ESTIMATION OF DIRECT RUNOFF IN MULTIRESERVOIR SYSTEM MRP COMPLEX FOR CRITICAL FLOOD DATA USING SCS CURVE NUMBER METHOD

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ABSTRACT

Intensity of flood from a catchment is primarily decided by the quantity and nature of runoff produced and the extent of land submergence. The available rainfall statistics of the study area for the critical flood period has been utilized for the estimation of runoff. The catchment is delineated as many sub basins by using Geographical Information System. The purpose of this study is to apply cluster analysis for catchment delineation and SCS CN method for estimation of direct runoff in Mahanadi Reservoir Project Complex consisting Ravishankar Sagar Reservoir, Mooramsilli Reservoir, Dudhawa Reservoir, Sikasar Reservoir and Sondhur Reservoir. SCS CN method depends on the watershed's soil, hydrologic soil group, cover type, treatment, and hydrologic condition.

KEYWORDS: GIS, Runoff, SCS Curve Number, Storm Water, Hydrological Modelling.

Despite flood hazards, since the dawn of civilization, mankind has shown a preference to settle near the rivers due to assured supply of water, facility of navigation and fertility of river valleys. Flood plays a great havoc and causes untold miseries in the area affected. It causes loss of life, disruption of human activities, damage to properties, agricultural crops and health hazard.

Mahanadi Reservoir Project (MRP) is a part of the integrated Mahanadi Complex being executed across river Mahanadi and its tributaries. The head works consist of five dams, namely Ravishankar Sagar, Dudhawa, Murramsilli, Sondur and Pairi high dam and New Rudri barrage replacing the existing Rudri pick-up weir. Out of these, the first four dams have already been completed and Pairi high dam is at survey and investigation stage. There are four main canal systems, namely Mahanadi Main Canal, Mahanadi Feeder Canal, Sondur Feeder Canal and Pairi Mahanadi Feeder canal. The reservoirs in this complex are monsoon fed and about 98% of rainfall is observed from June to November.

From the history of flood events in the study area it has been seen that before construction of Ravi Shankar Sagar reservoir in the Mahanadi Reservoir project complex (MRP), 73 flood peaks have been observed during a period of 102 years at the Rajim confluence, confluence of Mahanadi and Pairi River, resulting from flow exceeding 60,000 cusecs. The highest observed flood during that period is 0.5 million cusecs in September 1834. Total 16 high flood peaks with the flow exceeding 60,000 cusecs have been observed within a period 1958 to 2003. The highest recorded flood has been occurred in August 1994 with a peak flow of 102500 cusecs.

Runoff estimation from a catchment is essentially required for planning, management and evaluation of the available water resources. The study aims to compute the runoff depth using Soil Conservation Service-Curve Number (SCS-CN) method for historical flood data at study area. The rainfall-runoff relationship is very complex, influenced by various storm and drainage characteristics. There are several approaches to estimate the runoff. The Soil Conservation Service Curve Number (SCS-CN) method developed by National Resources Conservation Service (NRSC), United States Department of Agriculture (USDA) in 1969, is simple, predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth. The SCS-CN is a quantitative description of land use / land cover / soil complex characteristics of a watershed. This model is a widely used hydrological model for estimating runoff using runoff and curve number (CN). The CN is an index that represents the watershed runoff potential. Base map, soil map, land use / land cover map and other associated map of the study area have been prepared using Indian Remote Sensing LISS-III data and Survey of India (SOI) topographic sheets.

SCS-CN METHOD

The area of land use/ land cover and hydrological soil type are used in the SCS-CN method for estimating runoff from the method for estimating runoff from the basin. This method is based on two concepts:

The first concept is that the ratio of actual amount of runoff to maximum potential runoff is equal to the ratio of actual infiltration to the potential maximum retention. This proportionality concept is expressed as:

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$$(P-Ia-Q)/s = Q/(P-Ia) \quad (1)$$

Where P = precipitation in millimeters (P>=Q)

Q = runoff in millimeters

S = potential maximum retention in millimeters

Ia = Initial Abstraction;

The second concept is that the amount of initial abstraction is some fraction of the potential maximum retention and thus expressed as:

$$Ia=\lambda S \quad (2)$$

For Indian condition Ia = 0.3S

$$\text{Where, } S= (25400/CN) - 254 \quad (3)$$

Solving equation (1) and using equation (2) we have

$$Q=(P-Ia)^2/(P-Ia+S) \quad (4)$$

For Indian condition Ia = 0.3S

Thus equation (4) becomes

$$Q=(P-0.3S)^2/(P-0.7) \quad (5)$$

Equation (5) is the rainfall – runoff relation used in the estimation of runoff from the storm rainfall.

Hydrologic Soil Group

In the determination of CN, the hydrological soil classification is adopted. As per National Engineering Handbook (NEH) developed by USDA, soils are classified in four groups A, B, C and D based upon the infiltration and other characteristics.

Group A: Soils in this group have low runoff potential and high infiltration rate when thoroughly wet. Water is transmitted freely through the soil.

Group B: Soils in this group have moderately low runoff potential and moderate infiltration rate when thoroughly wet. Water transmission through the soil is moderate.

Group C: Soils in this group have moderately high runoff potential and low infiltration rate, when thoroughly wet. Water transmission is somewhat restricted through the soil.

Group D: Soils in this group have high runoff potential and low very low infiltration rate, when thoroughly wet. Water transmission is restricted through the soil.

Antecedent Moisture Condition (AMC)

AMC indicates the moisture content of soil at the beginning of the rainfall event. The AMC is an attempt to account for the variation in curve number in an area under consideration from time to time. Three levels of AMC were documented by SCS AMC I, AMC II & AMC III. The limits of these three AMC classes are based on rainfall magnitude of previous five days and season (dormant season and growing season).

Table 1: AMC for determination of CN value

AMC	Total Rain in Previous 5 days	
	Dormant Season	**Growing Season**
I	Less than 13 mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

STUDY AREA

Location of study area MRP complex is from longitude 80°30″ to 82°50″ E and latitude 19°20″ to 21°50″ N having catchment area 8086 sqkm. Some of the data needed for the study were available from various sources and some of them were procured. The data sources are:

- Topographic data from Survey of India (SOI) toposheets (2005-2006) of scale 1:50,000 used to identify the study area.
- Satellite Imageries: The Indian Remote Sensing satellite with Linear Imaging Self Scanning sensors (IRS – LISS III) satellite data of scale 1:50000 were collected from Bhuvan portal of Indian Space and Research Organization (ISRO), to use land use/ land cover of the study area.
- Rainfall data from Water Resources Department Chhattisgarh were used.
- The soil data from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP).

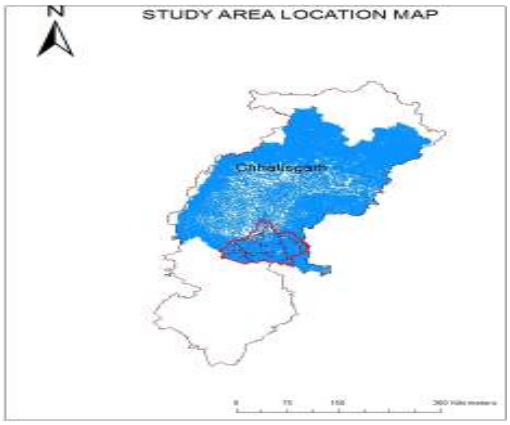

Figure 1: Index map of study area

Figure 2: Location map of projects

METHODOLOGY

The basic data required for the study: rainfall-runoff data, land use /land cover from satellite imagery, topographic sheets, reservoir details have been procured from the different sources. The processing and analysis of the basic data is done for adjusting the data for its consistency. With the help of Arc GIS software thematic maps have been prepared. Bhuvan raster images have been downloaded and mosaic tool was applied on the tiles for merging operation to convert it into a single image. With the help of ArcHydro tool watersheds were delineated from the mosaic image. All the thematic maps such as soil map, land use-land cover map, drainage map, river map etc. have been prepared for the study area. Direct runoff for all the reservoirs have been computed by SCS CN method and tabulated as given in table. Dudhawa catchment consists of two, Morromsilli consists of five, RSS consists of seven, sikasar consists of one and sondhur consists of one rain gauge stations.

Table 2: Catchment Area Under The Given RG Station

S. No.	Rainfall Station	R.S.S. (C.A. SQKM)	Dhudhawa (C.A. SQ.KM.)	Moorumsill (C.A. SQ.KM.)	Mahanadi Remaining (C.A. SQ.KM.)	Sikasar (C.A. SQ.K.M.)	Sondur (C.A. SQ.KM.)	Pairi remaining (C.A. SQ.KM.)
1	Gangrel	678.058	0	231.013	73.966	0	0	0
2	Kanker	1747.432	144.793	11.844	0	0	0	0
3	Charama	498.496	0	0	0	0	0	0
4	Mayana	441.113	0	0	0	0	0	0
5	Gurur	63.645	0	0	0	0	0	0
6	Chatti	27.49	0	16.073	616.638	0	0	0
7	Bhatagaon	213.766	0	0	0	0	0	0
8	Budeni	0	0	0	417.034	0	0	202.3534
9	Sondur	0	535.477	74.392	0	0	391	0
10	Gariyaband			151.008	178.611	437	0	731.639

Table 3: Computation of direct runoff

Date	DIRECT SURFACE RUNOFF IN MM				
	Sondhur	**RSS**	**Sikasar**	**Moroomsilli**	**Dudhawa**
01/06/1994	0	0	0	0.00	0
02/06/1994	0	0	0	0.00	0
03/06/1994	0	0	0	0.00	0
04/06/1994	0	0	0	0.00	0
05/06/1994	0	0	0	0.00	0
06/06/1994	0	0	0	0.00	0
07/06/1994	0	0	0.59	0.00	0
08/06/1994	0	0	1.66	0.01	0
09/06/1994	0	0	0	0.00	0
10/06/1994	0	0	0	0.00	0
11/06/1994	0	0	0	0.00	0

12/06/1994	0	0	0	0.00	0
13/06/1994	0	0	14.99	0.97	0
14/06/1994	1.63	0	0.56	0.05	1.28
15/06/1994	1.06	1.91	7.28	1.95	1.31
16/06/1994	0.81	2.44	8.2	2.43	0.74
17/06/1994	0	0	0.01	0.00	0
18/06/1994	0	0.44	0	0.00	0
19/06/1994	10.73	3.84	18.08	9.75	10.71
20/06/1994	0	0	0	0.00	0
21/06/1994	3.09	13.23	21.14	18.13	4.07
22/06/1994	7.06	3.55	5.93	3.89	11.33
23/06/1994	0.06	0	0	0.00	0.02
24/06/1994	0	0	0	0.00	0
25/06/1994	0	0	0	0.00	0
26/06/1994	14.42	0	0	0.76	13.72
27/06/1994	0.26	0.46	13.52	1.45	0.34
28/06/1994	0	0	0	0.00	0
29/06/1994	0	0	0	0.00	0
30/06/1994	0	0	0	0.00	0
01/07/1994	0	0	0	0.00	0
02/07/1994	0	0	0	0.00	0
03/07/1994	10.73	7.2	2.97	3.00	13.78
04/07/1994	2.53	0.75	1.32	2.89	2.05
05/07/1994	0	0	0	0.00	0
06/07/1994	0	0	0	0.00	0
07/07/1994	0	0	0	0.00	0
08/07/1994	1.63	8.62	0	8.16	1.65
09/07/1994	3.95	5.4	8.25	6.25	4.17
10/07/1994	54.43	68.02	242.62	110.34	60.13
11/07/1994	5.93	118	38.89	101.17	12.73
12/07/1994	0	6.29	0	0.26	0
13/07/1994	0	1.21	0	0.00	0
14/07/1994	0	0	0	0.00	0
15/07/1994	0	0.07	0	0.00	0
16/07/1994	0	0.45	2.36	0.16	5.56
17/07/1994	4.92	45.7	0	8.09	0
18/07/1994	0.06	0.22	0.03	0.00	0
19/07/1994	0	0.28	0	0.00	0
20/07/1994	0.06	10.18	5.28	3.48	0
21/07/1994	0	0	0	0.00	0
22/07/1994	0	0	0	0.00	0.16
23/07/1994	0	0	0	0.00	0.01
24/07/1994	0	0	0	0.00	0
25/07/1994	0	0	0	0.00	1.74
26/07/1994	0	0	0	0.00	0
27/07/1994	0	0	0.01	0.00	0.16
28/07/1994	0	0	0	0.00	7.22
29/07/1994	0.26	0	0	0.00	0
30/07/1994	0	0	0	0.00	0

31/07/1994	0	0	0.14	0.00	1.84
01/08/1994	0.06	1.65	1.41	0.15	40.36
02/08/1994	0	0	0	0.00	67.34
03/08/1994	0	0	0	0.00	0
04/08/1994	1.63	1.38	1.56	0.83	0
05/08/1994	0.06	0	0	0.00	0
06/08/1994	0	0	0	0.00	25.55
07/08/1994	0	0.42	0.72	0.70	0
08/08/1994	0	0.02	0	0.02	0
09/08/1994	0.26	0	0	0.00	0.51
10/08/1994	7.06	0	0	3.76	0.36
11/08/1994	0	0.41	2.97	0.62	0
12/08/1994	0	0	0	0.00	10.34
13/08/1994	0	0	0	0.00	116.04
14/08/1994	0	0	0	0.00	0
15/08/1994	0	0	0	0.00	0
16/08/1994	0	0	0	0.00	0.13
17/08/1994	2.33	0.68	6.02	1.03	0.06
18/08/1994	34.98	7.11	82.95	27.64	42.11
19/08/1994	77.48	34.1	2.97	38.32	20.92
20/08/1994	0	0.05	0	0.00	0
21/08/1994	0	0	0	0.00	0
22/08/1994	0	0	0	0.00	0
23/08/1994	32.25	8.57	28.39	19.82	0
24/08/1994	0	0	11.83	0.73	0
25/08/1994	0	0	0	0.00	0
26/08/1994	0.81	0	0	0.05	0
27/08/1994	0.59	0.19	0	0.01	0
28/08/1994	0	0	0	0.00	0.05
29/08/1994	13.47	5.08	15.57	8.65	0
30/08/1994	140.66	47.14	77.48	57.30	0
31/08/1994	0	0.09	0.62	0.02	70.42
01/09/1994	0.01	0.17	0.41	0.05	0
02/09/1994	0.26	1.51	0.72	0.24	0
03/09/1994	0.14	0	0	0.00	0
04/09/1994	52.36	0.41	14.65	6.73	0
05/09/1994	21.05	45.87	20.69	49.90	0
06/09/1994	0	0	0	0	0
07/09/1994	0	0	0	0	0
08/09/1994	0	0	0	0	0
09/09/1994	0	0	0	0	0
10/09/1994	0	0	0	0	0
11/09/1994	0	0	0	0	0
12/09/1994	0	0	0	0	0
13/09/1994	0	0	0	0	0
14/09/1994	0.06	0	0.44	0	0
15/09/1994	0	0	0	0	2
16/09/1994	0	0	0	0	0
17/09/1994	81.83	6.08	34.04	16.89	0.00

18/09/1994	0	0.75	3.98	0.29	0.29
19/09/1994	0	0	0	0.02	0.02
20/09/1994	0	0	0	0.00	0.00
21/09/1994	0	0	0	0.00	0.00
22/09/1994	0	0	0	0.00	0.00
23/09/1994	0	0	0	0.00	0.00
24/09/1994	0	0	10.83	2.89	1.64
25/09/1994	0	0	0	0.25	0.83
26/09/1994	0	0	0	0.00	0.00
27/09/1994	0	0	0	0.00	0.00
28/09/1994	0	0	0	0.00	0.00
29/09/1994	0	0	0	0.00	0.00
30/09/1994	0	0	0	0.00	0.00

RESULTS AND CONCLUSION

The SCS-CN model is used to estimate runoff volume for the historical flood data of study area. Land use/ land cover, hydrological soil condition and antecedent moisture condition factors were considered for computing the runoff of the study area for various curve numbers, the runoff estimated for different AMC conditions. The sample of daily rainfall runoff computation is shown in Table 3. The runoff depths are computed for all the reservoirs of MRP complex because in the year 1994 at confluence of the Mahanadi and Pairi River flood peaks were observed at confluence point which is at the downstream of all the reservoirs. The result thus obtained can be used for further studies for flood management and control. This method is simple, predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth.

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