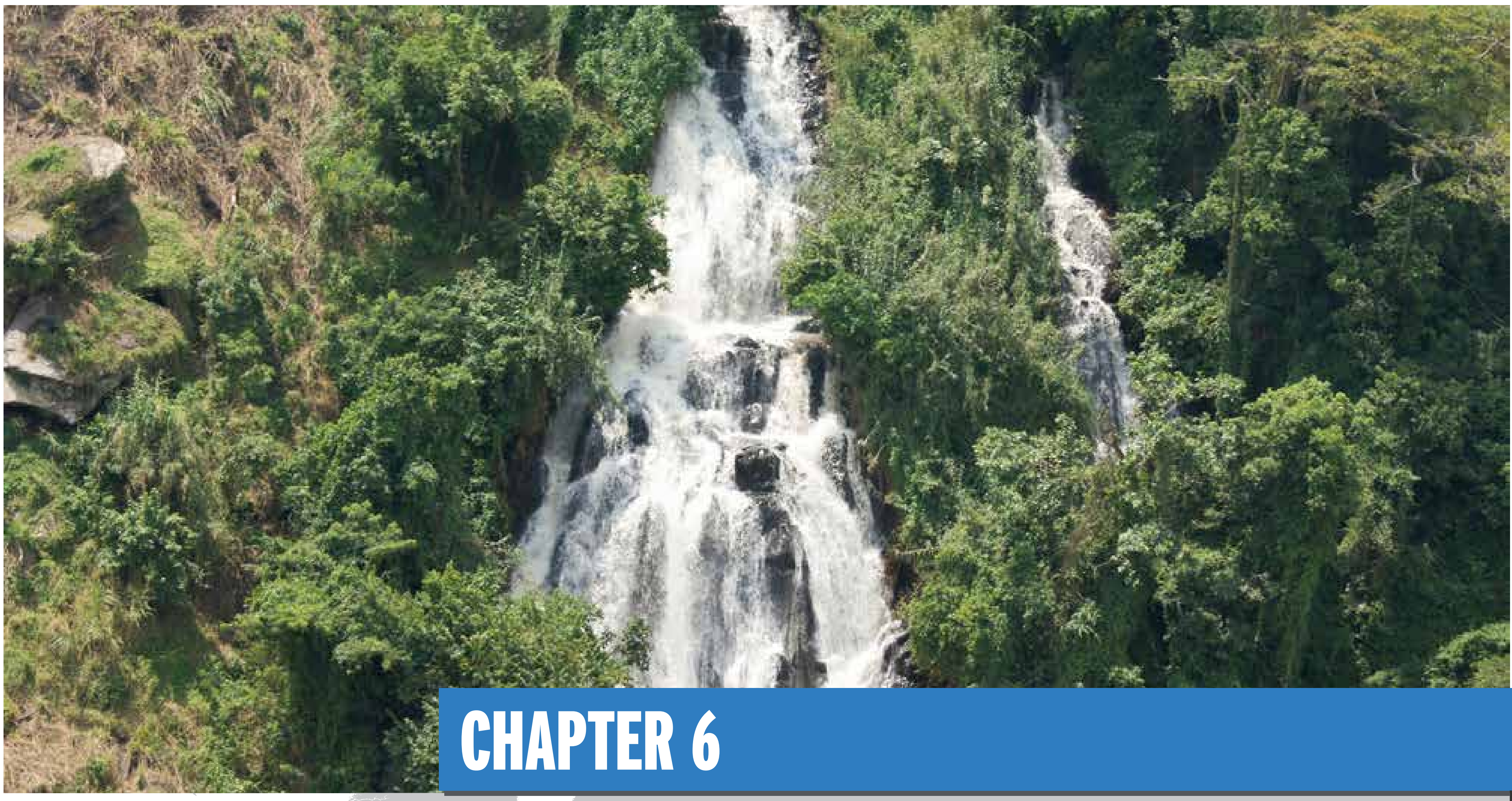


CHAPTER 6

HYDROLOGY OF THE NILE

KEY MESSAGES

The Nile River basin has very complex hydrology with high interconnection between floodplains, wetlands, swamps, lakes, highlands and the rivers drainage networks systems, some with strong seasonality and others with year-round consistent flows – call for an integrated approach.

The highlands subjects to soil erosion and land degradation, particularly the Eastern Nile system. The Ethiopian highlands generates huge volumes of sediment as compared to the other parts of the basin. Call for joint regional efforts by riparian countries on watershed management to improve land management practices, improve livelihood - to protect and restore degraded lands.

The selection of the stations presented in this chapter was solely based on availability of data of fairly good quality and longer record. Data scarcity and reliability has been a huge problem in hydrologic system, actual data is an indispensable in rivers basins. Efforts should be made to establish network of gauges and strengthen capacity for a better understating of the temporal, spatial characteristics and provide a better insight of the basin system.

The Nile basin has such a huge hydrological diversity. The basin, like any other part of the world experiences extreme events including droughts, floods, landslides, heat waves, etc. – efforts need to be exerted to improve on hydrologic modelling, climate change scenarios and forecasting.

Groundwater is widely used across the basin for domestic water supply (for drinking and other domestic uses) for both rural and urban communities. However, the basin ground water has not been adequately studied and so, information in this area is still scanty.

INTRODUCTION

Photo: istock

River Nile scenery around Murchison Falls

The hydrology of the Nile is mainly characterized and influenced by high variations in climate and altitude/topography which have a great bearing on flow magnitudes and patterns in the different parts of the basin. These differences are more pronounced in the two tributaries of the Nile; the White and Blue Nile with the White Nile exhibiting relatively steady flows and the Blue Nile exhibiting highly seasonal flows. Presentation of the hydrology of the Nile in this atlas focused on key stations within the sub basins of the Nile starting from down stream to upstream; Main Nile, Tekeze Atbara, Baro Akobo Sobat, White Nile, Bahr el Jebel, Bahr el Ghazal, Albert Nile and ends with Lake Victoria sub-basin. There are also swamps and wetlands in the Nile basin which play and influence the hydrology of the Nile mainly the Sudd, Bahr el Ghazal swamps, and the Machar marshes.

As seen in the graphics in this chapter, discharge of the Nile River is highly dependent on the flow patterns from the river tributaries which are principally dependent on rainfall and climate patterns save for areas where infrastructure and regulation influence the downstream flow. Flows from the White Nile are seen to contribute small but more consistent year-round flow.

This chapter presents the water towers of the Nile Basin and an analysis of selected key stations along the Nile followed by the individual sub basins.

MAJOR NILE BASIN WATER TOWERS

Water towers are considered to be the areas that generate high stream flows in comparison with others. Within the Nile basin, highlands and other elevated areas greatly contribute to total stream flow of the major rivers in the basin. These areas, referred to as water towers, normally receive more rainfall than their lower surroundings. They also usually lose less water to evapotranspiration because temperatures are lower. The major water towers within the Nile Basin are shown in the figure below.

Photo: Jørn Eriksson/flickr.com

Rwenzori mountain

Major Nile Basin water towers

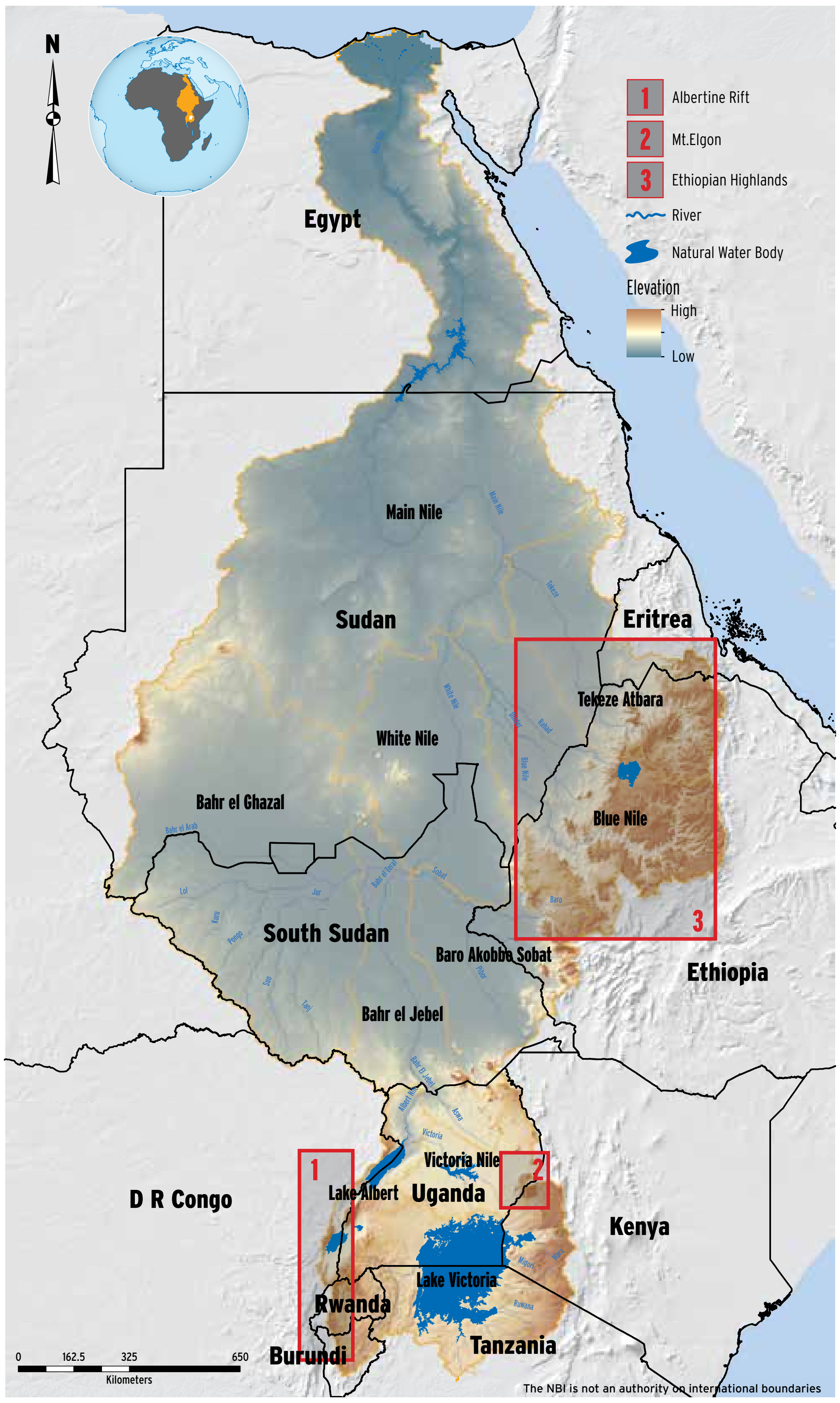


photo: International space station

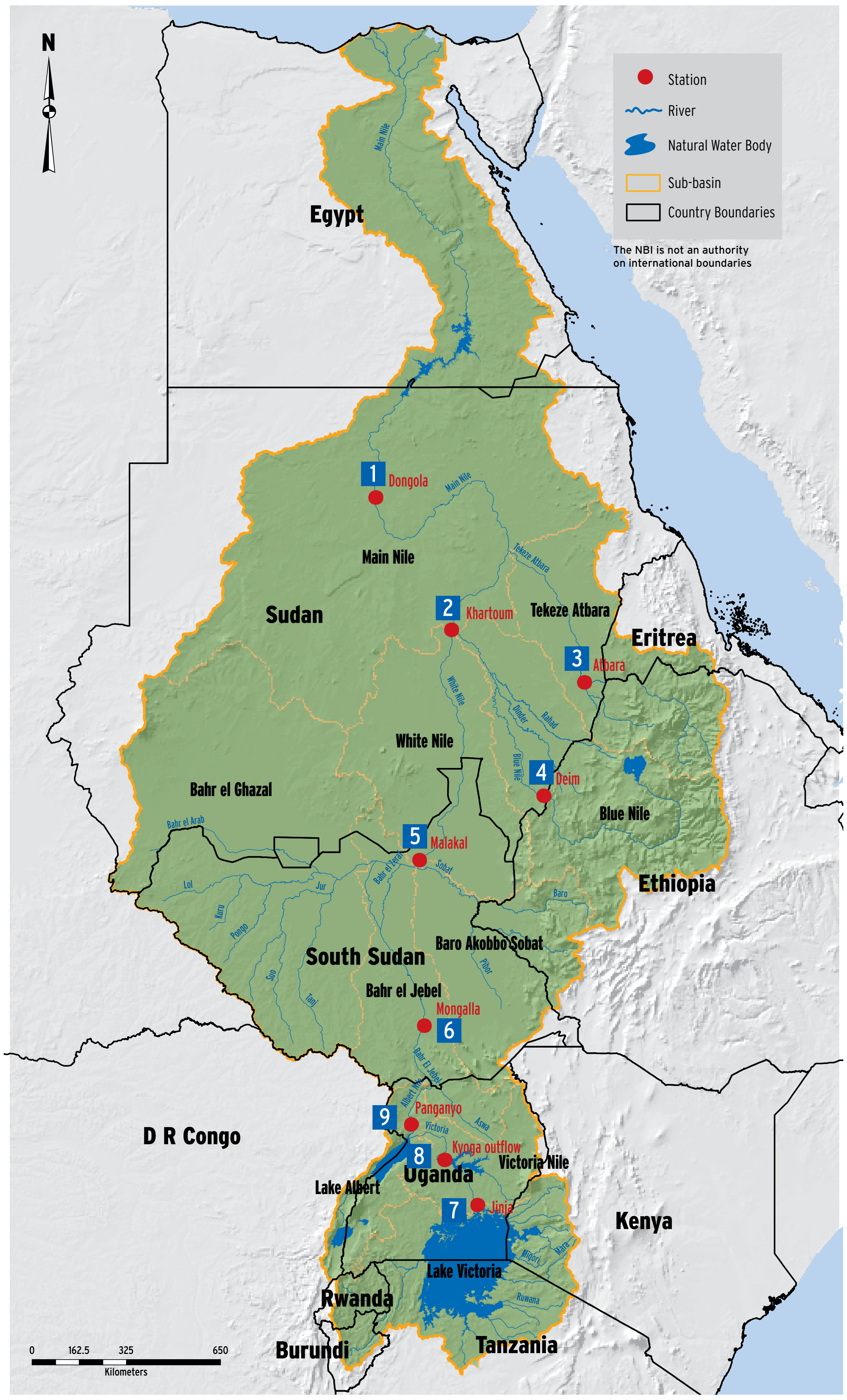
Mount Elgon at the border of Uganda and Kenya photographed from the International Space Station 13:55 GMT January 14, 2012

Photo: Arne Hoel / World Bank

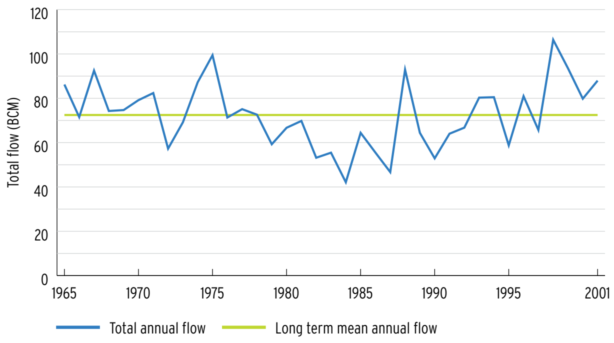
View from Entoto Mountain in Ethiopia

ANNUAL RIVER FLOW PATTERNS FOR KEY NILE HYDROLOGICAL STATIONS

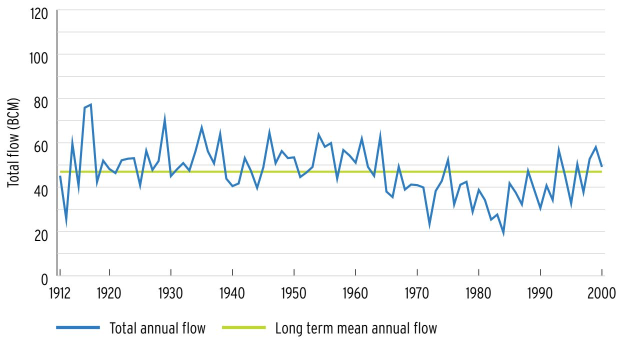
Along the River Nile, there are quite a number of hydrological stations as shown in the basin monitoring network. However, a few key stations have been selected for presentation in the map below to the annual flow patterns along the Nile. The annual volumes are seen to be highly variable across the years apart from flow at Malakal. Upstream of the stations White at Malakal, Blue Nile at Diem, where the Atbara tributaries enter the Sudan, the Nile tributaries undergo very little alternations due to man-made interventions. Therefore, the flows at these stations can be considered approximately natural flow conditions. Downstream of these stations the Nile River undergoes considerable changes due to flow regulation through dams and major abstractions for consumptive use. In addition, downstream of these stations, the Nile receives very little flow contributions from surrounding catchments as this part of the Nile Basin obtains very little rainfall.



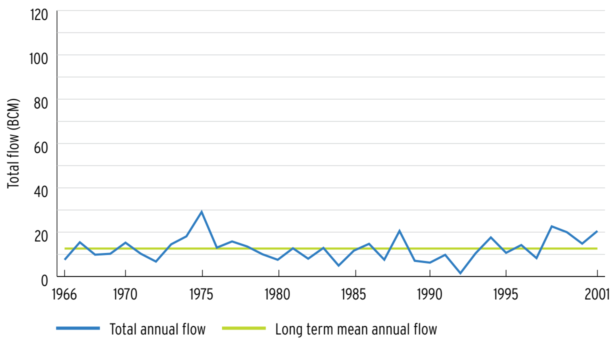
1 Annual flow volume - Dongola



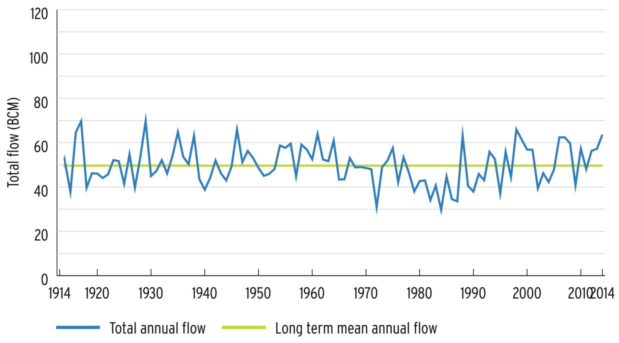
2 Annual flow volume - Khartoum



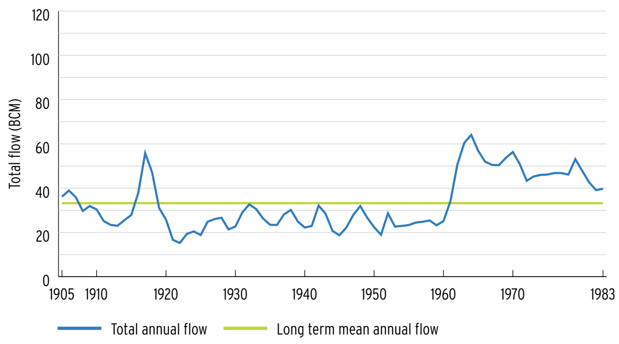
3 Annual flow volume - Atbara (on Atbara River)



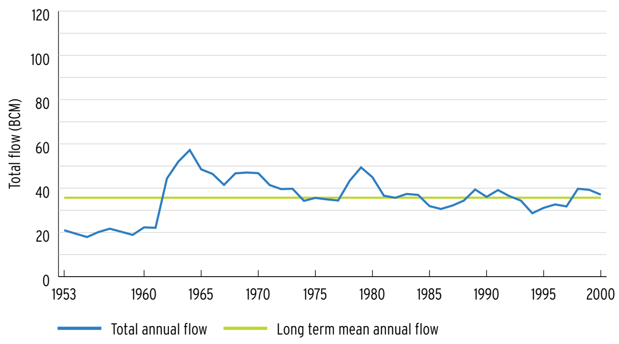
4 Annual flow volume - Diem



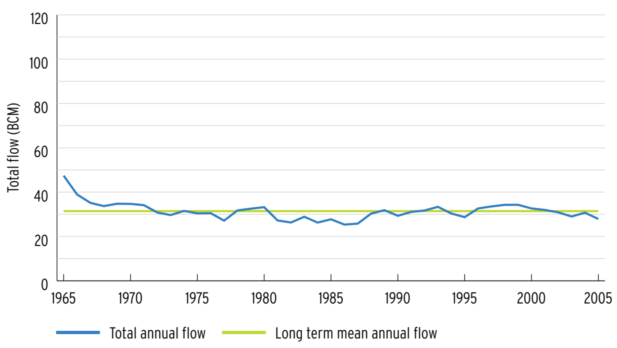
6 Annual flow volume - Mongalla



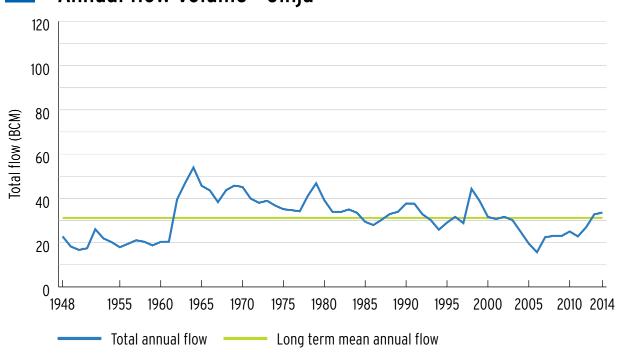
8 Annual flow volume - Kyoga outlet



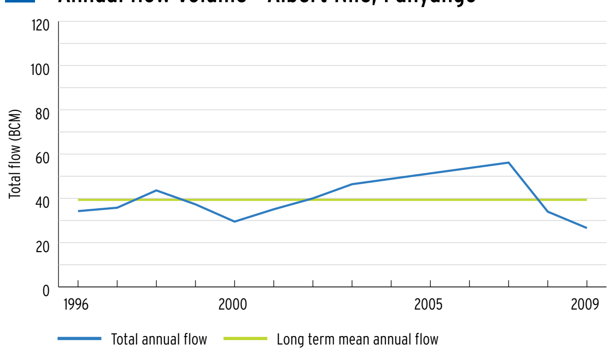
5 Annual flow volume - Malakal



7 Annual flow volume - Jinja



9 Annual flow volume - Albert Nile, Panyango



SEASONAL FLOW PATTERNS

Main Nile Sub-basin

This sub section highlights the seasonal patterns, key statistics, and flow reliability of selected stations within the basin presented sub basin by sub basin. In doing this, mean monthly flow has been presented together with the standard deviation, then the Box Plot indicating the Maximum, Minimum. Median as well as the 1st and 3rd Quartiles on a monthly basis, and the monthly flow duration curve. Presentation of this follows the sub basins Upstream (in the Nile Equatorial Lakes region) followed by the Eastern Nile and the main Nile. The selection of the stations presented in this chapter was solely based on availability of data of fairly good quality and longer record. The image below is the key for interpretation of the box plots for the monthly flow statistics in this section.

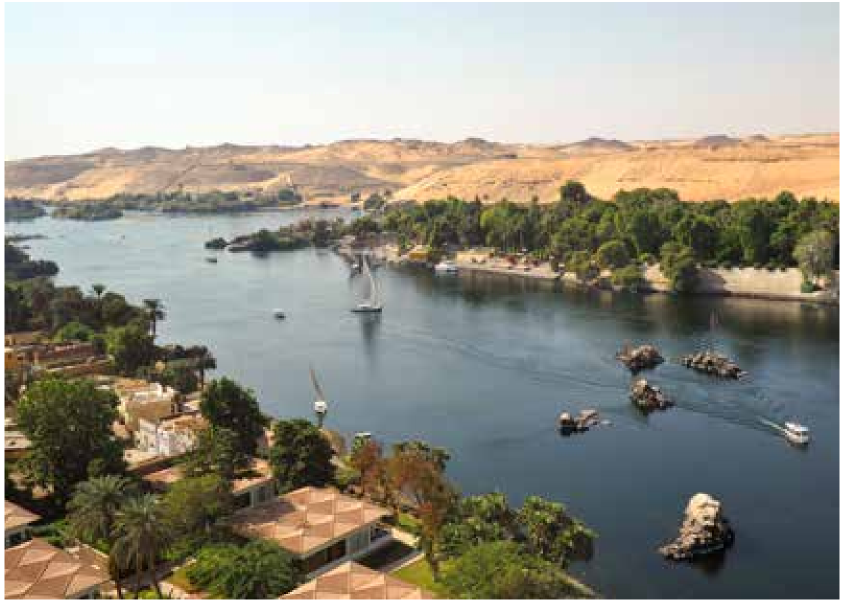
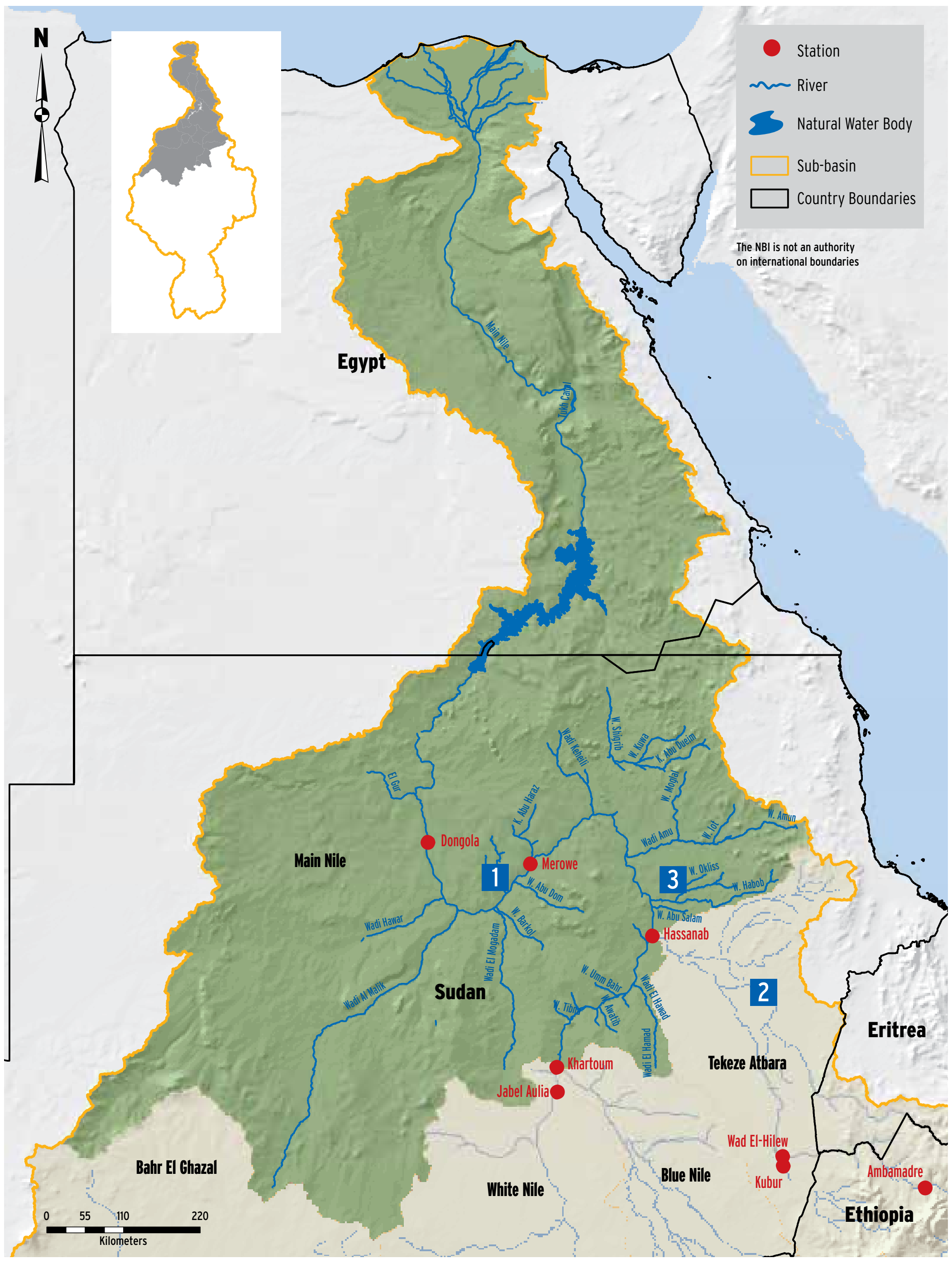


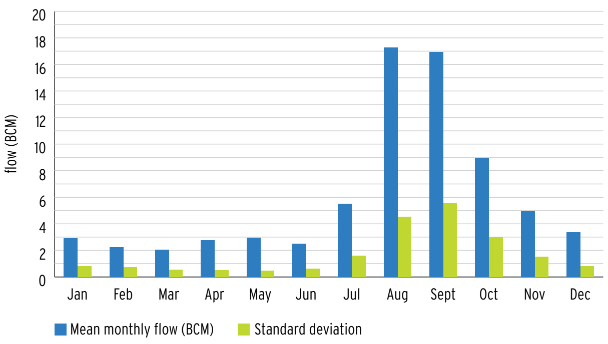
Photo: istock

Aswan Dam

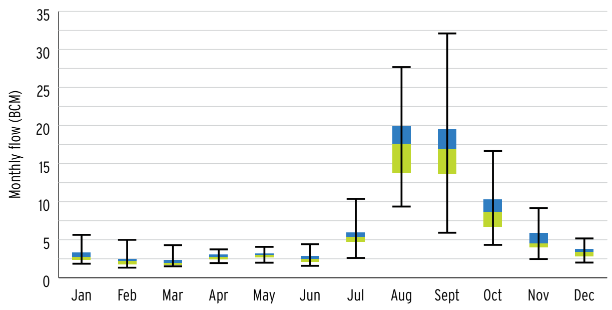
This is the most downstream part of the Nile Basin where more than 80 percent of the current consumptive water use occurs. Major features of the hydrology of this sub-basin include High Aswan Dam, which has the capacity to store nearly twice the annual average flow of the Nile and the Merowe Dam (live storage of 12.5 BCM) built in Sudan. The monthly flows depict peaks between August and September as a result of high flow from the Blue Nile within this time of the year.



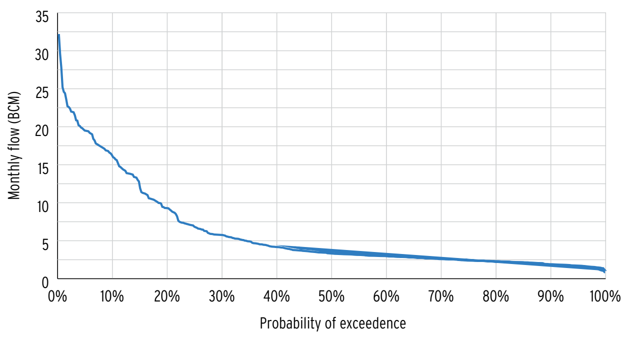
1 Monthly Flow Distribution - Dongola



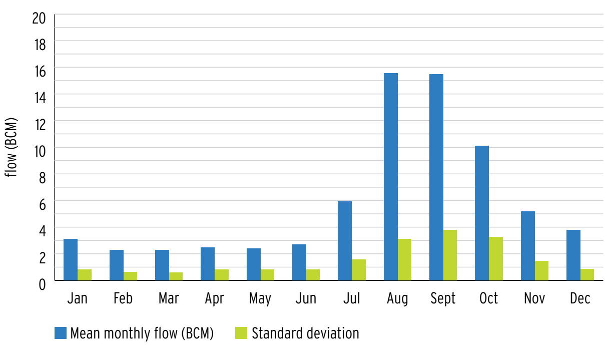
1 Monthly Flow Statistics - Dongola



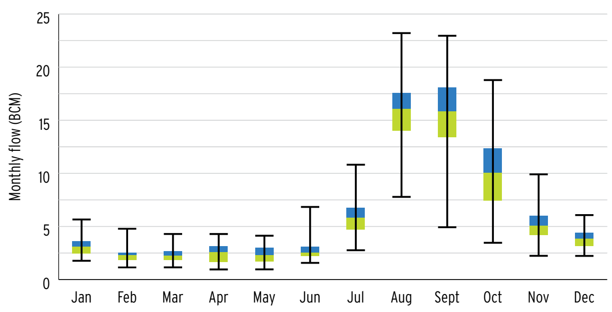
1 Flow Duration Curve - Dongola



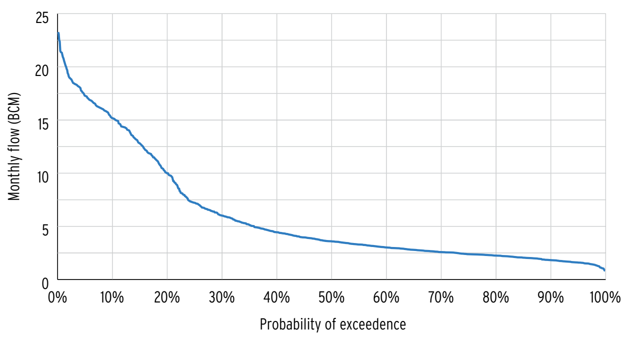
2 Monthly Flow Distribution - Hassanab



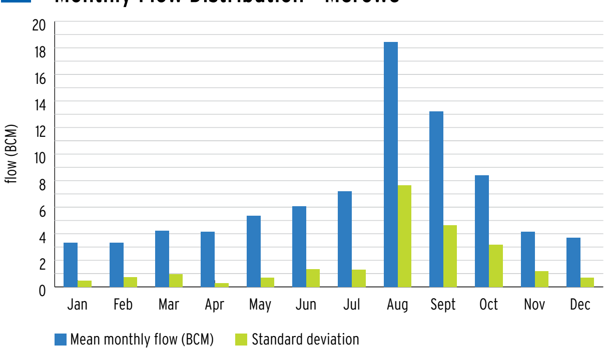
2 Monthly Flow Statistics - Hassanab



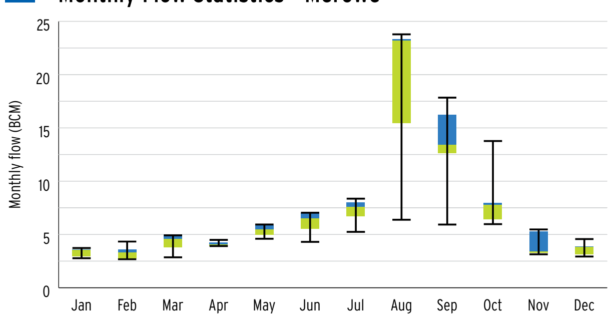
2 Flow Duration Curve - Hassanab



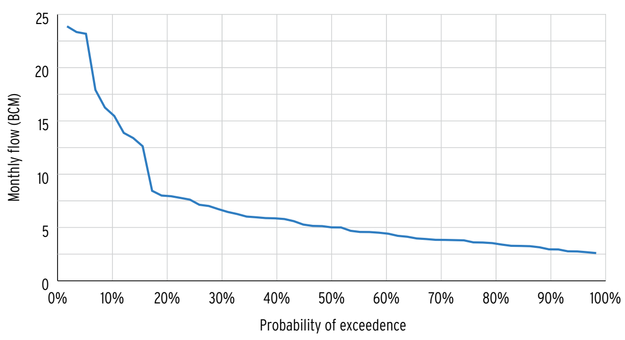
3 Monthly Flow Distribution - Merowe



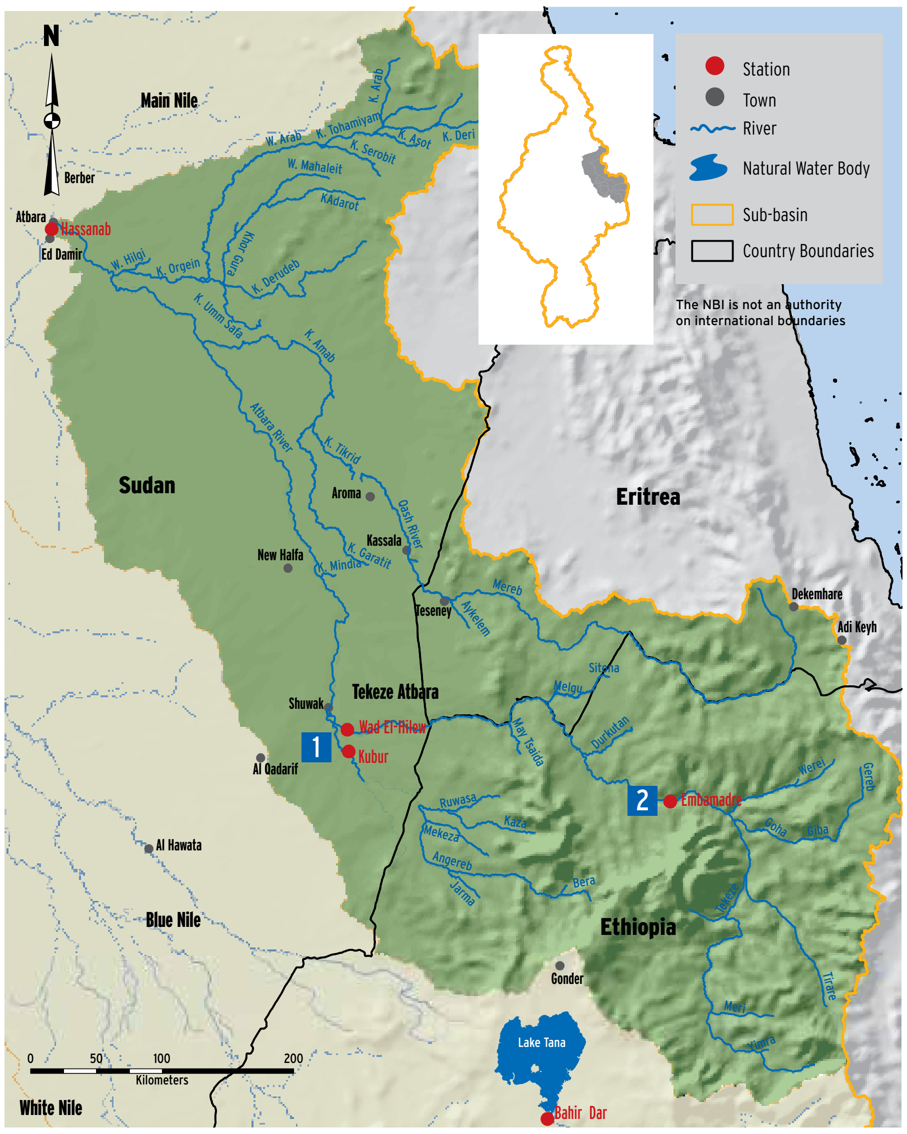
3 Monthly Flow Statistics - Merowe



3 Flow Duration Curve - Merowe



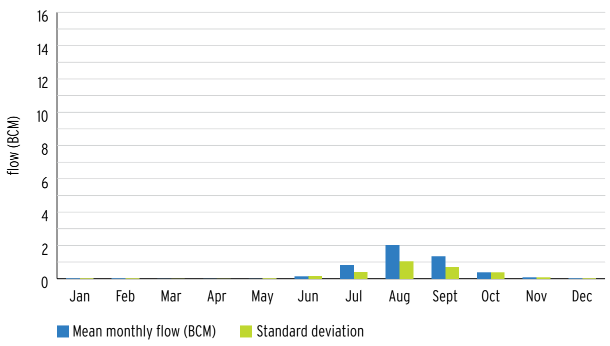
Tekeze-Atbara Sub-basin



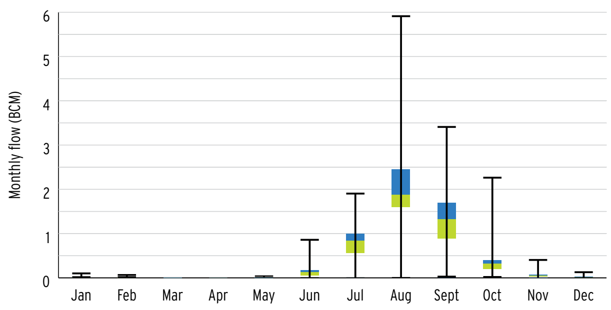
Simien Mountains, Ethiopia

The main rivers of the sub-basin are the Tekezze (also known as Setit), Angereb (a tributary of Gwang) and Gwang. The Atbara is formed after Tekezze (Setit) is joined by Gwang River. The Atbara is the most seasonal of major tributaries of the Nile as can be deduced from the charts of monthly stream flow. There are three storage dams in the sub-basin: TK5 (live storage: 9.2 BCM) in Ethiopia, Khashim el Girba Dam (live storage: 654 MCM) Sudan and the new Atbara dam complex recently built by Sudan to increase water supply for irrigation downstream. The average annual flow for River Atbara at Khashim el Girba dam is 11.4 BCM.

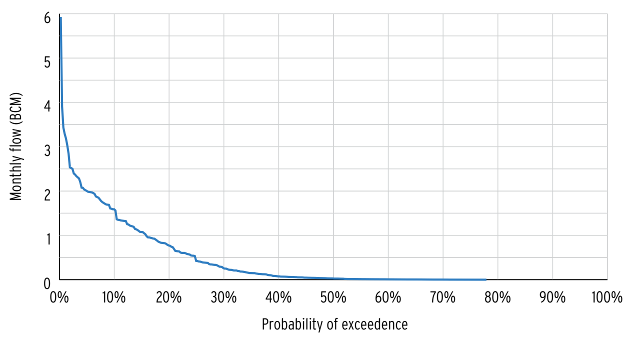
1 Monthly Flow Distribution - Kubur



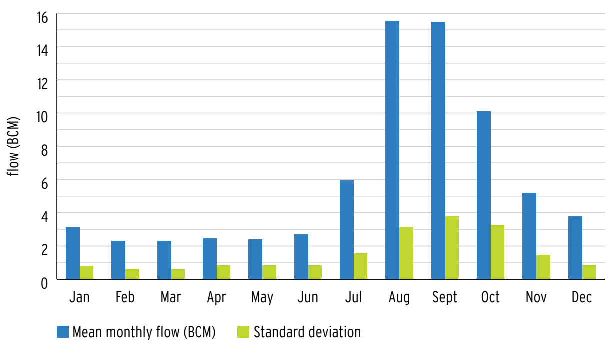
1 Monthly Flow Statistics - Kubur



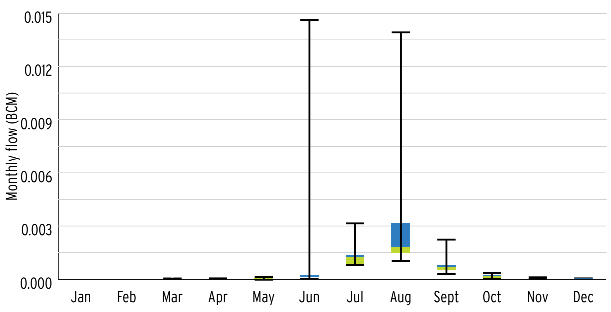
1 Flow Duration Curve - Kubur



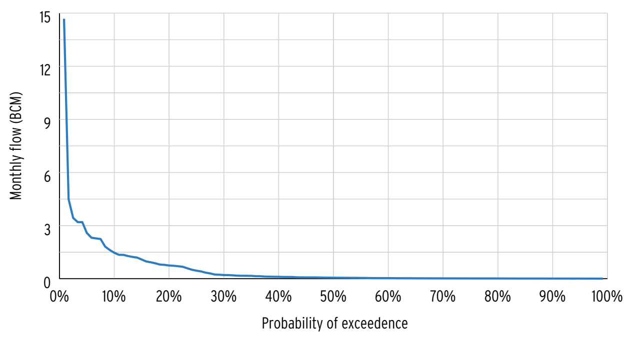
2 Monthly Flow Distribution - Embamadre



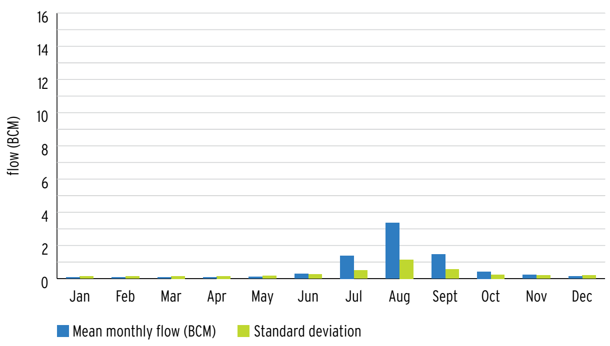
2 Monthly Flow Statistics - Embamadre



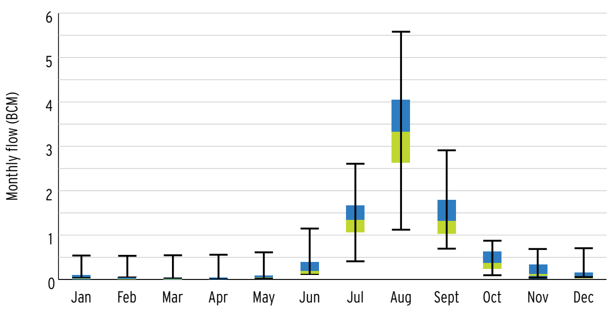
2 Flow Duration Curve - Embamadre



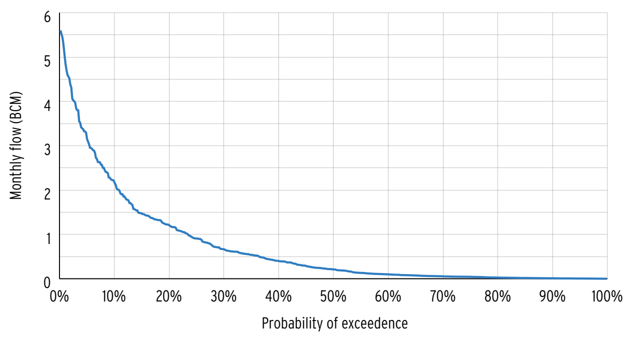
3 Monthly Flow Distribution - Seteit



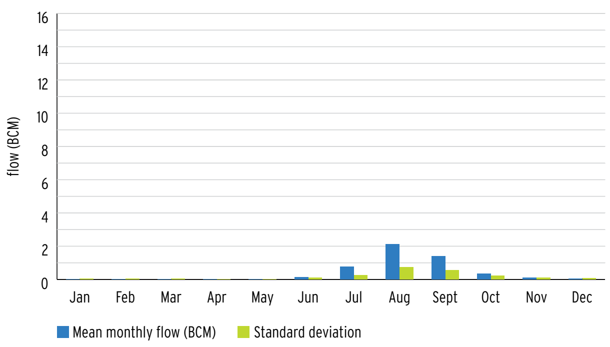
3 Monthly Flow Statistics - Seteit



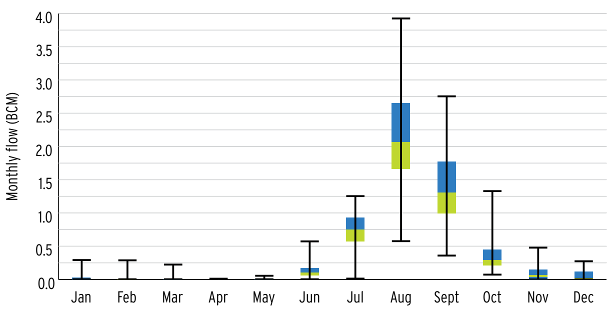
3 Flow Duration Curve - Seteit



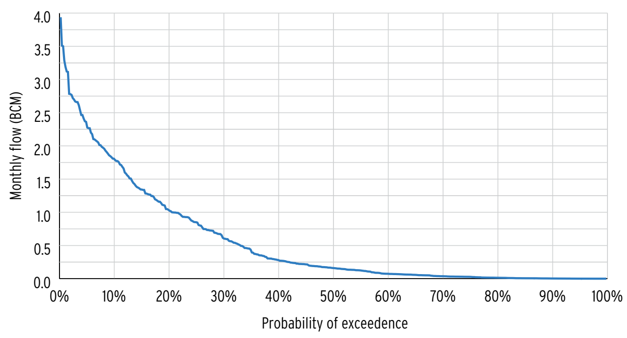
4 Monthly Flow Distribution - Upper Atbara



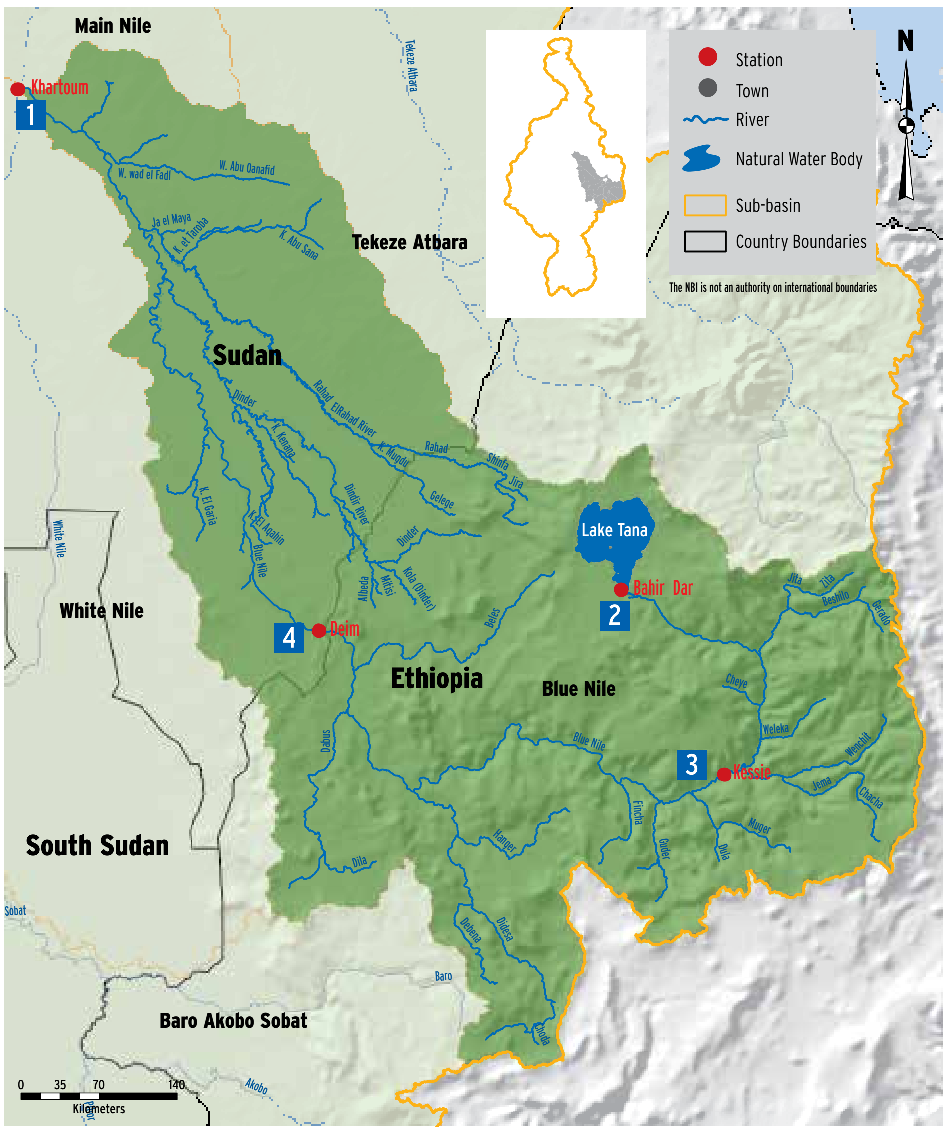
4 Monthly Flow Statistics - Upper Atbara



4 Flow Duration Curve - Upper Atbara



Blue Nile Sub-basin



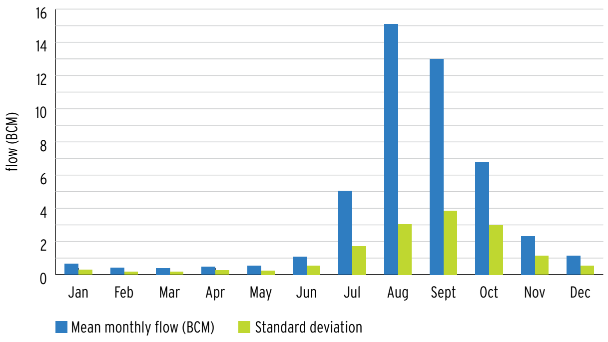

Blue Nile Falls from the Air

Photo: Travel Aficionado/flickr

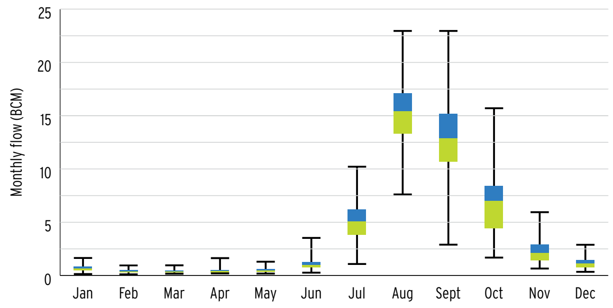
The Blue Nile is the largest contributor of flow to River Nile. For the period 1915 to 2014, the average annual river flow at the Diem station is about 50 BCM. The total contribution of the major tributaries of the Blue Nile including Dinder and Rahad) is about 55BCM which is about 60 percent of the combined flows of all Nile tributaries.

The Blue Nile is highly seasonal in with approximately 70 percent of its flow occurring in just 4 months (peak flows registered between July-September).

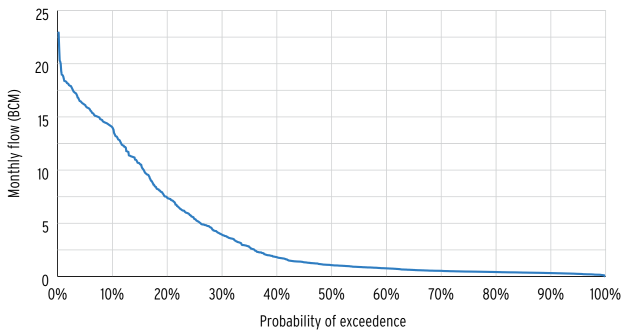
1 Monthly Flow Distribution - Khartoum



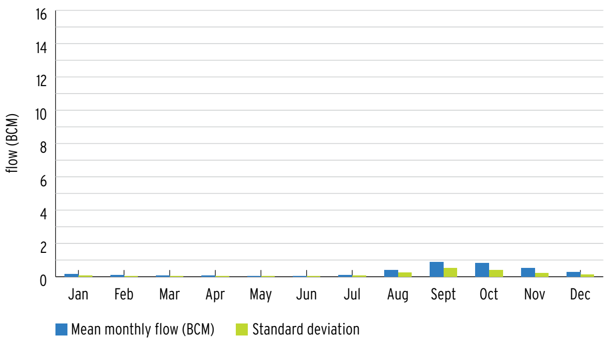
1 Monthly Flow Statistics - Khartoum



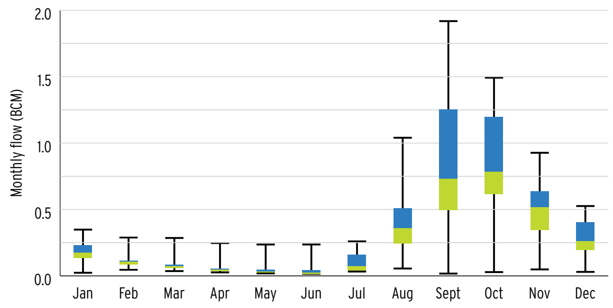
1 Flow Duration Curve - Khartoum



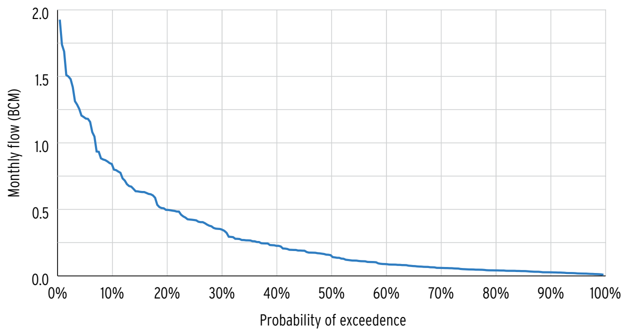
2 Monthly Flow Distribution - Bahir Dar



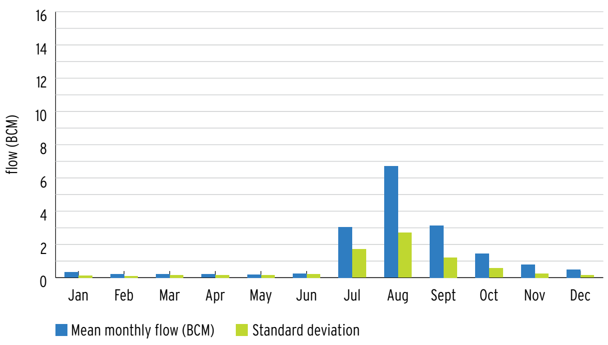
2 Monthly Flow Statistics - Bahir Dar



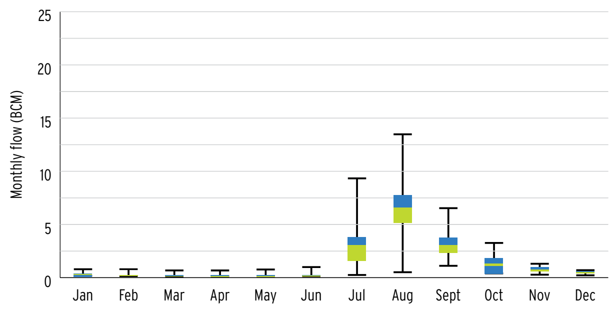
2 Flow Duration Curve - Bahir Dar



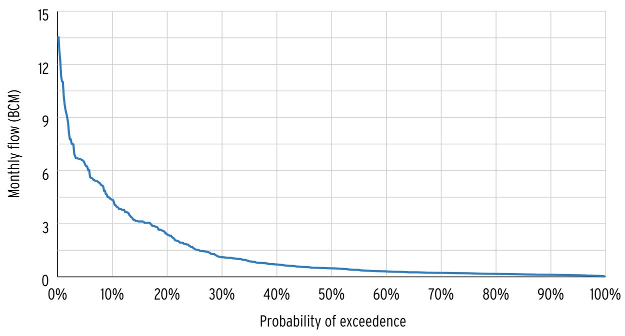
3 Monthly Flow Distribution - Kessie



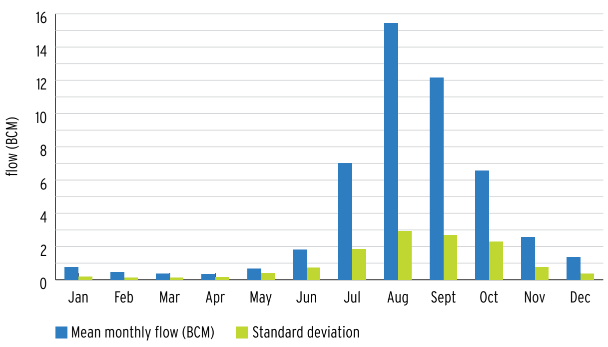
3 Monthly Flow Statistics - Kessie



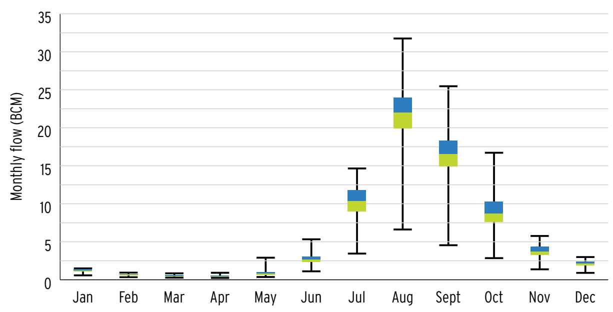
3 Flow Duration Curve - Kessie



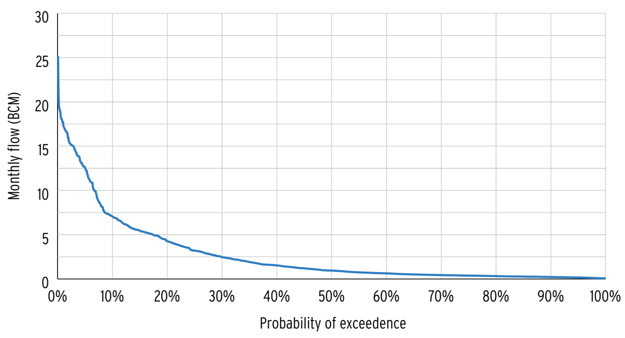
4 Monthly Flow Distribution - Diem



4 Monthly Flow Statistics - Diem



4 Flow Duration Curve - Diem



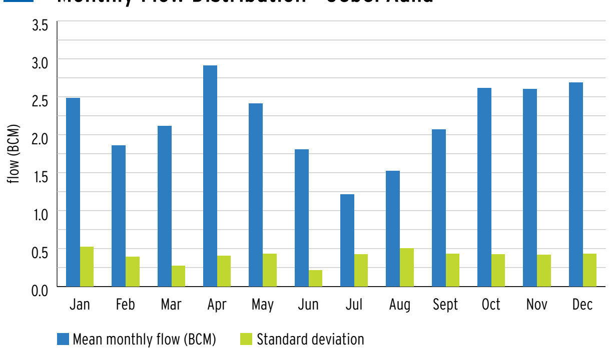
White Nile Sub-basin

Jebel Aulia dam

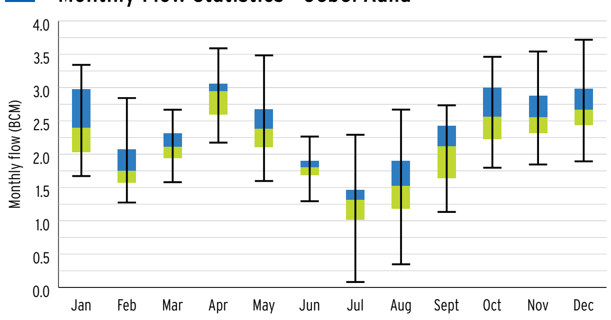
White Nile

A major feature in the White Nile sub-basin is the Gebel Aulia dam whose backwater curve is reported to extend for more than 600 kilometers. The flow recorded at Mogren station in Khartoum is the release from the dam. In the months of July – August, the Blue Nile acts as a barrier and causes the White Nile to back up and slow down.

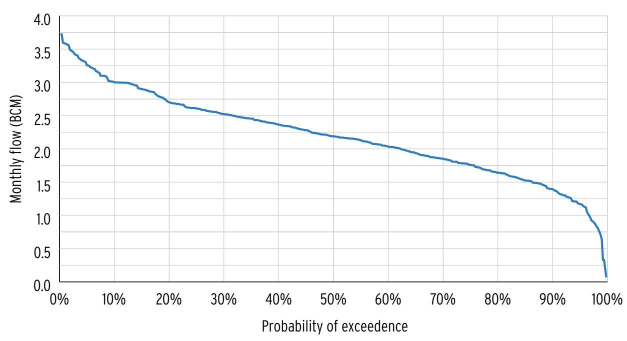
1 Monthly Flow Distribution - Jebel Aulia



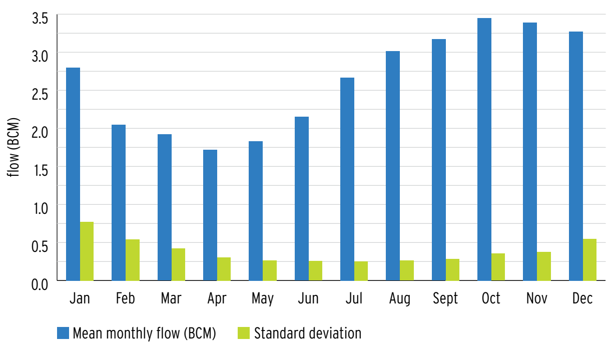
1 Monthly Flow Statistics - Jebel Aulia



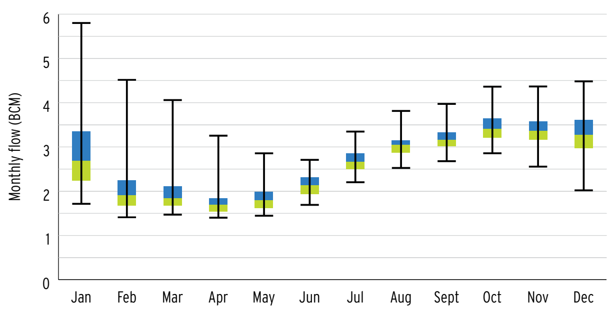
1 Flow Duration Curve - Jebel Aulia



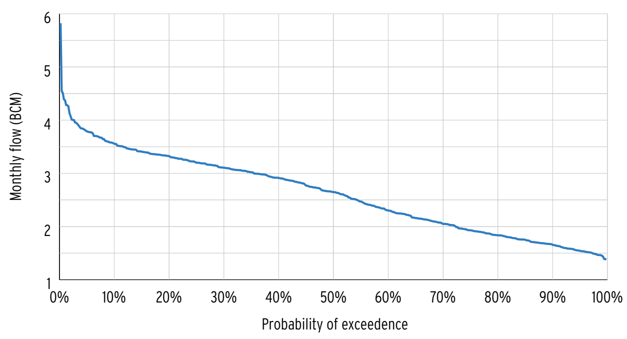
2 Monthly Flow Distribution - Malakal



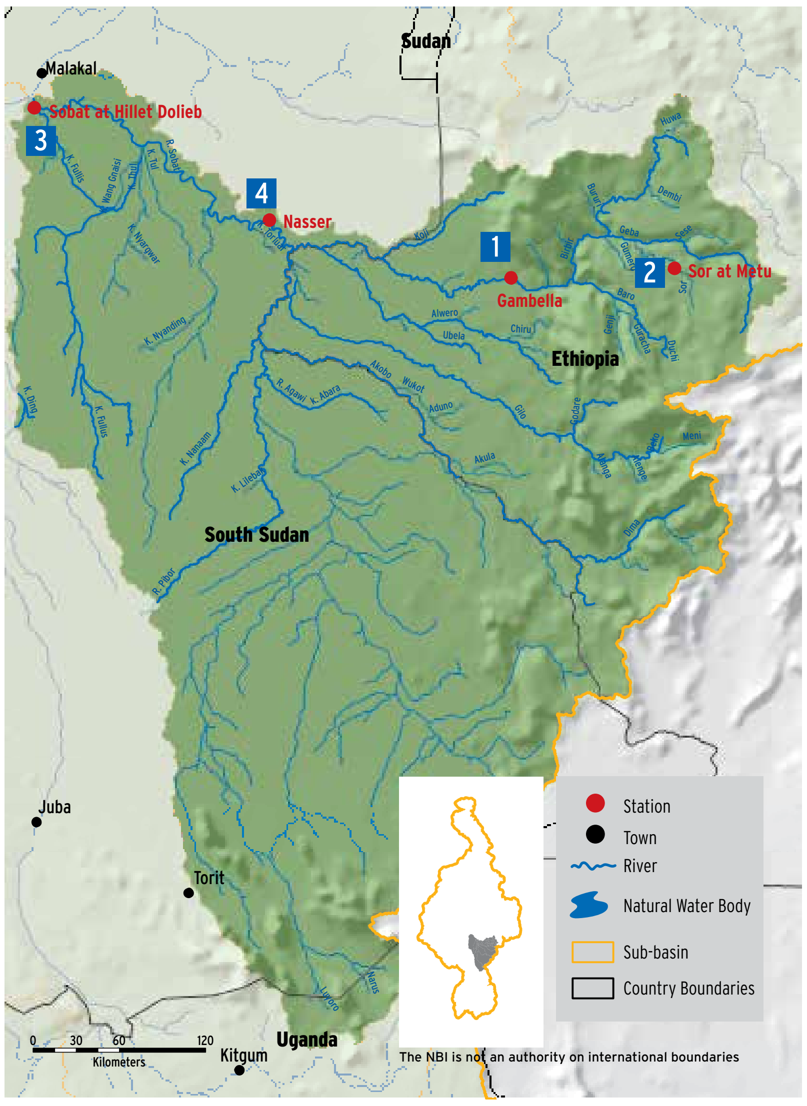
2 Monthly Flow Statistics - Malakal



2 Flow Duration Curve - Malakal



Baro Akobo Sobat Sub-basin

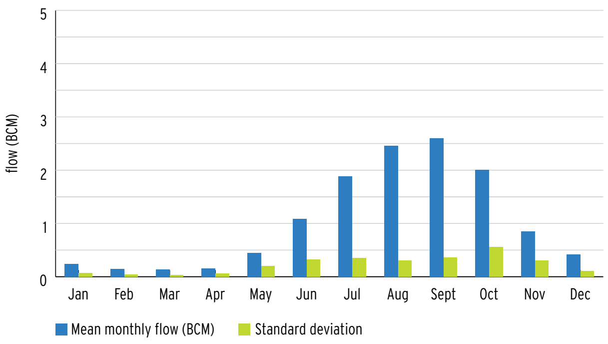


The Sobat River on the edge of Nasir, South Sudan

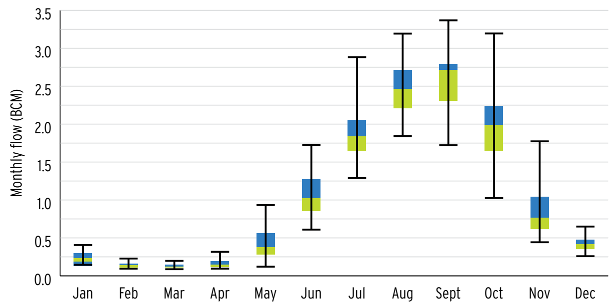
Photo: Owen Fuller/flickr.com

Flow in the Baro Akobo Sobat Sub-basin is characterized by high seasonality with a distinct high flow season occurring between July and October. This sub-basin is one of the least monitored Sub-basins and yet has very complex hydrology. A key feature of this sub-basin is high interconnection between floodplains and the river network with braided and bifurcating streams. Downstream of Gambella station, Baro River overflows into the Machar marshes, which are in the White Nile sub-basin.

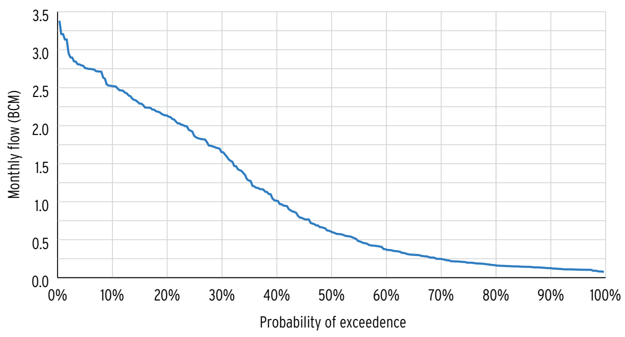
1 Monthly Flow Distribution - Gambela



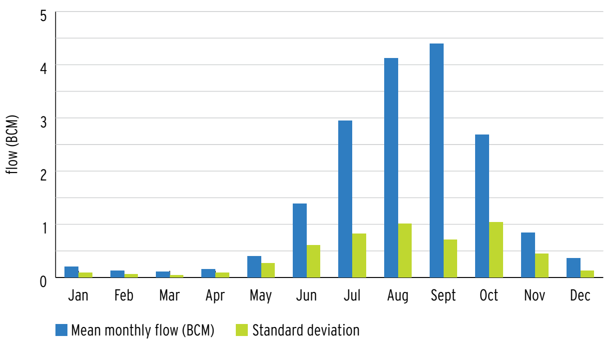
1 Monthly Flow Statistics - Gambela



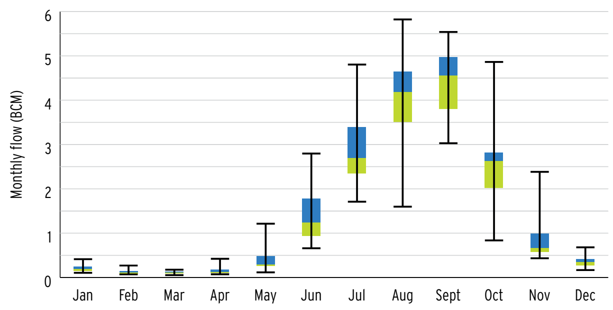
1 Flow Duration Curve - Gambela



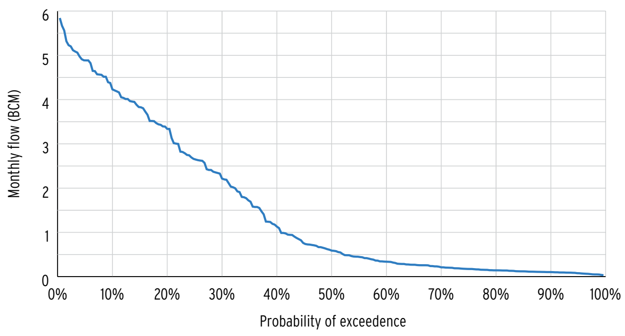
2 Monthly Flow Distribution - Sor



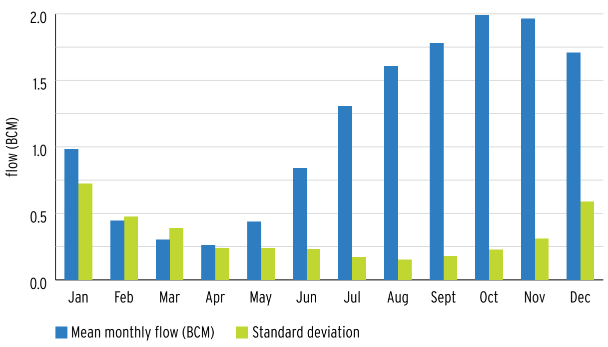
2 Monthly Flow Statistics - Sor



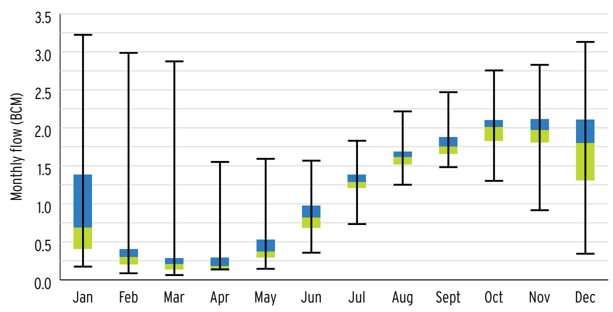
2 Flow Duration Curve - Sor



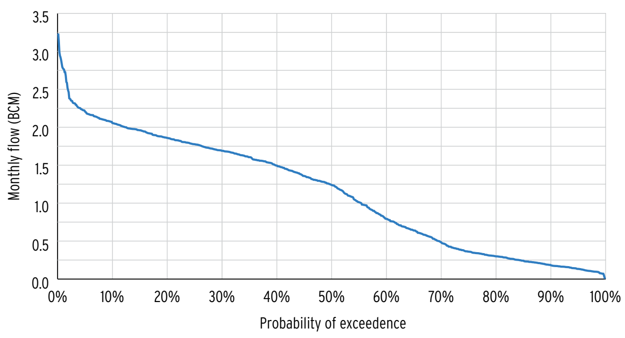
3 Monthly Flow Distribution - Sobat at Hillet Dolieb



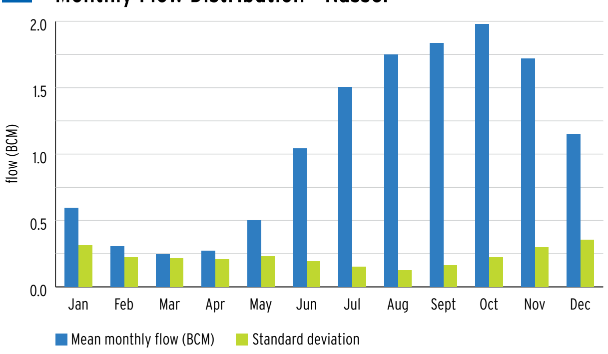
3 Monthly Flow Statistics - Sobat at Hillet Dolieb



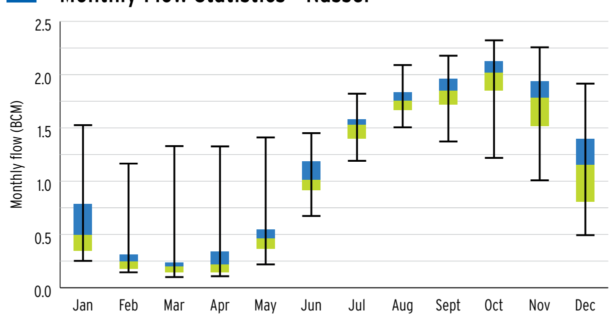
3 Flow Duration Curve - Sobat at Hillet Dolieb



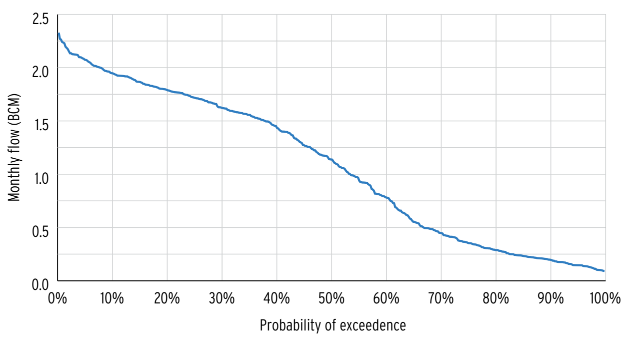
4 Monthly Flow Distribution - Nasser



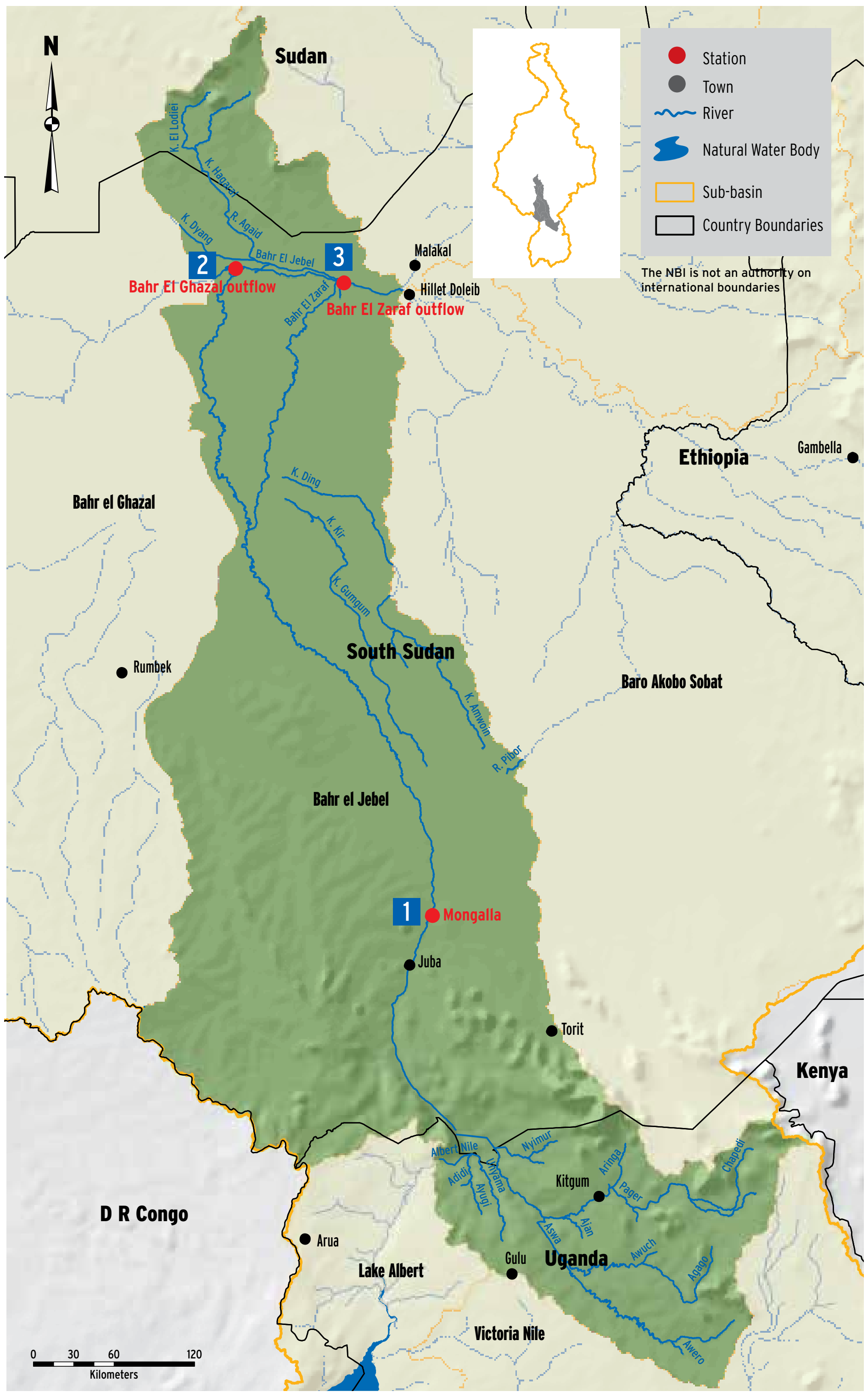
4 Monthly Flow Statistics - Nasser



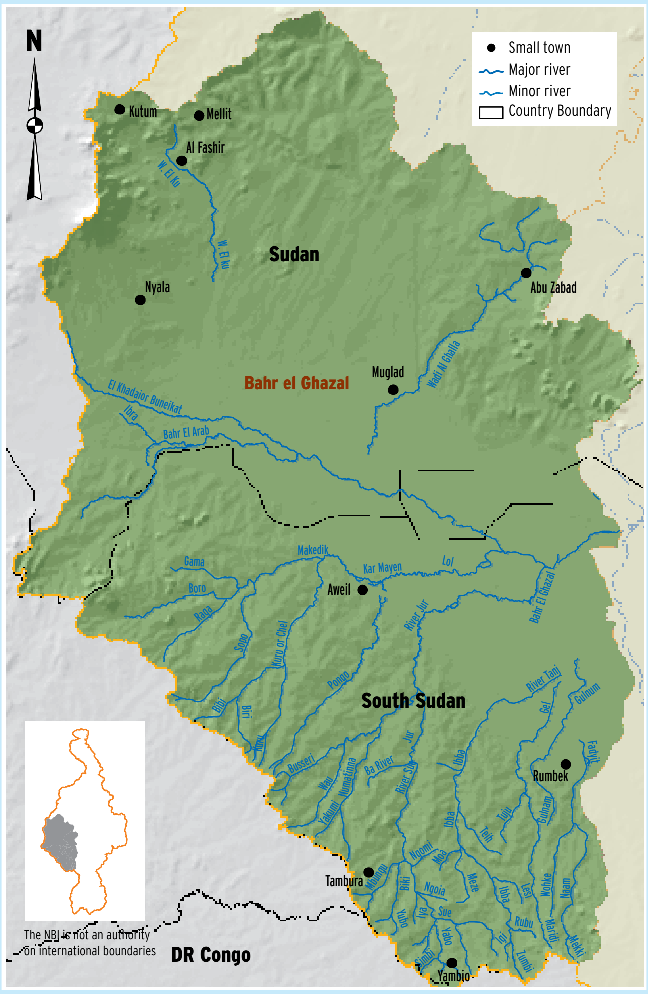
4 Flow Duration Curve - Nasser



Bahr el Jebel Sub-basin



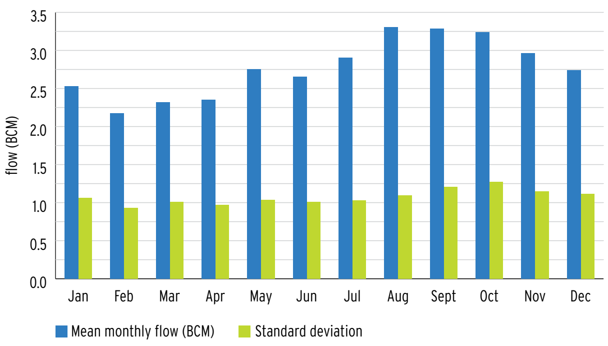
Bahr el Ghazal Sub-basin



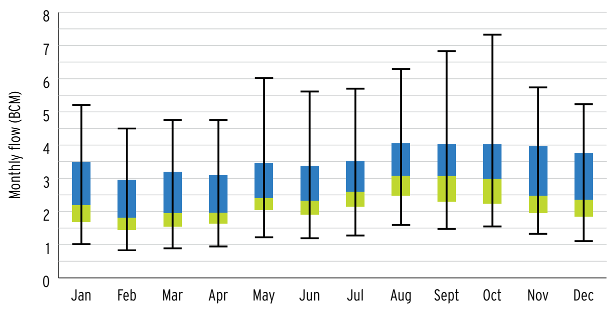
Bahr el Jebel and Bahr el Ghazal sub-basins are one of the least understood major sub-basins of the Nile and yet the existing hydro-met monitoring network is also very limited. The few available stream flow records exhibit substantial breaks and are of very poor quality

Seasonality the Bahr el Jebel Sub-basin is seen to have a single peak occurring between August and October as opposed to the two seasonal peaks in the upstream part of the Nile Basin. The standard deviation of the monthly flows is also seen to be high as gauged at Mongala partly because of the steeper section with rapids and rock outcrops as flow enters into the sub-basin from the Albert Nile and the various torrential streams entering the Bahr el Jebel (with a single seasonal peak) before the gentle slope.

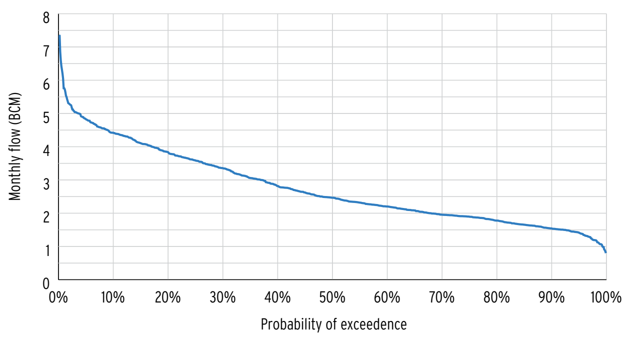
1 Monthly Flow Distribution - Mongalla



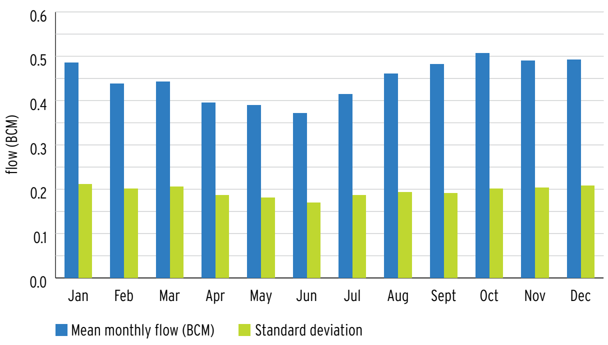
1 Monthly Flow Statistics - Mongalla



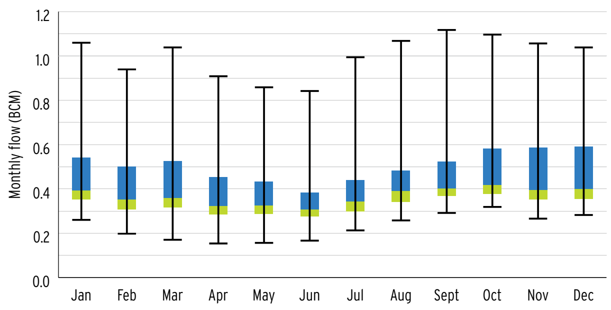
1 Flow Duration Curve - Mongalla



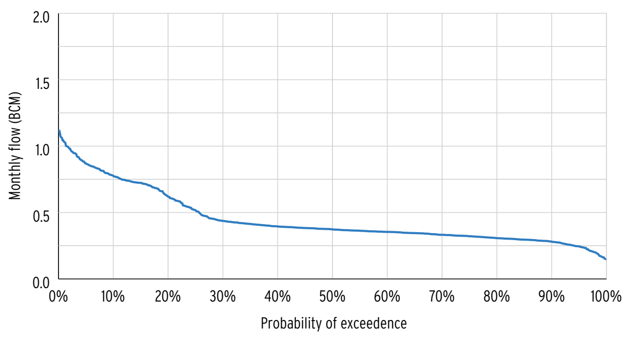
2 Monthly Flow Distribution - Bahr El Ghazal outflow



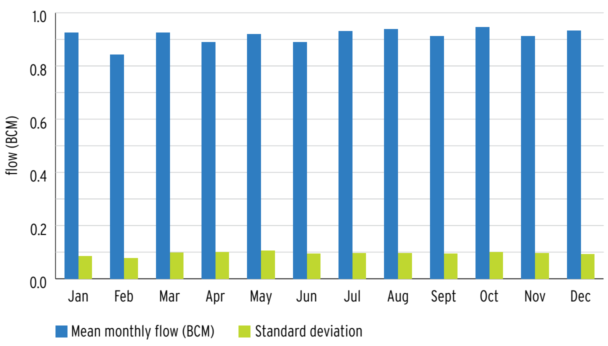
2 Monthly Flow Statistics - Bahr El Ghazal outflow



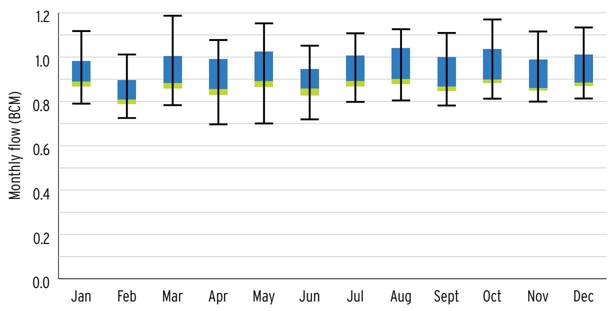
2 Flow Duration Curve - Bahr El Ghazal outflow



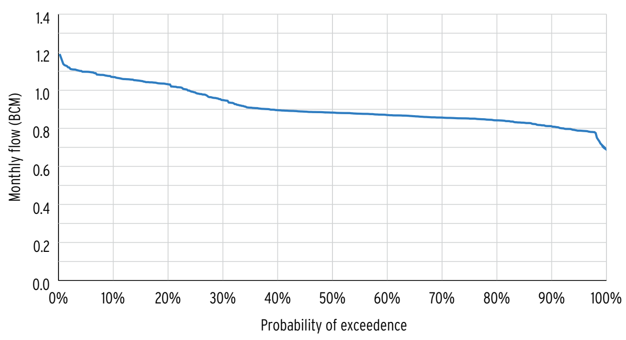
3 Monthly Flow Distribution - Bahr El Zaraf outflow



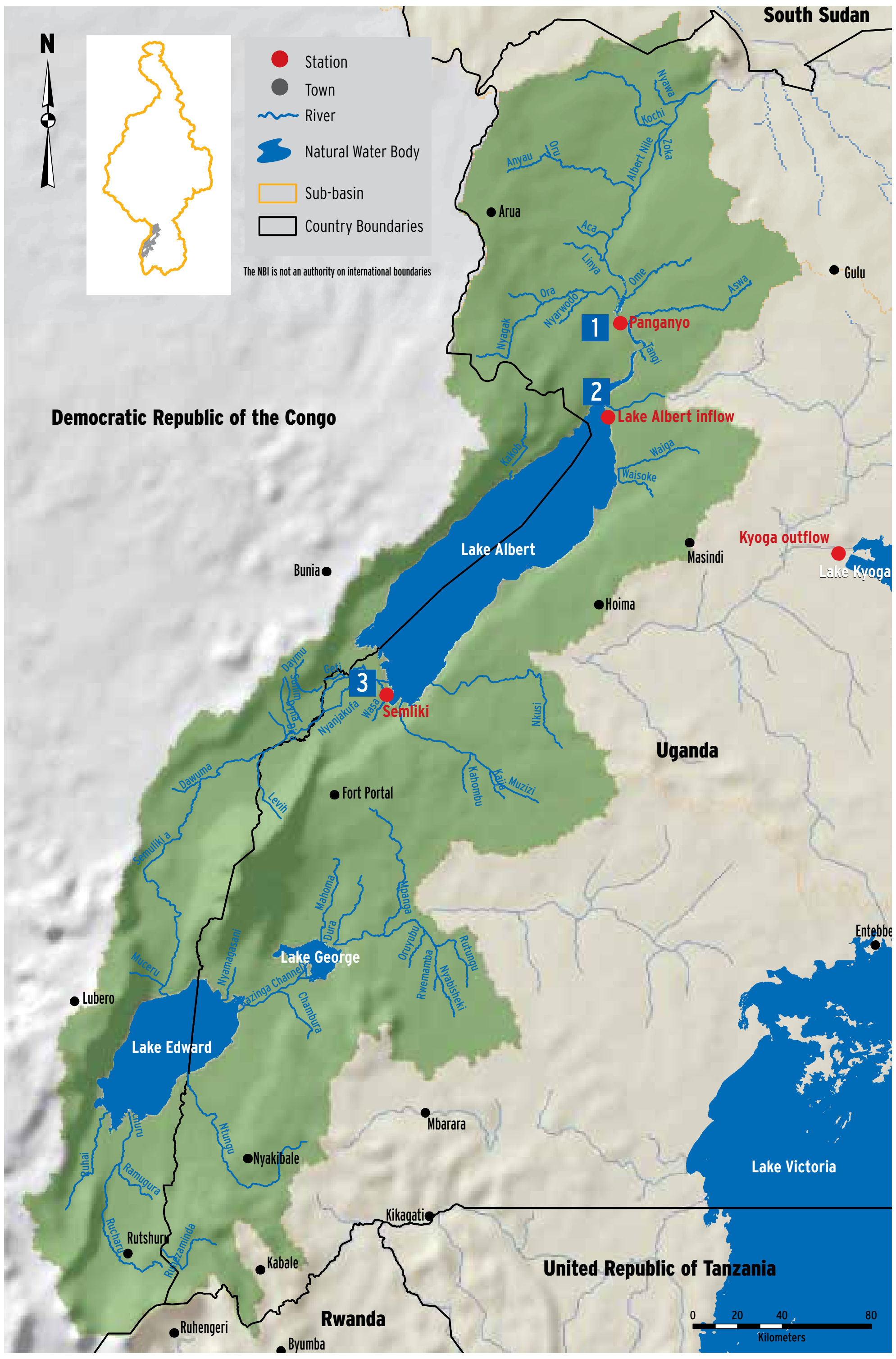
3 Monthly Flow Statistics - Bahr El Zaraf outflow



3 Flow Duration Curve - Bahr El Zaraf outflow



Lake Albert Sub-basin

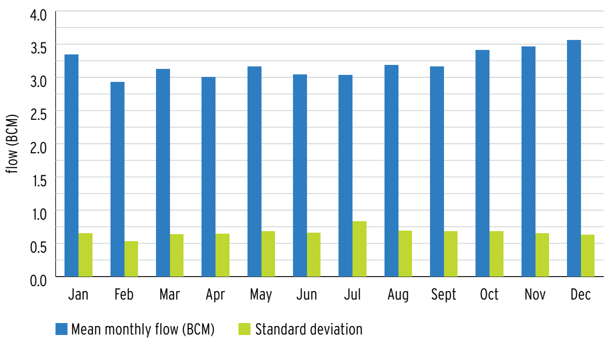


Murchison Falls

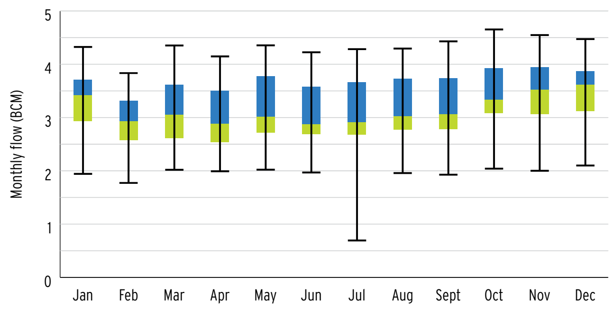
Kazinga Channel - The channel joins Lake Edward and Lake Albert and has one of the highest concentrations of wildlife in Africa.

There are two distinct seasons with high flows into Lake Albert, the peaks of which appear in May and November respectively. However, this is not reflected in the outflows partly because of the inflow from the Victoria Nile and water use and storage effect within the lake itself.

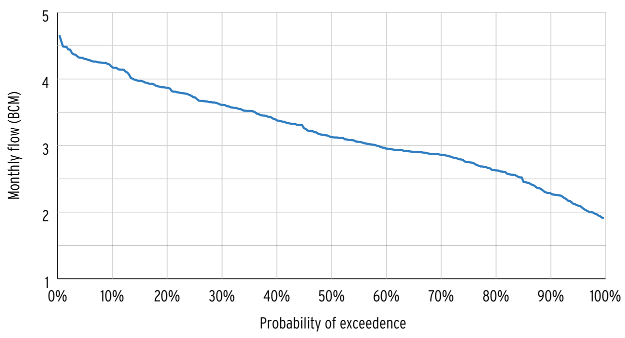
1 Monthly Flow Distribution - Panyango



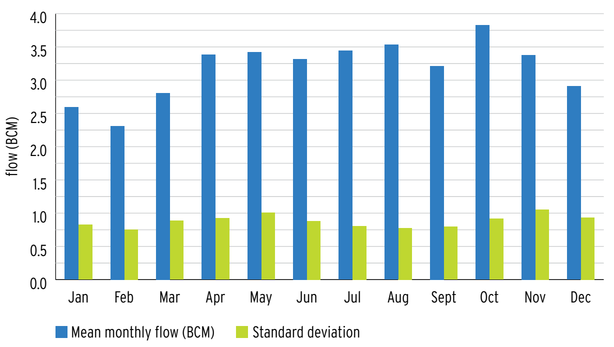
1 Monthly Flow Statistics - Panyango



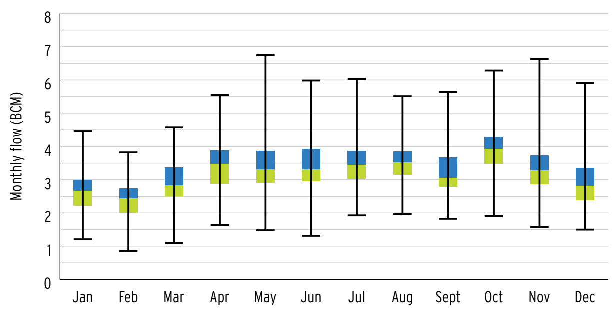
1 Flow Duration Curve - Panyango



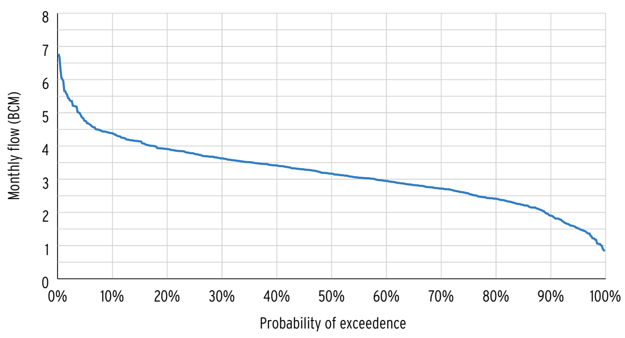
2 Monthly Flow Distribution - Lake Albert Inflow flow



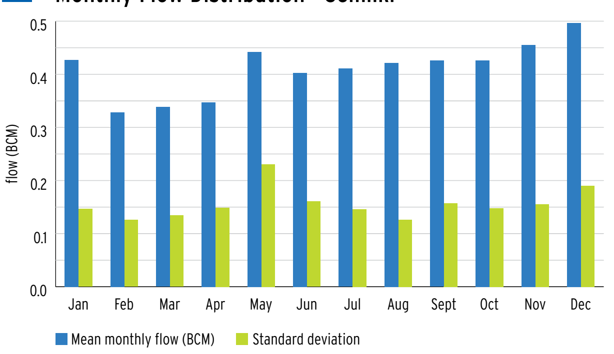
2 Monthly Flow Statistics - Lake Albert Inflow flow



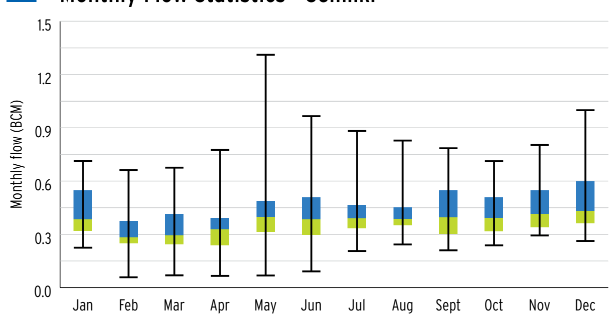
2 Flow Duration Curve - Lake Albert Inflow flow



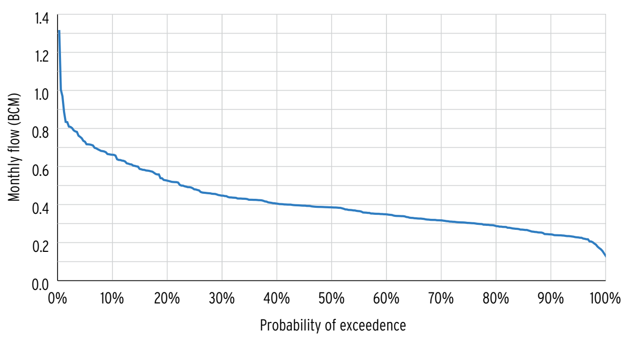
3 Monthly Flow Distribution - Semliki



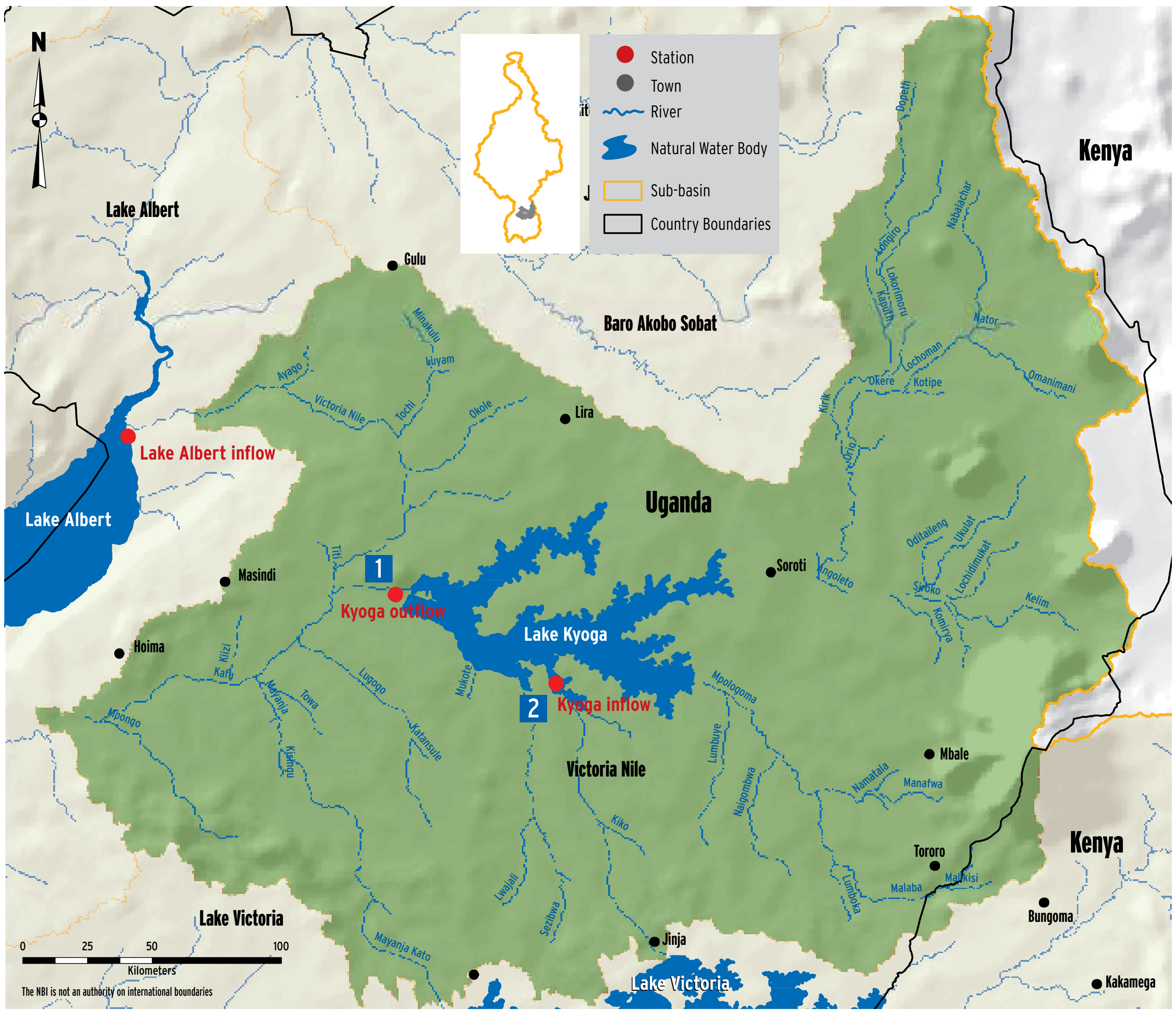
3 Monthly Flow Statistics - Semliki

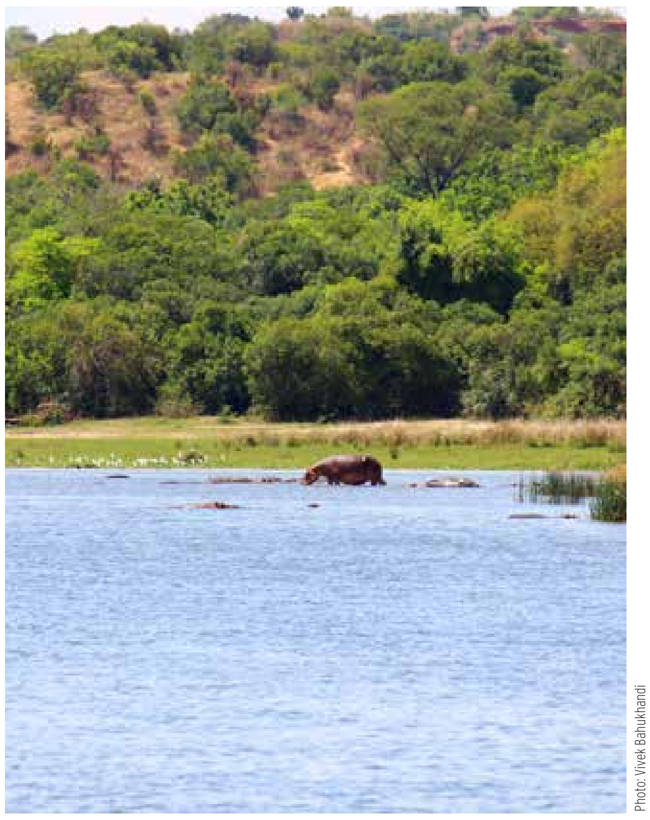


3 Flow Duration Curve - Semliki



Victoria Nile Sub-basin

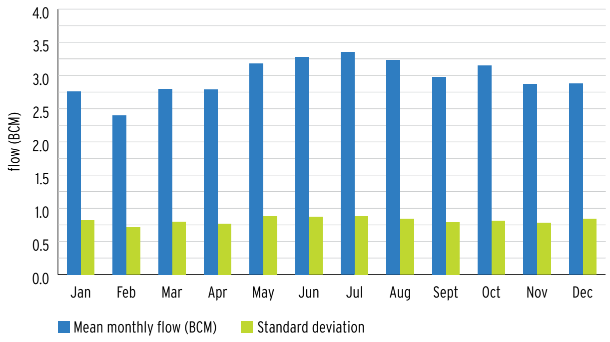




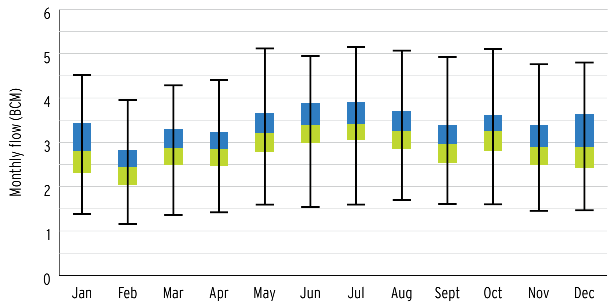
Albert Nile in Uganda

The outflow from the lake seems to indicate that the lake has minimal effect on inflow from the Victoria Nile since the major patterns are maintained both in the inflow and outflow.

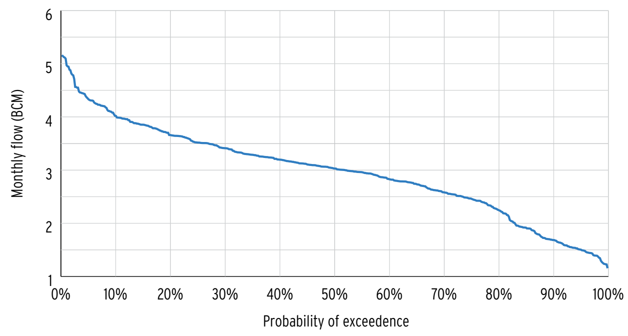
1 Monthly Flow Distribution - Kyoga outflow flow



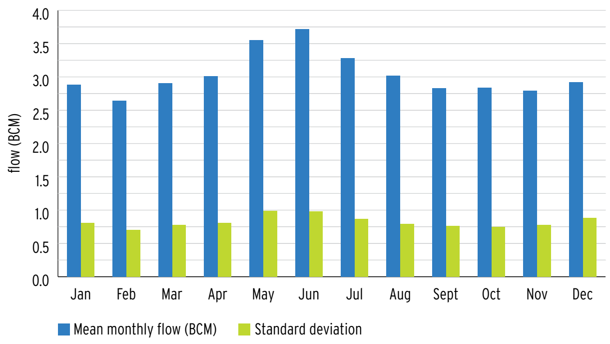
1 Monthly Flow Statistics - Kyoga outflow flow



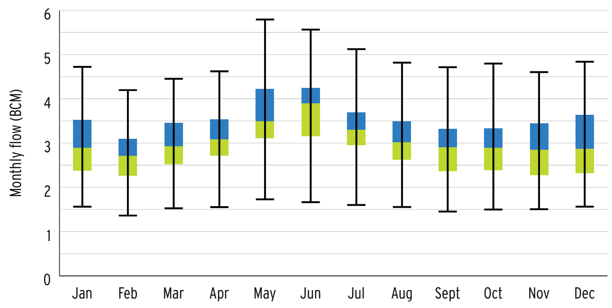
1 Flow Duration Curve - Kyoga outflow flow



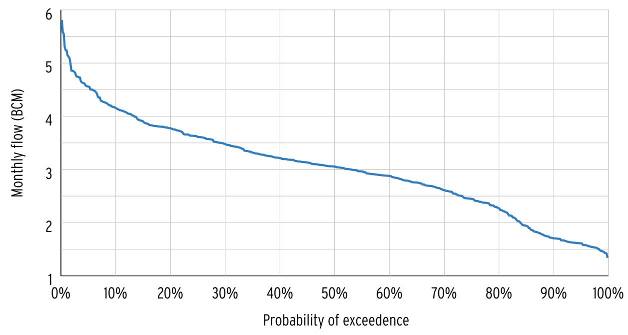
2 Monthly Flow Distribution - Kyoga inflow flow



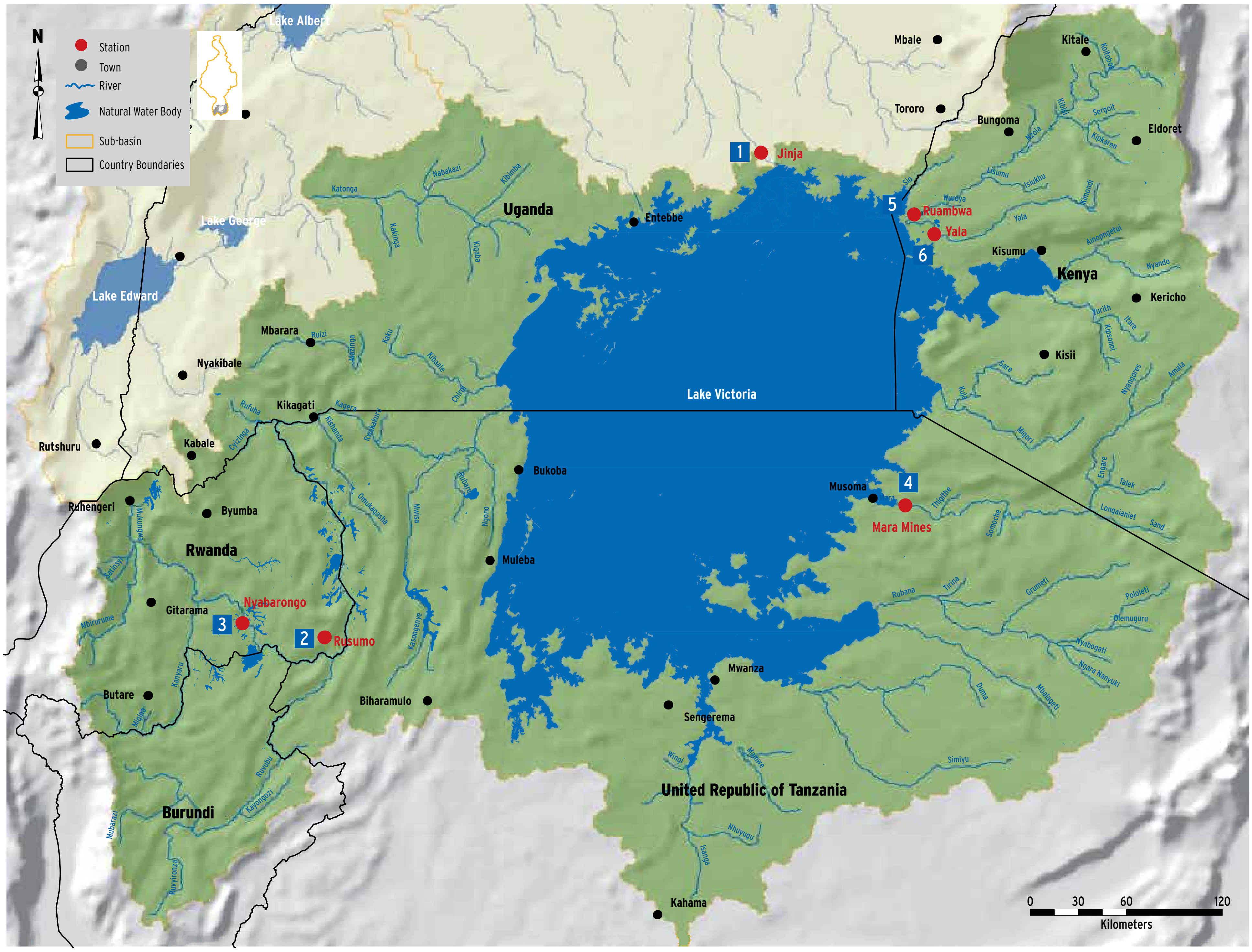
2 Monthly Flow Statistics - Kyoga inflow flow



2 Flow Duration Curve - Kyoga inflow flow

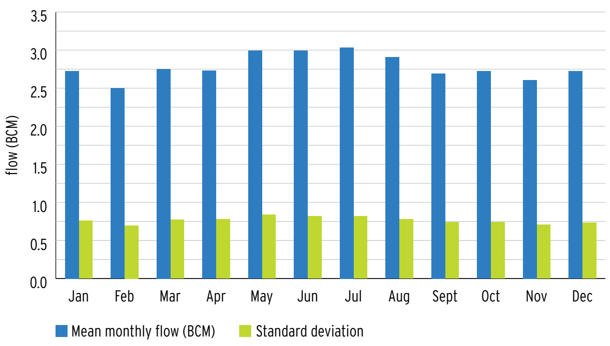


Lake Victoria Sub-basin

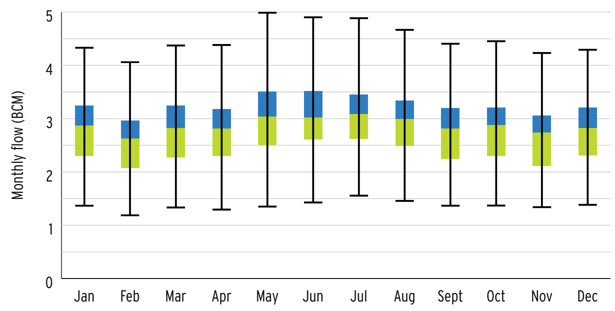


Lake Victoria within the Lake Victoria Sub-basin is a large buffer zone that not only allows for inter-annual storage but also regulates outflows. As seen, inflows from the upstream catchments depict seasonality but this variability is damped as the Victoria Nile outflows from Lake Victoria due to this regulation.

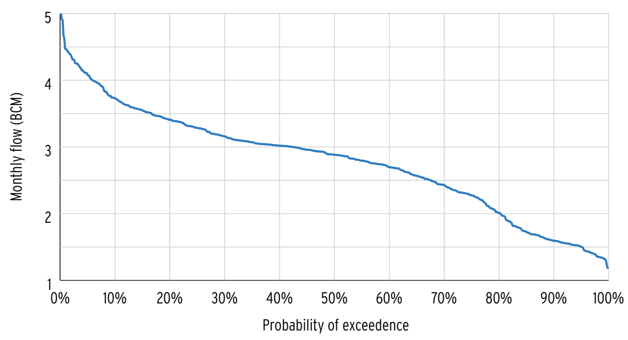
1 Monthly Flow Distribution - Jinja



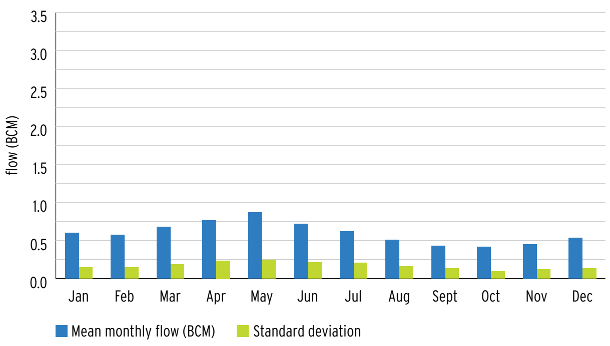
1 Monthly Flow Statistics - Jinja



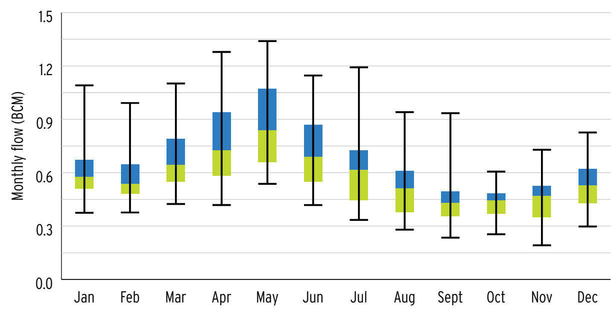
1 Flow Duration Curve - Jinja



2 Monthly Flow Distribution - Rusumo



2 Monthly Flow Statistics - Rusumo



2 Flow Duration Curve - Rusumo

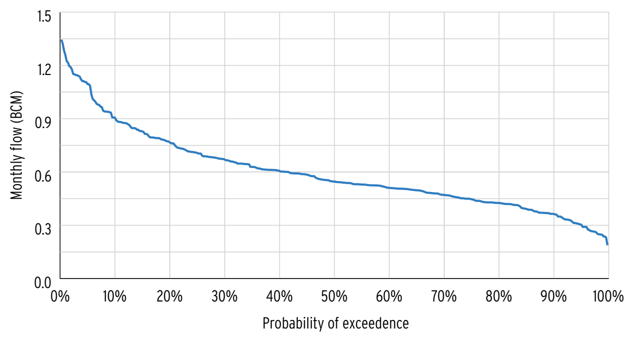
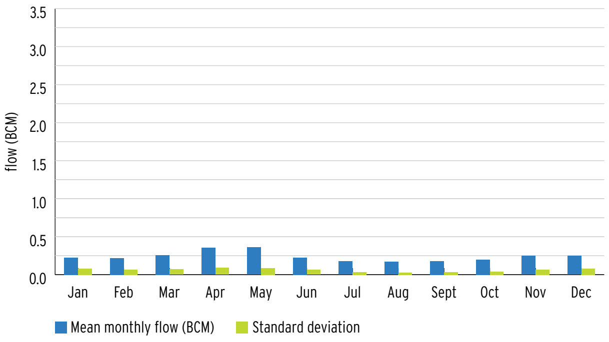


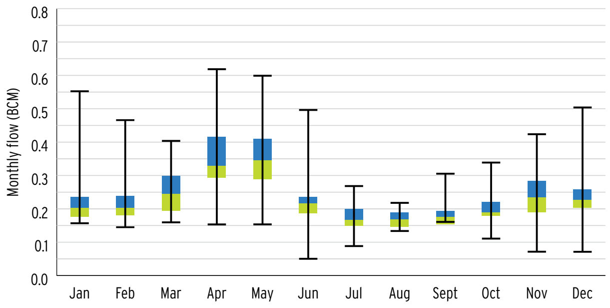
Photo: LMTP/flickr.com

Lake Victoria: The source of the Nile river

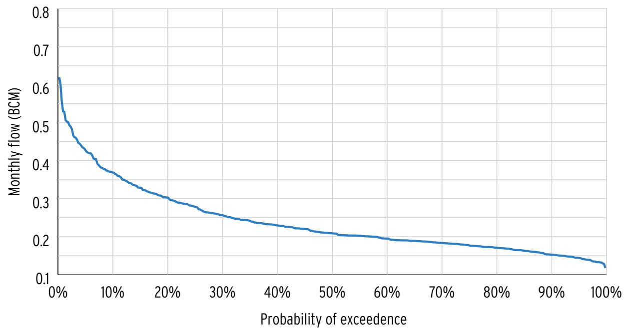
3 Monthly Flow Distribution - Nyabarongo



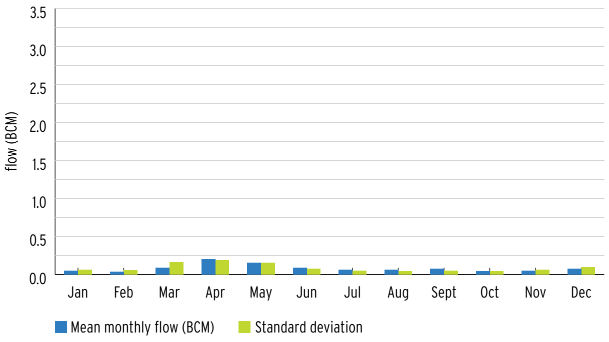
3 Monthly Flow Statistics - Nyabarongo



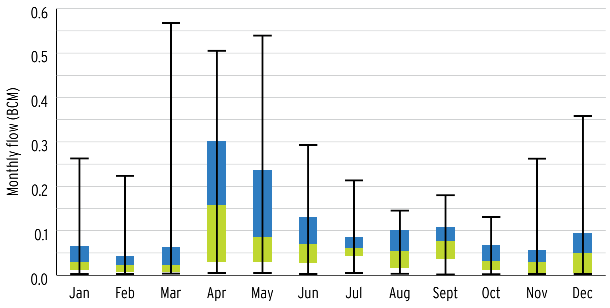
3 Flow Duration Curve - Nyabarongo



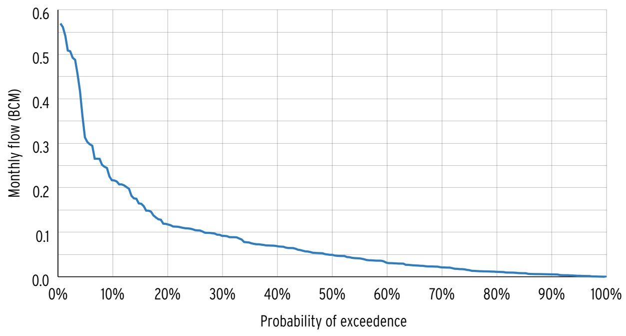
4 Monthly Flow Distribution - Mara Mines



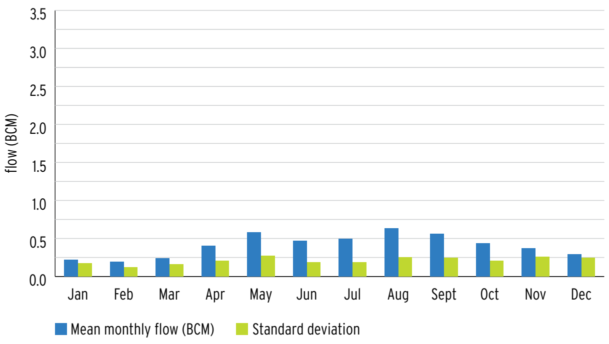
4 Monthly Flow Statistics - Mara Mines



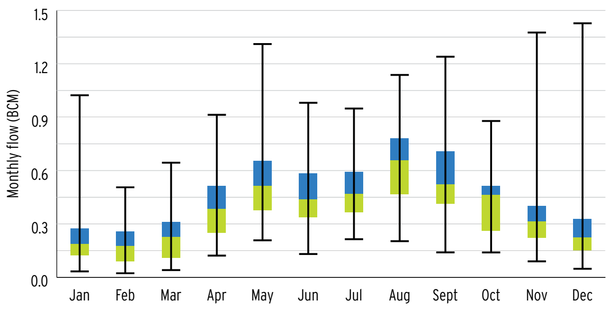
4 Flow Duration Curve - Mara Mines



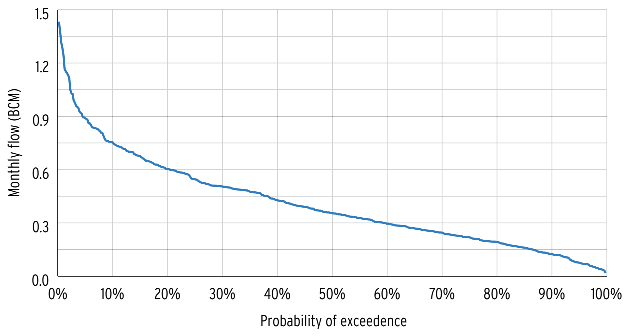
5 Monthly Flow Distribution - Ruambwa



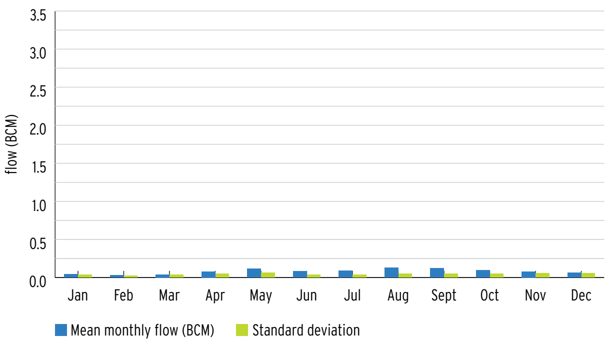
5 Monthly Flow Statistics - Ruambwa



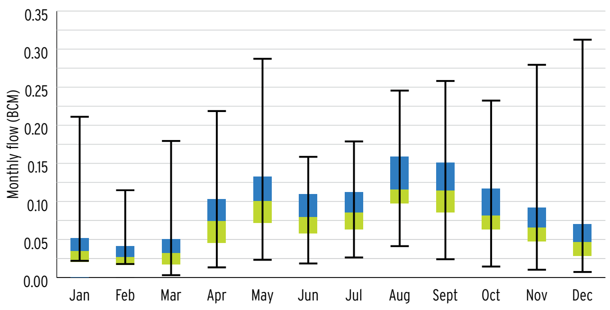
5 Flow Duration Curve - Ruambwa



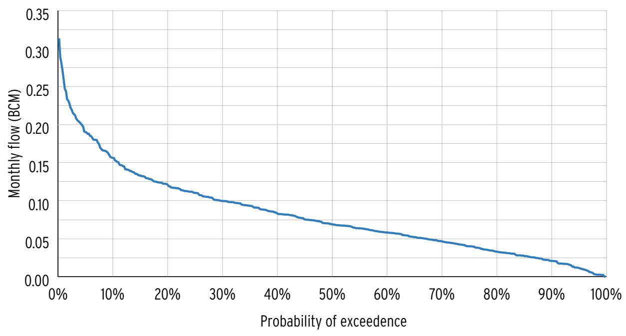
6 Monthly Flow Distribution - Yala



6 Monthly Flow Statistics - Yala

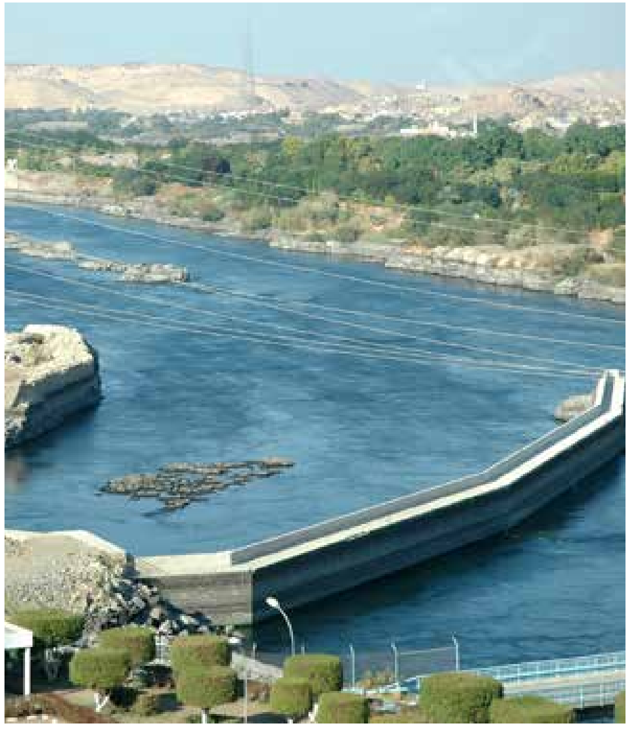


6 Flow Duration Curve - Yala



ANNUAL FLOW PATTERNS

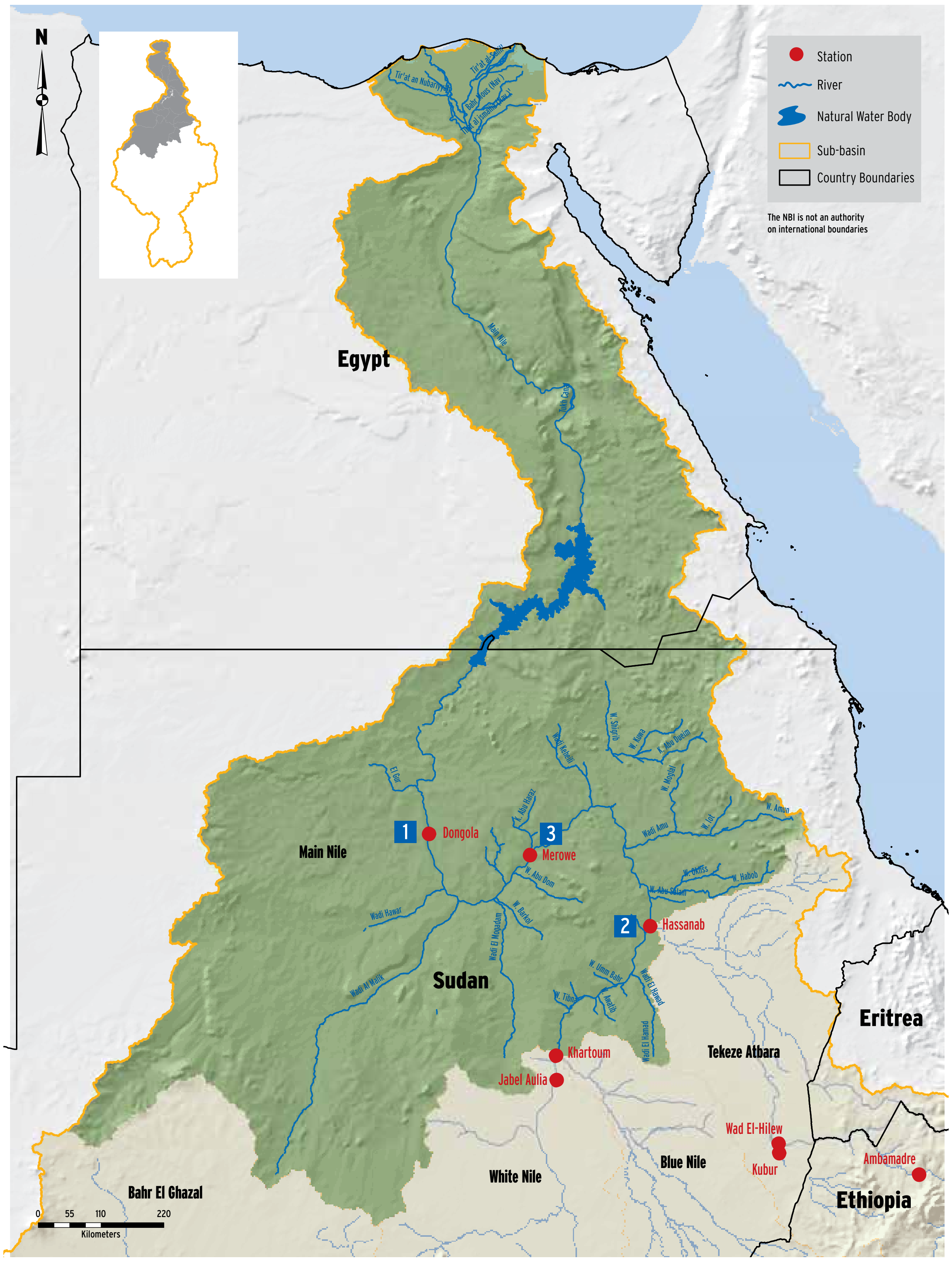
This sub section presents the annual flow patterns together with the long term mean annual flow for selected stations within the Nile. Again this has been presented per Sub-basin and it follows the Sub-basin presentation sequence similar to the previous section.



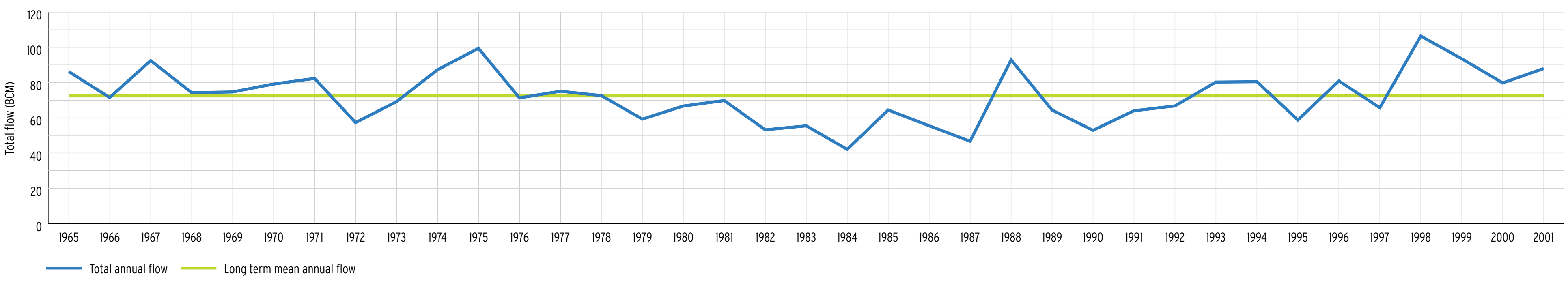
Aswan high dam

The long-term annual flows are shown in the charts. The part of the Main Nile downstream of the High Aswan Dam is fully regulated and, therefore, the flows there are controlled releases for various uses in Egypt. The part of the Nile upstream of the High Aswan Dam is partially regulated by the dams in Sudan. The Nile in this sub-basin is highly altered in its flows due to the abstractions of water for various uses and the flow records no longer represent natural flow conditions. The long-term flow at the Dongola station is about 72 BCM. The average discharge of the Nile into the Mediterranean Sea through its two branches in Egypt is estimated as 10 – 12 BCM per year.

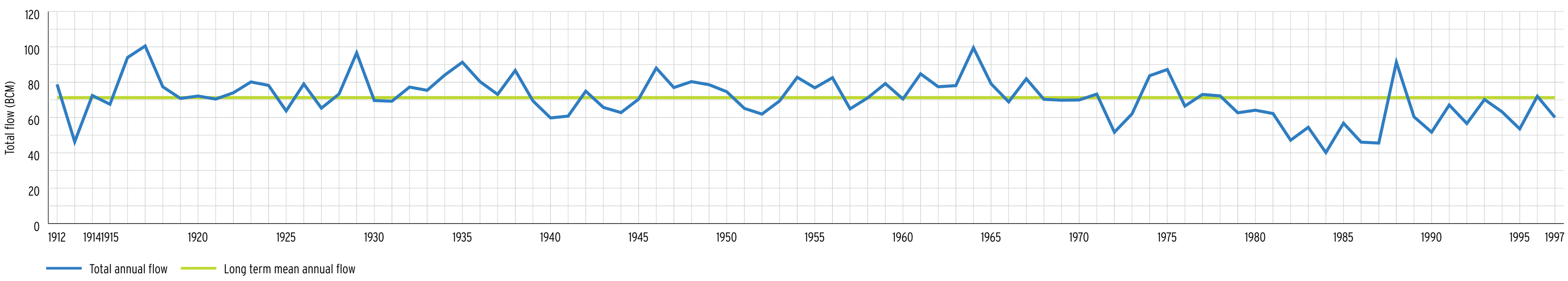
Main Nile Sub-basin



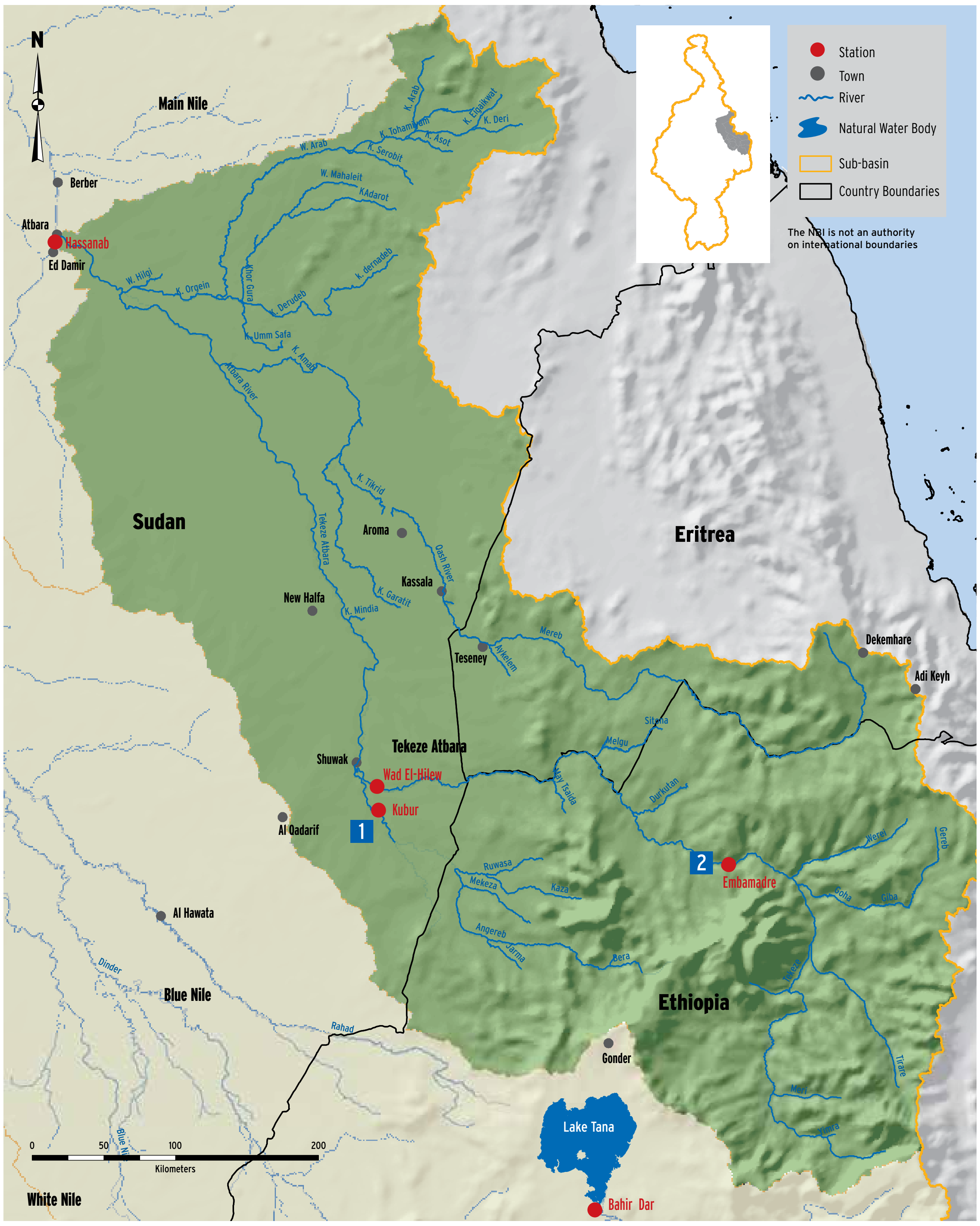
1 Annual flow volume - Dongola



2 Annual flow volume - Hassanab

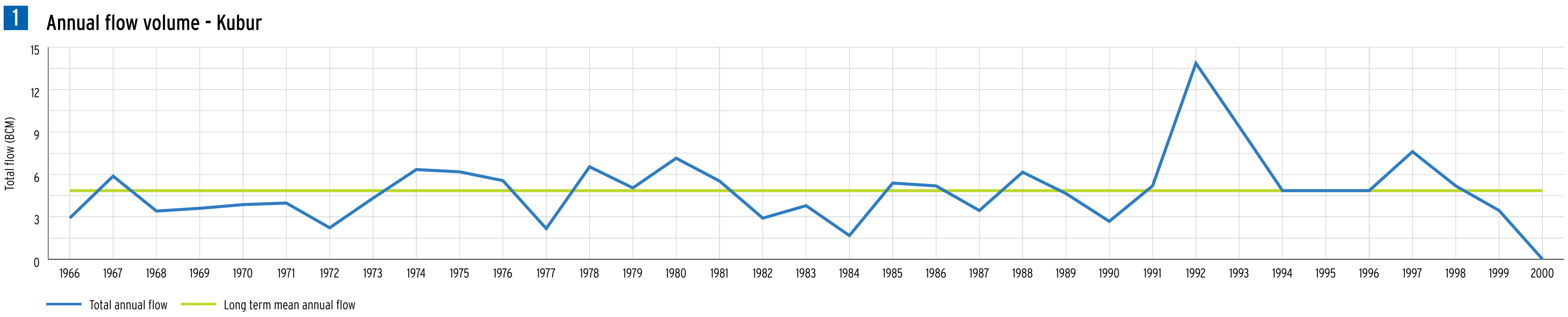


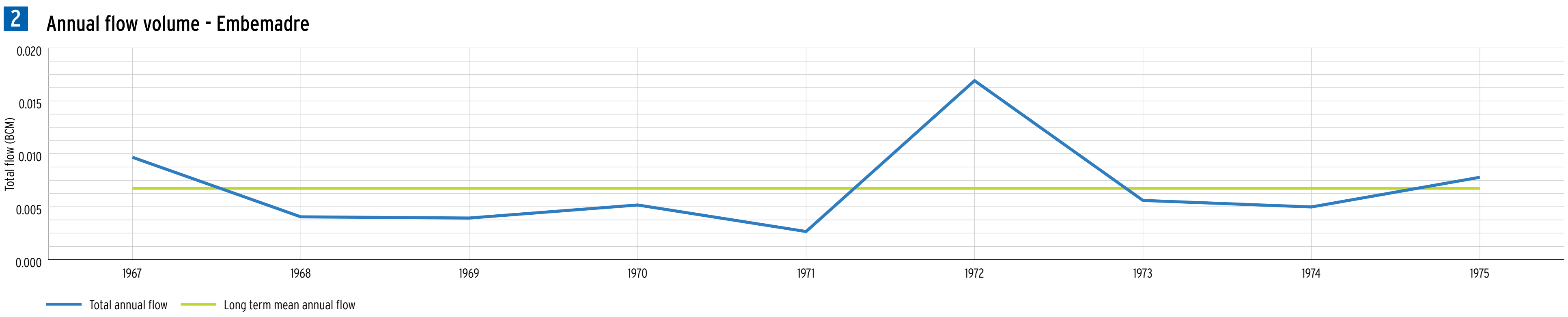
Tekeze Atbara Sub-basin



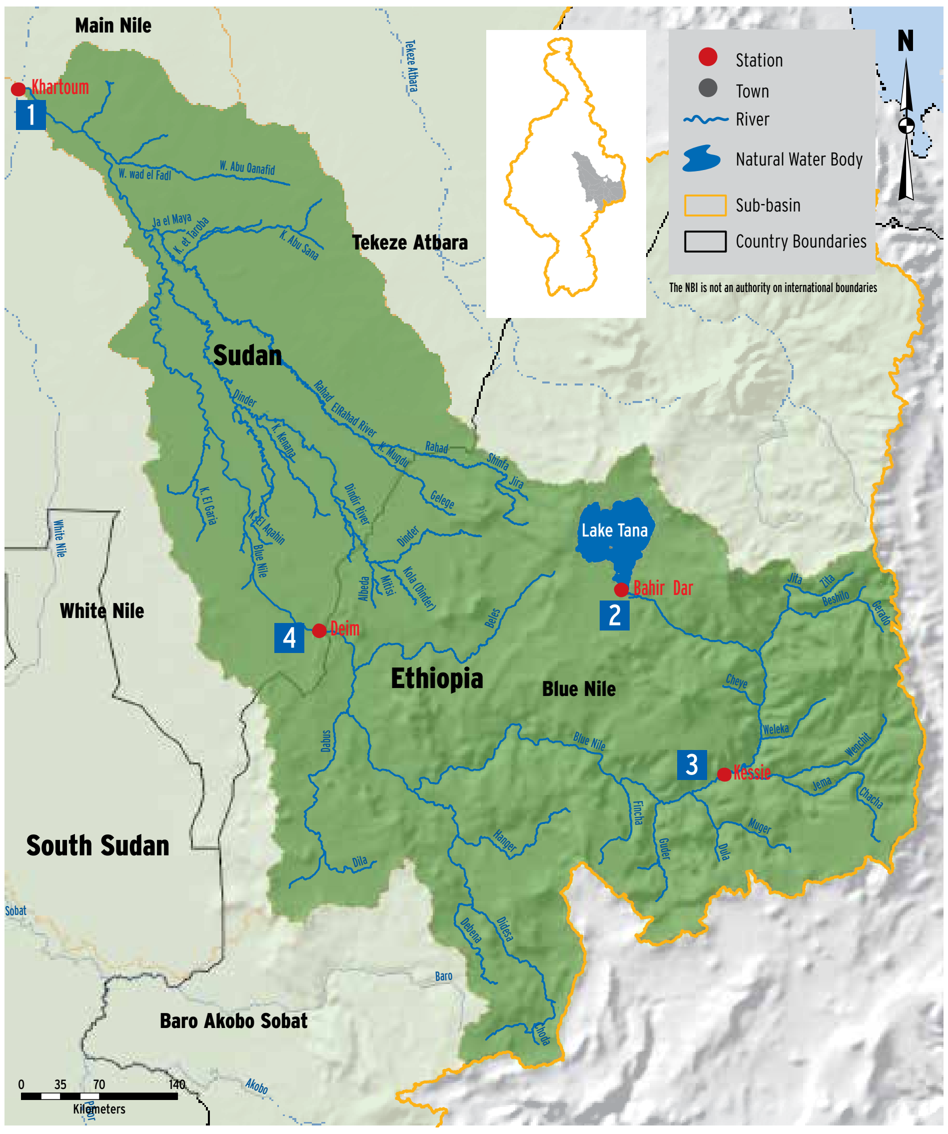
Simien Mountains, Ethiopia

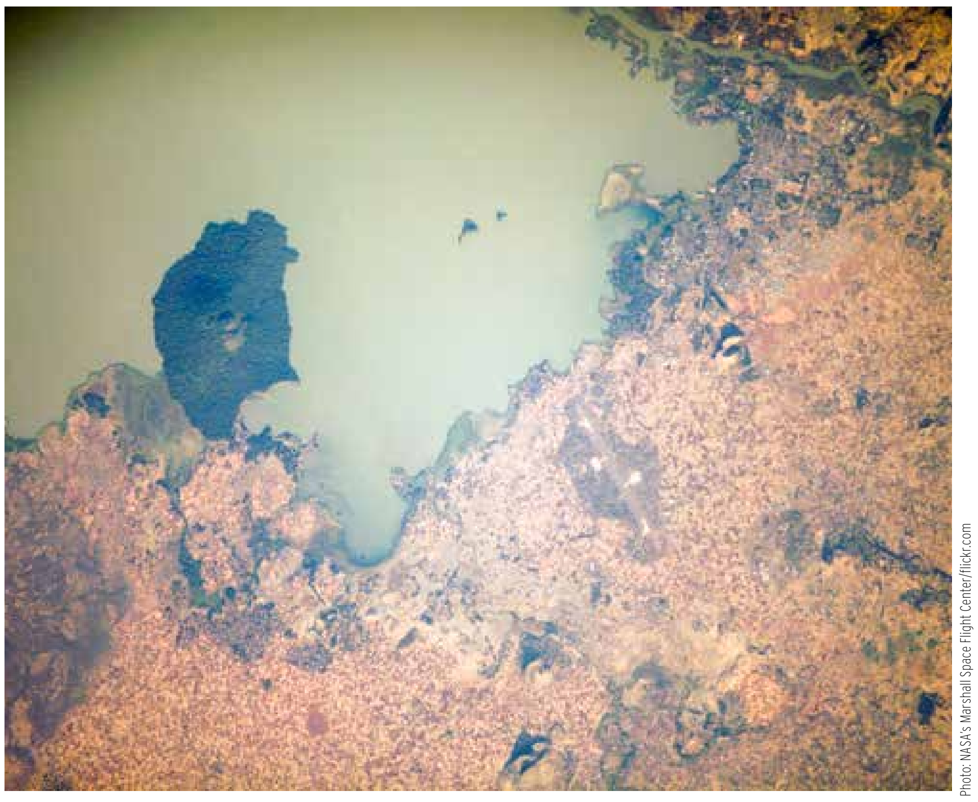
The long-term annual yield of the Atbara catchment is estimated at 11.4 BCM. The inter-annual variability is very high and in its lower reaches, the river flow is very low.





Blue Nile Sub-basin

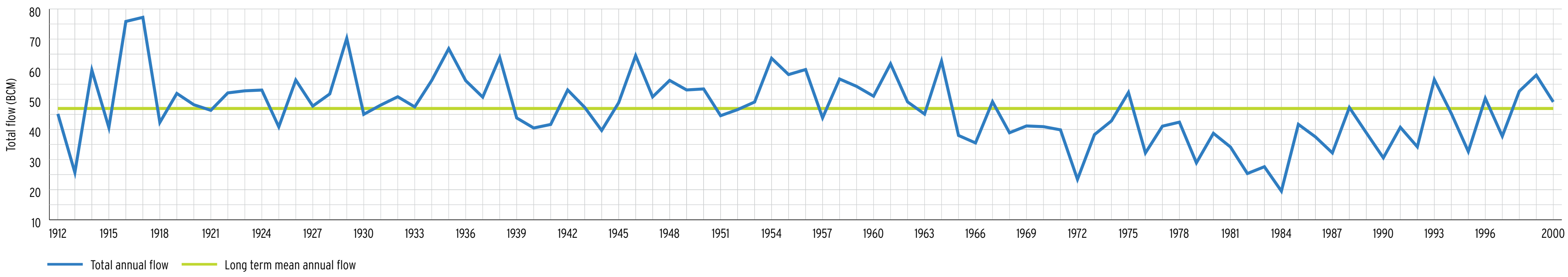




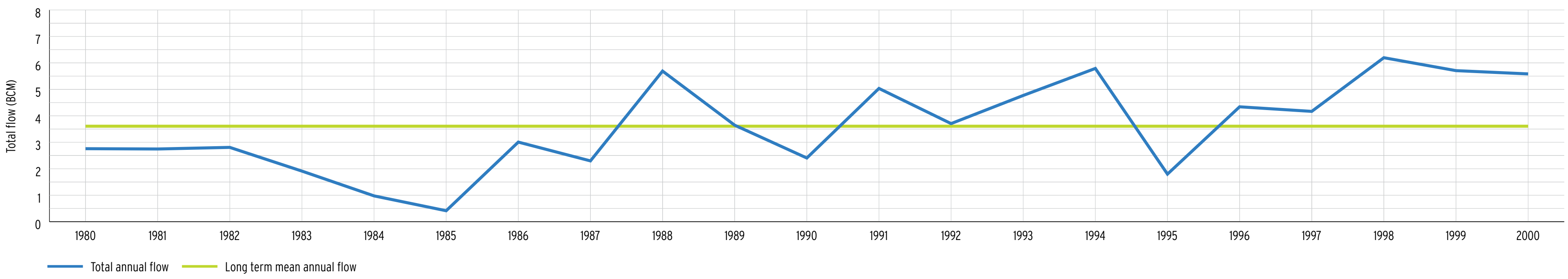
Lake T'ana, Bahir Dar, Ethiopia (NASA, International Space Station, 12/29/07)

The long term (1915 – 2014) average annual flow at Diem station is about 50 BCM. However, the annual flows of the Blue Nile show strong inter-annual variability. The 1980's have been particularly dry period. Known years of low flow are: 1978 (annual flow: 26 BCM), 1979 (38 BCM), 1982 (28.8 BCM) and 1984 (29.7 BCM). Years of high flows were: 1961 (63.8 BCM), 1964 (60.9 BCM), 1988 (63 BCM), 1998 (65.9 BCM), and 2014 (63.6 BCM). Due to these high fluctuations in the flow, any meaningful use of the river requires storage dams to regulate the flow and thereby provide reliable water supply.

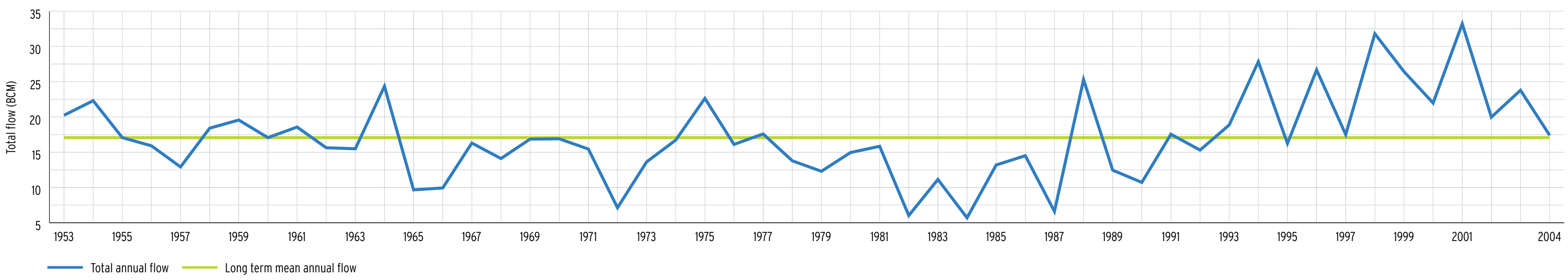
1 Annual flow volume - Khartoum



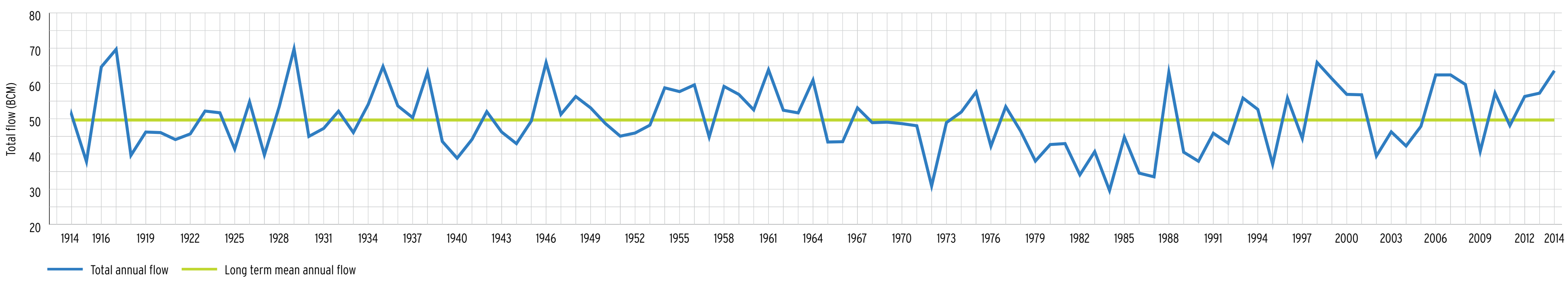
2 Annual flow volume - Bahir Dar



3 Annual flow volume - Kessie



3 Annual flow volume - Diem



White Nile Sub-basin


Photo: David Stanley/flickr.com

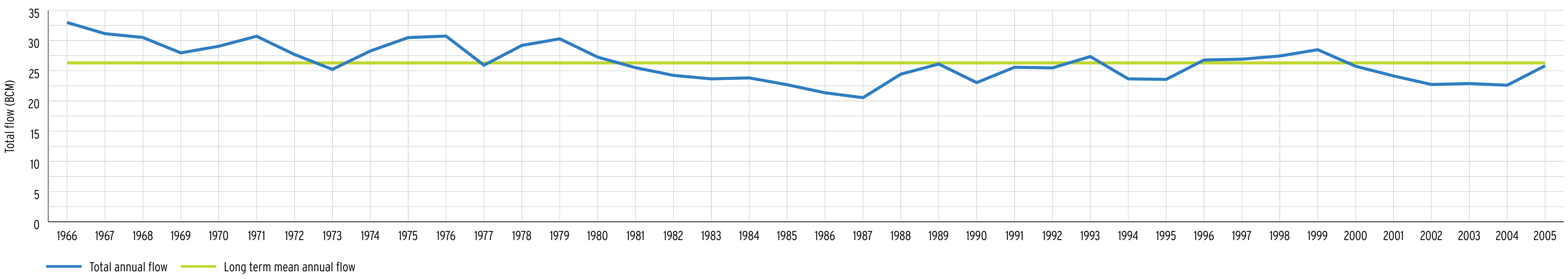
White Nile Bridge Khartoum


Photo: Arne Hoel/The World Bank

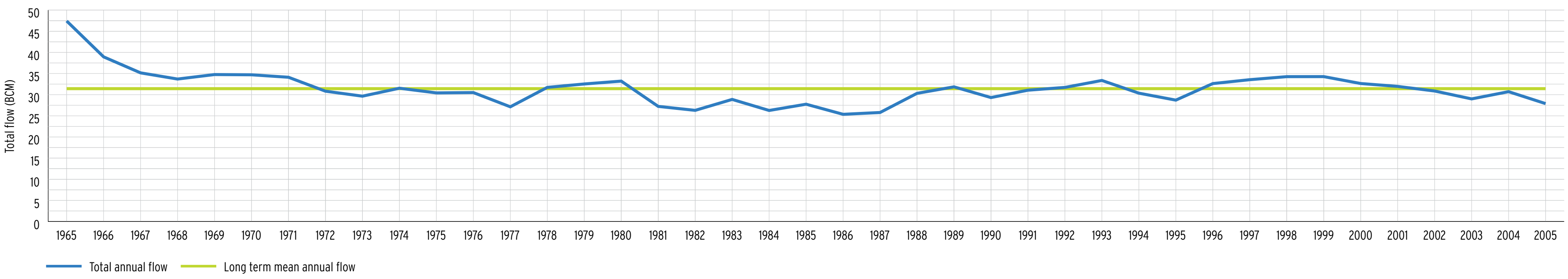
Sudan

The long-term average annual flow of the White Nile measured at Malakal is about 31 BCM. This value is reduced to about 26 BCM at Mogren in Khartoum. Major changes between Malakal and Mogren are the abstractions for irrigation and the evaporation from the Gebel Awlia dam, which is estimated to be approximately 2.25 BCM per year.

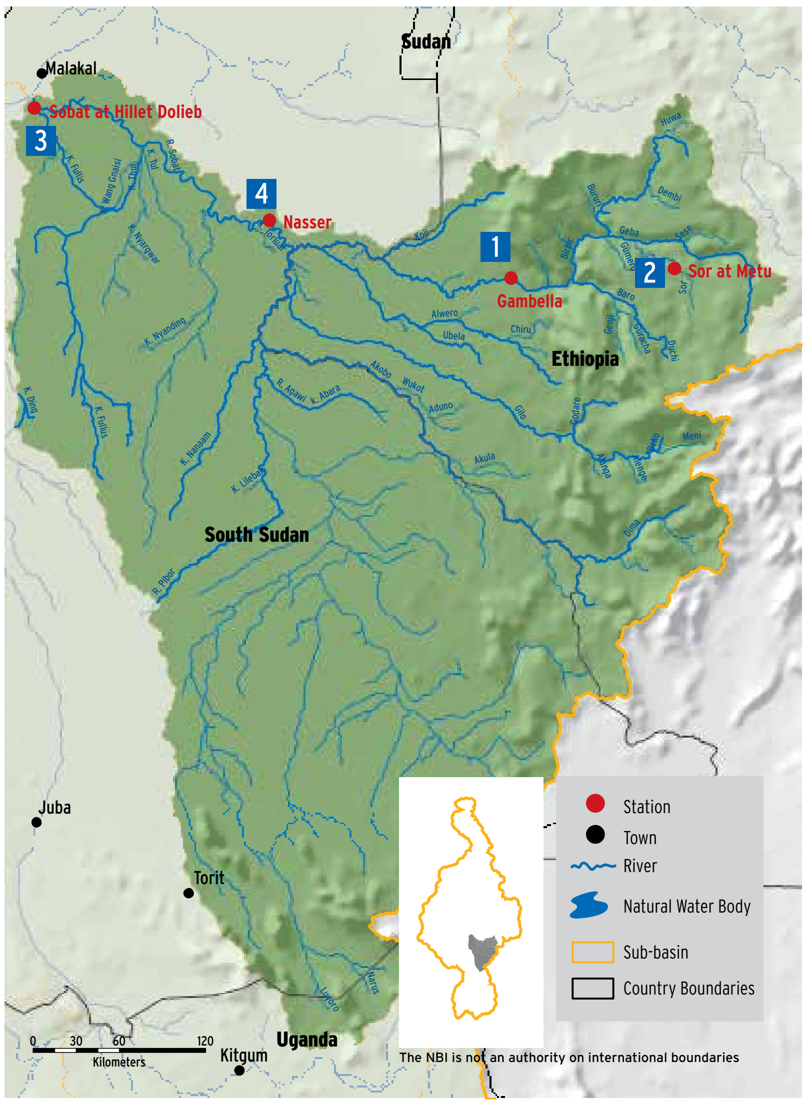
1 Annual flow volume - Jebel Aulia



2 Annual flow volume - Malakal



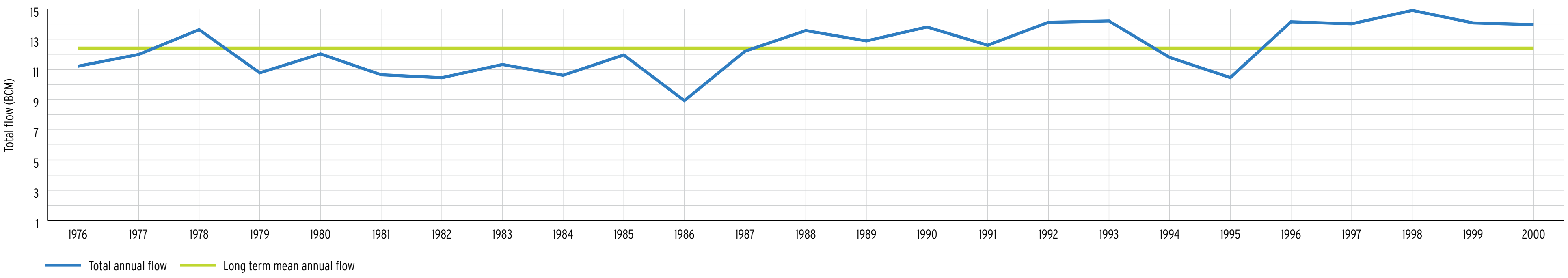
Baro Akobo Sobat Sub-basin



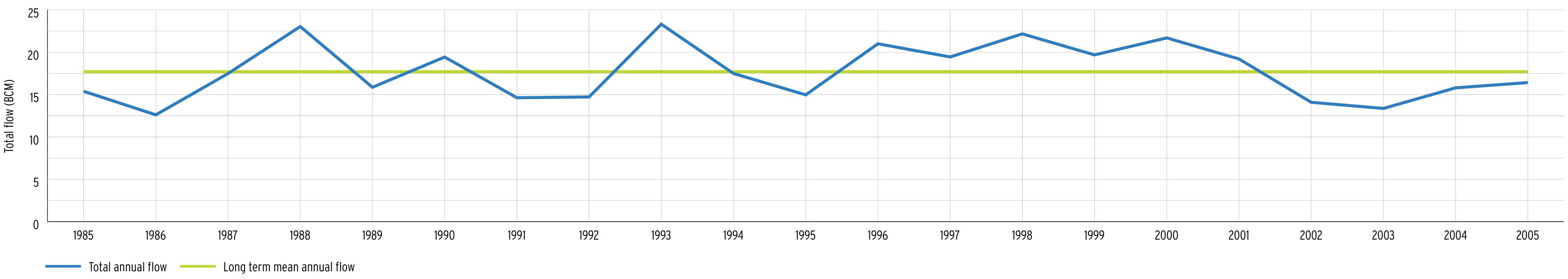
The Sobat River on the edge of Nasir, South Sudan

The long-term average annual flow of the White Nile measured at Malakal is about 31 BCM. This value is reduced to about 26 BCM at Mogren in Khartoum. Major changes between Malakal and Mogren are the abstractions for irrigation and the evaporation from the Gebel Awlia dam, which is estimated to be approximately 2.25 BCM per year.

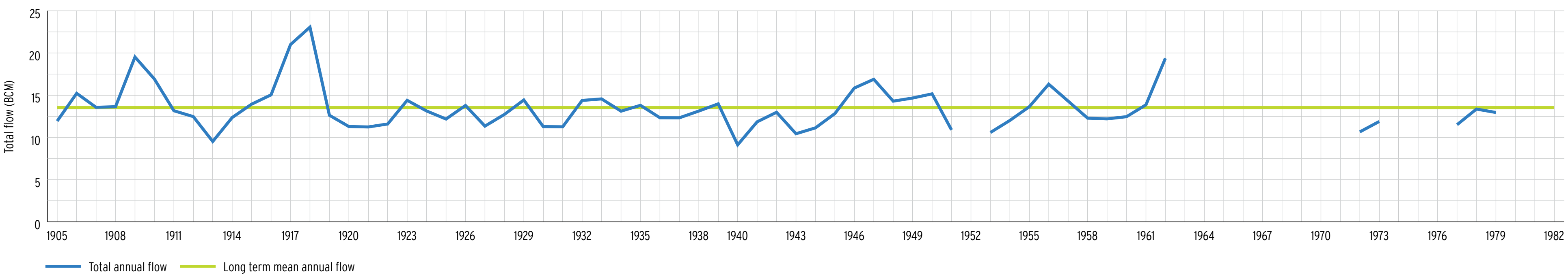
1 Annual flow volume - Gambela



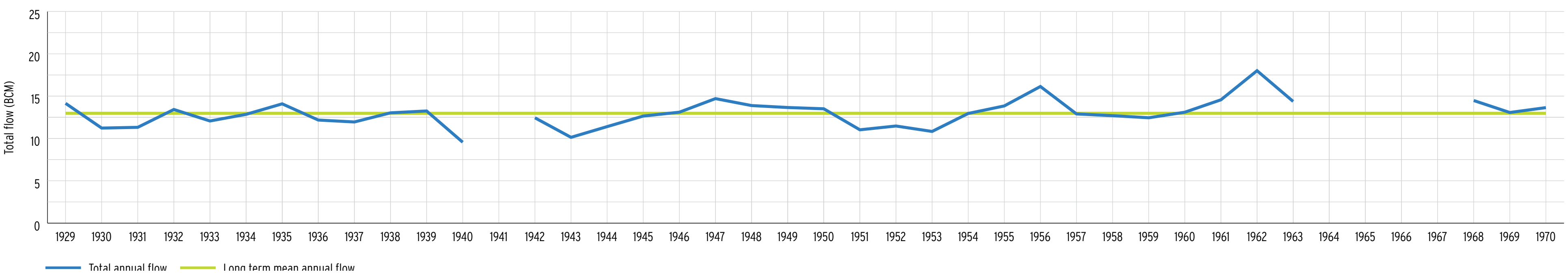
2 Annual flow volume - Sor near Metu



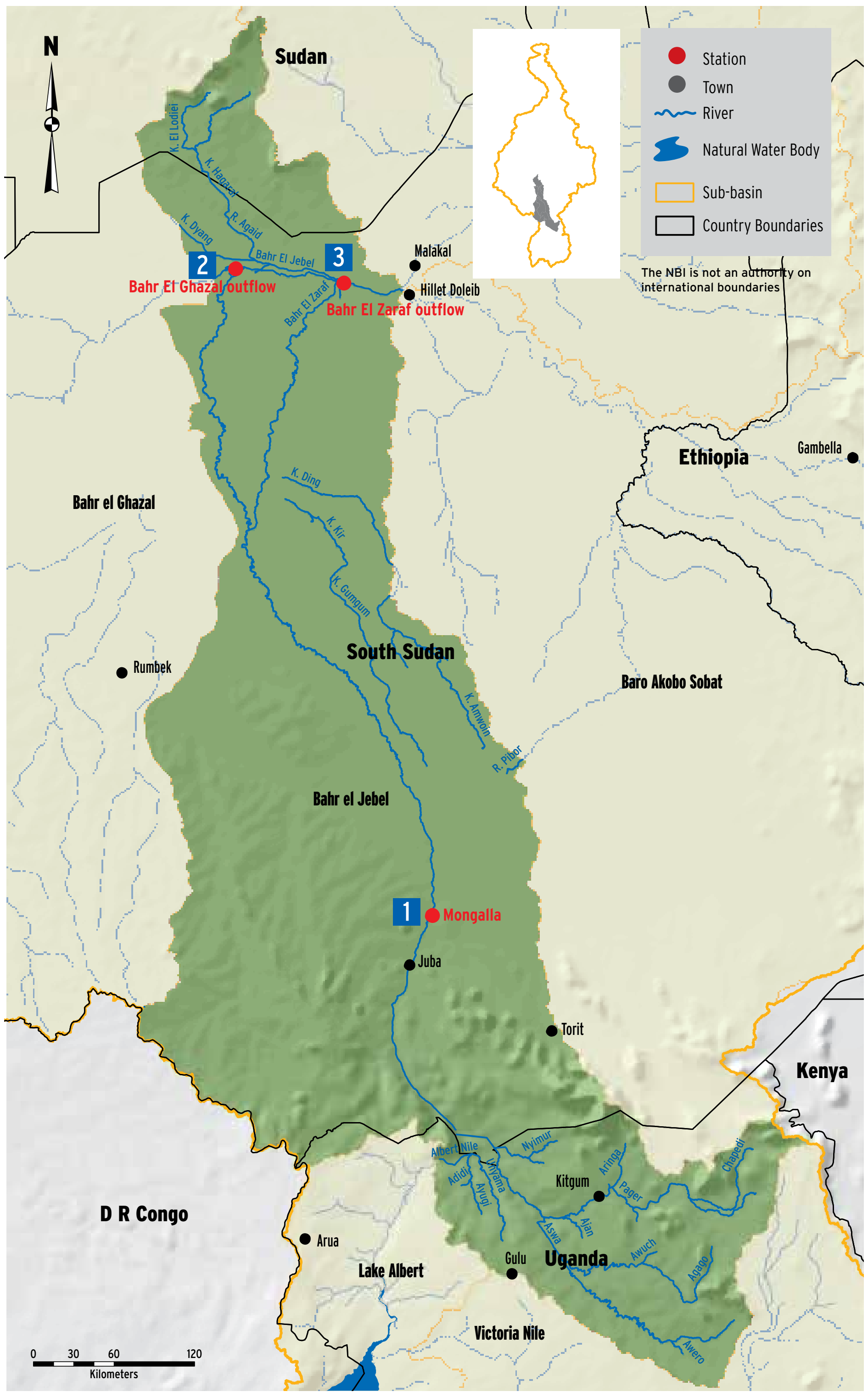
3 Annual flow volume - Sobat at Hillet Dolieb



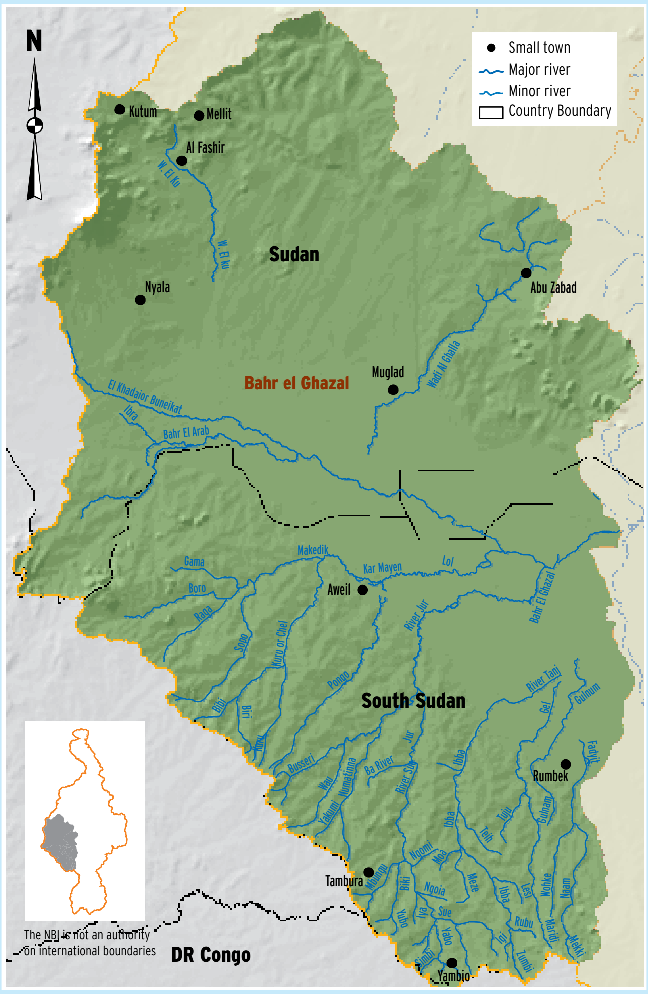
4 Annual flow volume - Nasser



Bahr el Jebel Sub-basin



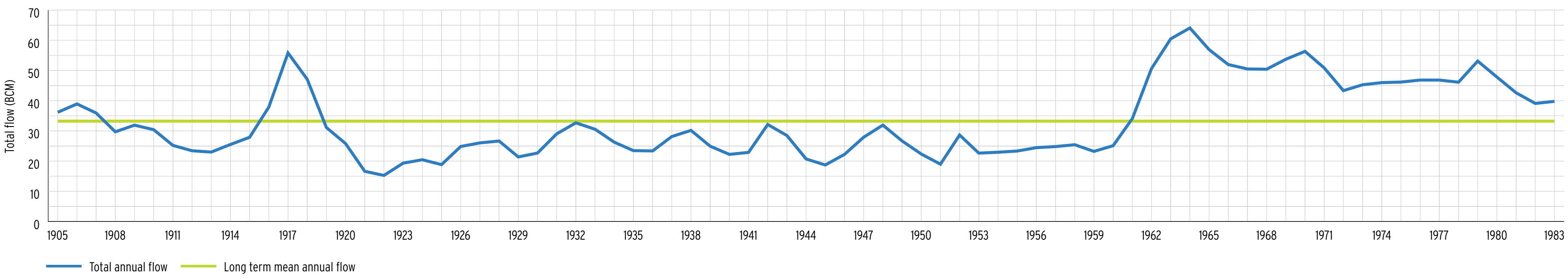
Bahr el Ghazal Sub-basin



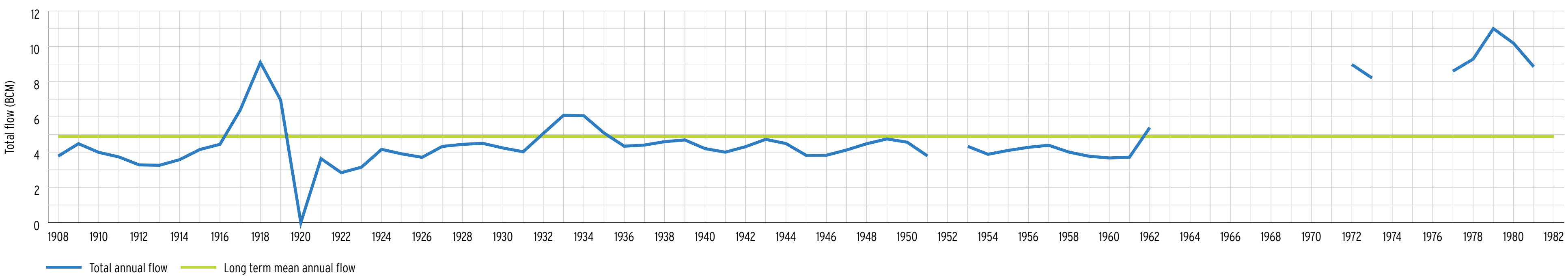
Bahr el Jebel and Bahr el Ghazal sub-basins are one of the least understood major sub-basins of the Nile and yet the existing hydro-met monitoring network is also very limited. The few available stream flow records exhibit substantial breaks and are of very poor quality.

This sub-basin is dominated by a system of wetlands that have substantial effect on river flow. The Sudd wetland, the second largest freshwater wetland in the world, is a major feature of this sub-basin. Nearly half of the river flow that enters the Sudd evaporates (or is transpired through plants). The mean annual flow at Mongala for the period 1905 – 1983 is estimated at 32 BCM. There is no flow measuring station at the outflow of Bahr el Jebel from the Sudd. However, estimates based on the flow of the White Nile at Malakal and the Sobat contribution (measured at Hillet Duleib) shows that the Sudd outflow is about 17 BCM.

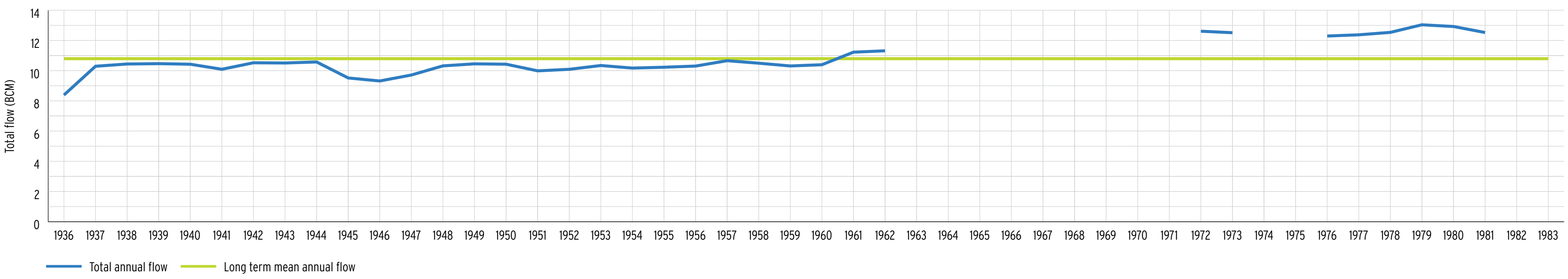
1 Annual flow volume - Mongalla



2 Annual flow volume - Bahr El Ghazal outflow



3 Annual flow volume - Bahr El Zaraf outflow



Lake Albert Sub-basin

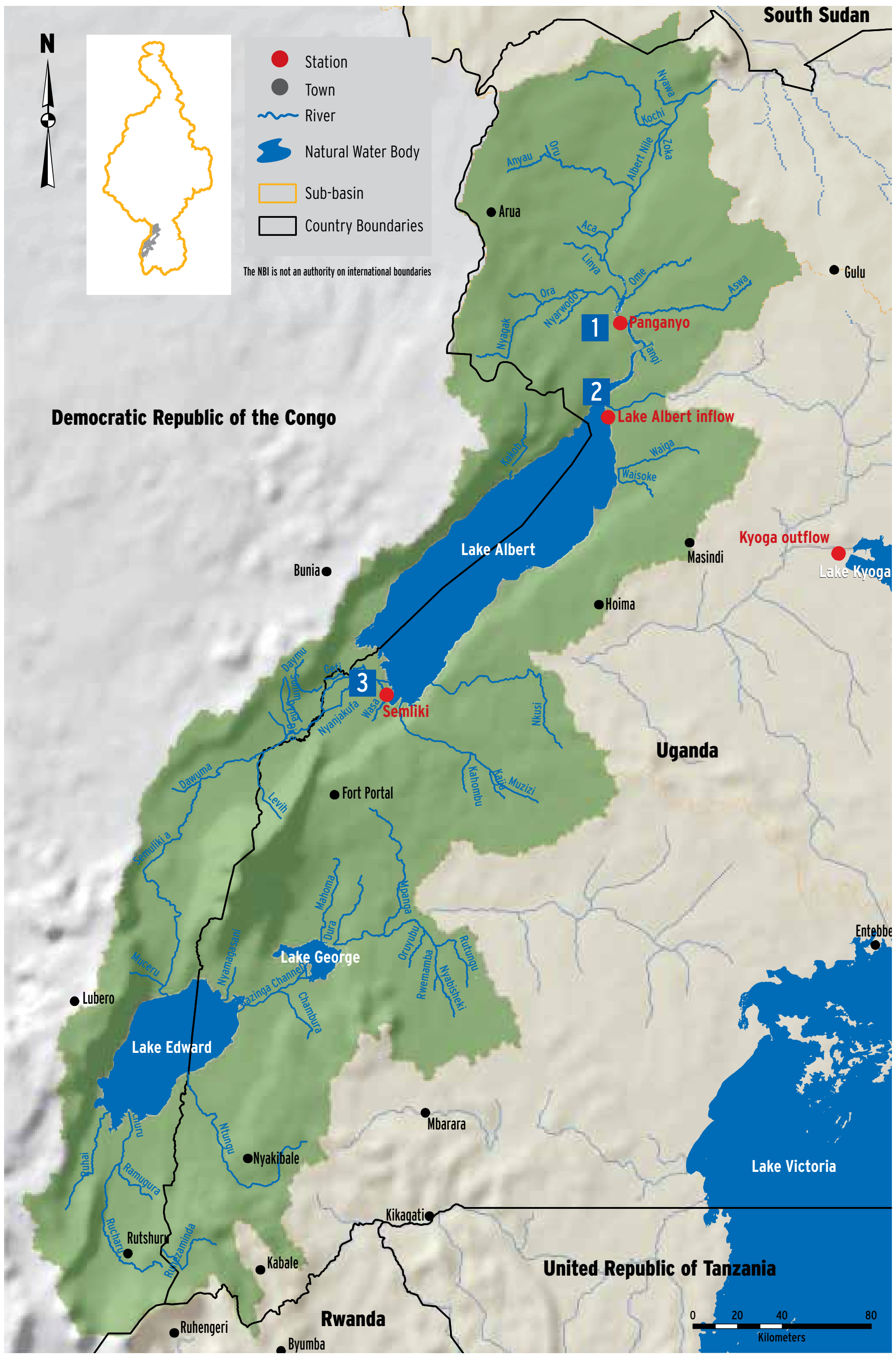



Photo: Vivek Bahukhandi

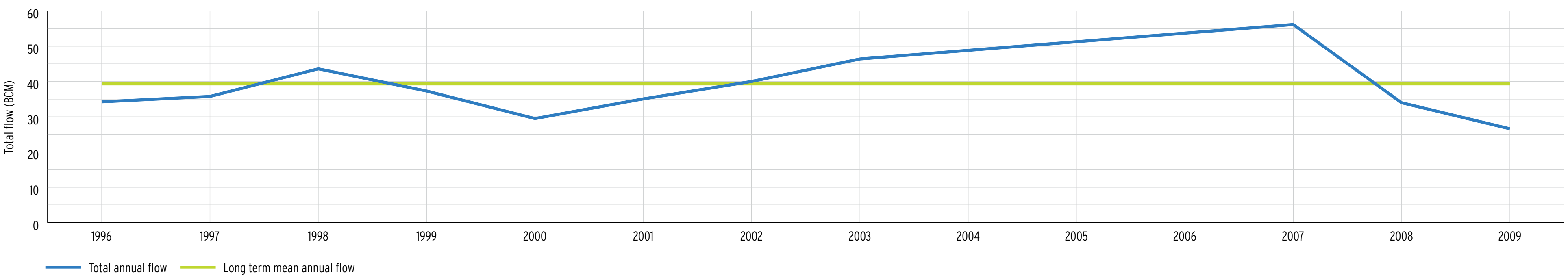
Ishasha River


Photo: Vivek Bahukhandi

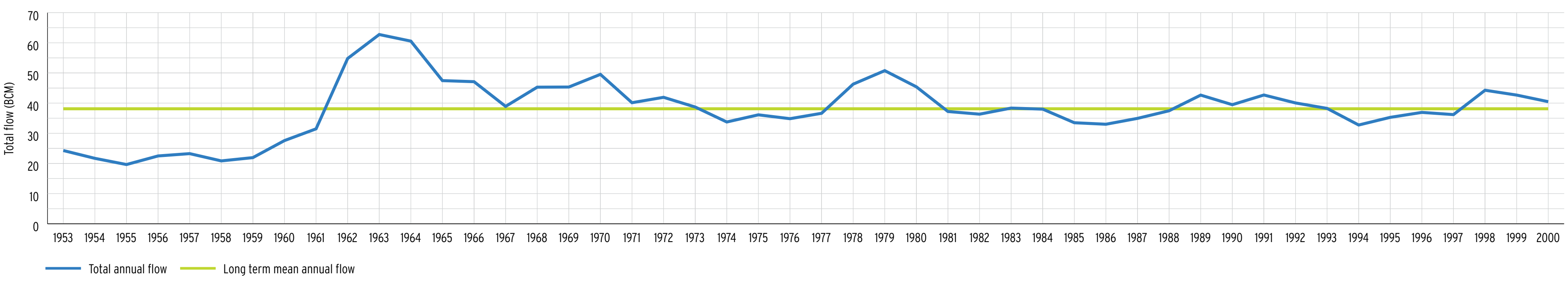
Virunga mountain range

The long term mean annual flow indicates an increment of about 2 BCM between the inflow and outflow of Lake Albert, which is mainly from the Lake Albert Sub-basin.

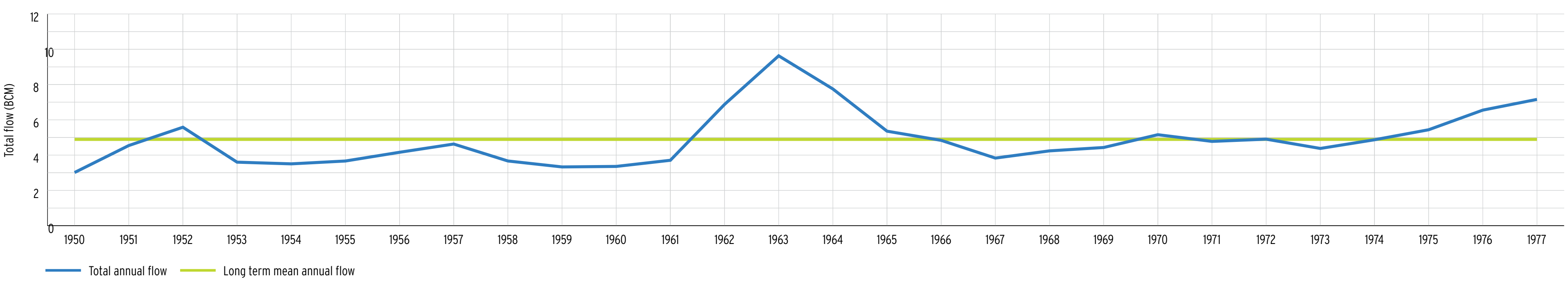
1 Annual flow volume - Panyango



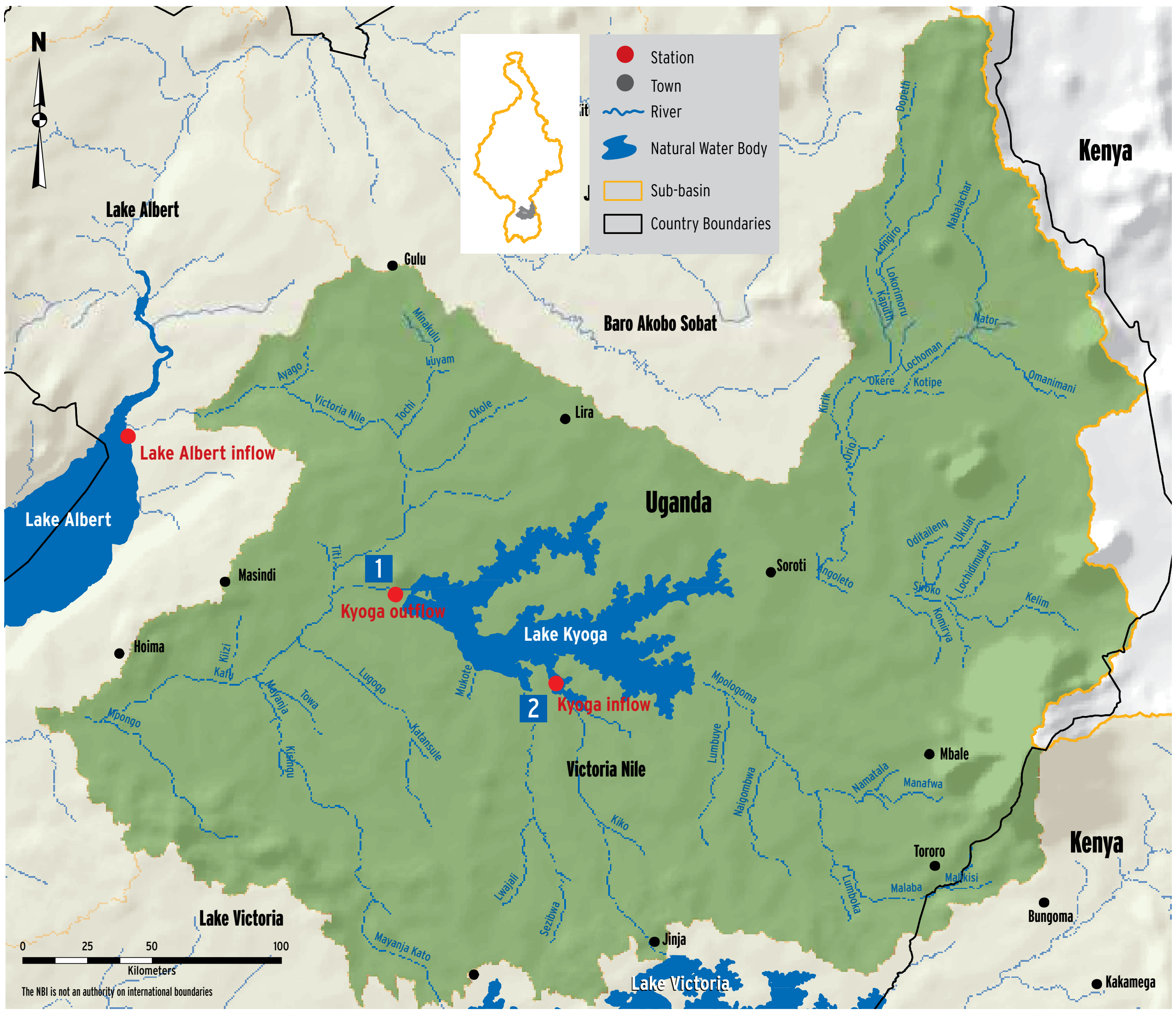
2 Annual flow volume - Albert inlet from Victoria Nile



2 Annual flow volume - Semliki



Victoria Nile Sub-basin

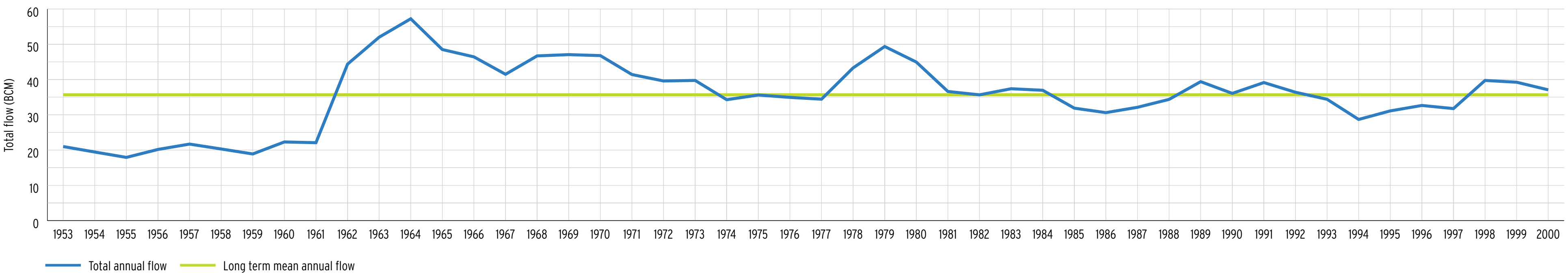



Sipi falls, Mount Elgon

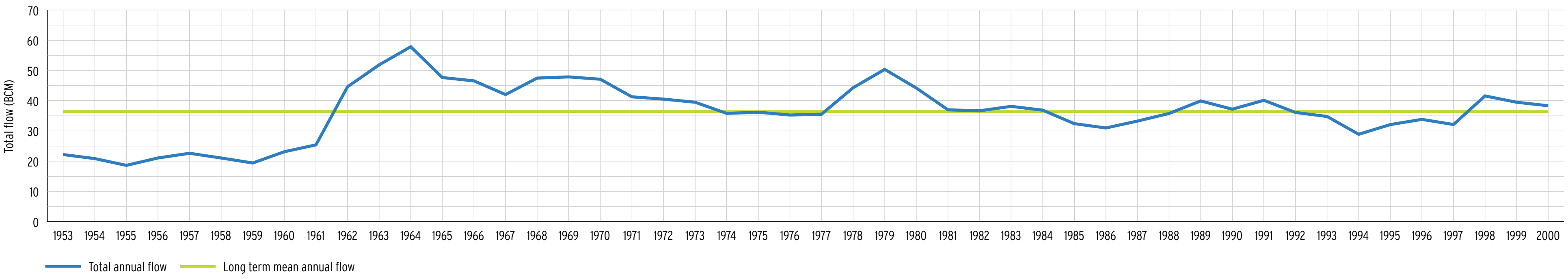
Photo: ©FAO/Matthias Mugisha

The annual flow pattern of the inflow into Lake Kyoga from the Victoria Nile and the outflow from the lake is similar with a small increment of about 0.68 BCM which could be flow from the other contributing upstream catchments of Lake Kyoga other than from the Victoria Nile

1 Annual flow volume - Kyoga outflow flow volume



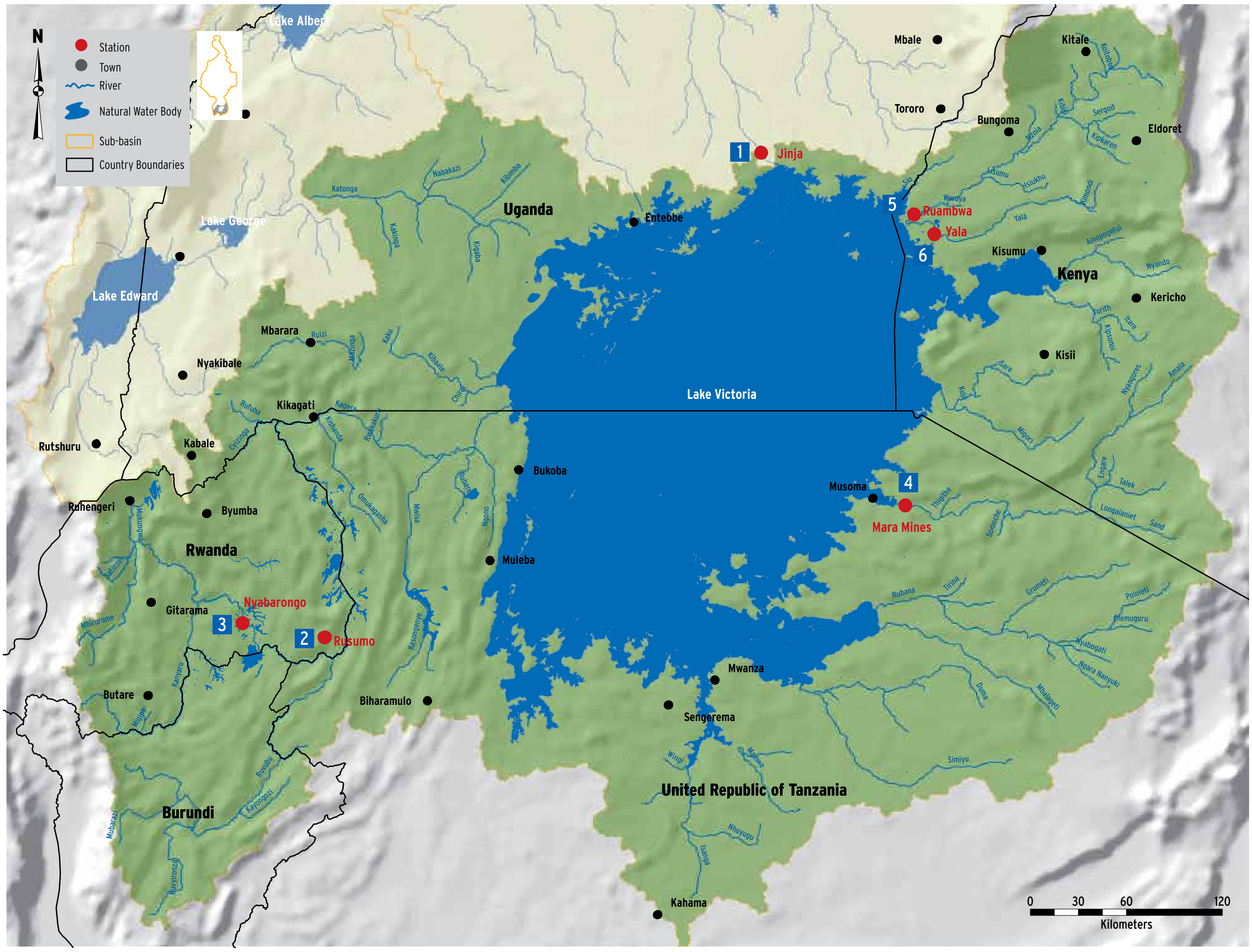
2 Annual flow volume - Kyoga inflow flow volume




Norera Damsite on Mara river in Kenya

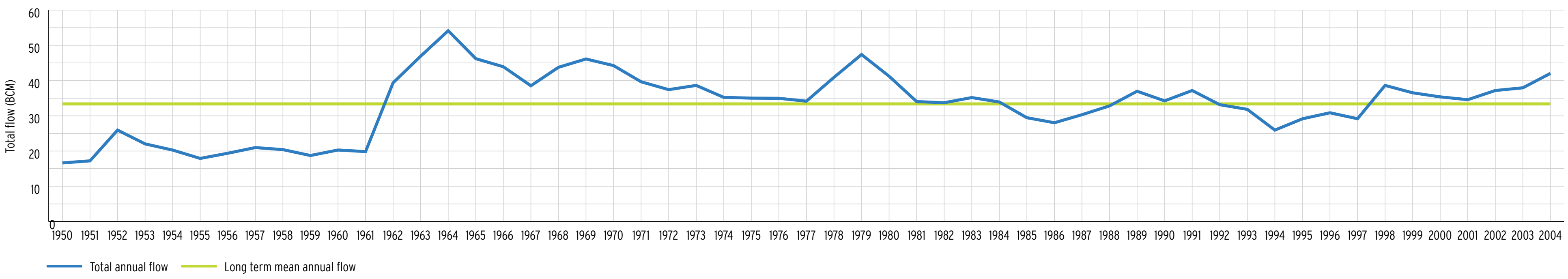
Photo: NBI

Lake Victoria Sub-basin

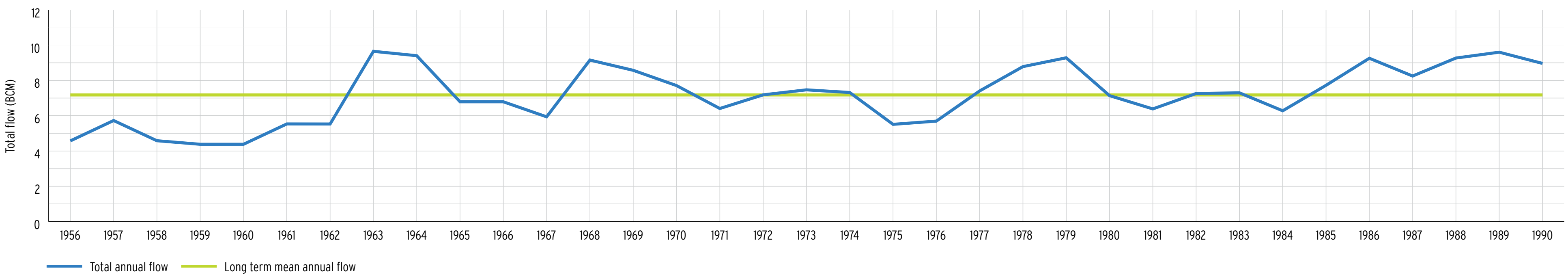


The Lake Victoria has many tributaries from the countries of Rwanda, Tanzania, Kenya, and Uganda with River Kagera as the main tributary. The lake which covers about a third of the basin area greatly influences the outflow due to storage and regulation with the average annual outflow of 33BCM. There is not much variation of the flow from the mean since there is high regulation of the lake. Rainfall and Evaporation over the lake plays an important role in the water balance of the lake and also has an impact on the outflow from the lake.

1 Annual flow volume - Jinja

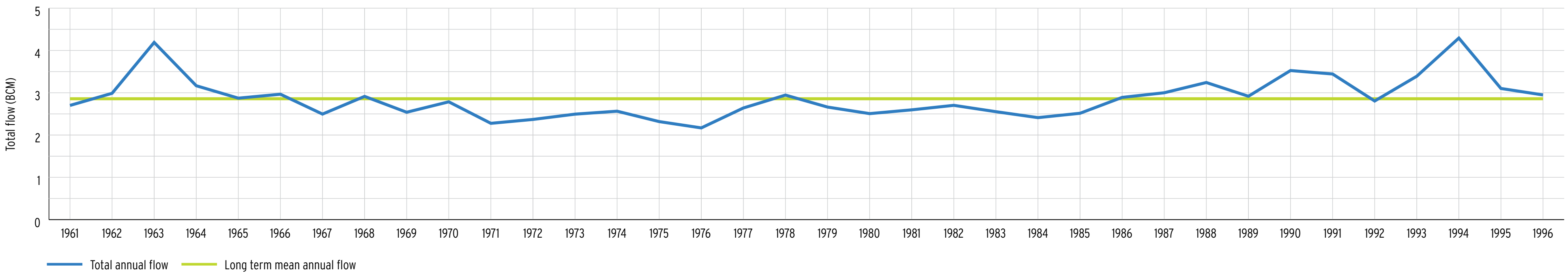


2 Annual flow volume - Rusumo

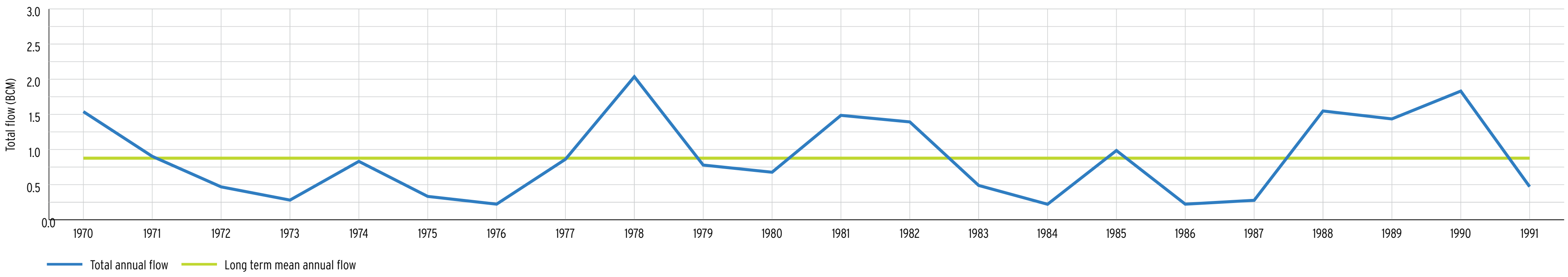


Jinja, Uganda

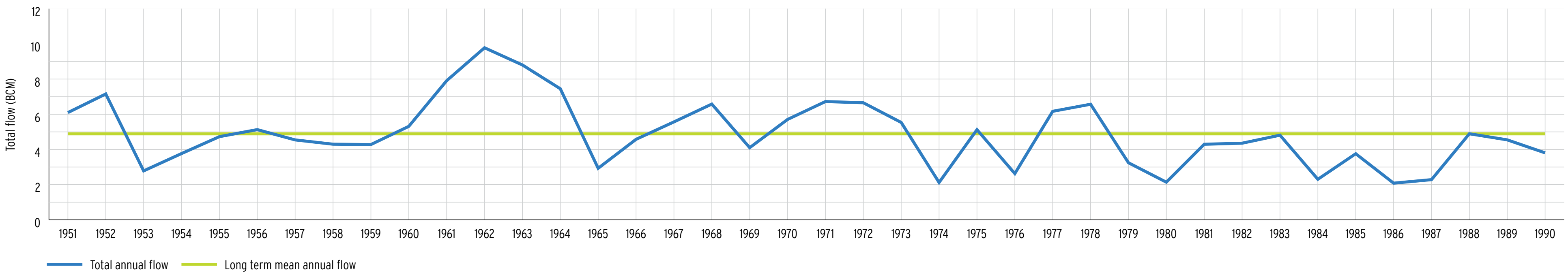
3 Annual flow volume - Nyabarongo



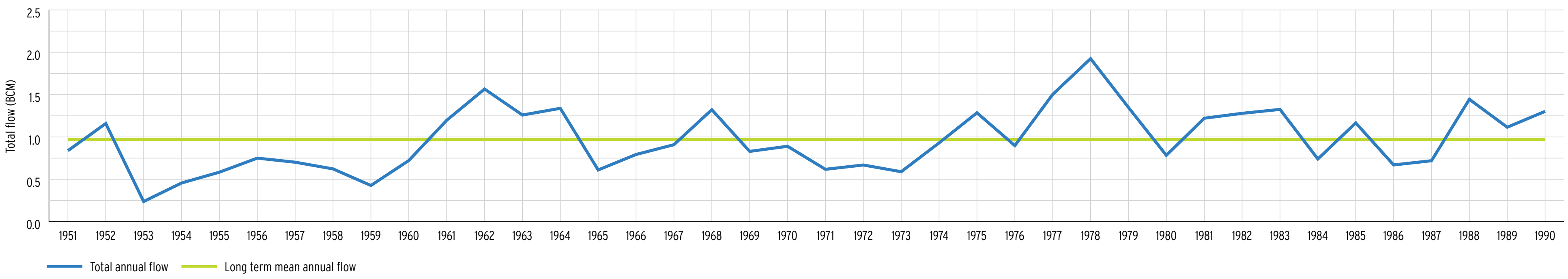
4 Annual flow volume - Mara Mines



5 Annual flow volume - Rwambwa



6 Annual flow volume - Yala



NILE LAKES AND WATER FLOW REGULATION

Storage and retention of water in the various lakes and wetlands in the Nile basin are of particular importance as they regulate and dampen the flows which results in an important role for local rainfalls as well as evaporation resulting in large water losses. The River Nile basin has numerous lakes, and water bodies, including some of the biggest freshwater lakes and man-made reservoirs in the world. Although the total area of open water in the Nile basin is vast, about 90 000 km², it represents less than 3% of the basin's total area (NIS 2013). The major lakes of the basin are found in the equatorial region, apart from Lake Tana which is to be found in the Ethiopian highlands. A summary of the Key characteristics of the Lakes is shown in the table.


Photo: Vivek Bahukhandi

Lake Victoria at Jinja, Uganda

Key facts about the major lakes in the Nile basin

Lake	Surface Area (km²)	Volume (km³)	Maximum depth (m)	Mean Depth (m)	Shoreline length (m)	catchment Area (km²)	Altitude (m)	Country location
Tana	3600	28	14	9	385	10000	1788	Ethiopia
Edward	2200	39.2	112	17		12000	912	Uganda, DRC
Albert	5300			58		17000	615	Uganda, DRC
George	250	0.8	4.5	2.4		9705	914	Uganda
Kyoga	1720		5.7			75000		Uganda
Victoria	68800	2750	84	40	3440	184000	1134	Uganda, Kenya, Tanzania

Lake Victoria

Lake Victoria, the largest lake in the Nile basin, is shared by Kenya, Uganda and the Tanzania; although Burundi and Rwanda are also part of its catchment area which covers 184 000 km² (ILEC 1999). Annual average rainfall on the lake is 1 500 mm, which represents about 85 per cent of the water entering the lake; the balance comes from the rivers that drain the catchment. The annual evaporation rate from the lake surface is about 1 260 mm (Fahmy 2006). The main outlet for Lake Victoria is the White Nile at Jinja linking to Lake Kyoga.

Lake Albert

Lake Albert lies along the shared border of Uganda and the DRC. It is about 160 km long and 30 km wide, with a maximum depth of 58 m and a surface elevation of 615 masl (ILEC 1999). Evaporation over the lake is estimated at 1 200 mm per annum and rainfall is 710 mm (Fahmy 2006).

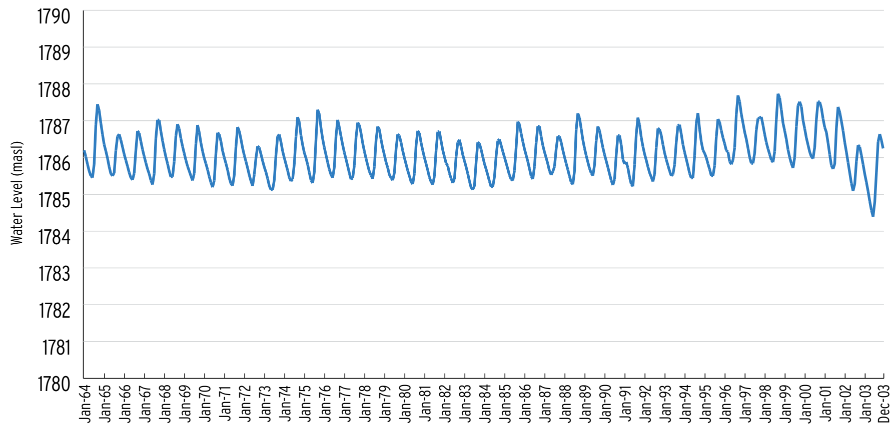
Lake George and Lake Edward

Lake George has a surface area of 250 km² and a catchment area of 9 705 km². Lake Edward has a surface area of 2 325 km² and its catchment's basin area is 12 906 km² (ILEC 1999). Lake George empties into Lake Edward via the Kazinga Channel. Queen Elizabeth National Park in Uganda extends from the eastern shores of Lake George and together with the adjacent Virunga National Park in the DRC completely surrounds Lake Edward. River Semliki receives flows from these two lakes and with runoff from its own catchment sends about 4 BCM of water to Lake Albert every year (Fahmy 2006).

Lake Tana

Lake Tana, found in the Amhara region in the north-western Ethiopian highlands, is the largest freshwater lake in Ethiopia. It is sited in a wide depression and has a surface area ranging between 3 000 and 3 600 km² depending on the season. It is about 84 km in length and 66 km wide, with a maximum depth of 14 m and an elevation of 1 788 m (Wale 2008, ILEC 1999). Lake Tana is fed by four main rivers: the Gilgel Abay, Ribb, Gumara and Magech; and discharges at Bahir Dar through the Blue Nile. The four inflowing rivers contribute 93 per cent of the lake's inflow (Anbah and Siccardi 1991). The average flow from Lake Tana was estimated at 3.8 BCM/year swelling to 54 BCM by the time it reaches Khartoum as a result of contributions from the Rivers Dinder and Rahed (Fahmy 2006).

Lake Tana WS Elevation



Inter-annual flow variability

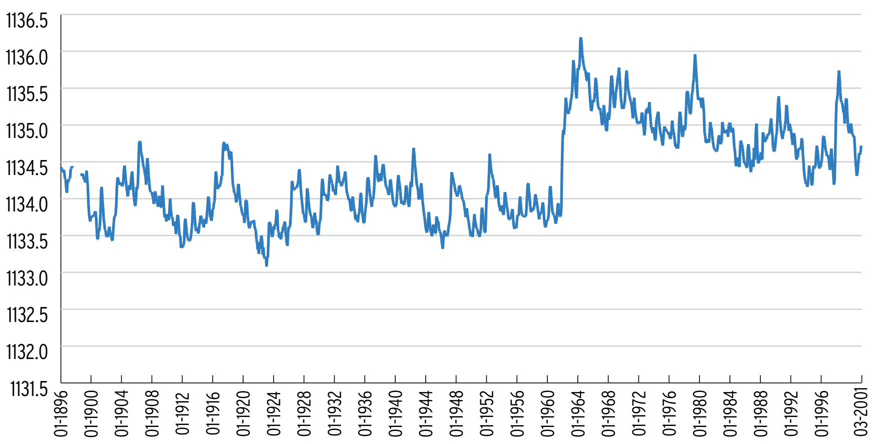
Over the last decades, the Nile Equatorial Lakes water system has experienced important inter-annual variability with sudden changes (rise or drop of water levels and flows) which would persist for some years because of storage. Regulation of Lake Victoria's outflow at Jinja, Uganda, has a clear effect on the lake's water levels (Sutcliffe and Petersen 2007) and less direct impacts on many of the lake's other ecosystem functions. These effects are also experienced by Tanzania and Kenya, who share the lake with Uganda, and to a lesser extent by all of the downstream countries in the basin.

Regulation of Lake Victoria

The quantity of water released from Lake Victoria through the Nalubale/Kiira power plants is constrained by an international

Observed water levels and discharge from the Lake Victoria from 1895 to 1998

Lake Victoria Elevation=Jinja+1122.86



Lake Victoria outflow (MCM)

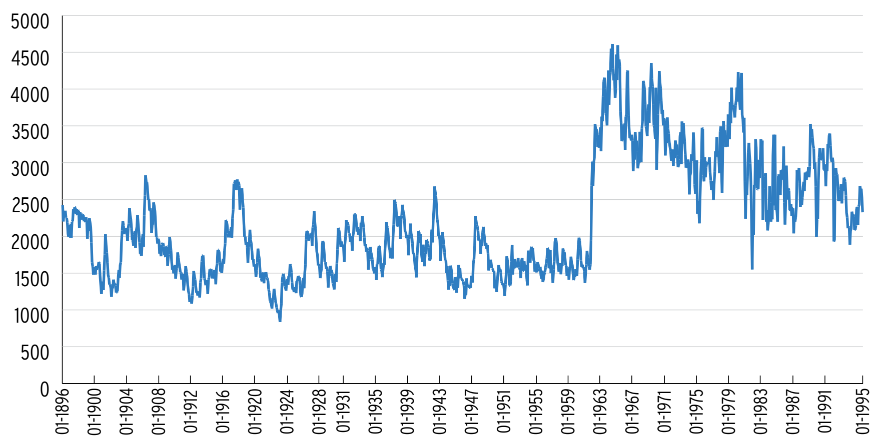


Photo: Vivek Bahukhandi

Swamps at Queen Elisabeth National park in Uganda

treaty which stipulates that the outflow should simulate the natural flow of the Victoria Nile, based on a ten-day average flow, as a function of lake level. This so-called 'agreed curve' safeguards the environmental integrity of the lake and guarantees water supplies to downstream users. However, a more flexible interpretation of the agreed curve - e.g. annual releases that follow the annual agreed curve release volumes - might make it possible to increase power production without serious impacts on the lake or the river downstream

The Agreed Curve allows for a release of 693 m^3/s at a gauge level of 1,134 m while the discharge would increase to 2,400 m^3/s at a gauge level of 1,137 m. The installed generation capacity of the two plants at Jinja (387 MW) cannot be achieved until a level of 1,137 m is reached. Levels above 1,137 m should be avoided since this could damage the dam and power plants, while technical considerations related to cavitation restrict operations at the Kiira facility when the lake level falls below 1,134 m. The effective range of lake level fluctuation for power production is therefore around 3 m. Because greater volumes can be released and more power generated when lake levels are high it is important to keep the lake level as high as possible and avoid a drawdown to low levels .

Recent investigations have found dramatic and sometimes rapid changes in the lake's level over the past two centuries (Sutcliffe and Peterson 2007, Nicholson and Yin 2000). The level of Lake Victoria remained fairly stable around 1,134 m up to 1960 but it rose rapidly thereafter to reach 1,136 m in the mid-1960s. Since then the level of the lake gradually declined, but heavy rains during the 1997 El Niño raised the level by more than 1 m, followed by a sudden drop around 2004. The lake level rise in the early 1960s was a result of abnormally heavy rains; in the last six months of 1961, 2323 mm of rain were recorded, nearly 100% higher than its average value. Very high rainfall was recorded during the first six months of 1962 (1884 mm/year, about 50-60% above average), and 1963 (1739 mm), and 1964 (1739 mm). As a result the lake rose by 2.5 m during those years.

The fall in lake level in the first decade of the 21 century was the result of poor rains and excessive releases of water at Owen Falls. After this sudden rise that changed the base flow downstream of the lake for years, the flows decreased steadily with gradually falling lake levels until in 2005, caused probably by over-release from the Nalubaale/Kiira dam hydropower stations, the lake levels dropped considerably leading to a now decreased flow after the increased flows that resulted from the increased hydropower operation. During these hydrological changes Lake Victoria as well as the consecutive lakes and swamps have functioned as a buffer so that the strong changes in upstream hydrological regime have less impact downstream.

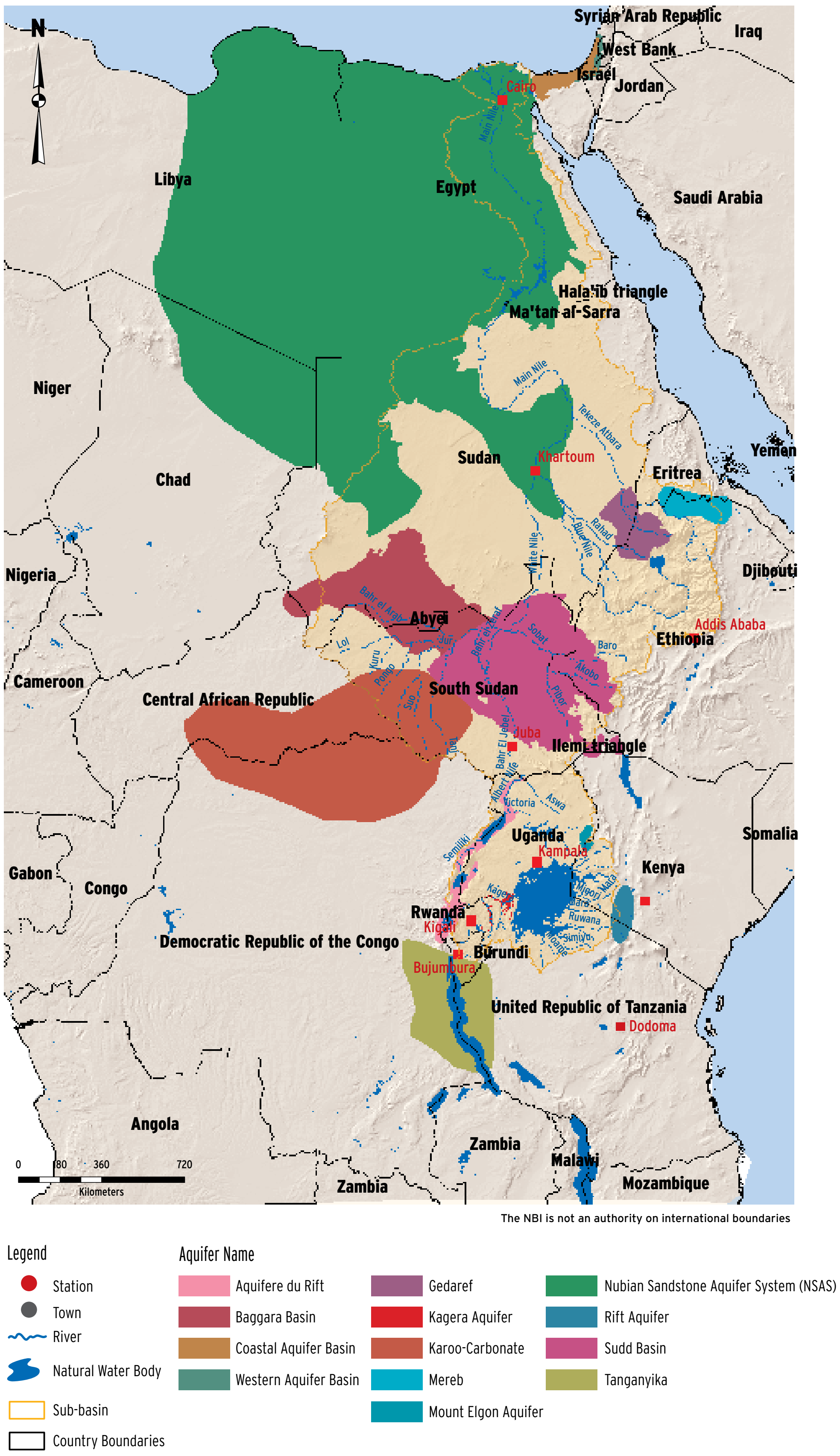
The basic determinants of Lake Victoria's water regime, direct rainfall on the lake and evaporation, are difficult to measure and not yet fully understood. The average difference between rainfall and evaporation over its 69,000 km^2 surface area is quite narrow, and its hydrological regime is therefore very sensitive to changes in climate. This is demonstrated by the considerable fluctuation in net basin supply. The water balance of the lake is also affected by inflow from the basin and irrigation developments could reduce this inflow and contribute to falling lake levels.

Assumptions about future water levels are necessary in planning Nile dams and their current and future operation. The future viability of hydropower from the Victoria Nile is generally as uncertain and variable as the climate. The lake's water level may also affect other ecosystem services, such as fisheries, wetlands, invasive species, water quality (Kiwango and Wolanski 2008) and malarial mosquito habitat (Minakawa and others 2008).

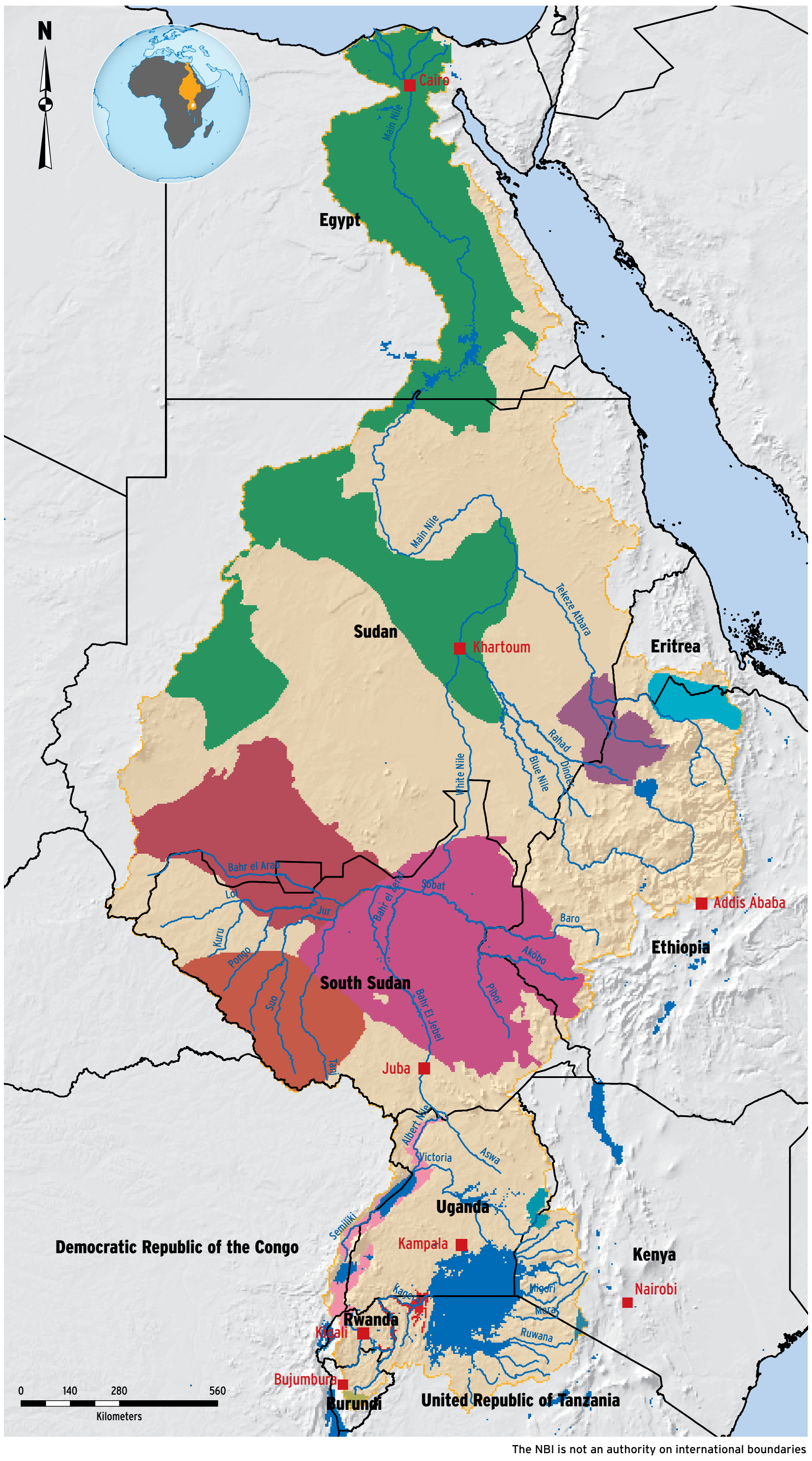
GROUNDWATER IN THE NILE BASIN

Basin ground water has not been adequately studied and so, information in this area is still scanty. An inventory of trans-boundary aquifers was obtained from International Groundwater Resources Assessment Centre (IGRAC), an organization which facilitates and promotes international sharing of information and knowledge required for sustainable groundwater resources development and management worldwide. The layer provided by IGRAC, identifies twelve (12) trans-boundary aquifers within the Nile basin, the largest being the Nubian Sandstone Aquifer System covering an area of about 567,344 Km² in the Nile basin.

Extents of transboundary aquifers shared in the Nile Basin



Transboundary aquifers in the Nile Basin



FID	Aquifer Name	Countries	Total Aquifer Area (Km²)	Aquifer Area in the Nile Basin (Km²)	% area within Nile Basin
1	Mount Elgon Aquifer	Uganda, Kenya	5,398.32	4,579.49	85%
2	Gedaref	Ethiopia, Sudan	57,830.51	51,369.10	89%
3	Mereb	Ethiopia, Eritrea	38,752.68	27,210.24	70%
4	Rift Aquifer	Kenya, Tanzania	21,145.08	1,780.24	8%
5	Kagera Aquifer	Tanzania, Rwanda, Uganda	5,778.95	5,218.10	90%
6	Baggara Basin	Central African Republic, South Sudan, Sudan	239,876.71	196,127.11	82%
7	Coastal Aquifer Basin	Egypt, Israel, Palestinian Territory	23,338.14	11.72521552	0%
8	Karoo-Carbonate	Central African Republic, Congo, South Sudan	604,596.15	120,947.00	20%
9	Tanganyika	Burundi, Democratic Republic of the Congo, Tanzania	184,594.89	2,279.49	1%
10	Nubian Sandstone Aquifer System (NSAS)	Chad, Egypt, Libya, Sudan	2,892,867.48	567,344.75	20%
11	Aquifere du Rift	Democratic Republic of the Congo, South Sudan, Uganda	44,632.12	30,023.07	67%
12	Sudd Basin	Ethiopia, Kenya, South Sudan	370,647.62	324,287.18	87%

Agricultural runoff, industrial waste and untreated municipal and domestic waste have led to seriously degraded water quality in Lake Victoria over the past few decades (Scheren and others 2000, USAID 2009). While industrial waste is generally confined to urban areas (Kampala, Mwanza, and Kisumu among others), untreated sewage and agricultural runoff occur all along the heavily populated shoreline. Phosphorous, and to a lesser extent nitrogen from untreated waste, put excessive nutrients into the water driving algae blooms and contributing to the water-hyacinth invasion seen in the mid-1990s (Scheren and others 2000, Williams and others 2005, Albright and others 2004).

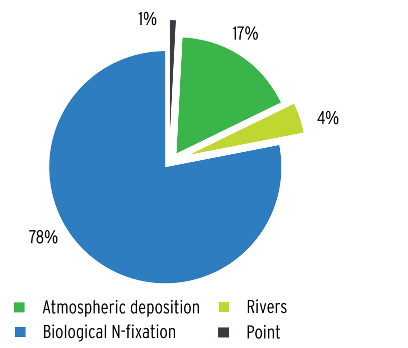
In addition, accelerated erosion from deforestation and agricultural conversion of natural areas has led to greatly increased sediment loads being carried into the lake (Machiwa 2003).

As the river flows through Sudan it also picks up substantial non-point source agricultural and urban runoff (NBI 2005a). While water quality has generally been found to be within World Health Organization standards (NBI 2005a) there are some localised high chemical pollution concentrations especially in the Khartoum area (NBI 2005a). In Egypt, water quality is under pressure from intense population and accompanying agricultural and industrial activity concentrated along the banks of the Nile. In Upper Egypt, this comes primarily from agro-industries particularly sugar cane (NBI 2005b,Wahaab 2004). Downstream, where populations are more concentrated, a wide range of industrial pollution and wastewater enter the river from Cairo and Lower Egypt's other urban centres (NBI 2005b, Wahaab 2004). While Egypt has made significant eff orts to construct additional wastewater treatment capacity, population growth has outstripped capacity and considerable domestic wastewater enters the Nile with no treatment (NBI 2005b). Intense agriculture and some mixing of industrial and domestic wastewater in irrigation-drainage canals make a source of multiple contaminants in Lower Egypt (NBI 2005b).

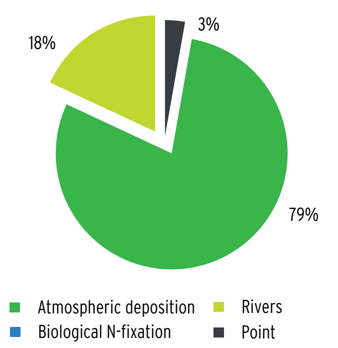
The annual increase in Lake TN is estimated using a TN: TP ratio for the current lake and assuming it applied in 1960.

Source	TN (t/y)	TP (t/y)
External loading	967700	50920
Annual Increase in Lake (1960-2000)	30360	2760
Permanent Burial	107000	24000
Outflow through Nile	56200	3410
Balance	774140	20750

Relative magnitude of loading sources to Lake Victoria % Nitrogen



Relative magnitude of loading sources to Lake Victoria % Total Phosphorus



Relative Magnitude of Loading Sources to Lake Victoria

It has been recognized by most of the scientific community that Lake Victoria is enriched with nutrients. There are, however, conflicting reports on the magnitude of nutrients received from different sources and the dynamics of nutrients in the Lake. Lake nutrient balance is essential for understanding primary productivity and ecosystem function and for planning nutrient management strategies. The Water quality and Ecosystems study under LVEMP I identifies major point and non-point sources of nutrients and estimated the rates of sedimentation into Lake Victoria. The determination of pollution loads from point sources was limited to the Biochemical Oxygen Demand (BOD5), Total-Nitrogen (TN), and Total-Phosphorus (TP). For the non-point pollution sources emphasis is given to Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS), the loads from rivers and atmospheric deposition are also estimated both due to their relevance as quality indicators and their contribution to eutrophication of the Lake. For the purpose of determining the nutrient balance of the lake, the sedimentation rates in the lake are also calculated as both fluxes per unit area and total lake bottom accumulation.

The annual increase in lake TN is estimated using a TN: TP ratio for the current lake and assuming it applied in 1960.

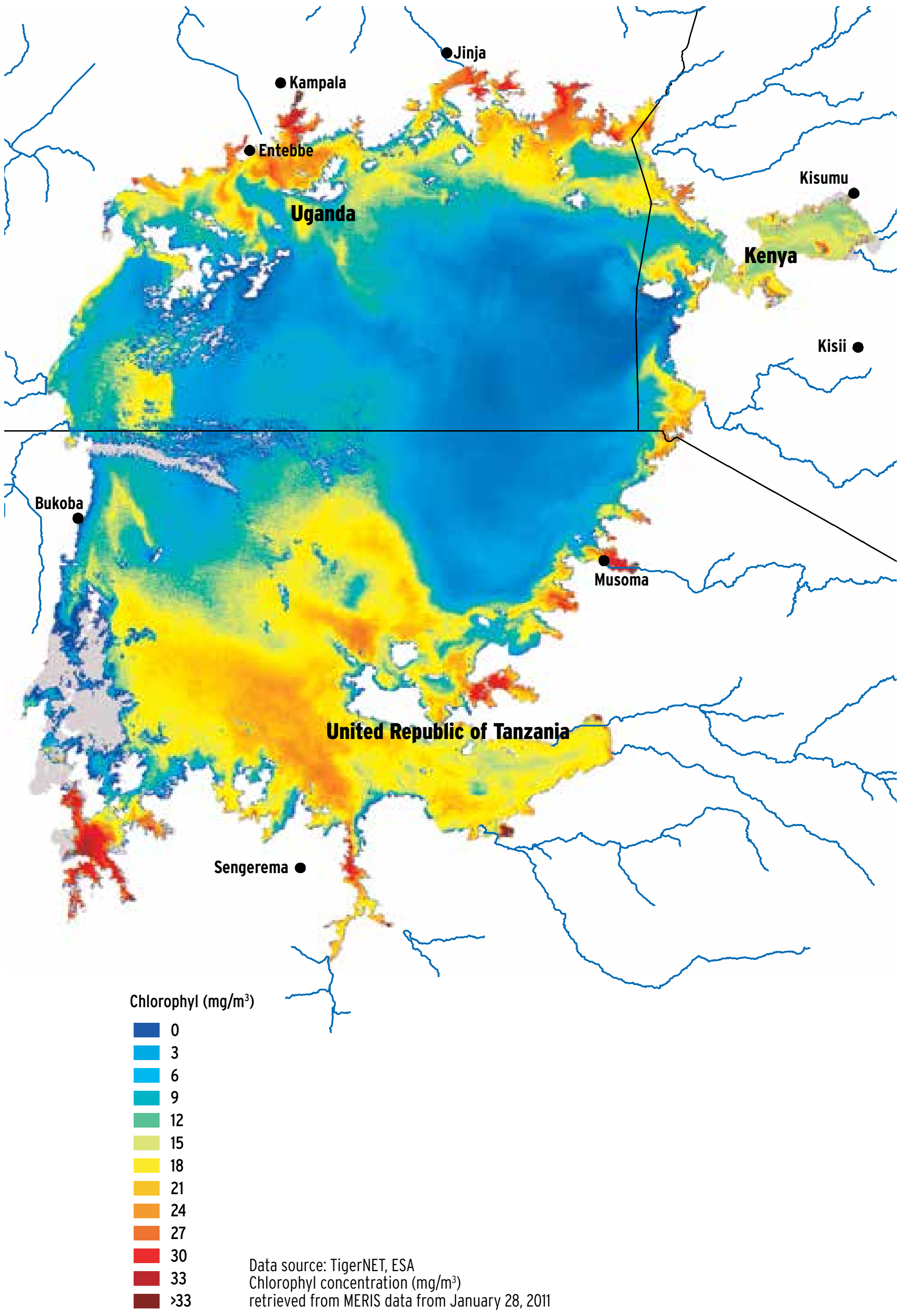
Variability in Lake Victoria river yields and chemical composition

The river basins have different physiographic characteristics such as altitude, rainfall, basin slope, vegetation cover, soils, and runoff coefficients that impose different yields of nutrients and sediments even under natural conditions. Agricultural use can alter those physical characteristics as well as add nitrogen and phosphorus as fertilizers and accelerate soil erosion. The resulting differences among the catchments in yields and composition of loads can be appreciated from the graph below which gives the yields per unit area of catchment and the ratios between the TN, TP and TSS yields which normalize the annual loads by the catchment area of the rivers

Summary of yields of sediments (TSS), TN and TP and ratios of TN to TP and the nutrients to sediment yields for the tributary rivers in the Lake Victoria Basin

River	Area Km^2	Discharge (m^3/s)	TSS ($t/km^2/y$)	TN ($kg/Km^2/y$)	TP ($Kg/Km^2/y$)	TN:TSS (Kg/Ton)	TP:TSS (kg/ton)	TN:TP (w/w)
Tanzania								
Kagera	59682	279.5	21.5	274	38	12.8	1.8	7.2
Mara	13393	41.7	22	123	17	5.6	0.8	7.2
Grumeti	13363	13	13.4	38	35	2.8	2.6	1.1
Simiyu	11577	43	179.2	146	164	0.8	0.9	0.9
South Shore Streams	8681	24.6	21.2	53	20	2.5	0.9	2.7
Isanga	6812	29.8	32.6	81	31	2.5	1	2.6
East Shore Streams	6644	20.2	42	120	135	2.9	3.2	0.9
Magogo-Moame	5207	8.9	12.8	32	12	2.5	0.9	2.7
Mbalageti	3591	5.3	20.3	58	53	2.9	2.6	1.1
Biharamulo	1928	18.4	57.3	367	73	6.4	1.3	5
Nyashishi	1565	1.7	7.9	20	16	2.5	2	1.3
West Shore Streams	733	21.3	175.1	1121	222	6.4	1.3	5
Kenya								
Nzoia	12842	115.3	52.8	422	66	8	1.2	6.4
Gucha Migori	6600	59.1	70.6	468	128	6.6	1.8	3.7
Nyando	3652	18	6.3	442	93	69.8	14.7	4.8
Yala	3357	35	52.2	479	41	9.2	0.8	11.8
Sondu-Miriu	3508	42.2	41.4	519	52	12.5	1.3	9.9
South Awach	3156	6	9.5	140	14	14.8	1.5	10.1
North Awach	1985	3.8	3.5	24	4	7	1.1	6.4
Sio	1437	11.4	22	241	37	11	1.7	6.5
Uganda								
Katonga	15244	2.3	0.2	28	2	127.6	8.3	15.4
Bukora	8392	7	5.6	41	13	7.3	2.3	3.2

Water quality Lake Victoria



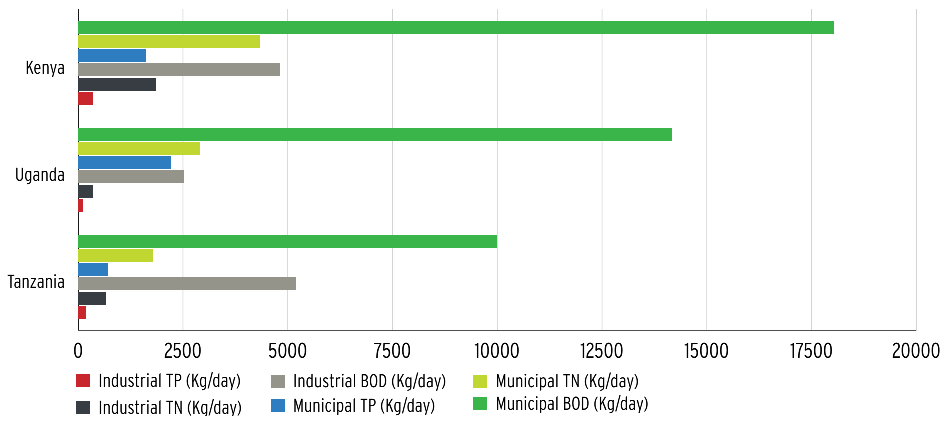
Eutrophication

The mean concentrations of macro-nutrients in Lake Victoria surpass the concentrations that have been recorded in other lakes and oceans, and the high mean concetrations of chlorophyll makes it one of the most eutrophide lakes in the world. Eutrophication has been identified as a greater threat to the value of the lake than other factors like fishing pressure. Eutrophication is associated with increase in chlorophyll concentration by x4 for offshore and x8 for inshore parts of the lake; and the algal community that is composed of different algae species with a distinct seasonal succession is presently predominated by cyanobacteria throughout the years. The increased alga biomass has been accompanied by reduced water transparency both inshore and off shore , increased rates of material decomposition have depressed dissolved oxygen to less than 1 mg/L over as much as the 30% of the water column8

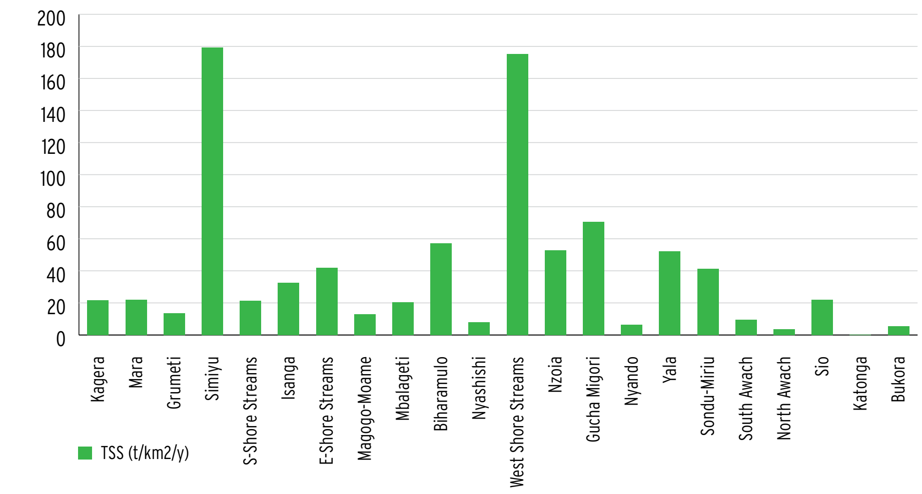
Mean Daily Industrial and Municipal Loads into Lake Victoria

Municipal effluent load are higher than industrial loads but both represent a threat to the community downstream the discharge point and the littoral zone of the lake. Municipal loads for BOD dominate over the industrial loads. Furthermore Kenya leads in municipal pollution loading followed by Uganda, while Kenya and Tanzania contribute industrial loads of the same magnitude. In Kenya and Uganda some industries are connected to the municipal sewer, hence they are captured as municipal loads. Cane sugar processing, soft drinks manufacturing, fish processing, vegetable oil processing, breweries and distillery industries are the major categories of polluters to the lake in a descending order.

Regional Summary of Municipal and Industrial Loads (LVEMP I)



Summary of yields of sediments (TSS) yields for the National rivers



Sediment yields in the Rivers flowing to lake Victoria

The Simiyu stands out for its high yield of sediments while the remaining rivers have sediment yields that are characterized as lightly to moderately disturbed by agriculture (Hecky et al 2003). The sediment yield of the Simiyu would place it among the highest disturbed catchments of the Lake Victoria. Simiyu is densely populated in its lower reaches and the flood plain has been occupied for agriculture. The Ugandan rivers and especially the low gradient Katonga River that is choked with papyrus have very low yields of sediments and nutrients. Among the Kenyan rivers the Gucha Migori has the highest yields of sediments. The upper catchment of Gucha Migori is hilly, steep, densely populated, with intensive agriculture characterized by simple farming practices and excessive rates of soil erosion.; while in the lower reaches the river flows through dry rangelands.

Total Non-Point Loads in Lake Victoria

The riverine loads are estimated at 9,270 of TP and 38,828 tons/y of TN respectively, and represented in both cases 80% of the total non-point load. Atmospheric deposition is estimated as the overall dominant source contributing about 39,978 and 167,650 tons of TP and TN respectively to the lake annually. The current non-point loadings whether from the atmosphere or rivers represent major losses of soils and nutrients from the agro-ecosystems and are symptomatic of degrading soil fertility in the lake Victoria catchment. Atmospheric deposition dominates the non-point loadings with some of the highest rates of deposition known globally. Although not widely appreciated as vector for nutrient loss, biomass burning does mobilize nutrients into the atmosphere and has likely been a major source of increased nutrient loading to Lake Victoria. Improved land management would be necessary to reduce the current loadings, but it will also preserve soil fertility by retaining nutrient on the land.

Photo: Milly Mbuliro

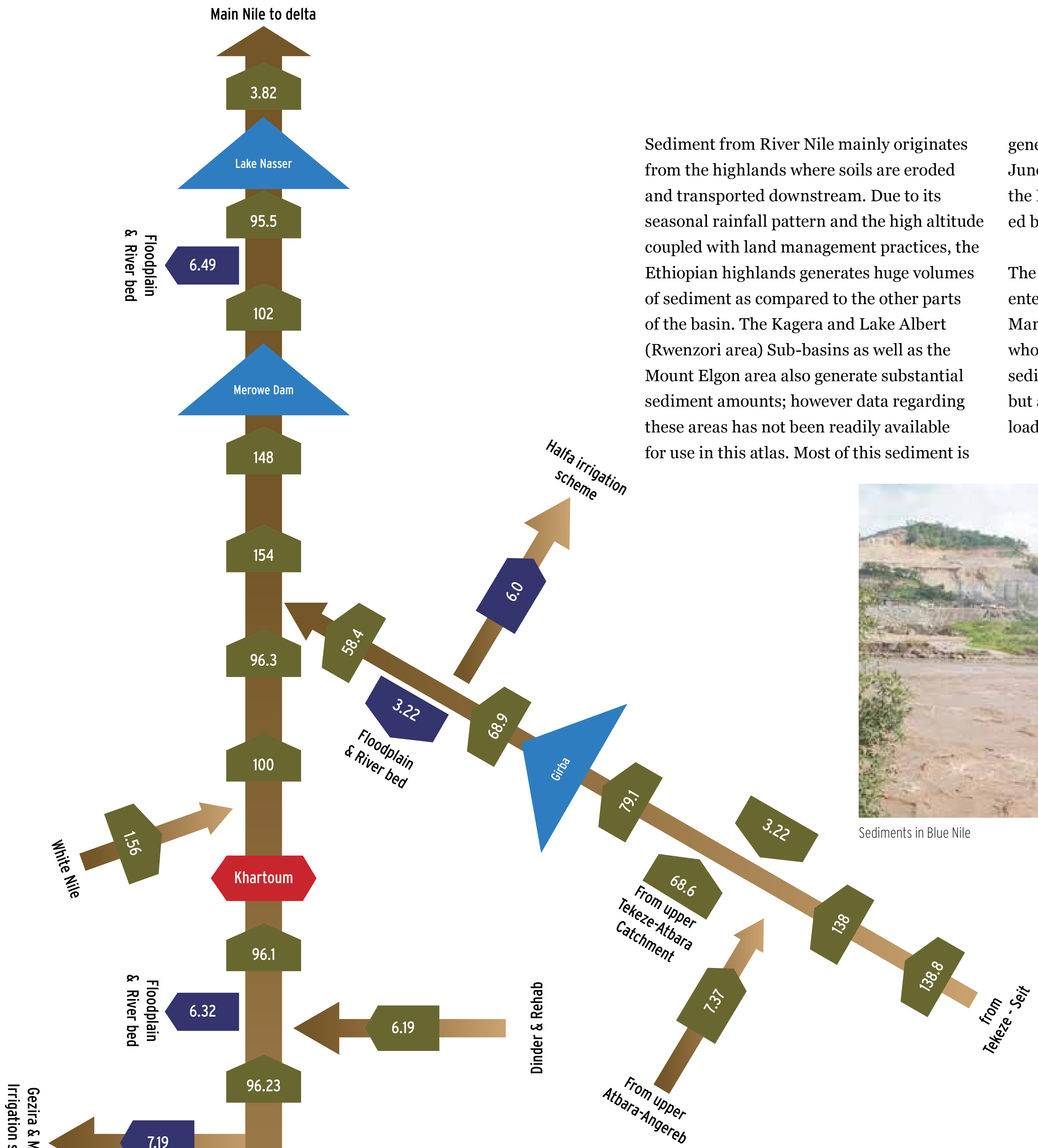
Kagera river

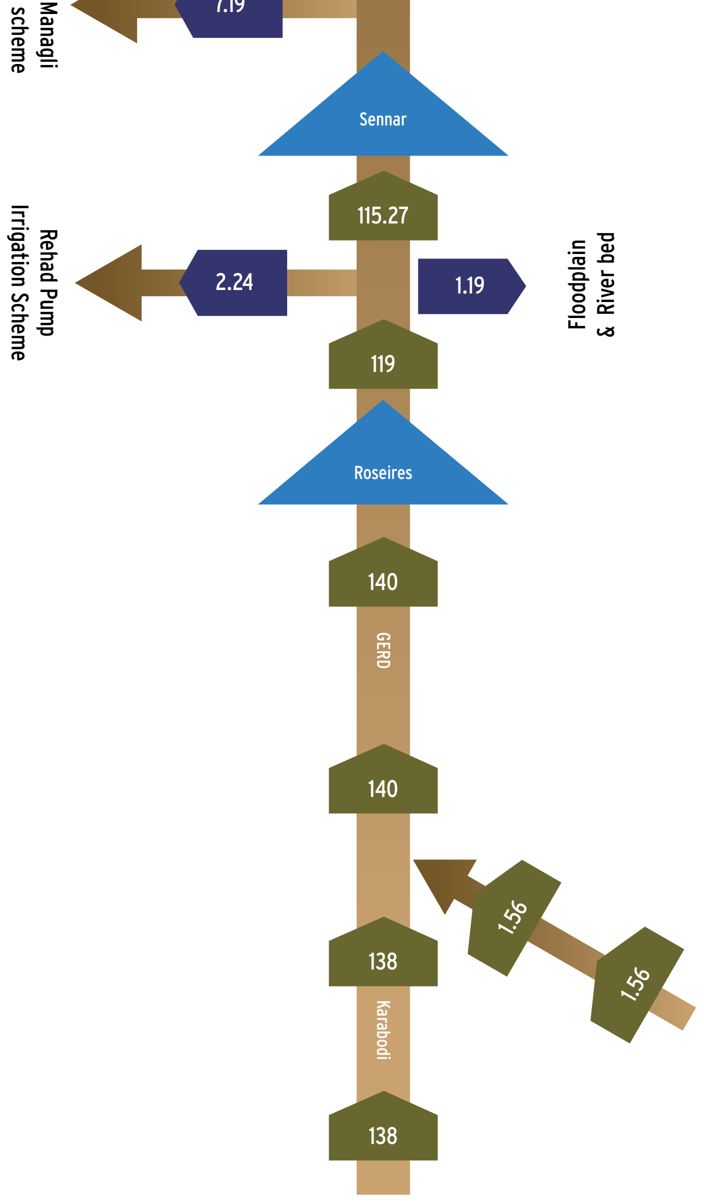
Estimates of total N, P and Suspended Sediment loads from the catchment and atmosphere

Parameter	Catchment (tons/Yr)	Atmospheric (tons/yr)	Total Load (tons/Year)	% Atmospheric	% catchment
TP	9247.0	39978.0	49225.0	81.2	18.8
TN	38828.0	167650.0	206478.0	81.2	18.8
TSS	6511950.0	-	6511950.0	-	-

Sediment from River Nile mainly originates from the highlands where soils are eroded and transported downstream. Due to its seasonal rainfall pattern and the high altitude coupled with land management practices, the Ethiopian highlands generates huge volumes of sediment as compared to the other parts of the basin. The Kagera and Lake Albert (Rwenzori area) Sub-basins as well as the Mount Elgon area also generate substantial sediment amounts; however data regarding these areas has not been readily available for use in this atlas. Most of this sediment is generated within the wet season; mainly from June – September. The chart presented shows the Eastern Nile Sediment balance as provided by ENTRO.

The graphs below show the average sediment entering the Gezira main canal, that from the Managil canal and the total sediment into the whole scheme. It is clear from this graph that sediment loads accumulate in the wet season, but also the fact that overtime the sediment loading is on an increasing trend.

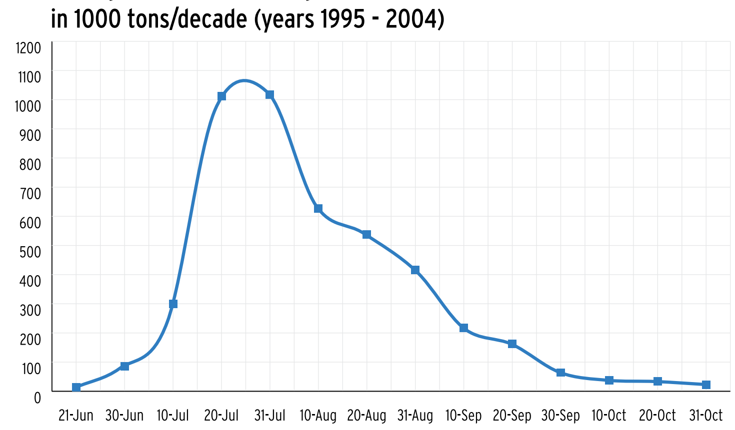




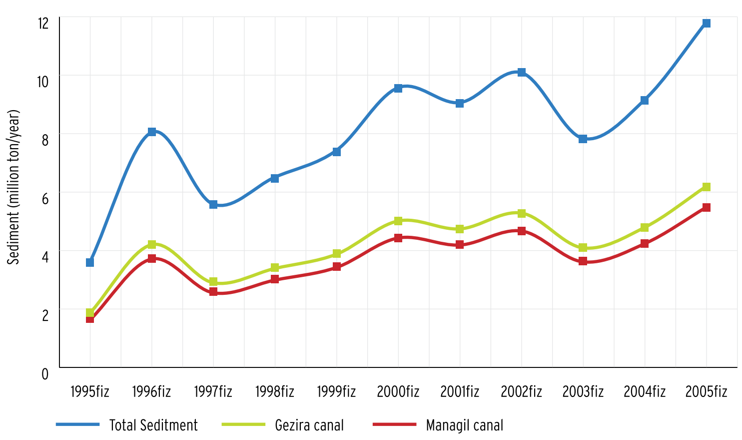
Sediments in Blue Nile

Photo: NBI

Average sediment entering Gezira main canals in 1000 tons/decade (years 1995 - 2004)



Total annual sediment into Gezira, 1995 - 2005

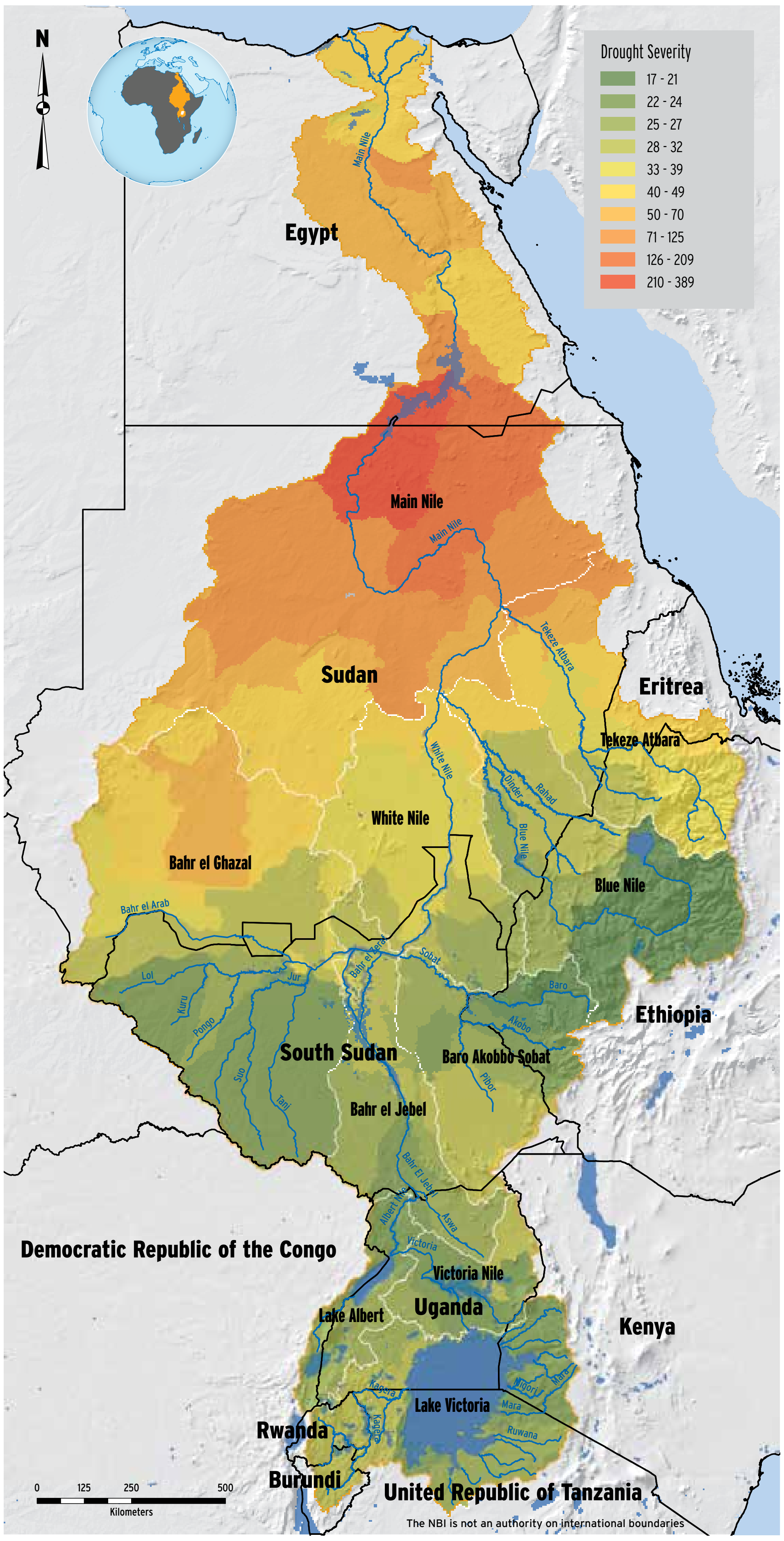


Source: ENTRO Sediment Tool

HYDROLOGIC EXTREMES

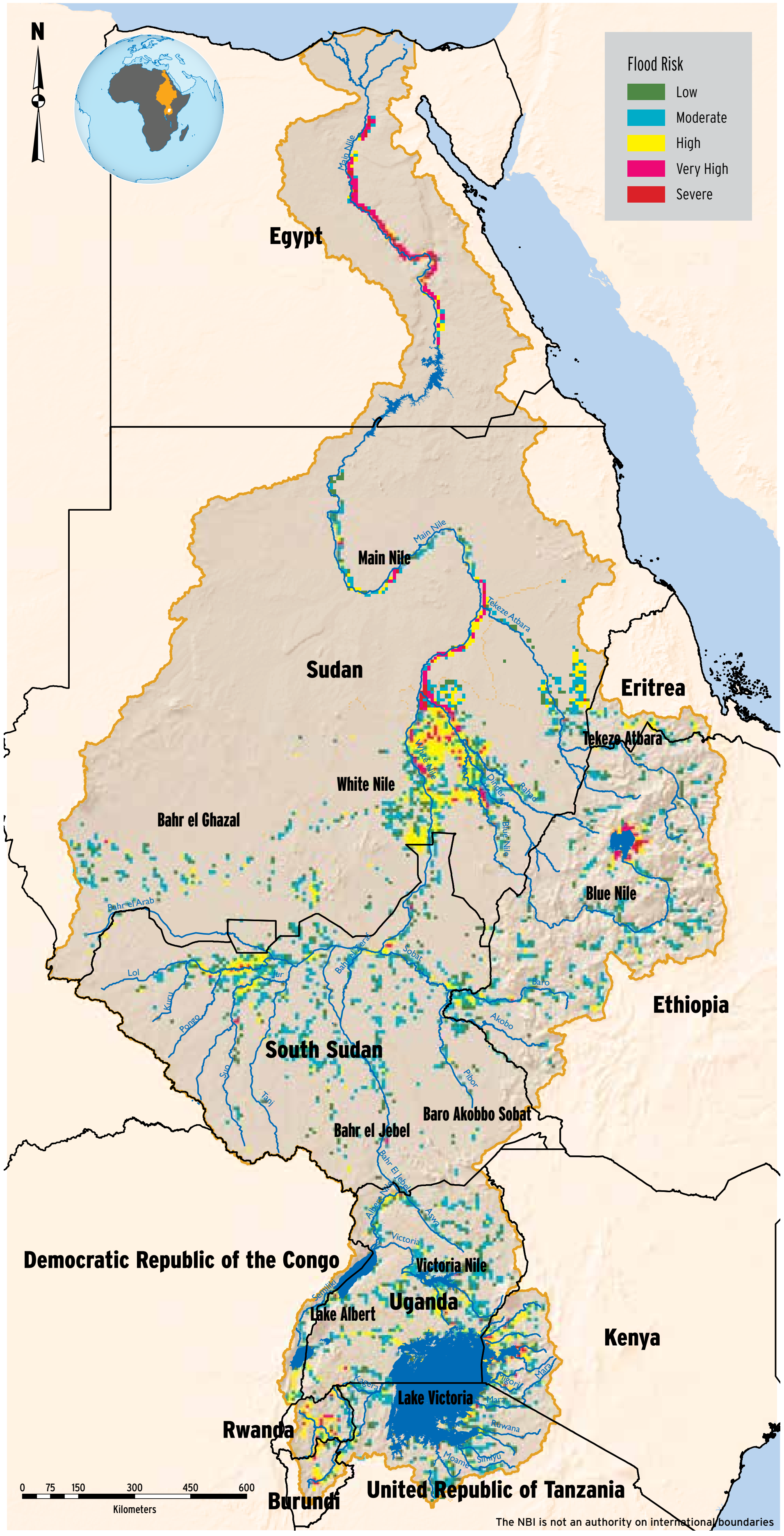
The Nile Basin, like any other part of the world experiences extreme events including droughts, floods, landslides, heat waves, e.t.c. The Equatorial lakes region and the Blue Nile including Khartoum experience flooding. The Darthmouth Flood Observatory had compiled an archive of the flooding events in the world; the "Global Flood Hazard Frequency and Distribution" and can be referred to for this information. In this atlas, we present the drought severity as a measure of the average length of drought times the dryness of the droughts from 1901 to 2008 as presented by aqueduct from Sheffield and Wood. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. The flood risk (estimate) map has also been presented clearly indicating areas which are at high risk of flooding with in the Nile basin. The flood risk index ranges from 1 (low) to 5 (extreme) as seen in the map. This product was designed by UNEP/GRID-Europe for the Global Assessment Report on Risk Reduction (GAR) and was modeled using global data.

DROUGHT SEVERITY IN THE NILE BASIN



Source: World Resources Institute, Aqueduct Global Maps 2.1 Data; http://www.wri.org/resources/data-sets/aqueduct-global-maps-21-data

FLOOD RISK IN THE NILE BASIN



Source: http://preview.grid.unep.ch/index.php?preview=data&events=floods&evcat=5&lang=eng accessed through http://www.preventionweb.net/english/maps/

Hydrologic extremes in Kenya

In Kenya, high inter-annual and intra-annual rainfall variability results in frequent and severe droughts and floods, negatively affecting the country's economic performance. Agriculture and animal husbandry, which together account for 28% of Kenya's national GDP and employ 70% of the total population, are particularly sensitive to climatic variations and have been adversely affected by the frequent occurrence of water shocks in recent years.

Droughts in Kenya

Kenya's droughts can have devastating consequences. Arid and semi-arid lands (ASAL) account for 80% of Kenya's land area, making the country poorly endowed with potential for rain-fed agriculture given the hydrologic variability that Kenya experiences. Since 2007, Kenya has suffered from two consecutive years of below average rains in most of the country, leading to one of the worst droughts in a decade. The devastating consequences included widespread famine as a result of severely depressed food production, with maize production alone down by 50% and up to 10 million people in need of food aid. The drought from 2007-2009 left Nairobi without water for a period of three weeks in November 2009.

Floods in Kenya

Although less well documented than the periods of drought, Kenya frequently experiences severe flooding about every three years. Kenya is affected by floods following torrential rain. Major floods occurred in 1937, 1947, 1951, 1957-1958, 1961, 1978, 1998, 2008 and 2010 with the largest flood having occurred in 1961 (UN-WATER 2005). Many parts of Kenya, particularly in the Rift Valley and Ewaso Ng'iro Basins, experience both floods and droughts on a regular basis. The floods between 1982 and 2008 affected more than 2.1 million people, mostly in Western and Nyanza provinces and in the Tana River district. While most parts of Kenya experience floods, severe floods regularly occur in most parts of the Kano plains (Nyando district, Nyanza Province), Nyatike (Migori district, Nyanza Province), Budalangi (Western Province, on the Nzoia River), and the lower parts of Tana River. People in informal settlements around Nairobi and other cities with homes near rivers are disproportionately affected. The most disastrous events occurred in 1997/98 when widespread floods throughout Kenya impacted about 1.5 million people. The 2008 floods affected 300,000 people (UN-WATER 2005). The areas that were affected by the various floods are shown in Table

Economic Implications of Hydrologic Extremes in Kenya

Climate variability negatively impacts national GDP and human development in Kenya. The World Bank estimated in 2004 that the losses from climate variability average about 2.4% of GDP per year with a further 0.5% loss from water resources degradation, constituting a serious impact on the country's competitiveness. For example, during the back-to-back floods (1997-98) drought (1998-2000) between 1997 and 2000, the World Bank estimated that water-related events caused GDP losses of 11%, 16%, and 16%, respectively, for each of the three years. Based on the GDP in those years, this is equivalent to an almost US$ 5 billion loss over those three years. Consequences included widespread famine as a result of severely depressed food production with millions of people in need of food aid, load shedding and extensive power rationing as a result of a near-halving of hydropower generation, and a decline in economic activities of all sectors (World Bank 2004a).

Heavy dependence on hydropower for electricity means that Kenya's economy is especially vulnerable to hydrologic variability. The droughts of 1999-2000 and 2007-2009 clearly illustrated this, when hydropower generation fell by almost half, resulting in massive load shedding, reliance on expensive emergency diesel, and large economic losses. The use of emergency diesel since 2006 has reached 14% of total generation (World Bank 2010c). Future growth will be dependent on better controlling existing hydrological variability, and putting in place policies and infrastructure to hedge against future climate uncertainty.

Year	Affected Areas	Number of Affected People
2008	Mandera, Budalangi, Coast Province, Nyando,Migori, Wajir, Siaya, Nyatike, Trans Nzoia, Meru/Tharaka-Tigania, Pokot Central	300000
2003	Nyanza, Busia, Tana River	170000
2002	Nyanza, Busia, Tana River	150000
1997-1998	Widespread	1500000
1985	Nyanza, Western Province, Tana River	10000
1982	Nyanza	4000

Cycle of poverty, droughts, floods in Sudan and South Sudan

Sudan and South Sudan like other countries of the Sahel, have long suffered from lengthy, devastating droughts. The most severe droughts of recent decades occurred in 1980–1984, 1989, 1990, 1997 and 2000, causing widespread population displacement and famine. In addition, floods in Sudan cause extensive damage, especially around the Nile and its main tributary, the Blue Nile.

Severe floods on the latter river in 1988 and 1998 caused property losses estimated at hundreds of millions of dollars. Flooding of the Nile proper in 2007 affected over 500,000 people and destroyed thousands of homes (WHO, 2008a). Seasonal rivers can also cause serious flood damage. In 2003, for example, heavy flooding along the Gash River affected 79% of the city of Kassala, leaving 80% of the population homeless, and inflicted heavy losses on agriculture in the region (NASA, 2008).

It is estimated that 85% of the two countries rural population lives on less than US$1 per day. Overall, some 20 million people were living in extreme poverty in 2002 (IFAD, 2008). The incidence of poverty varies considerably because economic growth is geographically uneven and conflict has devastated parts of the country. Severe regional inequalities exist in access to even the most basic services, such as education, sanitation, safe drinking water and job opportunities. For example, health services in South Sudan reach only about 25% of the population. People living in areas that have been or continue to be affected by drought and conflict –– are the most vulnerable to poverty (IFAD, 2008)


Photo: Salahadeen Nadir / World Bank

Water point to allow people and their animals to access clean drinkning water as they move in search of pasture

CONCLUSION

Photo: istock

The hydrologic regime of the Nile River, in particular the discharge regime, is distinctly influenced by the south and eastern highlands precipitation patterns. The hydrology of the Nile is mainly characterized and influenced by high variations in climate and altitude/topography which have a great bearing on flow magnitudes and patterns in the different parts of the basin. The Nile receives its flow from a network of various hydraulic systems, draining the Ethiopian Plateau and the Equatorial Lake Plateau. The network within the basin is of diverse hydrological processes, e.g. tributaries ad streams, wetlands, open water, man-made infrastructures. The Atlas also identifies and presents the water towers of the basin, as the high altitude area (Rwenzori Mountains in western Uganda, Mount Elgon, and the Ethiopian highlands) with registered rainfall in excess of 1,500 mm, they also usually lose less water to evapotranspiration because temperatures are lower.

Presentation of the hydrology of the Nile in this Atlas focused on key stations within the sub-basins of the Nile starting from downstream to upstream; Main Nile, Tekeze Atbara, Blue Nile, Baro Akobo Sobat, White Nile, Bahr el Jebel, Bahr el Ghazal, Lake Albert, Victoria Nile, and ends with Lake Victoria sub-basin. There are also swamps and wetlands in the Nile basin which play and influence the hydrology of the Nile mainly the Sudd, Bahr el Ghazal swamps, and the Machar marshes.

The Ethiopian highlands through the main tributaries (the Blue Nile, Atbara River, Baro-Akobo) are contributing most of the annual flow to the Nile (85%), but its contribution is highly seasonal - highest flows in four months (July – October). The discharges of the Equatorial watersheds into the White Nile are of low magnitude compared to the Ethiopian highlands. However the Equatorial sub-basins contribute more consistent and steady year-round flow. The Nile River course north of Atbara in Sudan receives no tributary and insignificant rainfall contribution. Thereafter, the Nile River flows through dry areas featured by extended desert, storage and the hydrology is dominated by management for multiple uses (irrigation, hydropower, navigation, tourism, etc.) - infrastructures and regulations influence the downstream flow. Further downstream, the Nile discharge into the Mediterranean Sea through its two branches in Egypt (Rosetta and Damietta).

Since the early years of the 20th century, records have been kept of the discharge at key stations of the Nile and its main tributaries. However, due to the fact that the stations records were for different time spans, they can be used to provide a good picture of the seasonal variation and quantify the relative contribution of the respective tributaries to the total Nile flow. The mean annual flow at Dongola station (immediate station upstream Aswan) is about 72 BCM. Inter-annual variability is very high for the long-term annual yield of the Blue Nile and Atbara rivers. While Atbara contributes an average flow of 11.4 BCM, the Blue Nile considered as the major Nile River yields an average of 50 BCM at Ed Deim station (spare its Dinder and Rahad downstream tributaries). Further upstream, the flow at Malakal averages 31 BCM (at the outlet of Baro-Akobo-Sobat, Bahr El Jebel, Bahr El Ghazal sub-basins), compared to an averages of 32 BCM at Mongola (upstream station of Bahr El Jebel sub-basin), which is close to the outflow from Lake Victoria averages 33 BCM. With average annual flow at Gambella of about 11.4 BCM, the Sudd outflow can be computed as 17 BCM. The outflow from the Bahr El Jebel varies little throughout the year because of the regulatory effect of swamps and lagoons of the Sudd region, about half of its water is lost in evaporation (or transpiration through plants), and seepage. Also, the flow duration curve depicts storage characteristics of the Southern stations (e.g. Malakal) compared to the Eastern tributaries.

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