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EVALUATION OF THE HYDROLOGICAL MODELLING USING CLIMATIC STATION DATA: (A CASE STUDY OF SAROBI SMALL DAM)

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Abstract — *In this paper an effort has been made to carry out the hydrological modelling using the available rainfall data. Hydrology plays the key role in the design of any hydraulic structure. If the discharge data is available for a certain place, then the frequency analysis is carried out using this discharge data. However if the discharge data is missing then the peak design flood is estimated from the rainfall data. Sarobi Small Dam located at North Waziristan KP, Pakistan was selected as the case study and the SCS-Curve number method was used to estimate the direct runoff because this model is simple and many researchers prefer this model for small watersheds [1]. The Gumble Extreme Value-I distribution was selected for the frequency analysis of rainfall in order to generate the peak rainfall for different return periods. The SCS type-2 distribution of rainfall was used for generating the peak storm hyetograph. The design rainfall for 10 & 200 years return period was found to be 4.06 and 6.99 inches. The design Hydrograph for different return periods was estimated using HEC-HMS software. The design hydrograph for the 10 & 200 years return period was found to be 83.4 and 191.5 cumecs respectively.*

Keywords*-SCS Curve Number, Hydrograph, Catchment Area, Peak Runoff, Design Storm*

I. INTRODUCTION

The objective of this research is to carry out the hydrological modelling of small dams in Pakistan using precipitation data available from conventional gauges. If the discharge data available at a certain location is available for a long period, then the frequency analysis of the discharge data is carried out in order to calculate the peak design flood. However, in Pakistan most of the time the discharge data is unavailable therefore the frequency analysis of the rainfall data provides the design storm which on further analysis give the peak design flood. The SCS-CN method was used to estimate the direct runoff from the design hyetograph. The initial abstraction ratio (λ) was assumed to be 0.2 [2]. The initial abstraction ratio must be calibrated for a watershed having rainfall-runoff data because this value varies from watershed to watershed [3]. Two different procedures exist to calculate the curve number for a watershed are estimation curve number from watershed characteristics and estimation curve number from observed rainfall-runoff data [4].

II. STUDY AREA AND AVAILABLE DATA

A. 2.1. Study Area

1) Project Location

The project area lies in the North Waziristan and falls in the Survey of Pakistan, Topographic Sheet No. 38 L/1. The latitude and longitude of the proposed dam site are 32° 52’ 27" N & 70° 03' 40" E as observed from hand held GPS at the dam site.

2) Catchment Area

The catchment area lies in Survey of Pakistan topographic sheet No. 38L/1 (Scale 1:50,000). The catchment area is 8.10 sq. Miles (20.97 Sq.Km). The catchment area is generally barren and hilly. The Upper reach of watershed is at elevation 1400 m and at proposed dam site nullah bed is at elevation of 1146 m. The Length of the main stem is 12.6 km. The Nullah bed average slope is 20m/km. The nullah under study carries some perennial flow of about 0.5 cusec.

B. Available Data

1) Discharge Data

No gauge data is available at project site.

2) Rainfall Data

Rainfall data of Bannu Gage Station have been adopted for the proposed dam site as it is the nearest gauge station. Daily rainfall data for Bannu has been collected from Pakistan Meteorological Department Peshawar for period of 1991-2011. Mean monthly rainfall varies from 0.23 inches to 2.63 inches. Mean annual rainfall is 12.96 inches and is shown in figure-1.

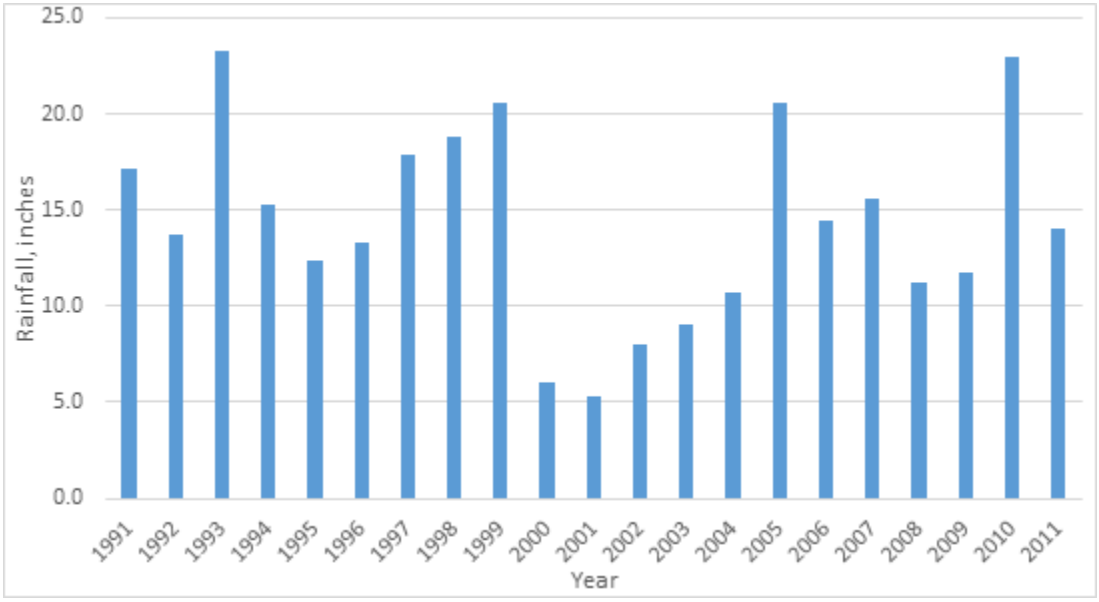

Figure 1-Mean Annual Rainfall for Bannu Gauge Station (1991-2011)

3) Evaporation Data

Monthly evaporation data of Bannu for the period 1970-2000 have been collected from Surface Water Hydrology Project (SWHP), WAPDA. Mean monthly evaporation at this station is shown in Figure-2. Mean annual evaporation for Bannu is 69 inches. Reservoir evaporation for the dam site is calculated accordingly by reducing it 70%.

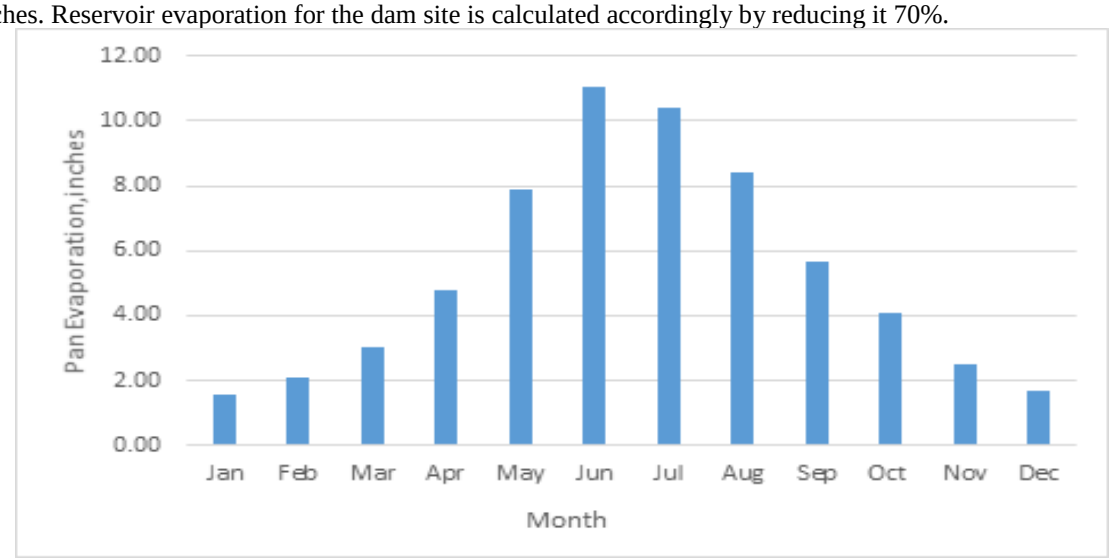

Figure 2- Mean Monthly Pan Evaporation at Bannu

4) Temperature Data

Monthly mean average maximum and minimum temperature data have been collected from Metrological Department for period of 1971- 2000. Mean monthly average, minimum and maximum temperature in Bannu is shown in Figure-3.

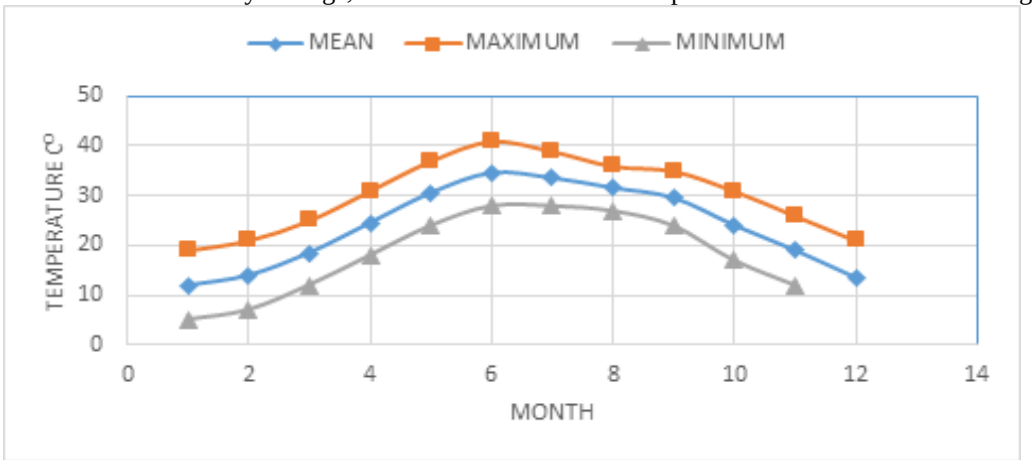

Figure 3 Monthly Mean, Maximum and Minimum Temperature at Bannu

III. METHODOLOGY, RESULTS AND DISCUSSIONS

A. Flood Studies

Basic purpose of flood studies is to establish design flood for spillway and diversion works.

1) Flood Data

Flood peaks data is not available at Project site.

B. Rainfall Frequency Analysis

1-day maximum rainfall data for Bunnu for period of 1970 to 2010 have been collected from Pakistan Metrological Department. 1-day maximum rainfall data is shown in figure-4. Rainfall data is subjected to frequency analysis and GEV-1 is fitted to the data. Summary of results against different return periods are given in Table-1

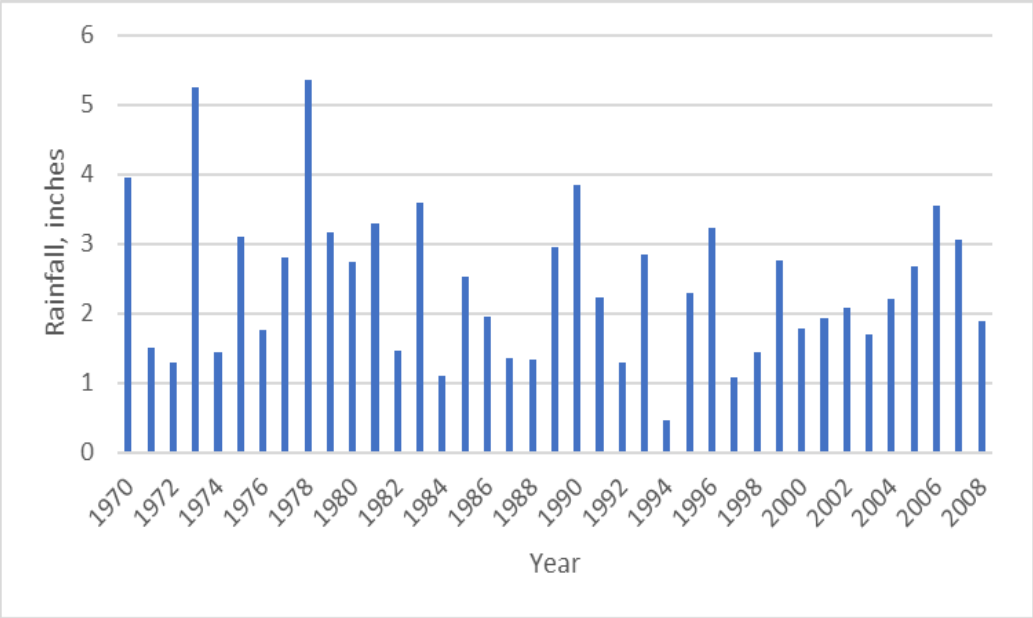

Figure 4 One Day Maximum Rainfall at Bannu Gauge Station

Table 1 Results of Frequency Analysis

Return Period (years)	Rainfall (inches)
10	4.06
100	6.32
200	6.99
500	7.87
1000	8.54

C. Estimation of Design Flood

Design flood against 10,100 and 200 years return period have been selected for spillway design. Design flood was estimated for Sarobi Small Dam site using Hydrological model HMS. HMS is rainfall-runoff model in which catchment area, characteristics in terms of loss rate, time of concentration and time distribution of rainfall is assigned as input and flood hydrograph at different junctions as output. Different parameters used for Hydrological model HMS to be used for the Basin are derived as under:

Time of Concentration

US SCS and USBR recommended Kirpich's equation from California Culverts Practice, California Highways and Public Works, September 1942. The equation is:

$$T_c = \left(\frac{11.9 * L^3}{H}\right)^{0.385} \quad (1)$$

Where,

L = length of longest watercourse in miles

H = elevation difference in feet

Table 2 Physical Parameters of the watersheds

Catchment Area	Sq. Miles	8.10
Length of Main Water Channel	Miles	6.25
Inlet Elevation	ft	5465.30
Outlet Elevation	ft	3763.31
Difference in Elevation	ft	501.99
Slope	ft/miles	80.32
Time of Concentration Tc.	hr.	1.97
Lag Time, Tlag	hr.	1.38

D. Derivation of Unit Hydrographs

Synthetic unit hydrograph for Sarobi Small dam catchment has been developed using SCS triangular hydrograph parameters and curvilinear dimensionless unit hydrograph. Computer model, HEC-HMS of US Army Corps of Engineer (ver 3.0.1, 2006) has been used for the derivation of unit hydrograph.

E. Estimation of Excess Rainfall

Excess rainfall, also called the effective rainfall, is the difference between the rainfall and the basin retention loss and produces the surface runoff to the streams of the basin. The basin retention loss is the sum of losses due to interception, infiltration and depression storage (detention loss). For estimation of direct runoff from rainfall, Design of Small Dams gives curves of rainfall-runoff relationships developed by Soil Conservation Service from analyses of rainfall and respective runoff records of numerous watersheds. The SCS curves are obtained using the equation:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad (2)$$

Where,

Q = direct runoff in inches

P = storm rainfall in inches, and

S = maximum potential difference between P and Q, in inches, at the beginning of storm.

Curve numbers CN are from 100 to zero and are given by condition, and (iii) the hydrologic soil-cover complex, are used to determine direct runoff from the curves. The hydrologic soil-cover complex represents soil group, land use or cover, and hydrologic condition for infiltration for the watershed.

After study of basin, the soil group, land use and hydrologic conditions of the catchment were evaluated. These hydrologic soil-cover complex data were then used to determine the SCS curve numbers of the catchment. Estimated curve number for watershed is 88.

With the help of HEC-HMS, rainfall excesses were computed from the provision that hourly retention rates (indicated by the use of runoff curves).

F. Results of HEC-HMS Model

The hydrograph for 10 and 200 years returns period calculated from HEC-HMS is given in figure-5. The design hydrograph for the 10 & 200 years return period was found to be 83.4 and 191.5 cumecs respectively.

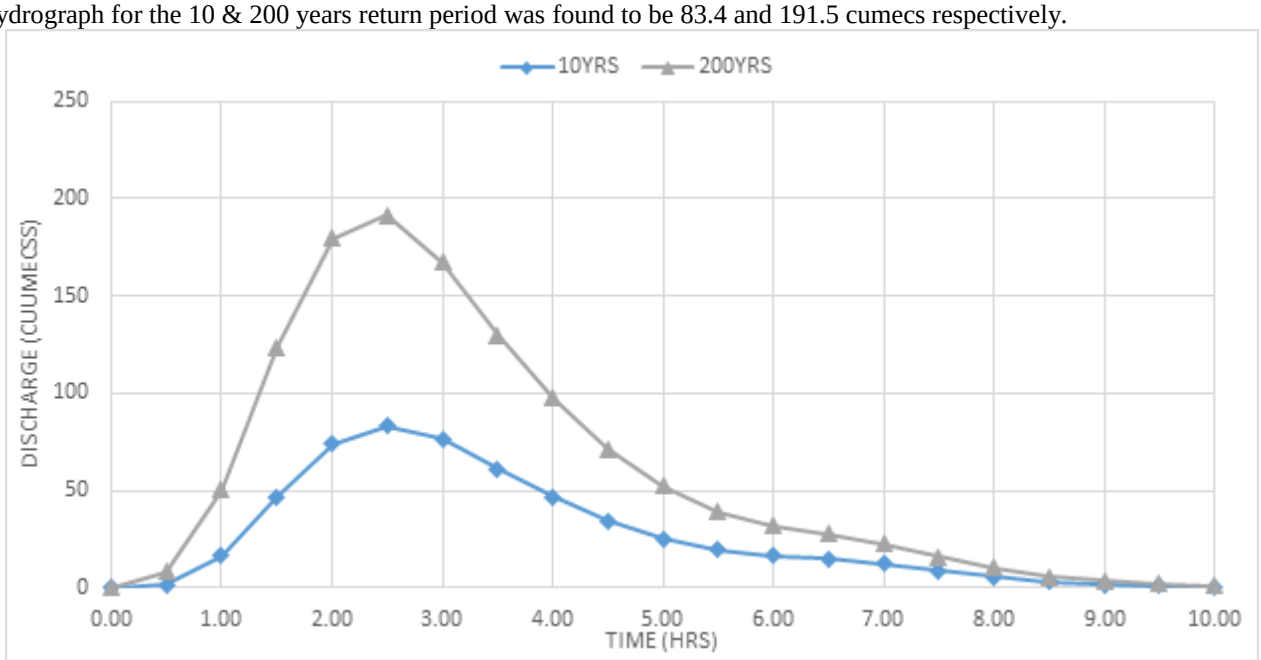

Figure 5 Hydrographs for 10- and 200-years design periods

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