctuations as a result of variations in rainfall in Angola.
- The extent of flooding in the Delta each year depends on inflow from Angola, the degree of flooding in the previous year, rainfall over the Delta and evaporation rates.