River Lubilia Water Resources Assessment

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1 Hydro-Climatology of the River Lubilia Catchment

1.1 Background

River Lubilia is situated in western Uganda originating from the Ruwenzori Mountain Ranges, and flowing southerly to join the bigger Lubilia-Tako, which forms a natural border with the Democratic Republic of Congo before draining into Lake Edward. The river is currently used used as a freshwater source for two water supply systems for the neighbouring communities; the bigger one being the Bwera Gravity Flow Scheme. In some literature the river name is written as Lhubiriha instead of Lubilia which is stated on the 1:50000 topographic sheet series for Uganda.

The proposed Lubilia mini-hydropower site is located at coordinates; E 00140761, N 0009518 (according to the Transverse Mercator Projection, UTM 36N). It lies in Bushangwa village in Ihandiro sub-county in Bukonjo County in Kasese District.

In order to assess its hydro-electric power potential, there is need to analyse its catchment characteristics and the discharge patterns including its low and high flows. The results of this analysis therefore, constitute an important input into the design process of the proposed Hydro-electricity facility and provide an indication of its safe capacity and hydrological reliability.

1.2 Catchment Characteristics

1.2.1 General Relief Profile

The headwaters of the Lubilia are located in the Ruwenzori Mountain ranges as is the case for a number of other rivers such as Mulusege, Kanyampara, Nyamwaba, Ruimi, Mobuku and Lubilia-Tako shown in figure 1.1 below.

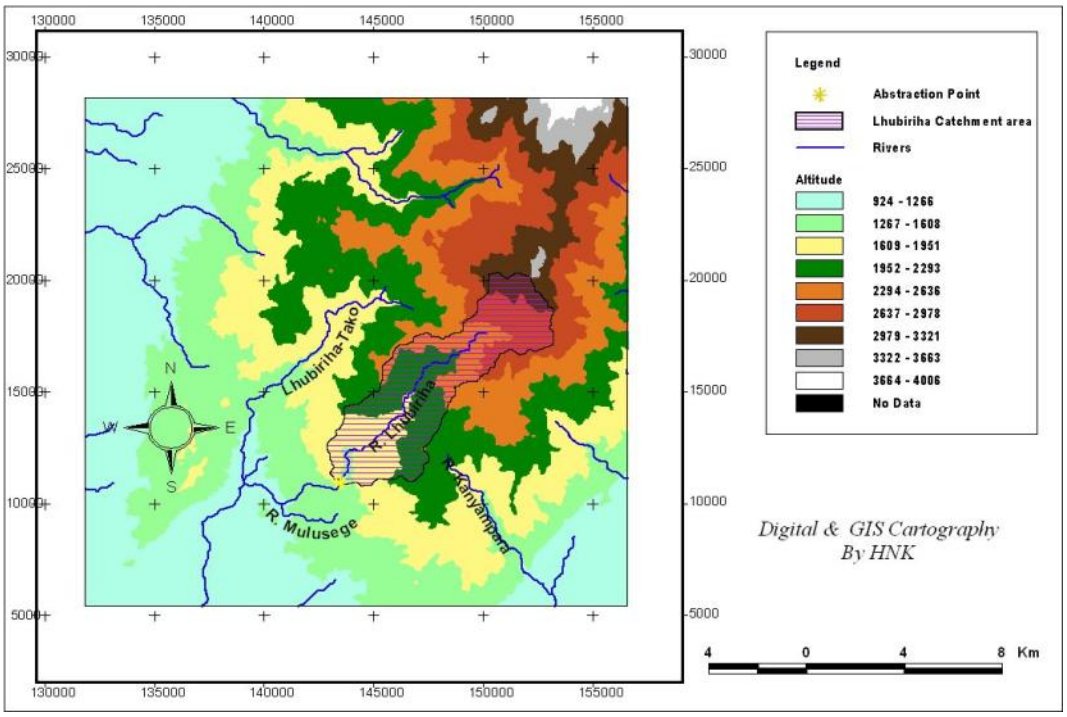


Figure 1.1 Location of take-off point

The ranges were formed through faulting activities, which were also responsible for the formation of the Albertine (western) Rift of the East African Rift, which forms part of the Great Rift Valley. The mountains are composed of metamorphic rock, which is believed to have tilted and squeezed upwards during plate tectonic activity and continental drifting, leading to the present mountain ranges. The Ruwenzori also forms part of several Great Rift Valley features such as lakes Albert, George, and Edward.

Figure 1.2 below shows that the entire Lubilia catchment is on the Ruwenzori Mountain slopes with its highest spot at 3354m amsl and the lowest point at 1525m amsl. The mean catchment slope is approximated at 30% although some areas have steep inclines standing at a slope of 102%.

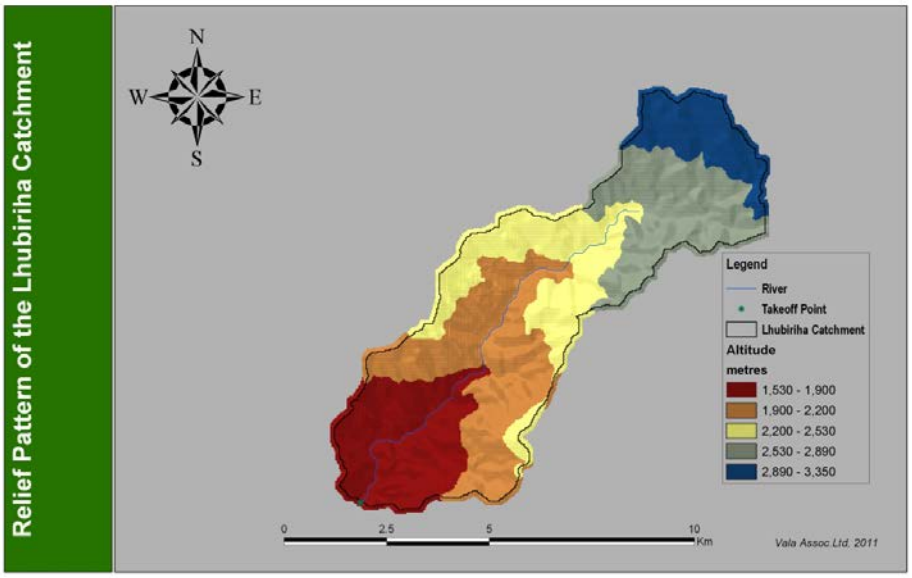


Figure 1.2 General relief profile of the Lubilia Catchment

The plate 1.1 shows the proposed takeoff point on the Lubilia River.

Plate 1.1 Takeoff Point on Lubilia

1.2.2 Land cover of the Lubilia Catchment

Land cover is an important variable in the assessment of potential runoff from a watershed and for River Lubilia; there are primarily two types of land covers i.e. tropical rainforests and subsistence farmlands. Figure 1.3 below, shows that the higher slopes are covered in well stocked tropical rainforests which is evidence of high mean annual precipitations in the high altitudes. In plate 1.2, it can be seen that down the slopes, the vegetation changes to depleted tropical high forest and subsistence farmland near the off-take point. Over 90% of the communities living on the mountain slopes depend on firewood for fuel leading to extensive destruction of the forests, which has accelerated the rate of soil erosion and frequency of landslides in the region.

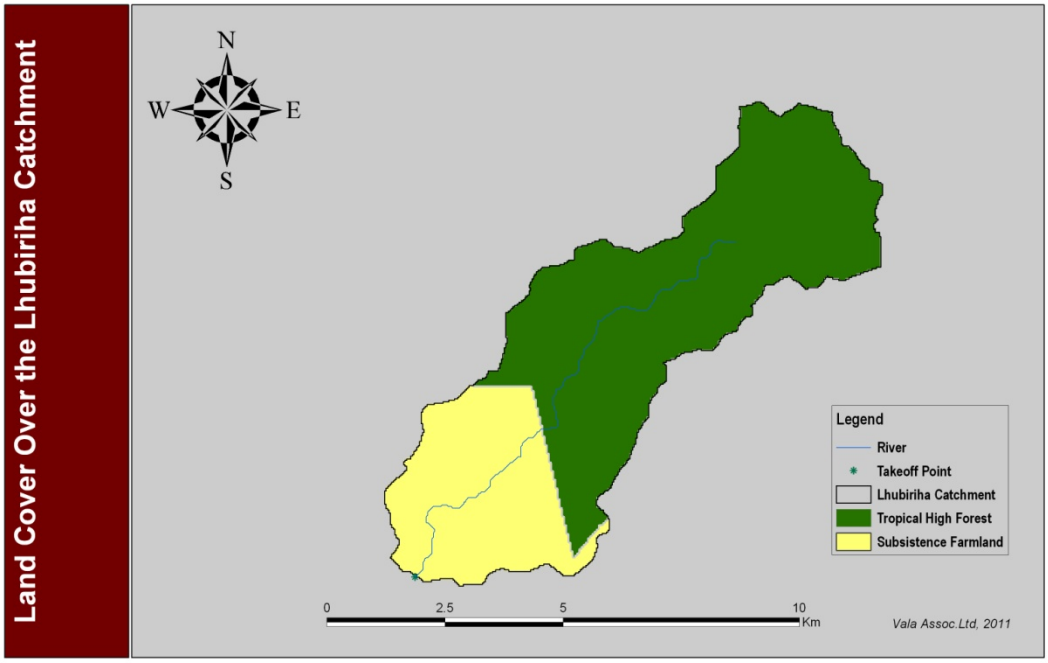


Figure 1.3 Vegetation cover of River Lubilia catchment

Plate 1.2 Land Cover on Slopes Downstream of Takeoff Point

1.3 Rainfall climatology in the catchment

1.3.1 Rainfall data and patterns for the Lubilia Catchment

The Ruwenzori ranges area receives variable amounts of rainfall throughout the year ranging annual means of 1690mm on the higher slopes to 850mm on the lower slopes towards the western rift valley.

Data from the rain gauge stations in Table 1.1, obtained from the Uganda Meteorological Department, was used in this hydrological assessment.

Table 1.1 Selected Gauging stations for River Lubilia Catchment

Station Name	ID	Longitude	Latitude	Elevation(m)
Mpondwe Customs Post	89290000	29.758	0.038	1050
Bwera	89290070	29.783	0.333	1200

The Lubilia catchment receives annual maximum and minimum of 1529mm and 1245mm respectively with an average mean of 1388mm. It is therefore a fairly wet sub-catchment.

The seasonal pattern of rainfall regime around River Lubilia is such that there are approximately two rain seasons with maximum precipitation occurring between April–June and August-September as demonstrated by the box plots of average monthly rainfall of selected stations (Figure 1.4). The bimodal pattern results from the regional movement of air masses associated with the inter-tropical convergence zone (ITCZ). Unlike typical monsoon climates that are derived from a reversal of wind currents from the northeast in January to the southwest in July, a north-south reversal in East Africa causes the heavy rains to occur in April and October.

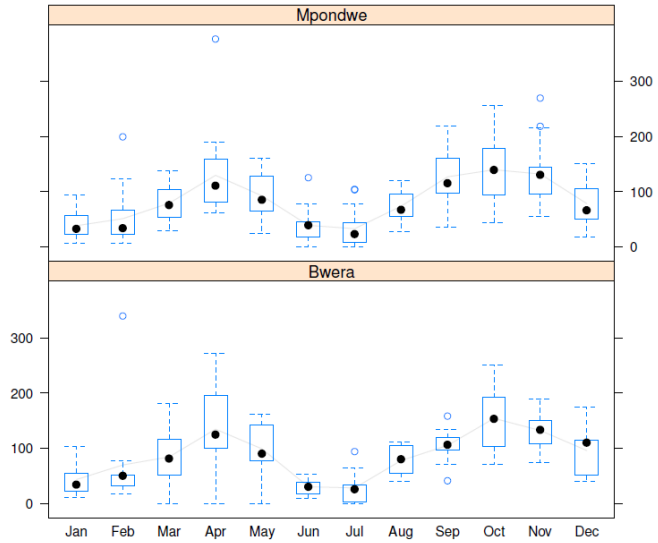


Figure 1.4 Monthly average rainfall for selected gauging stations

1.3.2 The spatial rainfall distribution in the Lubilia Catchment

Using GIS tools, the rainfall spatial distribution for the Lubilia catchment (Figure 1.5) was obtained from the national mean annual rainfall GIS map that was developed by the Water Resources Management department (WRMD) and the Uganda Meteorological Department (UMD) – (MoWE, 2003)

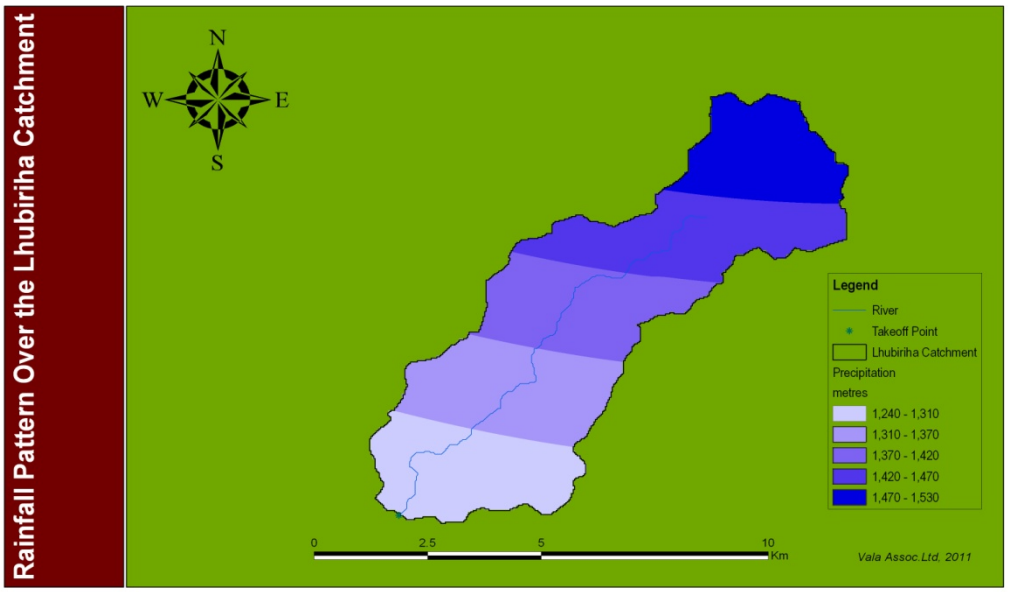


Figure 1.4 Average annual spatial Distribution of rainfall in Lubilia basin

From Figure 1.5, one notes that entire area upstream of the take-off points for the Lubilia project are quite wet, with annual rainfall ranging between 1250mm-1520mm on the Mountain upper slopes respectively. There would seem to be correlation between altitude and rainfall. The average rainfall for the catchment is 1388mm.

2 The Lubilia River flow characteristics

2.1 River Discharge data

2.1.1 Hydrographs of nearby discharge stations

There has been no operational discharge gauge on River Lubilia in the last decades. However, there are several other rivers (Table 2.1) which originate from the Mountain Ruwenzori whose discharge measurements have been recorded for various lengths. Figure 2.1 show the R Kanyampara and R. Nyamugasani hydrographs while Figure 2.2 shows there seasonal variability.. It will be readily observed that R. Kanyampara is a tributary of R, Nyamugasani. A staff gauge was recently installed and daily readings taken for the past 12 months. At the time of the field visit, on 24/03/2011, the river was flowing at an approximately depth of 0.31m. It was not possible to obtain the discharge – stage relationship for this gauge; and as such these recent records have not been used in the analysis

Table 2.1 Discharge stations on nearby rivers (to River Lubilia)

Station ID	Description	Latitude	Longitude	Drainage Area (km^2)
84218	R. Kanyampara at Equator Road	0: 0:40 S	29:52: 0 E	109
84228	R. Nyamugasani at Katwe - Zaire Road	0: 7:23 S	29:51:00 E	507
84224	R. Rukoki at Fort Portal - Kasese Road	0:15: 0 N	30: 7: 0 E	212

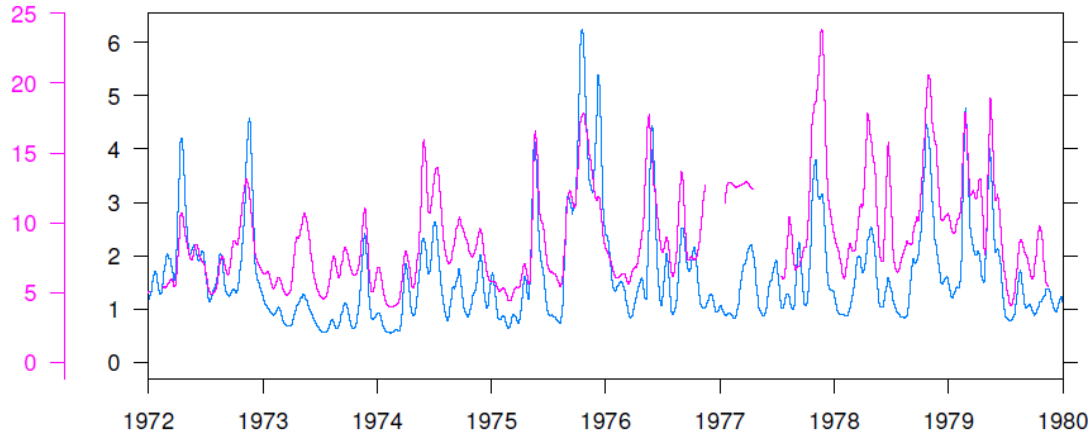
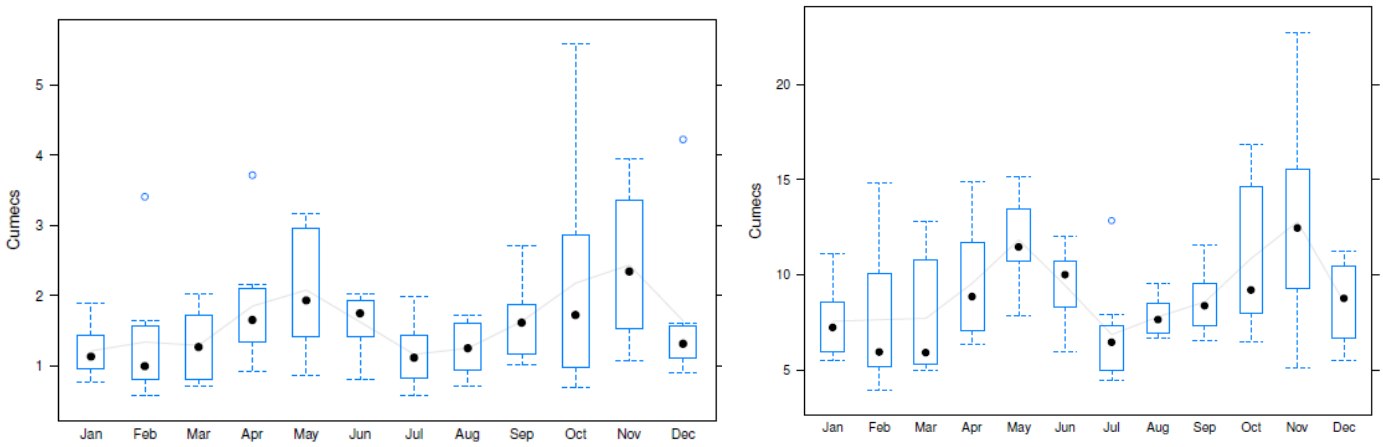


Figure 2.1 Hydrographs for Rivers Kanyampara and Nyamugasani (Blue and pink respectively, units are m^3/s)

It will be observed that generally the peaks of the rivers are coterminous (they happen at the relatively the same time). This is to be expected since Kanyampara is a tributary of Nyamugasani.



(a) R. Kanyampara (b) R. Nyamugasani

Figure 2.2 Mean monthly flows for Rivers Kanyampara and Nyamugasani

2.1.2 Brief Discussion of the available discharge data

Station 84228: River Nyamugasani is a gauged perennial river with its source in the Ruwenzori Mountain ranges. From its sources it flows southwards over the mountain slopes to the more flat valley areas of the Western East African Rift Valley, including Katwe-Kabatooro and finally into Lake Edward. It is the current source of water for the existing water supply system in Katwe-Kabatooro town council. It is located only 3km from the town. R. Nyamugasani has a catchment area of about 507km^2. The catchment is mountainous in the northern part (closer to its source) but then becomes fairly flat in the rift valley toward its final destination to Lake Edward. This is unlike the Lubilia catchment which does not have any flat portions.

Station 84218: River Kanyampara: This is one of the principal tributaries of R. Nyamugasani. Its catchment lies adjacent to that of R. Lubilia. The catchment characteristics of the two rivers (Kanyampara and Lubilia) such as slope, vegetation cover, rainfall are fairly similar. The catchment area of Kanyampara is 109km^2 while that of Lubilia is 42km^2. The average annual rainfall for Lubilia is slightly higher at 1380mm compared to that of Kanyampara which stands at 1250mm. A bigger portion of the Lubilia catchment is covered with pristine forests compared to Kanyampara. The later includes a segment of the western rift valley. The geographical proximity of these two catchments is shown in Figure 2.3 below.

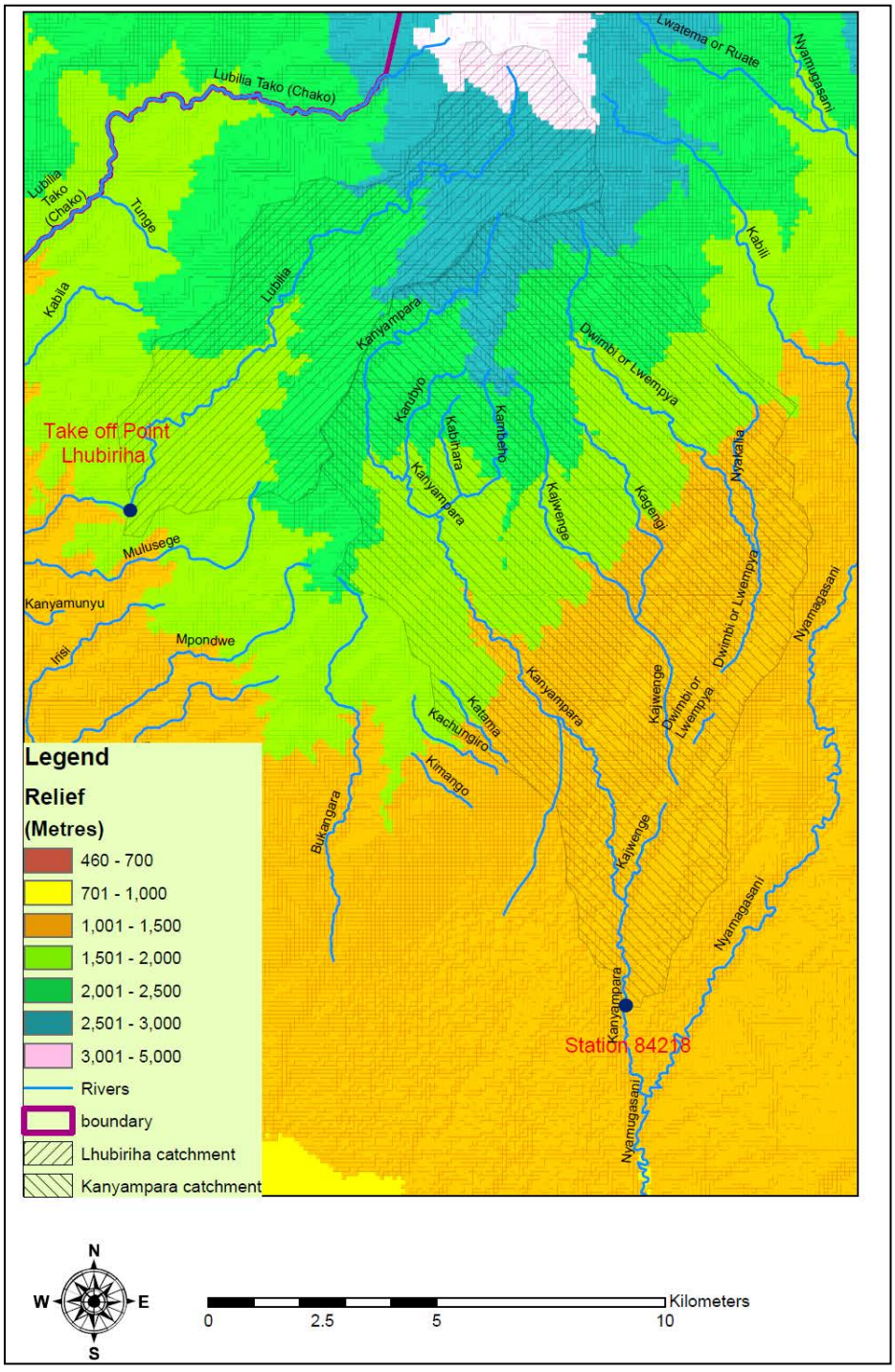


Figure 2.3 Geographical proximity between the Kanyampara and Lubilia catchments

2.1.3 River Lubilia Profile

The River Lubilia channel width is approximately 12m by 2m depth at the takeoff point; flows at an approximate average gradient (slope) of 0.0796 between its source and the proposed take-off point. Its river bed is underlain by fractured gneisses rock; the rocky bed will provide a good foundation for the weir. There were also visible rock outcrops at the top of hills further downstream that would be a good source of aggregate during construction.

Figure 2.4 below is its hypsometric curve.

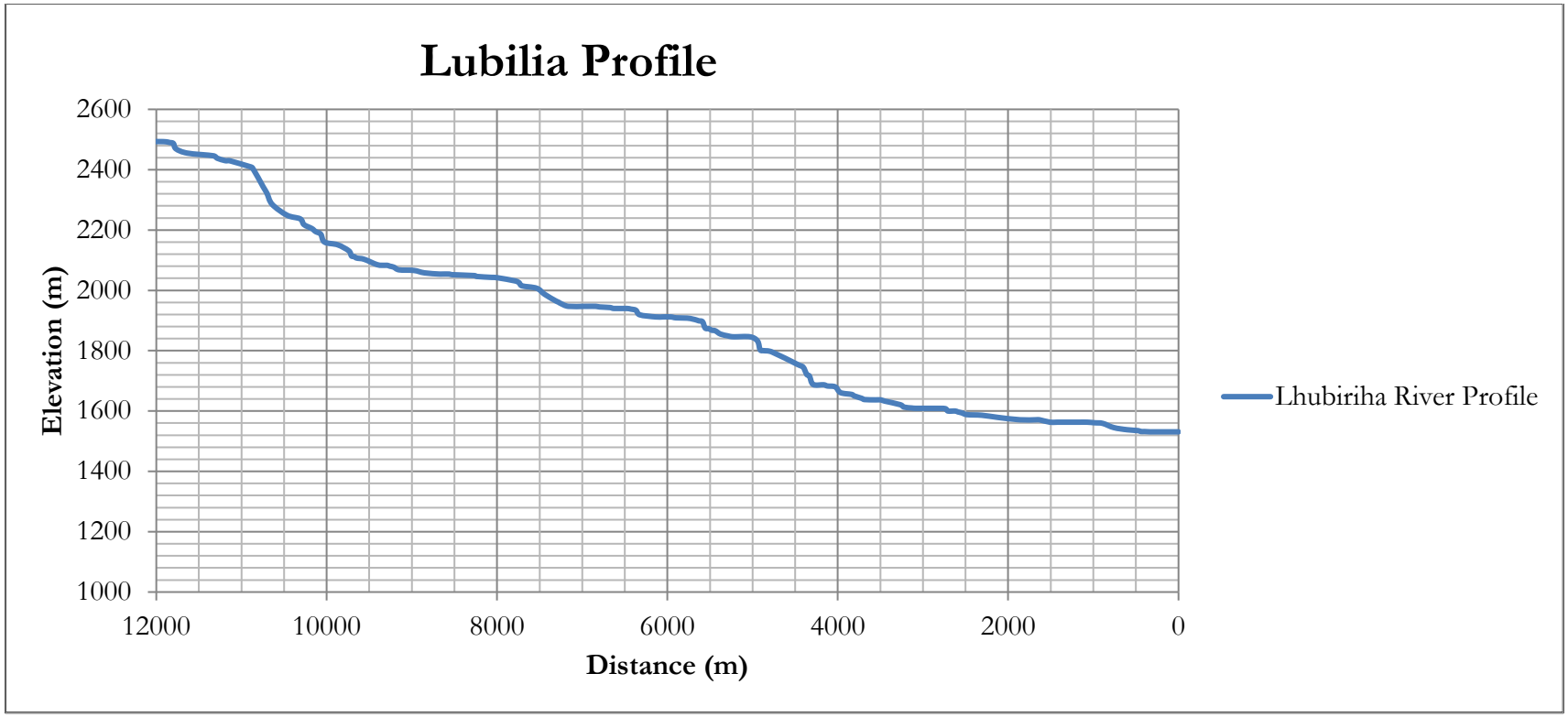


Figure 2.4 Hypsometric curve for River Lubilia

2.2 Generation of the River Lubilia Discharge data

Since R. Lubilia is ungauged, its discharge has to be arrived at using proxy methods. The method of choice was to use selective linear regression between The Lubilia catchment and the Kanyampara catchment parameters listed in Table 2.2 below.

Table 2.2 Catchment characteristics of Kanyampara discharge station and the Lubilia takeoff point

ID	Area km²	Area/ Perimeter ratio	Slope (%)			Elevation (m)			Equivalent length (km)
			Min	Max	Ave	Min	Max	Ave	
Takeoff Point	42.66	2.30068	0.000	91.185	25.846	1027.00	2892.00	1659.90	17.637
R. Kanyampara	109.73	1.16873	0.573	83.258	29.914	1493.00	3357.00	2303.33	15.529

The derived mean monthly flows for the period 1968 – 1980 are presented in Annex 1 while the annual summary statistics for the catchment are presented in Table 2.3.

Table 2.3 Summary Statistics of Lubilia derived Flows (1968-1980)

Year	Number of missing daily records	Minimum m^3/s	Maximum m^3/s	Mean m^3/s
1968	212	0.70	4.68	1.29
1969	0	0.49	4.48	1.09
1970	0	0.69	9.16	1.93
1971	0	0.49	6.52	1.08
1972	0	0.62	10.77	1.60
1973	0	0.41	5.02	0.76
1974	0	0.37	5.28	1.04
1975	0	0.36	10.55	1.81
1976	0	0.59	11.12	1.29
1977	0	0.54	9.73	1.29
1978	0	0.59	12.36	1.37
1979	0	0.51	11.42	1.33
1980	178	0.47	8.63	1.29

2.3 The Flow Duration Curve

The (derived) Lubilia takeoff Flow Duration curve was constructed and is presented in Figure 2.5 below.

Percentage of the time flow is exceeded	Discharge m^3/s
95%	0.42
90%	0.51
85%	0.58
80%	0.62
75%	0.65
70%	0.69
65%	0.73
60%	0.77
55%	0.82
50%	0.86
45%	0.93
40%	1.01
35%	1.08
30%	1.16
25%	1.27
20%	1.43
15%	1.65
10%	2.01
5%	2.53
1%	3.55

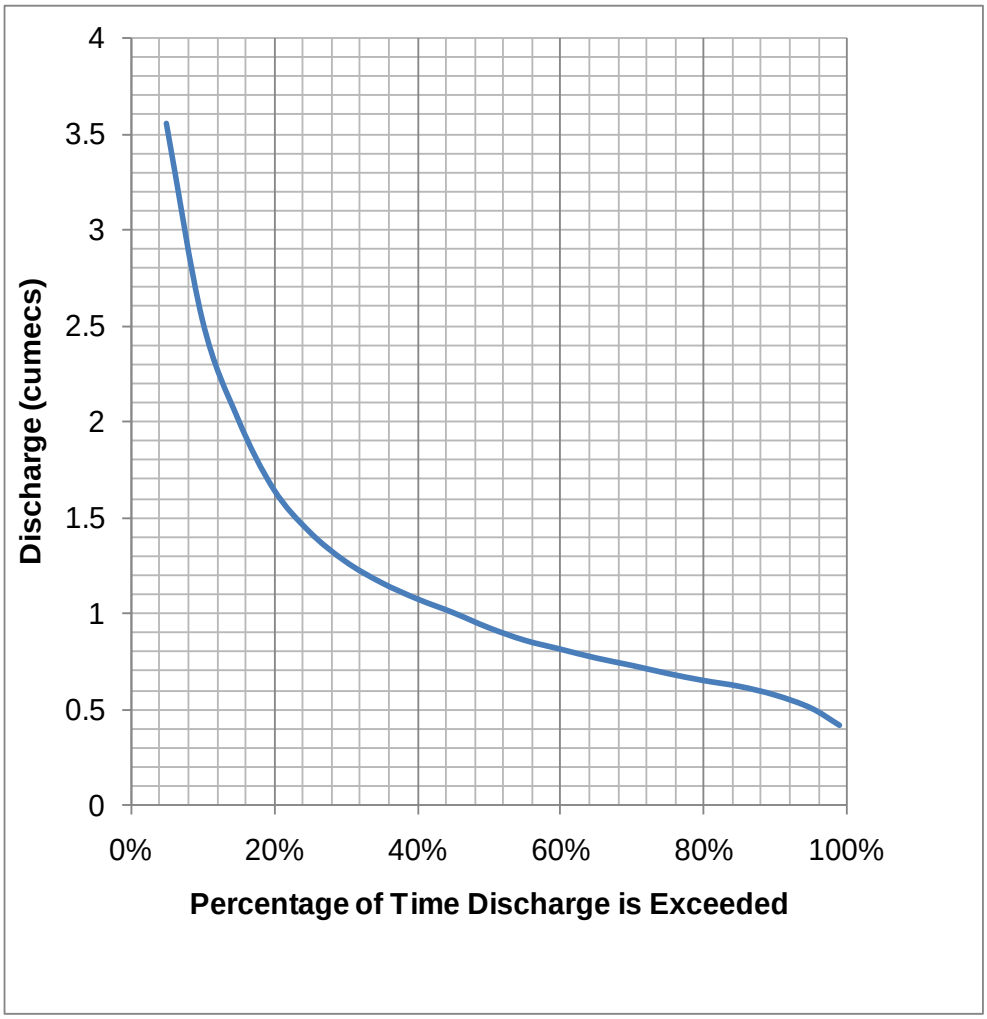


Figure 2.5 Lubilia Flow duration curve

2.4 Flood Frequency Analysis

The annual maximum flow series was formed by selecting the highest daily mean flow occurring in each year of the record. The set of the derived average maxima are assumed to be a random statistical sample from the population of all possible maxima at the site. The Gringorten plotting formula (i-0.44)/(N+0.12), was used in the analysis. This formula is suitable when fitting any of the family of General Extreme Value distributions (GEV) to the data.

2.4.1 Lubilia Flood Frequency curve

Figure 2.6 demonstrates the results of the successfully fitted the Extreme value distribution (EV1) to the annual maximum flow series for the derived River Lubilia data.

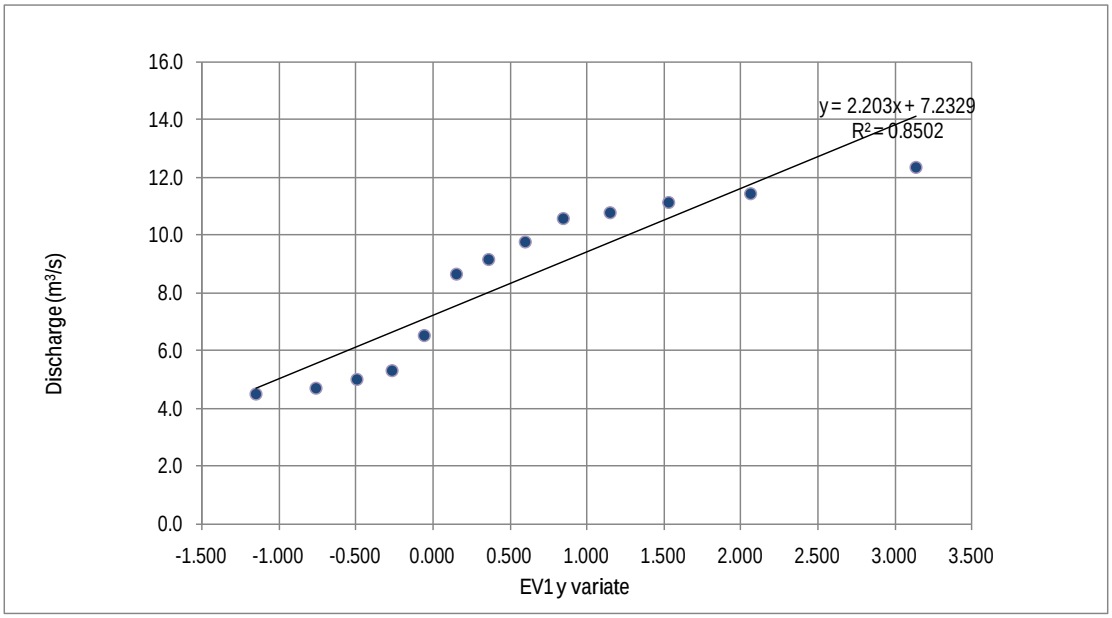


Figure 2.6 Lubilia annual maxima discharge fitted with the Gumbel distribution

After fitting the distributions, floods of specific return periods were computed and are given in Table 2.4 below.

Table 2.4 Annual Maximum flows for 2 to 10,000 year return period for R. Lubilia take off point

Return Period T (Years)	Maximum River Discharge (m^3/sec)
2	7.97
5	10.48
10	12.15
30	14.66
100	17.35
1000	22.46
10000	27.56

2.4.2 Low flow characteristics of R. Lubilia Takeoff.

The Log-Normal distribution was fitted to the annual minimum series for R. Lubilia takeoff from which the extreme low flows were computed as shown in Table 2.5. From the table, it is expected that once in every 50 years, there is a day with negligible or zero mean flow.

Table 2.5 Annual Minimum flows for 2 to 50 year return period for Lubilia Takeoff.

Return Period T (Years)	Minimum River Discharge (m^3/sec)
2	0.52
5	0.43
10	0.39
15	0.37
25	0.35
50	0.32

Appendix 1: Derived monthly discharges for R. Lubilia (1968-1980)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	NA	NA	NA	NA	NA	NA	NA	0.78	0.79	1.33	1.72	1.84
1969	1.21	1.50	1.50	1.38	1.53	0.90	0.70	0.70	0.93	0.75	0.96	1.03
1970	1.20	0.99	2.42	5.99	2.74	1.52	0.93	1.82	1.78	1.54	1.27	0.92
1971	0.79	0.65	0.77	1.13	1.45	0.96	0.78	0.65	0.69	1.74	2.30	1.00
1972	1.26	1.32	1.26	2.97	1.71	1.61	1.04	1.37	1.04	1.30	3.16	1.23
1973	0.81	0.78	0.56	0.73	0.96	0.64	0.45	0.56	0.83	0.55	1.58	0.71
1974	0.61	0.45	0.65	1.08	1.37	1.62	1.59	0.86	1.14	0.72	1.42	0.91
1975	0.99	0.62	0.64	1.05	2.53	1.20	0.68	1.28	2.18	4.47	2.57	3.38
1976	1.51	1.18	0.76	1.19	2.21	1.41	1.24	1.27	1.47	1.46	0.85	0.86
1977	0.77	0.66	1.35	1.64	0.69	1.47	0.93	0.83	1.43	1.68	2.81	1.18
1978	0.76	0.80	1.41	1.72	1.29	1.05	0.85	0.68	1.52	2.91	2.16	1.28
1979	1.02	2.73	1.62	1.44	2.53	1.38	0.64	1.13	0.81	0.85	1.03	0.90
1980	0.66	0.58	1.17	1.20	2.82	1.25	NA	NA	NA	NA	NA	NA