HYDROLOGICAL MODELLING OF AN URBAN WATERSHED GUWAHATI CITY DRAINAGE -A CASE STUDY

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1.0 INTRODUCTION

The Guwahati City, the capital of Assam state is the biggest city in entire North-Eastern region. The city is not only the political and commercial capital of Assam but also gateway to the North-Eastern region comprising of seven states. The greater Guwahati area is located at latitude 26^0-10' N and longitude 92^0-49' E. The river Brahmaputra flows along the north of Guwahati city in the westerly direction. The city extends upto 24 km. along the river and at an average width of 9.60 km. along North-South. The city covers an area of 217.60 sq. km. in the south of the river Brahmaputra. The average ground level of the city near the Brahmaputra river is 51.30m, except the hilly areas in the eastern zone of the city. The Western range has an average ground water level of 45.00 m. The central area includes Fatasil Ambari hill zone with pockets of low lying areas with ground water level of 49.00 m on an average. The average annual rainfall in greater Guwahati area is 1864 mm. The climate of the city is moderate with temperature variation between summer and winter. As per the provisional estimates of the 1991 census, the city has a population of 5,77,591.

2.0 EXISTING DRAINAGE FACILITY

The natural drainage system of the city area (Fig.1) comprises mainly of Bahini, Basistha, Bharalu, Mora Bharalu and Bondagan channels. The run-off from the Meghalaya hills comes through Bahini and Basistha channels. From Bahini, a part of discharge goes to Basistha channel through a diversion, which drains water to 'Deepar Beel', a low lying area and the balance is discharged by the river Bahini, which is thereafter known as Bharalu channel. It also carries lot of local discharge with other sewage disposal. A tributary carrying combined discharge of local rainfall by feeder channels as well as by channels coming from Guwahati Refinery areas comprising Noonmati, Jyotinagar, New Guwahati Rly. colony and other areas joins Bharalu near R.G.Barua road. The Bharalu channel joins the river Brahmaputra near Bharalumukh. A sluice gate is provided across the Bharalu to regulate the flow when the mighty river Brahmaputtra is in high spate with a capacity of 20 cumecs. A new sluice gate is also being constructed with a discharge capacity 72 cumecs at upstream of about 200m from confluence point. The chronic drainage problem after shifting of capital to the Guwahati city is rapidly increasing due to unplanned and haphazard growth of the city for the past two decades.

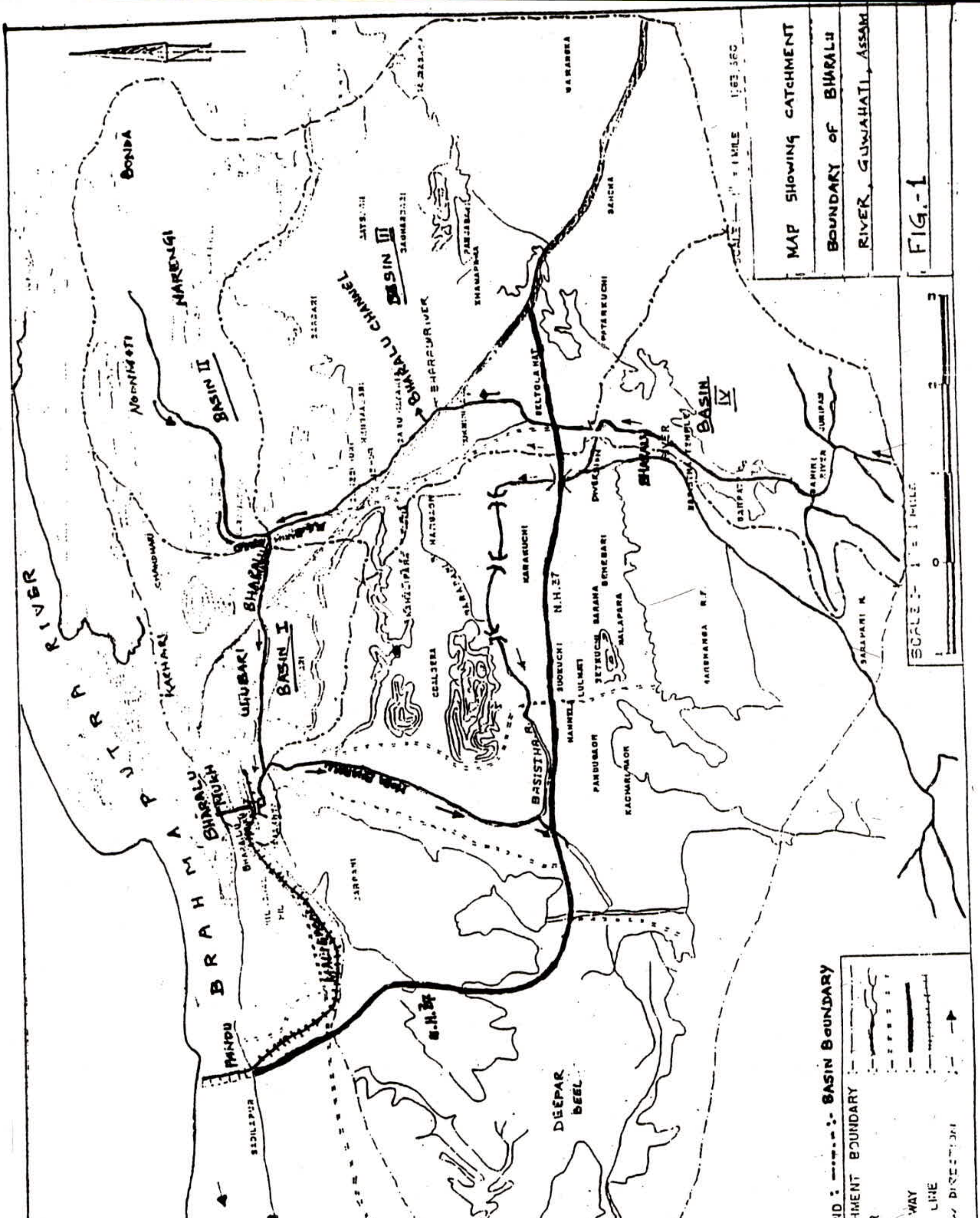

Fig. 1: Natural Drainage System of the City Area

The central and eastern part of greater Guwahati suffers a lot due to water logging when the river Brahmaputra is in high flood due to the sudden closure of sluice gate of the Bharalu channel. During such sudden closure, a pumping station is maintained by Guwahati Municipal Corporation to release the excess water from upstream side of sluice gate to the downstream side by pumping. This pumping is done with four number of pumps with each capacity 36000 lpm. Another channel called 'Mora Bharalu' is running towards south starting from Bharalu, 400m upstream of sluice gate and it drains the Fatasil area. It joins the Basistha river near NH 37. This channel is being planned for diverting Bharalu water when the Brahmaputra is in high spate. But the channel is flowing towards the Bharalu at present.

3.0 RAINFALL RUNOFF MODELLING

The rainfall-runoff process is believed to be highly non linear, time-varying, spatially distributed, and not easily described by simple models. Conceptual rainfall-runoff (CRR) models are designed to approximate within their structures (in some physically realistic manner) the general internal sub processes and physical mechanisms which govern the hydrologic cycle. Most conceptual watershed models assumed lumped representation of the parameters. Conceptual watershed models are generally reported to be reliable in forecasting the most important features of the hydrograph, such as the beginning of the rising limb, the time and the height of the peak, and volume of flow. However, the implementation and calibration of such a model can typically present various difficulties, requiring sophisticated mathematical tools, significant amounts of calibration data, and some degree of expertise and experience with the model. Conceptual models are of importance in the understanding of hydrologic processes.

During the last 20 years, hydrologists have paid considerable attention to the effects of urbanization. Due to increased impervious cover provided by parking lots, streets, roofs, which reduces the amount of infiltration but also increases the volume of surface runoff. Changes in hydraulic efficiency associated with artificial channel, curbing, gutters, storm drainage collection system increase the velocity of flow and the magnitude of flood peak. A study is planned to assess the expected maximum discharge in the channel Bharalu due to urbanization. For this purpose, based on remote sensing data, the SCS method rainfall runoff analysis has been applied for Bharalu watershed (Urban watershed) to estimate the yield from the catchment.

4.0 SCS CURVE NUMBER METHOD

Soil conservation service, USA 1972 developed the SCS curve number method. For the storm as a whole, the depth of excess precipitation or direct run-off P_e is always less than or equal to the depth of precipitation P. Likewise, after run-off begins, the additional depth of water retained in the watershed, F_a is less than or equal to some potential maximum retention S. There is some amount of rainfall I_a (initial abstraction before ponding) for which no run-off will occur, so the potential runoff is $P-I_a$. The hypothesis of SCS method is

$$\frac{F_a}{S} = \frac{P_e}{P - I_a} \tag{1}$$

From continuity principle

$$P = P_e + I_a + F_a \tag{2}$$

i.e.

$$P_e = \frac{(P - I_a)}{P - I_a + S} \tag{3}$$

It is the basic equation for computing the depth of excess rainfall or direct runoff from a storm by the SCS method. By study of results from many small experimental watersheds, an empirical relation was developed.

$$I_a = 0.2S \tag{4}$$

$$\text{Hence, } P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{5}$$

To standardize curves, a dimensionless curve number CN is defined such that $0 \le CN \le 100$. For impervious surfaces CN = 100 and for natural surfaces $CN < 100$. The curve number and S are related by

$$S = \frac{1000}{CN} - 10 \tag{6}$$

Where S is in inches. The CN is applicable for normal antecedent moisture conditions (MAC II). For dry conditions (AMC-I) or wet conditions (AMC III), equivalent curve numbers can be computed. (Chow et al. 1988).

Curve numbers have been tabulated by the SCS on the basis of soil type and land use. For a watershed made up of several soil type and land uses, a composite CN can be calculated.

5.0 STUDY PERFORMED

For the Bharalu watershed land use pattern is decided based on remote sensing data ["urban land use study of Guwahari city" – ARSAC, Guwahati]. For this study, the Bharalu catchment is divided into four sub basins within which population is approximately 1 lakh. The Khanapara IMD station rainfall data are used for the analysis. Similarly the soil group data is obtained from remote sensing observations. Table 1 gives the various sub basins considered for the analysis. Table 2 gives the land use pattern and the computed average CN for the sub-basins considered.

Table 1: Sub Basin Details

Sl.No.	Sub-basin	Details	Remarks
1	I	From R.G. Barua road to Bharalumukh (channel length 6.2 km) Basin area 15 sq. km. (Bharalu main) natural channel	High urbanization
2	II	From Narengi side to R.G. Barua road artificial channel basin Area 22.50 sq. km.	Medium urbanization
3	III	From diversion point to R.G. Barua road partly natural and Partly artificial channel (Bahini) basin area 56 sq. km.	Medium to high urbanization
4.	IV	From origin Bahini to diversion point natural channel Basin area 18.50 sq. km.	Low urbanization

Table 2: Land use Details of the Sub Basins

Sl. No.	Sub-basin	Soil group	Land use pattern (% area)	CN	Average CN		
					CN II	CN III	CN I
1	I	B	Built up - 70	92	83.9	92.3	68.6
			Wasteland - 10	79			
			Waterbodies - 20	58			
2.	II	B	Built up - 30	92	79.75	90.05	62.32
			Wasteland - 55	79			
			Waterbodies - 15	58			
3	III	B	Built up - 40	92	80	90.2	62.7
			Wasteland - 40	79			
			Waterbodies - 20	58			
4	IV	B	Built up - 40	92	76.1	88	57.22
			Wasteland - 40	79			
			Waterbodies - 20	58			

For the analysis the peak rainfall for different years and some moderate intensity rainfall values are considered. The results are shown in table 3.

Table 3 : Discharge Computation (SCS method)

Basin	Area (Sq. km.)	Rainfall (mm)	AMC condition	Estimated discharge (MCM/day	Date	Total discharge MCM/day
I	15	143.4	III	1.82	6/7/97	12.82
II	22.5	143.4	III	2.58		
III	56.00	143.4	III	6.44		
IV	18.5	143.4	III	1.98		
I	15	59.8	II	0.384	2/7/98	2.26
II	22.50	59.8	II	0.45		
III	56.00	59.8	II	1.14		
IV	18.5	59.8	II	0.29		

6.0 SEWAGE ESTIMATION

The Bharalu channel is also draining the sewage water from the entire Guwahati city. Generally the sewage is equal to almost 80 percent of the total quantity of water supplied. Based on population, expected sewage quantity can be computed. For the catchment population of 1 lakh, sewage produced per capita is 115 litre per day. Further, sewage is continuously varying from hour to hour of the day as well as season to season. The magnitude of the variation in sewage quantity varies from place to place and it is very difficult to predict. Here ratio of maximum to averge sewage flow is taken as 2, as the catchment population is 1 lakh, from Babbit and Hermon's formula.

Sewage quantity = 115 liters/day/capita

For the entire catchment sewage quality = 115/1000* 1000 m^3/day

= 11500 m^3/day

For peak sewage discharge = 2 x 11500m^3/day

= 0.023 x $10^6 m^3$/day

7.0 DISCUSSIONS

This negligible quantity of sewage, does not have much influence over the peak flow. This study reveals that the peak discharge expected during a high rainfall time with AMC conditions III is around 12.82 MCM per day. The new sluice gate constructed now can discharge 6.22 MCM per day. So a high intensity rainfall will be leading to water logging in many parts of the city's low lying areas. It is interesting to note that the Bharalu bed level at Bharalumukh is 44.00 m. The

Brahmaputra river level in a high flood season during 1988 reached 51.370 m. In lean periods the river level is about 43.900m. This huge fluctuation of water level influences the urban drainage of Guwahati city. During high flood time, the sluice gate of Bharalu river is closed to avoid the entry of Brahmaputra river water into city through Bharalu channel. If the peak flow of Bharalu channel occurs during the high flood time of Brahmaputra river, then the Mora Bharalu channel can be used for diverting the Bharalu channel water. But the Mora Bharalu channel will be not sufficient enough to discharge this huge quantity since its carrying capacity is about 750 cusecs. Further, the Mora Bharalu channel needs slope resectioning. The existing arrangement can manage the quick disposal of flood water during moderate rainfall with the successful completion of the new sluice gate provided Brahmaputra level is not so high.

8.0 CONCLUSION

Guwahati city drainage suffers due to fast siltation and encroachment. The peak flow in Bharalu channel in the worst flood condition of Brahmaputra cannot be managed with the Mora Bharalu channel diversion and pumping. The study clearly indicates that even the new sluice gate may not be sufficient enough to discharge the high peak flood. Hence the regradation of Mora Bharalu and enhancement of its capacity is very essential.

REFERENCE

Chow. V.T., Maidment, D.R., Mays, L.W., (1988), "Applied Hydrology", McGrew Hill.

Hsu, K.L., Gupta, H.V., Sorooshian, S. (1995), "Artificial Neural Network modelling of the Rainfall-run off Process", Water Resources Research journal. Vol. 31, No.10, p.2517-2530.

"Urban Land use Studies of Guwahati City" – Assam Remote Sensing Application Centre, Guwahati 1995.