

REGION 2

NORTH EAST AFRICA

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| Burundi | Rwanda |
| Djibouti | Somalia |
| Egypt | Sudan |
| Ethiopia | Tanzania |
| Kenya | Uganda |

Introduction

This, the largest of the five regions, covers 6 995 265 km² and comprises those countries which drain in substantial part to the Nile, together with Djibouti and Somalia. It is also the most populous region having supported more than 166 055 000 persons in 1983. It stretches 4790 km from north to south between Sidi Barrani (31°38'N) on the Mediterranean coast and a point (11°45'S) on the Rovuma River in Tanzania, and 3195 km from west to east between longitudes 21°49'E on the Sudan/Chad border and 51°22'E at Cape Xaafuun on the Somalian coast.

There is a coastline of some 10 370 km. The Mediterranean coast extends for approximately 1100 km between Libya and Israel, in addition to which there are 575 km of lagoonal shores in the Nile Delta. The eastern shore stretches from the head of the Gulf of Aqaba to the tip of the Sinai Peninsula, around the Gulf of Suez, along the western shore of the Red Sea to the Indian Ocean, and thence south to the Mozambique border, a distance of 8685 km. Parts of the eastern coast are rugged, falling precipitously into the sea, other parts are low lying and sandy, while yet other parts, particularly in the south, are highly indented and fringed by numerous small offshore islands.

The coastal plains are generally narrow, 3-30 km wide, except in Kenya and southern Somalia where they attain widths of 150 km. Mountains rise behind the coastal plains lining the old rift valleys of the Red Sea and its northern gulfs, reaching 2637 m asl at Gebel Katherina (28°30'N/33°57'E) and 2187 m at Gebel Shayib el Banat (26°59'N/33°29'E) in Egypt, 2260 m at Jebel Oda (20°08'N/36°40'E) in Sudan, and 2416 m at Shimbiris Peak (10°40'N/47°11'E) in Somalia on the Gulf of Aden. South of this is the great highland massif of Ethiopia, divided by an arm of the East African Rift Valley into western and eastern blocks. In the

Western Highlands 6 peaks rise to over 4000 m asl; Mts. Ras Dashen (13°12'N/38°25'E-4620 m), Abune Yosef (12°08'N/39°13'E-4193 m), Guna (11°44'N/38°14'E-4231 m), Talo (10°44'N/37°54'E-4154 m), Abuye Meda (10°27'N/ 39°47'E-4000 m), and Margherita (6°10'N/37°25'E-4200 m). In the Eastern Highlands Ch'ilalo (7°45'N/39°23'E-4133 m), K'ech'a (7°24'N/39°06'E-4190 m) and Batu (6°56'N/ 39°47'E-4307 m) are the highest peaks.

Still farther south, major highlands occur to both east and west of Lake Victoria. East of the lake there are high points of 4321 m at Mt. Elgon (1°12'N/34°30'E) on the Kenya/Uganda border; 3994 m at Mt. Satimma (0°17'S/36°38'E) in the Aberdare Mountains; 5199 m at Mt. Kenya (0°11'S/37°23'E); 4565 m at Mt. Meru (3°16'S/36°44'E), and 5895 m at Mt. Kilimanjaro (3°04'S/37°20'E). There are other high peaks in the Cherangany Hills (1°12'N/35°27'E) and in the Ngorongoro district (3°01'S/35°49'E). Altogether 3185 km² of land rises above the 3000 m contour, and approximately 33 000 km² above the 2000 m contour. West of Lake Victoria, mountains rise along the eastern border of the Western Rift Valley, sloping steeply down to Lakes Kivu and Tanganyika on the valley floor. Land rises to 5110 m at Mt. Stanley (0°24'N/29°53'E), to 4127 m at Mt. Muhavura (1°24'S/29°40'E) and to 4507 m at Mt. Karisimbi (1°31'S/29°27'E) on the Rwanda/Zaire border. In the far south of the region the Kipengere Range at the northern end of Lake Malawi reaches 2959 m asl at Rungwe Mountain (9°08'S/33°41'E), while in the far west Jebel Gimbala rises to 3071 m (12°57'N/24°20'E) close to the Sudan/Chad border.

Climate

During the northern winter, northeasterly winds predominate over almost the entire region. These winds blow from SW Asia and Saudi Arabia and are hot and dry, but in the northern summer the wind systems are more complex. In the northern parts of the region, winds are then from the west, off the Sahara. Thus, the northern part of the region is arid all year round, generally receiving less than 100 mm rain/yr, indeed large areas of Egypt and the Sudan receive significantly less than this, although rain storms sometimes occur in the hills along the Red Sea in winter and there may be falls along the Mediterranean coast. Mean annual rainfall at Alexandria (31°12'N/29°58'E) is 175 mm, but at Cairo it is only 25 mm.

In passing inland the desert eventually gives way to a Sahel zone, extending between latitudes 12 and 16°N, and this in turn grades into a Soudanian Savanna zone, at latitudes below 12°N, with a progressive increase in rainfall to the south. Both these zones experience a harsh dry season in winter and a relatively short wet summer season. The Soudanian Savanna zone grades into

more humid tropical savannas towards the equator, but conditions are modified by altitude and the presence of the highland massifs.

In summer, winds over most of the central and southern parts of the region are from the southwest. Humid air from the high pressure zones of the South Atlantic and Gulf of Guinea moves across central Africa, bringing rain to the highlands of Tanzania, Burundi, Rwanda, Uganda, Kenya and Ethiopia, and lighter falls to the Soudanian Savanna and Sahel zones. At the same time the SE Trade Winds blow in from the Indian Ocean across the coasts of Somalia, Kenya and Tanzania, again bringing rain. However, these winds are most persistent in the south of the region and bring little rain to Somalia. On rising inland, these winds veer southwesterly, joining the stream from the Atlantic, and contributing to the falls on the highlands.

At El Obeid ($13^{\circ}10'N/30^{\circ}12'E$) in the Sahel zone, 560 m asl, mean annual precipitation is 362 mm. In the Soudanian Savanna zone, Gallabat ($12^{\circ}57'N/36^{\circ}10'E$), 760 m asl in the western foothills of the Ethiopian Massif, receives an average of 890 mm rain/yr. Malakal ($9^{\circ}33'N/31^{\circ}40'E$), at the northern edge of the Sudd, receives 787 mm/yr, while Bor ($6^{\circ}16'N/31^{\circ}33'E$), at the southern edge, receives 905 mm. Still farther south, Mongalla ($5^{\circ}12'N/31^{\circ}42'E$) has a mean annual rainfall of 945 mm.

Rainfall is generally between 1000-1500 mm over the Ethiopian Highlands, but reaches 2000 mm on the SW faces of the highest peaks. Adis Abeba (2440 m asl in the centre of the massif has a mean annual receipt of 1302 mm, while Dese ($11^{\circ}05'N/39^{\circ}40'E$), 250 km NNE (2220 m), receives 1118 mm/yr. Adi Ugri ($14^{\circ}47'N/38^{\circ}50'E$) at the far northeastern end of the massif, close to the Red Sea, but again at a similar altitude (2022 m), receives only 730 mm/yr, the SW winds having lost much of their moisture before reaching here. The Rift Valley which divides the highlands into eastern and western blocks is quite arid, and the Danakil Desert occupies the area between the highlands and the Gulf of Aden, being in the rainshadow of the mountains. The southeastern lowlands of Ethiopia, which lead into Somalia and Kenya, have two rainy seasons, one in spring and another in autumn, but are comparatively dry, with annual falls of 400-500 mm. The higher plateau areas of Somalia and Kenya, east of the mountains, are semi-desert zones, locally receiving less than 250 mm rain/yr.

There is no harsh dry season around Lake Victoria nor over the Western Rift Valley. March-September is the wettest period and October-February the driest, but some rain falls in all months. Mean annual receipts may be as high as 3000 mm on some of the highest peaks, e.g. Mt. Stanley, but generally precipitation does not greatly exceed 2200 mm in these mountains. In the far south of the Western Rift, at an altitude of 1550 m, Tukuyu ($9^{\circ}14'S/33^{\circ}39'E$) on the SW slopes of the Kipengere Range, receives 2303 mm/yr. Close to, and over Lake Victoria, mean annual precipitation

averages 1000-1500 mm, e.g. 1020 mm at Mwanza (2°31'S/32°56'E) on the central southern shore; 1295 mm at Kisumu (0°08'S/34°44'E) on the eastern shore; and 1505 mm at Entebbe (0°04'N/32°27'E) on the northwestern shore. However, Bukoba (1°19'S/ 31°49'E), on the midwestern shore, receives 2025 mm.

The northern coasts are extremely arid, e.g. 3 mm/yr at Hurghada (27°18'N/33°47'E) on the Red Sea, but precipitation increases patchily to the south so that Mits'iwa (15°38'N/39°25'E) in Ethiopia receives 165 mm/yr. Large annual variations occur; for example the lowest annual total recorded for Suakin (19°38'N/37°18'E) is 33 mm, and the greatest 617 mm. Although the Red Sea reaches 350 km in width, it is only 33 km wide at its confluence with the Indian Ocean and at this point a submarine ridge impedes the free exchange of water, so that the waters of the Red Sea are unusually warm and saline.

The north Somalian coast is extremely arid, but rainfall increases steadily in passing southwards reaching 600 mm/yr in southern Somalia, 900 mm/yr at Lamu (2°17'S/40°54'E) on the north Kenyan coast, and 1200 mm/yr at Mombasa (4°01'S/39°32'E). It is highest on the Tanga coast, probably reaching 1400 mm/yr locally, but then declines in passing farther southwards, to 1110 mm at Dar es Salaam (6°51'S/39°18'E) and 936 mm at Lindi (10°00'S/39°41'E). This rainfall is seasonal, deriving from the SE Trade Winds, and it decreases progressively away from the sea. However, falls on the series of scarp slopes, encountered in passing inland, tend to be equivalent to those at the coast, especially those inland of the Tanga coast. Here, at Amani (5°09'S/38°36'E), at the southern tip of the Usambara Mountains (910 m asp, mean annual rainfall is 1946 mm, and over 2200 mm falls on the summits (c. 2400 m asp. The flatter areas of the eastern interior, between scarps and peaks, are comparatively dry with mean annual receipts of 700-1100mm

Large seasonal and diurnal temperature variations occur in the northern deserts. At Alexandria, on the Mediterranean coast, January minima and maxima range from 11- 18°C, while at Aswan they range from 10 to 23°C, but summer temperatures can reach 48°C in the interior and can fall to 10°C at night. Temperatures along the Red Sea may also reach 48°C in summer, but diurnal variations are not so great as in the interior. The Ethiopian Highlands enjoy a temperate climate because of their altitude. Although seasonal variations are not great here, diurnal ones are substantial, most stations having daily ranges of 13-16°C. The mean annual temperature at Adis Abeba, at an altitude of 2439 m is 16°C, while at sea level, at Mits'iwa, it is 31°C.

At Shambe (7°07'N/30°47'E), on the banks of the Nile in the Sudd, March is the warmest month with a mean daily maximum of 38.6°C (range 35-44°C) and a mean daily minimum of 23°C (range 18-26°C) and a mean

monthly temperature of 30.8°C. August is the coolest month with a mean daily maximum of 31°C (range 27-34°C), a mean daily minimum of 21°C (range 19-23°C), and a mean monthly temperature of 26°C. The regime at Malakal, north of the Sudd, is very similar, but April is the warmest month with a mean temperature of 31.1°C, while August is the coolest month with a mean temperature of 26 °C. At Bor, on the southern edge of the Sudd, March is the warmest month with a mean temperature of 28°C and September is the coolest month with a mean temperature of 25°C.

Mean temperatures in Equatorial East Africa are closely related to elevation. The highest temperatures are recorded in the arid regions along the coast of Somalia, and in lands to the west of Lake Turkana. In these places mean night-time minima may be as high as 29°C. Frosts occur in the mountains above 3000 m, and permanent snows occur above 4850 m, e.g. on Mts. Stanley, Kenya and Kilimanjaro. Diurnal temperature ranges are of the order of 18°C in the highlands and 8°C at the coasts. March is the warmest month at Mombasa, with a mean daily maximum of 32.8°C, a mean daily minimum of 24°C, and a mean monthly temperature of 28.4°C. July is the coolest month with a mean daily maximum of 28°C, a mean daily minimum of 20.2°C, and a mean monthly temperature of 24.1°C. At Kisumu (1157 m) February is the warmest month, with corresponding figures of 31°C, 17.5°C and 24.2°C, while July is the coolest month with figures of 27.6°C, 16°C and 21.8°C. At Nakuru (1850 m), February is the warmest month, with figures of 29°C, 8.8°C and 18.9°C, while July is the coolest month with figures of 24°C, 10.2°C and 17.1°C. Here diurnal variations are much greater in February than in July.

Drainage

Drainage is complex. Run-off from the region finds its way to the Mediterranean Sea via the Nile and various minor watercourses, and to the Gulfs of Suez and Aqaba, the Red Sea, the Gulf of Aden, the Indian Ocean direct, the Indian Ocean via Lake Malawi and the Zambezi, the Atlantic Ocean via Lake Tanganyika and the Zaire River, and to numerous endorheic lakes and depressions.

The Nile

The principal drainage system is that of the Nile, the longest river in the world. The source farthest from the sea flows as the Luvironza River in Burundi (3°44'S/29°47'E), rising about 1750 m asl in mountains on the eastern side of Lake Tanganyika. From this point the river flows 6695 km to the Mediterranean Sea, which it reaches at 31°38'N at the extremity of its delta, having traversed 35°22' of latitude. The published area of the

drainage basin varies greatly, e.g. by 1 448 870 km² between the Times Atlas (1985) which gives an area of 1 900 000 km² and the Encyclopaedia Britannica (1975) which gives 3 348 870 km². Most other sources place the area in the vicinity of the latter figure. Welcomme (1972) for example gives 3 004 400 km². These discrepancies probably arise because much of the northern basin is extremely arid and of little relief, and thus does not provide active drainage to the river. Our calculations for the basin give an area of 3 026 000 km². The eastern watershed runs SSE through Egypt and Sudan, along a mountainous crest parallel with the Red Sea. From Port Sudan it runs inland, SSW, passing east of Kassala in Sudan, it then snakes southeastwards through the Ethiopian Highlands to the vicinity of Dese, and then SSW, looping east of Adis Abeba, and passing west of Lakes K'ok'a, Ziway, Abiyata, Shala, Awasa, Abaya, Ch'amo and Turkana (Rudolph), thus encompassing much of the Western Highlands. Thereafter it passes east and south of Lake Victoria, closely skirting the southern shore, before finally running west to the source of the Luvironza in Burundi.

The western watershed at first runs SE across Egypt, roughly parallel with the river valley, but then swings westwards, encompassing a vast region including part of SE Libya, and Northern and Southern Darfur where it follows the Sudan/Chad border. Thereafter it runs SE through the Bahr el Ghazal District of Sudan along the Sudan/Zaire border. Finally it crosses into Zaire, where it encompasses Mt. Stanley (0°26'N/29°52'E 5110 m) by running along a crest just west of Lakes Albert and Edward, and finally runs up to Mt. Karisimbi and along a crest above the eastern shore of Lake Kivu to the source of the Luvironza.

The Nile proper has five major tributaries, the Bahr el Jebel (River of the Mountains), the Bahr el Ghazal (River of Gazelles) and the Sobat River, which unite to form the White Nile, and the Blue Nile and Atbara River. The southernmost headwater stream, the Luvironza River, flows south for some 20 km, then north for 100 km, before swinging eastwards past Gitega (3°23'S/29°56'E) when it becomes the Ruvuvu River. Two other important headwater streams, the Akanyaru and Nyawarungu Rivers rise well above the 2000 m contour in Rwanda, east of Lake Kivu, and some 150 km north of the source of the Luvironza. At first these both flow eastwards in parallel, but then they diverge, the Akanyaru to the south and the Nyawarungu to the north, until having both described imperfect semi-circles, they meet in central Rwanda. Prior to their confluence they both drain swampy lakes, and below it the combined stream traverses extensive swamps en route to the Rwanda/Tanzania border where it joins the Ruvuvu River, thereafter being known as the Kagera River. This latter stream is the largest affluent of Lake Victoria. It flows north for 250 km through a shallow swampy valley containing 14 major lakes and

innumerable minor ones, before turning sharply east near Kakitumba (1°04'S/30°45'E) to flow for a further 230 km to Lake Victoria. It enters the lake through another 30 km of valley swampland near the midpoint of the western shore at an altitude of 1134 m asl.

Lake Victoria is the third largest lake in the world, in terms of area, after the Caspian Sea and Lake Superior. It is a shallow lake, with a maximum depth of 85 m, several small islands, and much swampy shoreline. Its southern shore receives many short seasonal streams, while its eastern shore receives a number of perennial rivers draining the mountains to the east. The most important of these rivers is the Mara which drains the Loita Plains and Lebetero Hills (2683 m) of SW Kenya, and the southern mountains of the Mau Escarpment along the western side of the Eastern Rift Valley, where there are several high wet peaks, e.g. Mau (3049 m) and Melili (3098 m). The Mara enters Lake Victoria about half way along its eastern shore, while a further 8 large perennial rivers, and several small ones, enter in the NE quadrant of the lake. These drain both the northern and central parts of the Mau Escarpment and the Cherangany Hills, and the massif of Mt. Elgon.

The western side of the Lake Victoria basin was tilted in the late Pleistocene. This reversed the flow of several rivers which used to flow westwards across the basin to Lakes Edward and Albert, and gave rise to Lake Victoria. The Katanga River now drains the country between Lake Victoria and Lake Edward, but a waterway is virtually continuous between the two lakes because there is now a swampy watershed from which the river flows both east and west. That the old river used to flow west to Lake Edward is clear from the incident angles of its tributaries, but since the basin was tilted, flow has reversed so that the eastern part now flows sluggishly to Lake Victoria, entering it through swamps. Moreover, flow in the old lower reaches, between Lake George and Lake Edward, is also sluggish and may reverse temporarily.

Some 86% of the water in Lake Victoria is derived from direct precipitation, and as much as 82% is lost by evaporation. Only 18% of the water which enters the lake continues downstream in the Victoria Nile, which leaves the lake close to its northern extremity at Jinja (0°27'N/33°12'E) in Uganda. The river used to cascade over waterfalls but these were submerged by the construction of the Owen Falls Dam in 1954. From here the river flows NNW for 150 km, before traversing the swampy southern basin of Lake Kyoga, to receive, still in swampland, the drainage of Lake Kwana. Thereafter the river flows west to a confluence with the Kafu River, another stream in which drainage has been partially reversed, so that although the river appears on maps as a continuous watercourse between the Victoria Nile and the top end of Lake Albert, water in it flows in opposite directions at its two ends. The Victoria Nile then descends the eastern wall of the Western Rift Valley by the Murchison Falls to enter Lake

Albert close to its northern end.

Lake Albert collects run-off from the mountains (Karisimbi and Muhavura) at the northern end of Lake Kivu, from the northern Mitumba Mountains of Zaire, and from Mt. Stanley, via Lake Edward and the Semliki River. These waters, together with those of the Victoria Nile, issue from the northern end of the lake as the swamp fringed, Albert Nile. Together with Lake Victoria, Lake Albert acts as a reservoir, collecting the run-off from the high rainfall areas of Equatorial East Africa. Both lakes remove sediment from the waters and buffer the flow of the upper Nile which, below Lake Albert, is clear. However, by contrast with the situation in Lake Victoria, only a small fraction of the water which enters Lake Albert is lost by evaporation. The mean annual discharge from Lake Albert was 22 102 million m³ between 1905-1962, giving a mean rate of flow of 700 m³/sec, but between 1963-1980 these figures doubled.

At a point (3°36'N/32°01'E) near Nimule, the river enters Sudan in a region of gorges, culminating in the Fola Rapids, and is then known as the Bahr el Jebel (River of the Mountains). It flows swiftly, and is confined to a narrow bed until Juba (4°44'N/31°37'E), about 330 km downstream, where it flows smoothly onto a very flat clay plain at an altitude of about 430 m. This plain descends a comparatively narrow valley, with hills on either side, at a mean gradient of 1:13 000. Here the river overtops its banks following seasonally heavy rain in the catchments, and inundates almost the entire valley floor.

A vast permanent swamp, known as the Sudd, begins below Mongalla (5°12'N/ 31°42'E), 75 km downstream from Juba. At first the Bahr el Jebel traverses a broad swampy trough in a well defined, but branched channel, with raised banks. However, below Bor the river banks are not discernible, the swamp widens progressively and there are numerous peripheral lakes and parallel streams, e.g. the Atem River. The river channels are deep, but beset with islands of floating vegetation, and the swamp extends northwards for 400 km, attaining a width of 100 km locally. Another river, the Bahr el Zeraf, rises in the swamps to the east of the Bahr el Jebel and the two streams are artificially united by short canals where they approach each other at Zeraf Cuts (7°47'N/30°32'E). Today only the southern canal remains open and water flows through this from the Bahr el Jebel to the Bahr el Zeraf, only to re-enter the Bahr el Jebel at a confluence east of Tonga (9°22'N/31°06'E). A large area, 180 km long and up to 65 km wide, known as Zeraf Island, is thus isolated between the two streams. This was once mostly dry land, but following the rise in water levels which has been sustained since 1963-1964 it is now almost totally inundated, and the total area of the swamps now approaches 1 650 000 ha. Around the periphery of the swamp is a large seasonal floodplain occupying about 1 500 000 ha.

Some 26 920 million m³ of water entered the Sudd each year between

1905-1960, but between 1961-1980 this had increased to 50 324 million m³/yr. Approximately 17 % used to be contributed by seasonal and torrential tributaries of the Bahr el Jebel, and 83% by discharge from Lake Albert, but these figures have changed slightly since 1961, with a higher % contribution from Lake Albert. In traversing the Sudd about 50% of the water is lost by evaporation and the rate of flow is much reduced. The mean annual discharge from the Sudd, measured above the confluence of the Sobat at Malakal, was 14 158 million m³ until 1960, but has averaged 21 387 million m³ in subsequent years. Long term changes in outflow from the East African lakes are responsible for the increased annual flows; they are well documented but poorly understood.

Because so much water is lost by evaporation in the swamps the Jonglei Canal is being cut to the east of the Sudd to bypass the swamp. The canal will run from Bor to a point just above Malakal. However, the reduction in volumetric flow is compensated for at the northern end of the Sudd by the inputs of three tributaries. The Bahr el Ghazal joins the Bahr el Jebel at Lake No, a large lagoon on the left bank, after which the stream swings sharply east for 150 km, receiving first the Atar and then the Sobat Rivers on the right bank. Below this the river again flows northwards and is referred to as the White Nile (Bahr el Abiad). Remarkably, although it flows freely after leaving the Sudd, the gradient of the river valley is less than in the Sudd, flattening here to 1:19 000.

The Bahr el Ghazal drains a dry plateau of that name on the Sudan/Zaire border, together with a part of Southern Darfur, but neither it nor the Atar contributes much water to the White Nile compared to the Sobat which drains the southeastern part of the Ethiopian Highlands. So high does the Sobat rise in flood that the volume of water carried between Malakal and Khartoum (15°34'N/32°32'E) may double in October and November.

Nevertheless, the mean annual flow at Malakal is only 17 000 million m³, 63% of what it is when entering the Sudd. The Jebel Aulyia Reservoir above Khartoum was constructed to hold back the floods created by the Sobat, and to regulate river flow downstream. This impoundment is the seventh largest in Africa with a surface area of 150 000 ha at capacity. Rain which falls on the catchments of equatorial East Africa reaches the lower Nile the following summer. This long delay is occasioned by retention in Lake Victoria and by the sluggish traverse of the Sudd. Between the Sudd and Khartoum much of the White Nile is fringed by swamps in strips generally about 300 m wide.

The volume of water carried by the Blue Nile changes quite dramatically through the year. Heavy rains fall over the Ethiopian Highlands in July and August and pass down the Blue Nile and Atbara Rivers to produce the deep sediment laden floods that develop in Egypt between September and

November. The Blue Nile is said to rise as the Abbai, the longest of several torrential, but seasonal, streams feeding Lake Tana, from which the Blue Nile *per se* emerges (11°34'N/37°28'E) at an altitude of 1829 m. Lake Tana is shallow and is situated in the Western Highlands of Ethiopia, where it is ringed round by high peaks including Mts. Ras Dashen, Guna and Amedamit. On leaving the lake, the Blue Nile flows swiftly southeastwards, plunging over rapids for 200 km in a deeply cleft valley, before traversing a giant bend in which it sweeps through 135°, to flow almost due west for a further 400 km. All along this deep valley, often over 1200 m below the level of the plateau, it receives tributaries, but then flows NW in a widening valley for 200 km to Er Roseires (11°49'N/34°20'E) where it is impounded in the foothills of the mountains, producing a lake with a surface area of 29 000 ha (at capacity). Below the dam the gradient flattens and the river meanders across the Sudan Plains for 330 km to Sennar (13°33'N/33°37'E) where it is again impounded (lake area 16 000 ha), before continuing NW for a further 330 km, to a confluence with the White Nile just below Khartoum. On this latter stretch the river receives its two most important tributaries on the right bank. These are the ad-Dindar and the ad-Rahad, both of which are perennial and drain the western slopes of the Western Highlands. Following summer rains in the mountains the Blue Nile begins to rise in June, and reaches a maximum at Khartoum in September. It is estimated that a mere 7% of the water reaching the confluence at Khartoum is derived from Lake Tana, the bulk being contributed by the many tributaries.

The Atbara River, and its principal tributaries rise on the western slopes of the mountains enclosing Lake Tana, and following the summer rains, they flow swiftly northwestwards, for 550 km to an impoundment at Kashm el Girba (14°53'N/35°55'E), which has produced an artificial lake with an area of 12 500 ha. The river continues less swiftly below the dam, but in the same direction, for 600 km to reach a confluence with the Nile at Atbara (17°43'N/34°00'E), 310 km below Khartoum. While the Atbara River is an important tributary of the Nile, it is reduced to a trickle, and sometimes to a series of shrinking pools, towards the end of the dry season. Nevertheless, when both the Blue Nile and Atbara are in flood, the rate of flow in the White Nile, below Atbara may increase seven fold. The Blue Nile may rise by more than 6 m at Khartoum in August and its flood then holds back the flow of the White Nile, creating local floods south of the city.