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PREDICTION OF UNGAGED BASINS (PUB) IN THE VICTORIA - RANDENIGALA - RANTAMBE (VRR) SANCTUARY OF SRI LANKA – APPROACH BASED ON SYNTHETIC UNIT HYDROGRAPHS

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ABSTRACT

A hydrologic study was performed for ungaged basins to examine synthetic discharge relations. Six sub-catchments in the Victoria - Randenigala - Rantambe (VRR) sanctuary, viz.: Kehelella Ela, Unagolla Kandura, Maha Oya, Ma Oya, Medagama Oya and Mala Oya, were selected for this study. Rainfall-runoff relationships developed by the National Environmental Research Council (NERC), UK were used for this study. Maps and reports provided basic data while climatological relationships were calculated using parameters obtained from the tables of the Flood Studies Report (FSR). These results provide parameters for synthetic unit hydrograph (SUH), 200-year flood peak predictions and regional coefficients for sub-catchments. The SUH show peak discharge within two to three hours from the onset of rainstorm and the time base shows an increment with increasing catchment area. A positive relationship between catchment slope and discharge is observed. The 200-year flood peaks vary between 57 and 194 m^3/s. The average flood peak in the left-bank sub-catchments of the area is 127 m^3/s and is lower than the Mala Oya sub catchment in the right bank. The regional coefficients for discharge vary from 0.0024 to 0.0145 with an average of 0.0110. These synthesized results need to be evaluated using simulated and/or long-term experimental data, so that the PUB based on SHU can be utilized as reliable tools in water management.

INTRODUCTION

In many engineering designs, hydrologists are faced with a difficult task of collecting reliable field hydrological data. Under such situations they approach for either synthetic or statistically generated data. In some cases, considering that the data would have a natural cycle, extrapolate them for continuous, discreet or random distributions. In the absence of above criteria, the data distribution based on arbitrary reasoning may provide necessary match. However, one should see how far the natural manifestation of morphology and precipitation on a terrain would affect the results of such predictions. Since remote sensing coupled with GIS techniques have been applicable nowadays in the process of unraveling such outcome, we could better approach to overcome the situations with lack of data. In the present study we aim to provide background hydrological information in solving problems anticipated in engineering designs of several catchments in the Mahaweli basin.

The preliminary study was carried out in a period between 1997 June to 1998 March (Dhanapala, 1998; Dhanapala and Jayasena, 2002). It comprised with limited field, but extensive desktop investigations and EXCEL spread sheet calculations with a view to develop a hydrologic model for selected sub-catchments in the VRR sanctuary within the central Mahaweli region of Sri Lanka. Desktop hydrologic analyses aided with empirical formulas were employed in obtaining necessary hydrological parameters.

The study area belongs to the central region of Mahaweli Ganga basin and is characterized by extremely complex and variable patterns of relief, agricultural land-use and forest cover. This study includes hydrologic analysis of six catchments, which cover an area of about 150 km^2 (about 58 mile^2). Kehelella Ela, Unagolla Kandura, Ma Oya, Medagama Oya and Maha Oya (Lower) basins falls in the left bank of Mahaweli Ganga and are adjacent to each other. They are located within the coordinates 7° 10′ to 7° 20′ N and 80° 49′ to 80° 59′ E. The Mala Oya basin falls in the right bank and is located within the coordinates 7° 06′ to 7° 11′ N and 80° 53′ to 80° 56′ E (figure 1). These basins discharge their waters to Mahaweli Ganga at various locations from Kimbulantota to Rantambe and provide water for the two artificial reservoirs viz: Randenigala and Rantambe.

Major objectives of the present work are:

1. To obtain discharge values based on drainage parameters of small watersheds,
2. To estimate flood peaks designed for a suitable return periods and
3. To derive regional coefficients from flood studies.

The method developed in the Flood Studies Report (FSR) of the National Environmental Research Council (NERC), U.K. (1975) was chosen for the present study.

We intend to use these results to develop more accurate hydrologic models for many other catchments. These models can be utilized as tools for designing water management programs, and engineering, hydrologic and flood prevention structures.

Rainfall Pattern And Distribution

The study area lies in the rain shadow of the Knuckles Range and the main mass of the hill country. This area comprises a greater part of the intermediate climatic zone of Sri Lanka. The precipitation, controlled by ITCZ (Intra Tropical Convergence Zone) and orographic effects, show distinct bimodal distribution with peaks from December to February (northeast monsoon) and from May to September (southwest monsoon). The highest rainfall usually receive during the northeast monsoon and proceeded inter monsoon convection rains.

Measures of rainfall in the area provide sufficient data to describe variations within the valley. The average annual rainfall for the area varies between 2000 to 3400 mm and increases northwards in many of the sub-catchments (Figure 1). The average annual temperatures vary from 20.0° to 22.5° C and decrease towards the Central Highlands.

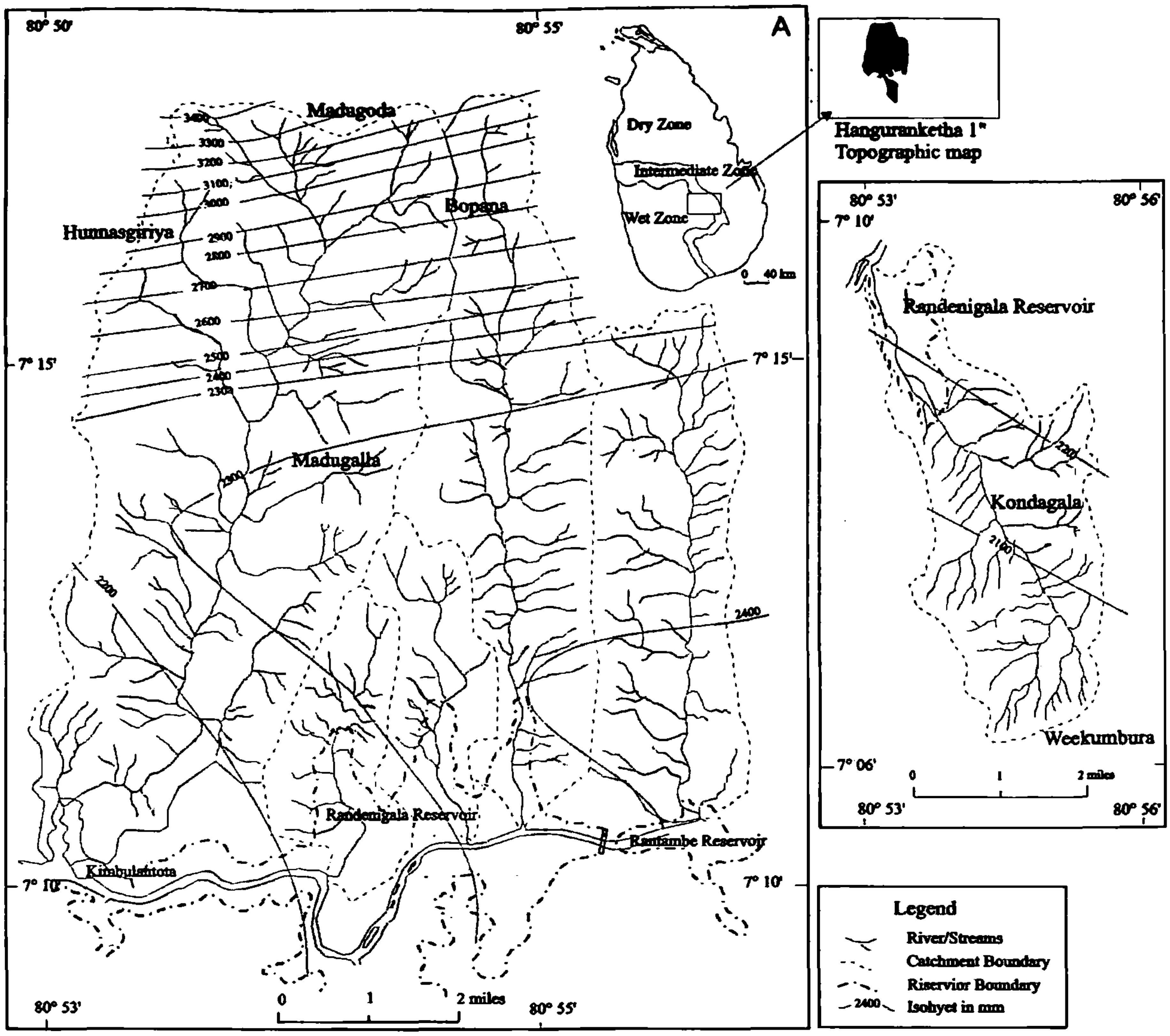

Fig: 1. The figure showing Kehelella Ela, Unagolla Kandura, Ma Oya, Medagama Oya and Maha Oya (Lower) basins in the left bank and Mala Oya basin in the right bank of the Mahaweli Ganga of Sri Lanka.

Physiography And Drainage

The study area consists of a series of massive, steep-sided, north trending strike ridges and valleys. The basement comprises high-grade, lithologically and isotopically distinct, Proterozoic metamorphic rocks, belonging to the Highland Complex of Sri Lanka (Cooray, 1984; Almond, 1994; Kröner et. al., 1991). Major rock types of this area are: Quartzites and quartz schists, Charnockitic Gneisses, Garnet-Biotite-Sillimanite Gneiss ± Graphite, Undifferentiated charnockitic biotite gneiss and Marble.

Drainage in the tributary streams within the selected basins generally confined to prominent geological structures such as joints, fracture zones and lineaments, and along weak rocks such as marble and khondalite. In general most of the highest order streams usually follow the same trend. The highest elevations of these basins vary from 305 m close to the Mahaweli River and about 750 m in the mountainous peaks (Anon., 1962). These basins therefore extend in the north south directions and bounded by elongated drainage divides. In addition, inter basin areas in which drainage systems were not developed, but drain waters directly into the Mahaweli Ganga are also considered. Usually discharge along the first and second order streams depend on the seasonal rainfall while higher order streams are usually perennial (Suhail, 1997). Fifth order stream was encountered for the largest basin selected for the region. Based on point discharge observations, stream segments have discharge values ranging from 2.5 to 200 m^3/s. These values have been obtained from Uma Oya, Kurundu Oya and Belihul Oya basins during the dry season (March to end of September) (Suhail, 1997).

Several distinctive land-use patterns have been identified in the study area. The permanently cultivated lands are mainly confined to the western end. However, strips of land occupying the wetter, higher areas on the southern slopes of the Knuckles Range and in the northern slopes of the main hill country are also found to be cultivated. Recently established Victoria-Randenigala-Rantembe (VRR) Sanctuary is covered with moderate to dense forest so that these areas are devoid of land use. Intermediate dry evergreen forests are also present in the study area (Gunathilleke and Gunathilleke, 1990). Since, many parts of the study area being degraded by various man-made practices, such as chena cultivation and forest fires, secondary forests have been later occupied the region. These sparsely distributed forest areas show open canopy with savannah grasslands at places, which may be quite significant in terms of hydrologic analysis. Riverine vegetation is associated with the streams and rivers.

Major soil groups in the region are Reddish Brown Earths (RBE) and Low Humic Gley (LHG) (National Atlas of Sri Lanka, 1988). However, some areas consist of Red Yellow Podzolic (RYP) soils. The flood plains have five to nine meters thick alluvial soils. Colluvial soils are also found in certain parts, which usually formed uniform slopes, while hummocky and carved topography occurred in the eroded regions (Suhail, 1997).

Methods Of Study

The study used the method developed by the National Environment Research Council (NERC) of UK (Flood Study Report -FSR in 1975). Wilson (1990) quoted the fundamentals of precipitation-runoff relationship through synthetic unit hydrograph from catchment characteristics using the FSR method. The FSR method is applied in this study to construct a unit hydrograph for each selected catchment.

In this method, a unit hydrograph is synthesized using the basic parameters selected by Snyder (1938) as follows:

i. hydrograph base width (T_B)
ii. peak discharge (Q_p)
iii. basin lag (T_p)

A number of fundamental meteorological, hydrological and geomorphological parameters were obtained from the available maps published by the different institutes and from other sources. The unavailable parameters were derived based on several assumptions. To compute T_B, Q_P and T_p, a stepwise approach developed by Wilson (1990) was used.

Synthesis Of The Unit Hydro-Graph For The Catchment

The flood peaks with a 200-year return period were estimated by means of synthetic unit hydrograph as discussed below. Individual parameter estimation was either obtained or calculated based on the following criteria as discussed by Wilson (1990)

Catchment Area (Area) And Main Stream Length (Msl)

Catchments, microbasins and interbasins of central region of the Mahaweli Ganga were established. The area of the catchment and the length along the longest stream on 1:63,360 scale topographic maps (Kandy, Hanguranketha, Nuwara Eliya) have been measured. The FSR though recommended 1: 25,000 scale maps for obtaining AREA and MSL, we used 1:63,360 scale maps and measurements were converted to above scale. The area measured by OTT Planimeter (Type 31 L) in square miles and the MSL parameter in miles.

Channel Slope (S1085)

Channel slope S1085 is the average slope in m/km between two points at 10 percent and 85 percent of the mainstream length measured from the outlet. The FSR suggests taking S1085 in m/km. The maps used for the present study (1:63,360 scale) show elevations in feet with contour interval of 100ft. The lengths were measured in miles. Therefore the slope was first measured as ft/mile and then converted into m/km.

The Standard Average Annual Rainfall (Saar)

The Standard Average Annual Rainfall (SAAR) was obtained by taking a weighted average over the catchment based on the monthly rainfall values. Monthly average rainfall in millimeters for 30 years have been collected form rain gauging stations established in the study area by the Meteorological Department of Sri Lanka. The isohyets with 100 mm intervals have been drawn for the study area (Figure 1). The average rainfall between two successive isohyets was calculated according to the proportion of area to obtain SAAR value for each catchment.

Rainfall Less Soil Moisture Deficit (Rsmd)

Rainfall less Soil Moisture Deficit (RSMD) values have been calculated and plotted in different intervals for the British Islands. Since, such maps were not available for Sri Lanka, an alternative approach was applied. The relationships associated with different parameters, which are reasonably well suited for the British Islands, were initially obtained and assumed to be applicable to the present study.

(a) 2-day M5 Rainfall
(average for the catchment)

There is a close relationship between SAAR and 2-day M5 value (identified from the maps reproduced by the NERC in the FSR, 1975). This relationship was applied to obtain the 2-day M5 values for the selected catchment.

$$\text{2-day M5 rainfall} \sim 0.0625\ \text{SAAR}.$$

(b) Rainfall Ratio, r
(average for the catchment)

$$\text{ratio } (r) = \frac{\text{60-minute M5}}{\text{2-day M5}} \text{ (as a percentage)} \quad (1)$$

Instead of finding 60-minute M5 values to calculate r, applying a relationship between 2-day M5 and r identified from the above maps is convenient. Therefore,

$$R \sim 0.45 \text{ 2-day M5 } \% \quad (2)$$

(c) 24-h M5 Values

This value is obtained from the model for M5 rainfall for duration up to 48 hours (FSR, 1975).

(d) 1-day M5 Value

Because of the difference between rainfall hours and rainfall days, it is necessary to multiply the M5 values for the days by the factors given in FSR (1975). Therefore, 1-day M5 value is obtained by multiplying 24-h rainfall value by the factor 1.11.

(e) Effect of Aerial Reduction

An ARF value was obtained from FSR (1975) considering the extent of the duration and the area. The effective 1-day M5 rainfall is given by:

$$\text{1-day M5 rainfall x ARF} \quad (3)$$

(f) Soil Moisture Deficit (SMD)

By deducting the soil moisture deficit (SMD) from the 1-day M5 rainfall (from step (e)), RSMD can be obtained.

$$\text{RSMD} = \text{1-day M5 rainfall} - \text{SMD} \quad (4)$$

Because of the unavailability of SMD data for the selected catchments, it was assumed to be 4.0 mm for each catchments of the study area.

Urban Development Fraction (Urban)

The Urban Development Fraction (URBAN) factor becomes zero when there is no significant urban development. This can be estimated from the available Land Use maps and found that URBAN = 0 for all the selected catchments.

Unit Hydrograph Parameters

The time to peak (T_p), peak discharge of the unit hydrograph (Q_p) and the time base (T_B) were estimated by the empirical relationships presented by NERC in the FSR (1975).

$$T_p = 46.6\,(\text{MSL})^{0.14}\,(\text{S1085})^{-0.38}\,(1+\text{URBAN})^{-1.95}\,(\text{RSMD})^{-0.4} \text{ (measured in hours)} \quad (5)$$

$$Q_p = 220/T_p \text{ (measured in m}^3\text{/s per km}^2\text{)} \quad (6)$$

$$T_B = 2.52\,T_p \text{ (measured in hours)} \quad (7)$$

These fundamental data were plotted to obtain the synthetic 1-h unit hydrograph (Fig. 2).

Estimation Of Flood Peaks Of A Catchment

Basic Data Interval

The basic data interval was determined by the time to peak (T_p) value.

$$T \sim T_p/5 \text{ (in hours)} \quad (8)$$

Storm Duration

The following equation was used to calculate the storm period. It is convenient to make D an odd integer multiple of the basic data interval (T).

$$D = (1 + SAAR/1000)\, T_p \text{ (in hours)} \qquad (9)$$

Return Period of the Storm

The return period of storm will produce the appropriate return period peak flow. The recommended return periods from 10 to 1000 years can be obtained, which illustrates relationships between flood peak and the rainstorm return periods (in years). For the present study, 200-year return period peak flow has been considered; hence the storm return period is 240 years (Wilson, 1990).

M5 Rainfall during the Storm Period

Using the r and D values obtained in previous steps, net M5 rainfall value for the storm duration can be evaluated (FSR, 1975).

Point Rainfall

This requires a growth factor to interpolate D-h M5 to D-h M240 because of the selected storm return period is 240 years. The tabulated growth factors given for British Islands as stated in the FSR (1975) by NERC have been used. A reasonable value for this study has been assumed accordingly.

Catchment Average (Rainfall P)

Aerial Reduction Factor (ARF) is used in interpolating this value. The ARF values for different rainfall duration and different catchment sizes were obtained from FSR (1975). An appropriate value was obtained using D and AREA parameters.

$$P = \text{D-h M240} \times \text{relevant ARF} \qquad (10)$$

Catchment Wetness Index (Cwi)

The recommended design values for CWI for different SAAR values were obtained from Wilson (1990).

Soil Parameter And The Runoff Percentage Parameters - Spr And Pr

As expressed in the FSR method, the SOIL is a composite index determined from soil survey maps. The derivation is based on the following formulae:

$$SOIL = \frac{(0.15\, S_1 + 0.30 S_2 + 0.40 S_3 + 0.45 S_4 + 0.5\, S_5)}{S_1 + S_2 + S_3 + S_4 + S_5} \qquad (11)$$

Where $S_1 \ldots S_5$ denotes the proportions of the catchment covered by each soil class. Although several soil classification maps of the study area are available, we figured that these data could not be directly applied to the present study. Therefore judgement based on FSR (1975) methods was used to obtain a reasonable estimate for the SOIL parameter.

The Standard Percentage Runoff (SPR)

$$SPR = 95.5\, SOIL + 0.12\, URBAN \qquad (12)$$

For the designed event, the appropriate runoff percentage (PR)

$$PR = SPR + 0.22(CWI - 125) + 0.1(P-10) \qquad (13)$$

Net Rain for the Unit Hydrograph

The net rain applied to the synthetic unit hydrograph can be obtained by P (PR/100) mm

Stepped Distribution Graph Of Rain And The 1-H Unit Hydrograph

The net rain calculated at the previous step must be applied to the hydrograph in accordance with a 75 percent storm profile (Wilson, 1990). This distribution should take place over the time period D. Therefore a stepped distribution graph will be generated with the basic data interval T. Each interval is approximately 100/D percent of the duration. These data are then tabulated and are arranged symmetrically about the centerline before applying to the synthetic unit hydrograph. The unit hydrograph ordinates were obtained from the plotted 1-h unit hydrograph with reference to the basic data intervals. Each increment as given in the convolution table (Wilson, 1990) is 1-h rain which is multiplied in turn by each hourly ordinate of the unit hydrograph. The successive products were moved successively 1-h to the right. This may be continued to the right to provide further ordinates of the total hydrograph. The maximum total value was selected as the peak surface flow of the flood of 200-year return period, excluding the base flow.

Baseflow

The term average non-separated flow (ANSF) has been proposed and is calculated as follows based on catchment characteristics of a large number of British catchments. The baseflow was calculated from the following equation, which gives the flow in $m^3/s/km^2$.

$$ANSF = (3.26 \times 10^{-4})(CWI - 125) + (7.4 \times 10^{-4}) RSMD + (3 \times 10^{-3}) \qquad (14)$$

Hence, Base flow = AREA x ANSF (in m^3/s) (15)

By adding the baseflow to the peak surface flow, the peak flow of the flood of 200-year return period can be obtained.

Derivation Of A Regional Coefficient For Peak Flows

This includes some of the catchment and meteorological parameters derived in previous steps. It also associates with the lake or reservoir fraction and the stream frequency of the catchment.

Fraction of Lake or Reservoir (LAKE)

The FSR method has defined a LAKE parameter, which is the fraction of catchment draining through lake or reservoir. Since there is no such significant area identified from the maps, LAKE = 0 for all the studied catchments

Stream Frequency (STRMFRQ)

Stream Frequency (STRMFRQ) was employed in the UK Flood Studies Report (Natural Environmental Research Council, 1975) reflecting the drainage density of a catchment. It was simply a measure by counting channel junctions on 1:25,000 maps and dividing it by the basin area.

STRMFRQ = Number of Stream Junctions/AREA. (16)

Although the FSR recommendation is to count stream junctions per km^2 on 1: 25,000 scale maps, for the present study 1: 63,360 (1-inch) maps were used.

Relationship between Peak Flow and other Catchment Characteristics

This relationship has been defined by NERC (1975) in FSR as follows:

$$Q_p = C\,(AREA)^{0.94}\,(STRMFRQ)^{0.27}\,(SOIL)^{1.23}\,(RSMD)^{1.03}\,(S1085)^{0.16}\,(1 + LAKE)^{-0.85} \quad (16)$$

C is a regional coefficient specific to the catchment. It was calculated by substituting the values for each parameter.

RESULTS AND DISCUSSION

Table 1 shows the derived fundamental basin parameters by FSR method. Several assumptions and approximations have been incorporated in obtaining these parameters as discussed above. The justification of their usage in making hydrological predictions is to be tested and refined later with more controlled calibration and validation process.

The peak discharge achieves within two to three hours from the onset of the rainstorm. It takes different time periods i.e. time bases (T_B) to reach its normal discharge conditions. The T_B shows an increment with the increasing catchment area (Figure 2).

Table: 1. *Derived fundamental basin parameters after FSR method*

Name of the Basin	AREA (km^2)	MSL (km)	SAAR (mm)	S1085 (m/km)	RSMD (mm)	SOIL	URBAN	LAKE	STRMFRQ (Junctions/ km^2)
1. Kehelella ela	24.605	13.52	2476.94	55.61	119.19	0.4	0	0	2.32
2. Ungolla Kandura	11.665	5.6	2329.11	58.06	113.03	0.4	0	0	2.23
3. Ma Oya	63.222	18.90	2617.38	25.79	126.00	0.3	0	0	1.90
4. Medagama Oya	8.651	6.88	2391.61	44.30	116.17	0.4	0	0	1.85
5. Maha Oya (Lower)	18.052	10.08	2416.67	68.54	117.43	0.4	0	0	3.10
6. Mala Oya	25.951	11.04	2181.04	80.89	104.51	0.4	0	0	2.62

The effect of catchment slope (S1085) on discharge is clearly seen when comparing synthesized discharge of Kehelella Ela and Mala Oya basins. Although both basins have almost similar parameters except the slope, the high S1085 value for Mala Oya may have resulted higher runoff than that of Kehelella Ela.

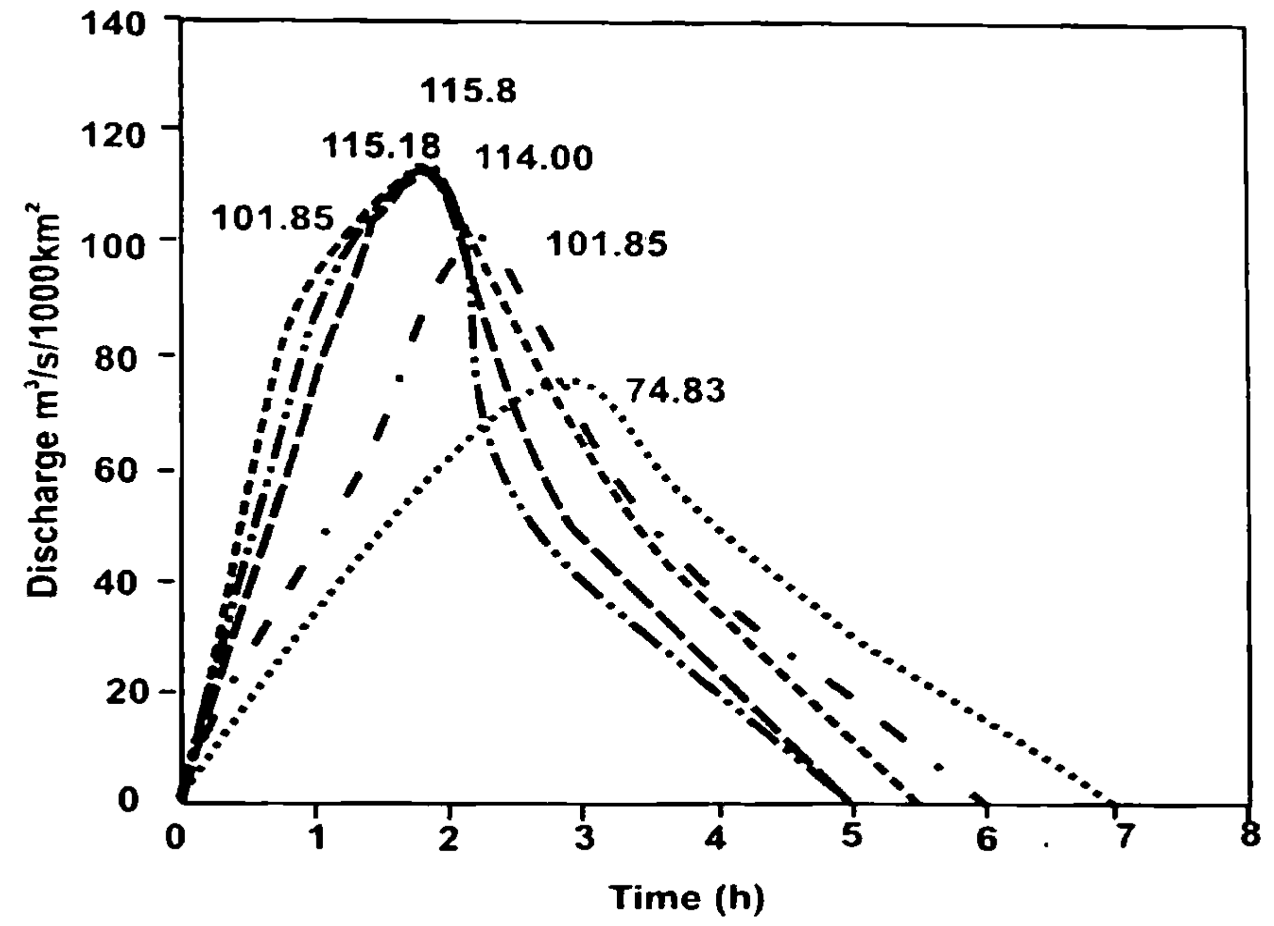

Fig: 2 Synthetic Unit Hydrographs derived for the six catchments in the Mahaweli basin

The 200-year return period flood peak values for the selected catchments vary between 57 and 194 m^3/s (Table 2). The highest flood peak is obtained from Kehelella Ela. However, the largest catchment, Ma Oya, which lies in a relatively high rainfall zone, does not show the highest peak. Since this may be due to the fact that it has a lower stream frequency (STRMFRQ) and gentle catchment slope (S1085). Although it is not the smallest catchment of the study area, Medagama Oya has the lowest flood peak. The average flood peak of the left-bank sub-catchments of the area is 127 m^3. It is required further analysis on several right-bank sub-catchments to compare the flood peaks. The base flow values cannot be compared meaningfully by using surface features since many subsurface features such as fracture density heavily control it. The regional coefficients for discharges based on the catchment characteristics vary within the range from 0.0024 to 0.0145. The highest value was resulted from Kehelella Ela and the lowest was from the Mala Oya of the right bank (Table 2). An average figure for this region can be given as 0.011. However, this regional coefficient is not the same, which was defined in the FSR (1975).

***Table:** 2. Summarized results for the six catchments*

Name of the Basin	T_p Time to Peak (Hr)	T_B Time base (Hr)	Q_p (m^3/s) for 200 km^2	Q_p (m^3/s) for the Basin	ANSF ($m^3/s/km^2$)	Base flow for Catchment (m^3/s)	200 year flood Peak discharge ($m^3/s/100km^2$)	Regional Coefficient
1. Kehelella ela	2.16	5.5	101.85	25.16	0.092	2.26	194.37	0.0116
2. Ungolla Kandura	1.91	5	115.18	13.40	0.088	1.03	68.79	0.0133
3. Ma Oya	2.94	7	74.83	47.31	0.097	6.13	179.87	0.0145
4. Medagama Oya	2.16	5	101.85	8.81	0.090	0.78	57.16	0.0123
5. Maha Oya (Lower)	1.93	5	114.00	20.58	0.090	1.63	136.59	0.0120
6. Mala Oya	1.91	5	15.80	30.05	0.081	2.10	147.18	0.0024

CONCLUSIONS

The PUB using SUH can be utilized as reliable tools in water management. However, these synthesized results need to be evaluated using simulated and/or long-term experimental data when applying for hydrological design studies. The rainfall-runoff relationships developed by the National Environmental Research Council (NERC), UK (1975) can provide synthetic data based on data obtained through maps and reports, while climatological relationships were calculated using parameters obtained from the tables of the Flood Studies Report (FSR). Suitable adjustments may need for some of these data. As per the six catchments that we used for the present study, a clear cut positive relationship between catchment slope and discharge is observed. The flood peak and the catchment area do not show a relationship since rainfall may have been influenced the discharge. One should notice that these results were based on the drainage characteristics of the region (obtained from maps) before impounding Randenigala and Rantambe reservoirs. Considerable portions of Unagolla Kandura and Medagama Oya basins are submerged by the impoundment of Randenigala reservoir so that the results may need adjustment. However, the results for other four subcatchments may not affect.

APPENDIX -CALCULATIONS

The calculation procedure is mentioned earlier in "Methods of Study". The calculations for the selected six catchments follow the same procedure. Therefore a master calculation is mentioned below for Kehelella Ela (mb). The parameters as calculated below were obtained from the tables given in the Flood Studies Report (FSR) (NERC, 1975)

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Calculation of Unit Hydrograph Parameters

(a) AREA = 24.605 km^2 MSL=13.52 km

(b) S1085 = 55.61 m/km

(c) SAAR = 2477.00 mm
(d) RSMD :

2-day M5 rainfall ~ 0.0625 SAAR = 154.81 mm
r ~ 0.45 2-day M5 = 69.66 %
24-h M5 rainfall = 92/100 x 154.81 mm = 142.43 mm
1-day M5 rainfall = 142.43/1.11 mm = 128.32 mm
ARF = 0.96 (from *Table 3 of the FRS*)
1-day catchment rainfall = 128.32 x 0.96 mm = 123.19 mm
Soil moisture deficit ~ 4.00 mm
Therefore, RSMD = (123.19-4.00) mm = 119.19 mm

(e) URBAN = 0

(f) T_p $= 46.6(\text{MSL})^{0.14}(\text{S1085})^{-0.38}(1+\text{URBAN})^{-1.99}\ (\text{RSMD})^{-0.4}$
$= 46.6\ (13.52)^{0.14}\ (55.61)^{-0.38}\ (1+0)^{-1.99}\ (119.19)^{-0.4}$
$= 2.16$ h

Q_P $= 220/T_p/100\ \text{m}^3/\text{s}/100\ \text{km}^2$
$= 220/2.16/100\ \text{m}^3/\text{s}/100\ \text{km}^2$
$= 25.06\ \text{m}^3/\text{s}$

T_B $= 2.52\ T_p = 5.5$ h
(See Fig. 2 for the derived unit hydrograph.)

Calculation for Estimation of Flood Peaks

(a) Basic data interval (T) $= T_p/5.5$ $= 0.4$ h

(b) Storm duration (D) ~ $(1 + \text{SAAR}/1000)\ T_p$ $= 7.51$ h (Take D as 7 h)

(c) 200-year peak flow return period =240 years (*from Fig.2 of FRS*)

(d) r = 69.66 % Therefore 69.66 % of 2-day M5 rainfall = 07.84 mm
(e) Growth factor =1.7 (Refer *Tables 4 a and 4 b of the FRS*)
Point rainfall = 107.84 mm x 1.7 mm = 183.33 mm

(f) ARF (from *Table.3 of the FRS*) = 0.94
Point rainfall (P) = 183.33 x 0.94 mm = 172.33 mm

(g) CWI (from *Fig. 3 of the FRS*) = 127

(h) SOIL: Slope $= \tan^{-1}(\text{S1085}/1000)$ $= 3.18°$
from *Table 5 of the FRS*, SOIL = 0.4
SPR = 95.5 SOIL + 0.12 URBAN = 38.2
PR =SPR + 0.22(CWI - 125) + 0.1 (P - 10)
= 38.2+0.22(127-125)+0.1(172.33 - 10)
= 54.87 %

The net rain applied to the unit hydrograph = P x PR
= 172.33 x 54.87%
= 94.56 mm

(i) Each hour rainfall percent = 14.3%

(j) Computation of Baseflow:

$$\begin{aligned}\text{ANSF} &= (3.26 \times 10^{-4})(\text{CWI-125})+(7.4 \times 10^{-4})\,\text{RSMD} + (3 \times 10^{-3}) \\ &= (3.26 \times 10^{-4})\,(127 - 125) + (7.4 \times 10^{-4})\,119.19 + (3 \times 10^{-3}) \\ &= 0.092\ \text{m}^3/\text{s}/\text{km}^2\end{aligned}$$

Base flow for the catchment $= \text{AREA} \times \text{ANSF} = 24.605 \times 0.092\ \text{m}^3/\text{s}$
$= 2.264\ \text{m}^3/\text{s}$

Derivation of the Regional Coefficient

(a) STRMFRQ = Number of Junctions/ AREA = 57/24.605 = 2.32

(b) LAKE = 0

(c) $Q_P = C\,[(\text{AREA})^{0.94}\,(\text{STRMFRQ})^{0.27}\,(\text{SOIL})^{1.23}(\text{RSMD})^{1.03}(\text{S1085})^{0.16}\,(1+\text{LAKE})^{-0.85}]$

$25.06 = C\,(24.605)^{0.94}\,(2.32)^{0.27}\,(0.4)^{1.23}\,(119.19)^{1.03}\,(55.61)^{0.16}\,(1+0)^{-0.85}$

$C = 0.0116$

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