

Technical Note: Hydrology of the Lukanga Swamp, Zambia

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Description

The Lukanga swamp is located approximately 50km west of the city of Kabwe, in the Central province of Zambia, within the catchment of the Kafue River. Situated between latitudes 14°08'S and 14°40'S and longitudes 27°10'E and 20°05'E at an altitude of 1,090 masl, the swamp occupies a shallow depression covering an area of approximately 2,590 km². The swamp is shallow with depth not exceeding 6.1 m, even at the height of the wet season. The area of permanent swamp and open water is approximately 2,100 km². The wetland comprises three characteristics types: palustrine, lacustrine and riverine. The palustrine wetland covers approximately 95% of the area and includes permanent swamp, termitaria grasslands and dambos. The lacustrine wetlands cover about 5% of the wetland. The riverine wetlands occur along the fringes of the Lukanga and Mushingashi rivers. Water in the swamp comes from three sources: direct rainfall into the swamp, inflow from tributary streams and spill from the Kafue River. The swamps significantly influence the flows into the Itezhi-tezhi reservoir, located downstream on the Kafue River. The catchment area of the swamps is approximately 14,245 km² (anonymous, undated)¹ with the main inflowing river being the Lukanga river, which originates to the north of the wetland in the Zambian Copper Belt (ZWA, 2005)

Climate

The climate of the region is largely controlled by the movement of air masses associated with the Inter-Tropical Convergence Zone (ITCZ). The wet season extends from November to March (Figure 1; Table 2). Mean annual precipitation for the catchment varies from approximately 900 mm in the vicinity of the swamps to 1,400 mm in the vicinity of the source of the Lukanga River in the north (ZWA, 2005). However, the rainfall pattern is irregular with significant variation from one year to the next and often several concurrent years of below average rainfall. Figure 2 shows the time series of rainfall from the nearest rain gauge to the swamp for which data are available. This highlights the high inter-annual variation and the fact that the mean annual rainfall is significantly influenced by a small number of very wet years (e.g., 1926, 1962, 1969 and 1978). There are long periods of below average rainfall (e.g. 1970-1973 and 1987-1994). Potential evapotranspiration exceeds rainfall in all months, except December to February (Figure 1). Average temperatures in the wet season range from 20-23°C and from 16-19 °C in the cool part of the dry season (May to August) and from 23-25°C in the hot part of the dry season (September to October) (Table 2).

¹ It is not stated explicitly in the note, but this is believed to be the catchment area of the Lukanga River to the point where it flows into the wetland. The ZWA Ramsar information sheet suggests a catchment area of 58,909 km² for the swamp. It is not clear how this latter area was determined. It may be the total area of the Kafue catchment including the Lukanga River catchment at the point where the Lukanga River joins the Kafue. However, the Kafue River only spills into the Lukanga swamps at high flows (see below).

Table 1: *Climate stations for which data obtained*

Nos.	Name	Latitude	Longitude	Altitude (masl)	Distance from wetland (km)	Rainfall data	Temperature data	Potential Evaporation
5431	Broken Hill	14.38 °S	28.38 °E	1,190	84.2	1910 – 1996 (mnthly total)	Monthly average only	Monthly average only
5432	Broken Hill Mine	14.40°S	28.41°E	1,180	87.6	1961-1989 (mnthly total)	1961-1989 (mnthly total)	N/A
5445	Mumbwa	15.06°S	27.18°E	1,218	92.9	1904-1995 (mnthly total)	N/A	N/A
5433	Kabwe	14.45°S	28.46°E	1,207	93.6	1910-1995 (mnthly total)	Monthly average only	Monthly average only
5434	Kabwe-Agric	14.40°S	28.50°E	1,165	97.3	1950-1978 (mnthly total)	N/A	N/A

(source: FAO databases FAOClim and LocClim)

Table 2: *Mean monthly climate data (simple arithmetic mean of data from different stations)*

Month	Catchment Precipitation (mm)	Potential Evapotranspiration (mm) (Penman-Monteith)	Mean Daily Temperature (°C)
Jan	238	124	21
Feb	193	109	21
Mar	114	130	21
Apr	31	126	21
May	5	121	18
Jun	0	111	16
Jul	0	118	16
Aug	0.3	152	19
Sep	1	180	23
Oct	22	205	25
Nov	97	153	23
Dec	241	136	22
Annual	941	1665	21

(source: FAO LocClim database)

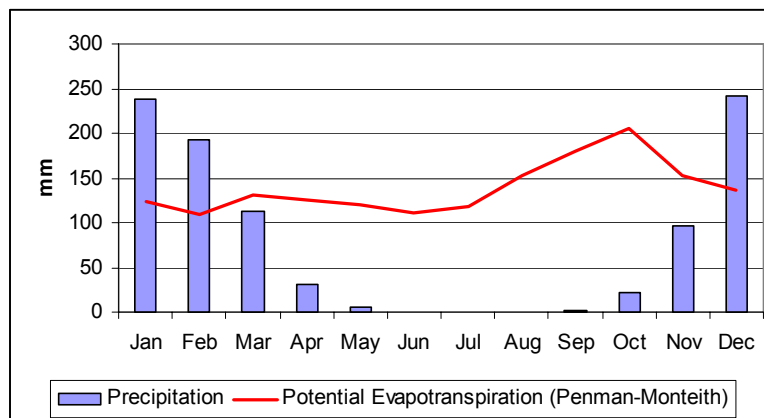


Figure 1: *Mean monthly rainfall and Potential Evapotranspiration (Penman-Monteith) derived from the FAO Loc-Clim database.*

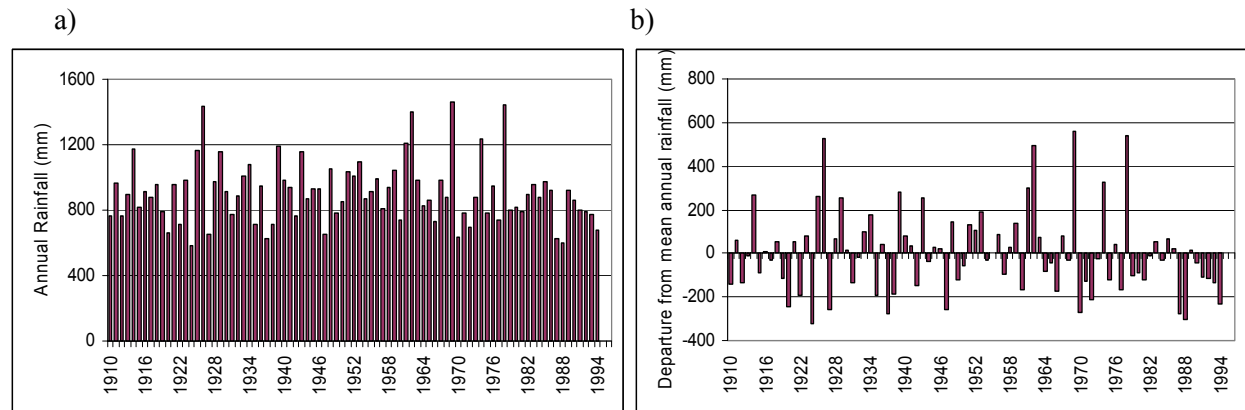


Figure 2: *Rainfall measured at Broken Hill: a) annual time series b) deviation from the annual mean*

River Flows

The main river flowing into the Lukanga swamps is the Lukanga River, a tributary of the Kafue River. The Lukanga River flows into the swamps in the north-eastern corner and then out again in the north-western corner. Other smaller rivers also flow into the swamps, but many of these are ephemeral. At times of high flow the Kafue River causes water in the Lukanga River to backup into the swamps and during very high floods, the Kafue River itself overflows into them (Seagrief, 19??). There are relatively few gauging stations in the area and the quality of data for those which do exist is poor with many gaps in the data series (Table 3).

Table 3: *Gauging stations in the vicinity of the Lukanga wetlands for which flow or water level data are available*

Gauge number	River	Length of record	Nos. of complete years	Latitude	Longitude	Catchment area (km ²)
4375 ⁺	Lukanda at Chikanda	1975-1997	10	13.92°S	28.55°E	80.0
4350	Kafue at Chilenga	1988-2006 (closed)	3	14.10°S	27.42°E	34,451
4400*	Lukanga swamp at twenty village	1962-1988	23	14.62°S	27.95°E	-

⁺ It is not clear if this is the main inflowing river (i.e. the Lukanga) or another river. The catchment area given is too small to be the main Lukanga River.

* Water levels measured in the swamp

Source: Ministry of Water Resources

Figure 3 presents the flow series for the Lukanda River at Chikanda. This highlights the high intra- and inter-annual variability in flow. On average 94% of the flow occurs in the months December to May. Mean annual flow is 8.35 Mm³, which from a catchment of 80 km² equates to runoff of 104 mm. If the average annual rainfall is 941 mm (Table 2) this corresponds to a coefficient of runoff of 11%.

Figure 4 shows the water levels measured in the swamp at twenty village. This indicates that in most years water-levels fluctuate over a range of much less than a meter (often less than 0.50m). Peaks in water levels typically lag a couple of months behind the end of the wet season, usually

occurring in May-July. However, the annual water level fluctuations are superimposed on a longer cycles of wetting and drying during which the swamps fill with water very rapidly (i.e. over a period of 1-4 months) and then dry gradually over a period of several years. It seems probable that the large and rapid increases (i.e. June 1965, February to May 1969 and February 1978 to May 1978) are largely a consequence of flooding from the Kafue River. The lack of a statistically significant correlation between mean annual water levels and local rainfall (Figure 5) confirms that direct rainfall into the wetland is not the main factor affecting swamp water levels.

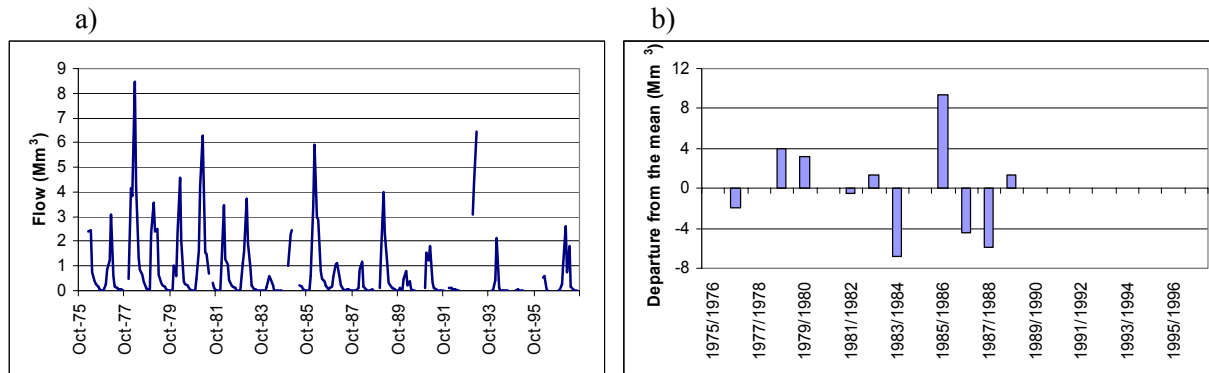


Figure 3: *Flow measured in the Lukanda River a tributary inflow into the Lukanga swamp: a) monthly time series; b) departure from the mean*

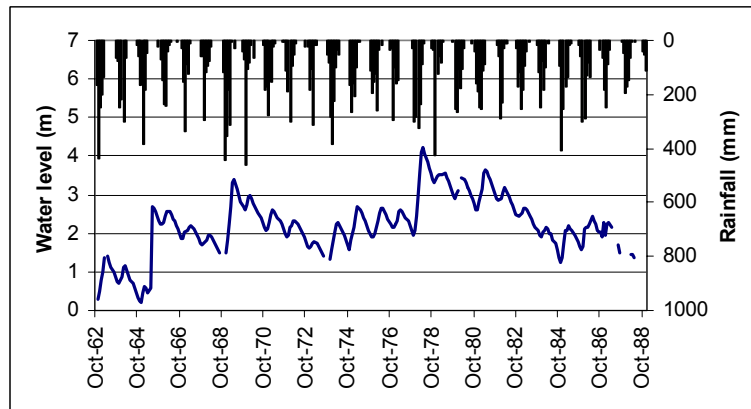


Figure 4: *Water levels in the Lukanga swamp (measured at twenty village) and rainfall measured at Broken Hill.*

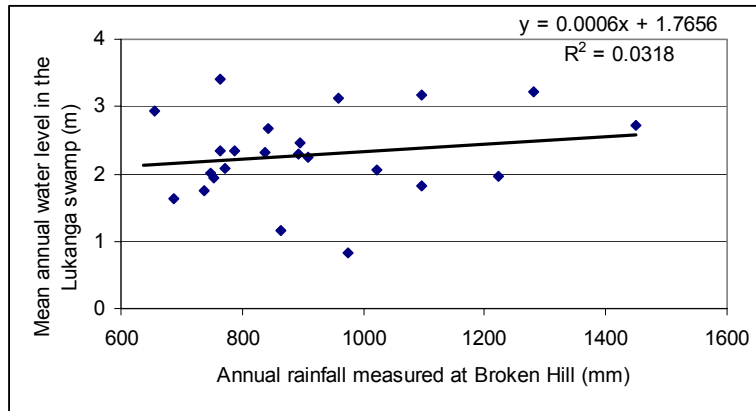


Figure 5: *Correlation between annual rainfall and mean water level measured in the Lukanga swamp*

Wetland water budget

A crude (back of the envelope) estimate of the average annual water budget for the wetland was determined. The water budget of the wetland is approximated by the equation:

$$P + Q_i = E + Q_o \quad (\text{equation 1})$$

Where:

- P = precipitation onto the wetland
- Q_i = inflow into the wetland
- E = evapotranspiration from the wetland
(a combination of open water evaporation and evapotranspiration from the swamps and grass)
- Q_o = outflow

This assumes that groundwater fluxes to and from the wetland are negligible. Mean annual evapotranspiration from the wetland was estimated to be 2,961 Mm³. This estimate was derived from assumed areas for the different wetland types and estimates of likely annual evapotranspiration losses (Table 4).

Table 4: *Estimated average annual evapotranspiration from different parts of the wetland.*

	Average Area	Evapotranspiration	
	(km ²)	Mm	Mm ³
Open water	130	2,070 ⁺	269
Swamp/dambos	1850	1,120 ⁺	2,072
Grass	620	1,000	620
		Total	2,961

⁺ Estimated Balek (1983)

Table 5 presents a summary of the mean annual water fluxes, with outflow (Q_o) computed from equation 1. The estimate indicates that approximately 54% of the water in the wetland originates

as direct rainfall onto the wetland, with 46% originating as inflow from the surrounding catchment and spill from the Kafue River. The spill from the Kafue is an estimate of annual average. However, as figure 4 indicates spill, may not occur every year, but when it does large volumes of water are transferred from the Kafue River into the wetland. The total storage in the wetland is estimated to be 7,398 Mm³ (anonymous, undated).

Table 5: *Estimate of the average annual water fluxes (Mm³) into and out of the Lukanga wetland*

	Annual
Direct rainfall onto the wetland ⁺	2,350
Evapotranspiration from the wetland	2,961
Inflow from catchment*	1,482
Inflow from the Kafue [^]	543
Outflow from the wetland	1,413

⁺ Estimated to be 904 mm (mean annual rainfall at Broken Hill)

* Assumed coefficient of runoff of 11% (i.e., as for the Lukanda catchment), catchment average rainfall of 941 mm (Table 1) and catchment area of 14,245 km²

[^] Estimate given in anonymous note.

Data requirements to improve the analyses

- i) Measured flow on the Lukanga River upstream of the wetlands
- ii) Better Kafue flow measurements, ideally from gauging stations located both upstream and downstream of Chilenga
- iii) Any reports/data indicating at what flows spill occurs from the Kafue into the wetland
- iv) A water-level volume relationship for the wetland
- v) Better estimates of areal coverage of different wetland/vegetation types and variation between the wet and dry season - from image analysis

References

Anonymous note (undated) Lukanga swamp

Balek, 1983.

Seagrief, S.C 19??. The Lukanga Swamps- Northern Rhodesia. *The Journal of South African Botany*.

Zambia Wildlife Authority (ZWA) 2005. Lukanga Swamps Ramsar Information Sheet.