

Hydrological assessment of flow in Uma Oya, Sri Lanka

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Introduction

A current meter is usually used in river flow measurements. However, if someone is interested in obtaining the temporal variation of a particular river, it may not be the easiest method in the world to use a current meter (i.e. daily) to measure the flow rate. In such events, the stage measurements can be taken and then, they can be converted to the flow rates (USGS, 2014). One can use the stage-discharge relationship to find the corresponding flow rate (Mortuza *et al.*, 2011; Raj and Azeez, 2009; Gupta and Chakrapani, 2005).

However, this method still requires some flow measurements to produce the stage-discharge relationship. Therefore, a current meter should be there to measure the velocities and then, to calculate the flow rates. In case of absence of a current meter, one has to think another way of obtaining the flow hydrograph. This paper presents a simple approach in obtaining the flow hydrograph for a river in Sri Lanka: Uma Oya. Uma Oya catchment is being modeled and this study shows some preliminary results. The detailed flow hydrograph for Uma Oya for a longer period is being developed for the frequency analysis. The developed flow hydrograph is being used to model the Uma Oya catchment in Sri Lanka.

Uma Oya catchment

The catchment of Uma Oya upper watershed was found to be around 750 km² (Dam safety and Water resources planning project component report, 2010; Dissanayake *et al.*, 2010). However, a detailed catchment analysis is being carried out and the catchment areas will be listed in the future publications. Since it is in upcountry of Sri Lanka, steep slopes are quite frequent along the river. It has even reached about 1900 m MSL (Dissanayake *et al.*, 2010). The catchment is basically a green catchment. Natural forests, tea estates, paddy fields and potato farming lands are commonly seen in the catchment (Dam safety and Water resources planning project component report, 2010; Dissanayake *et al.*, 2010). Natural forests cover the highest elevations. Then, tea estates, potato farms and other vegetable and paddy fields cover the lower elevations.

Uma Oya is one of the main tributaries in Mahaweli River. It flows into the Rantambe reservoir (refer Figure 4). The upper catchment is hardly conserved from soil erosion; therefore, a significant amount of sediment flows into the reservoir. Sediment deposition can be visually evidenced in the Rantambe reservoir. Therefore, the reservoir faces the reduction of its water holding capacity and then, the reduction of electric generation capacity. In addition, Uma Oya catchment is one of the rainy catchments in the country. Therefore, it has a wealthy sediment flow.

Rainfall patterns in Sri Lanka

Sri Lanka is a country blessed with water resources. Unlike most of the other countries in the region, it has rain throughout the year. It has two monsoons and two inter-monsoon rainy seasons. The diagram given in Figure 01 shows the rainfall patterns in Sri Lanka throughout the year. Temporally, Sri Lanka has no dry seasons; however, spatially, there are some dry periods to some parts of the country. For example, some locations in Jaffna, Batticaloa and Mannar get a little rain during the south-west monsoon season (May to September).

Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1st Inter-monsoon season		South-west monsoon season					2nd Inter-monsoon season		North-east monsoon season		

Figure 01: Rainfall patterns in Sri Lanka

Since this paper targets the catchments of Uma Oya, the discussion of rainfall is limited to a particular one season; north-east monsoon season. North-east monsoon season dominates most of the north and eastern part of the Sri Lanka including Uma Oya catchment. The Figure 02 gives the spatial variation of rainfall during the north-east monsoon season. Northern and eastern slopes of the hill country and the eastern slopes of the Knuckles / Rangala ranges experience the highest rainfall from this monsoon (Meteorology department, Sri Lanka). The maximum-recorded rainfall was to Kobonella estate whereas the minimum was to Chilaw. According to the Figure 02, it can be clearly seen that Uma Oya catchment gets a significant amount rainfall during the months of December to February (red squared section).

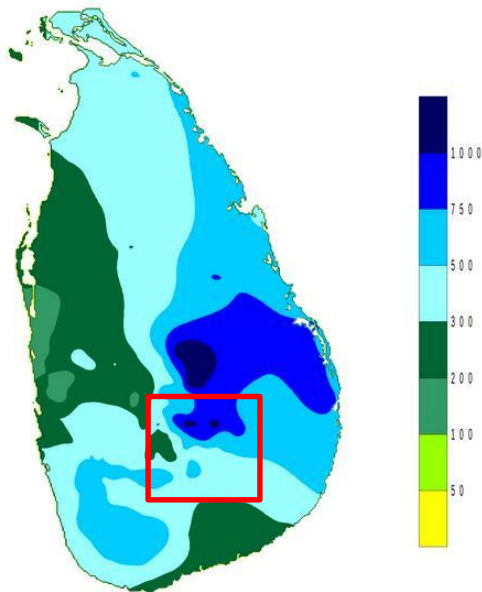


Figure 02: Rainfall variation across Sri Lanka due to north – east monsoon (Department of Meteorology, Sri Lanka)

Flow hydrograph from Uma Oya to Rantembe reservoir

A schematic diagram of a reservoir is presented in Figure 03. I_t and O_t are the inflows and outflows from the reservoir, respectively.

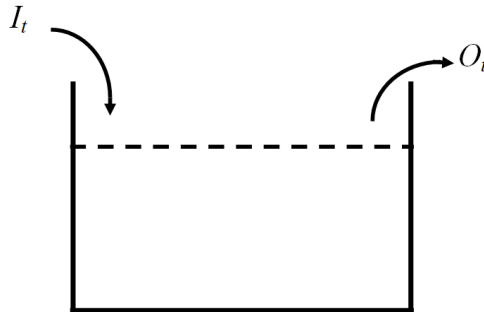


Figure 03: Schematic diagram of a reservoir

Referring Figure 03, a simple continuity equation for reservoir routing can be drafted (Equation 01). This equation can be used to calculate the temporal variation of any unknown from inflow, outflow or capacity while the other two variables are given.

$$\frac{S_{t2} + S_{t1}}{\Delta t} = \left(\frac{I_{t1} + I_{t2}}{2} \right) - \left(\frac{O_{t1} + O_{t2}}{2} \right); \quad \Delta t = t2 - t1 \quad (01)$$

where S_{it} , I_{it} and O_{it} are the capacity of the reservoir, inflow to the reservoir and outflow from the reservoir at time t_i , respectively. Δt is the time step for the temporal variation.

Rantembe reservoir has two main and one minor inflows as shown in the Figure 04 (I_R , I_U & I_M). I_R represents the outflow from the Randenigala reservoir. This outflow can be either the flow from Randenigala hydropower station or the summation of hydropower station and any spilling. I_U is the flow from Uma Oya and I_M stands for the inflow from a small creek called Maha Oya. However, compared to I_R and I_U , I_M is much lower (as it is a small creek).



Figure 04: Flow characteristics for Rantembe reservoir (Photo – Google maps)

Given that the temporal variations of storage in Rantambe reservoir and the outflows from Rantambe reservoir (both for hydropower generation and spilling flows) are available, one can find the temporal variation of the inflow to the Rantambe reservoir from Uma Oya. Therefore, the flow hydrograph of the Uma Oya at Rantambe reservoir is available.

The height VS volume curve for Rantambe reservoir is available. The reservoir specific curve is given in the Figure 05. Assuming that the curve hasn't been deviated its original from the sediment inflow, it can be used to find the volume of the water stored in the reservoir by measuring (observing) the water height in the reservoir. Therefore, this relationship can be effectively used to calculate the S_{t1} and S_{2} terms in Equation 01.

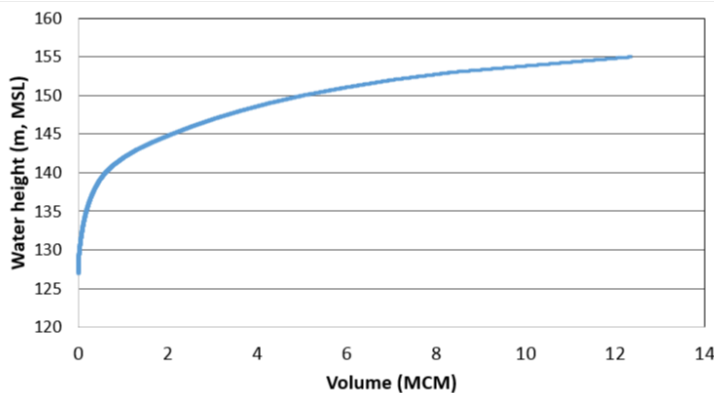


Figure 05: Rantambe reservoir height VS volume relationship

The outflow (O_{t1} and O_{2}) from the reservoir can be found from the data available on spills and electricity generation. Therefore, the temporal variation of inflows can be calculated.

Result and Discussion

Figure 06 shows the flow hydrograph from Uma Oya to Rantambe reservoir during several days in the month of December in year 2004. This figure clearly shows the diurnal pattern of the flow. Daily average flow is found to be $180.7 \text{ m}^3/\text{s}$. However, the maximum flow rate during this period was $605.5 \text{ m}^3/\text{s}$ while the minimum was $8.6 \text{ m}^3/\text{s}$. It can be clearly seen herein that the peak flows are usually during the night or late night time of the day.

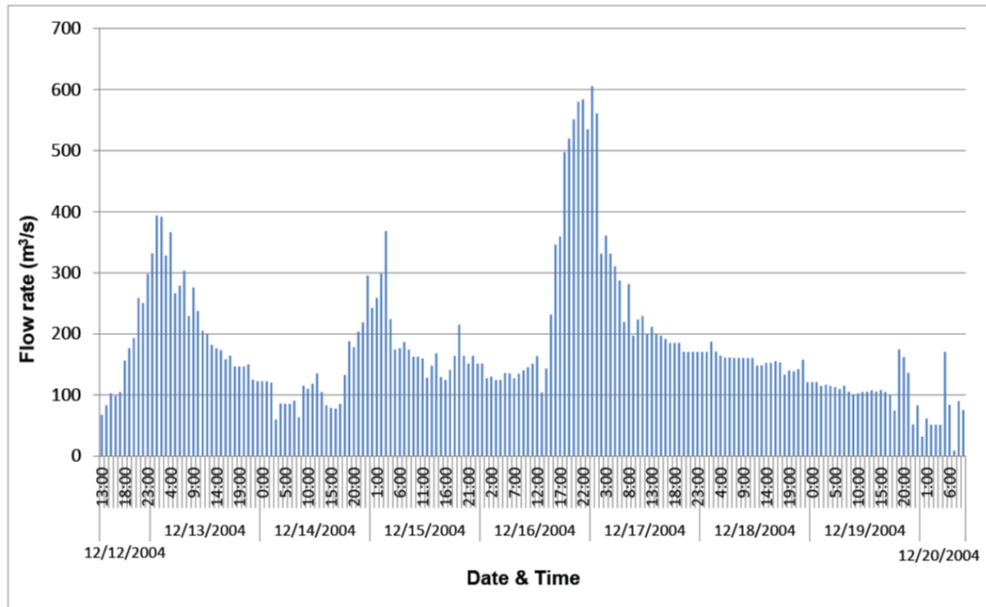


Figure 06: Flow hydrograph for Uma oya

However, the developed hydrograph is for a limited period. Therefore, this hydrograph can not be used for a frequency analysis. However, the research is being carried out to develop a detailed hydrograph for Uma Oya.

Conclusions

Uma Oya catchment is being modeled. This paper shows the preliminary results of obtaining the flow hydrograph of Uma Oya. The flow hydrograph for Uma Oya at Rantembe reservoir is developed; however, the completed flow hydrograph is being developed for the hydrological analysis of the Uma Oya catchment.

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