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RAINFALL - RUNOFF MODELING OF BAITARANI RIVER BASIN UPTO ANANDAPUR USING HEC-1

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PREFACE

The Baitarani river is one of the major rivers in the Orissa state. It brings heavy flow and creates havoc in the lower reaches during monsoon, causing loss to the public life and the property. There is no major flood control project available in the main river at present.

It was suggested that a system for forecasting the river flows would have been helpful for protecting the public from hazardous floods. Accordingly, on the recommendations of CE & BM, Lower Mahanadi Basin, Bhubaneswar a study has been conducted to develop a suitable Rainfall- Runoff modeling system for the river Baitarani.

HEC-1 model, developed by US Army Corps of Engineer, was used for Rainfall- Runoff modelling in Baitarani River basin upto Anandapur gauging site. The HEC-1 model provides a powerful automatic optimisation technique for estimation of some of the parameters. The optimisation technique of the model has been utilised in the present study and model parameters has been calibrated and validated for the study area.

The present study has been carried out by P. C. Nayak, Scientist 'B' and S. M. Saheb, SRA under the guidance of Dr. K. S. Ramasastri, Scientist 'F' and Coordinator.

(K.S. RAMASASTRI)
DIRECTOR

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ABSTRACT

A hydraulic simulation model, HEC-1 has been applied to Baitarani river for modelling hourly flows of the river at Anandapur gauging site. The model has been designed to simulate the response and flood events of a basin to precipitation events. The study area lies between the latitude 22° 15' to 21° 20' N and longitude 85° 10' to 86° 55' E and falls within the states of Orissa and Bihar. The river Baitarani drains an area of about 8570 sq. km upto the gauging site and length of the main river upto gauging site is about 232 km.

In the present study, the HEC-1 model has been successfully used for simulation of peak flood. Hourly discharge data, hourly and daily rainfall data were used for calibration and validation of the model for years 1991 to 1994. The model parameters such as time of concentration, storage coefficient, initial and constant loss rate parameters were optimised and fixed for the basin during calibration. Clark technique for unit hydrograph and empirical equation for base flow separation were utilised in the model. The simulation results show fairly good peak flood, stream volumes and hydrograph obtained by the calibrated model.

INTRODUCTION

In Rainfall- Runoff process, input rainfall is distributed into various components viz. evaporation, infiltration, detention or depression storage, overland flow and eventually stream flow. The actual shape and timing of the response hydrograph for a particular watershed have been shown to be a function of many physiographic, landuse, and climatic variables. Rainfall intensity and duration are the major driving factors of the rainfall-runoff process followed by watershed characteristics that translate the rainfall input into an output hydrograph at the outlet of the basin.

The uses of advanced computing method combined with larger and more extensive data monitoring effort have allowed for the development and application of simulation models in hydrology. Such models incorporate various equations to describe hydrologic transport process.

Hydrologic simulation models in watershed analysis include lumped parameter versus distributed parameter, event versus continuos, and stochastic versus deterministic. Lumped parameter model transform actual rainfall input into runoff output by conceptualising that all watershed process occurs at one spatial point.

The present study aims at modeling the storm event of river Baitarani at Anandapur gauging site. The river originates from Guptaganga hills in Keonjhar district of Orissa. The river covers partly Singhbhum district of Bihar state and rest lies inside the state of Orissa. The total length of the river upto Anandapur gauging site is 232 Km., and its drainage area is 8570 sq. Km.. HEC-1 model was used for modeling in the present study.

HEC-1 model is an event based lumped model, developed by Hydrologic Engineering center, US Army Corps of Engineers. This model is suitable for simulating single storm response for given rainfall input data (Jha et. al, 1995 and Jain, 1991). Unit Hydrograph concept was employed for the model to generate storm event. In the present study, HEC-1 model has been used for the simulation of flood events of Baitarani river basin upto Anandapur. The description of the model used, study area, methodology, and simulation results are presented in the following chapter of the report.

1.1 BASIN DESCRIPTION

River Baitarani, one of the major rivers of the Orissa, drains an area of 14,218 sq. Km to Bay of Bengal. The basin lies mostly in the state of Orissa excluding 736 sq. Km in Singhbhum district of Bihar state. In Orissa part, the districts Keonjhar, Mayurbhanj, Balasore, Cuttack, Sundergarh and Dhenkanal are coming in the basin of the Baitarani where as Keonjhar district covers the major portion of the basin area. The river Baitarani originates from Guptaganga hills in Keonjhar district of Orissa, about 2Km. from Gonasika village, at an elevation of 900m. at an latitude 21^0-31' North, and longitude 85^0-33' East (Fig. 1). Initially the river flows in northern direction for about 80Km. and then takes a sudden right angled turn. In this reach the river serves as a boundary between Bihar and Orissa state for a certain length that is upto the confluence of Kangira river.

The river while flowing towards south enters the plains at Anandapur and further downstream meets the deltaic zone at Akhudapada, where it branches off and bifurcated. Further it meets the Brahmani and renamed as Dhamara and joins in the Bay of Bengal after traveling a distance of 360 Kms. There are 64nos. of tributaries of Baitarani river out of which 35nos. joins in the left and 29nos in right side. The prominent tributaries are Kangira, Khairi, Bhandan, Deo, Kanijhar, Sita, Kusai and Salandi.

During the flood the river Baitarani turns into a large turbulent stream poising potential threat to the life and property of the population residing in the basin. The maximum flood observed has been recorded as 4.36 lakh cusecs in the year 1960 at Birdi G&D site. At

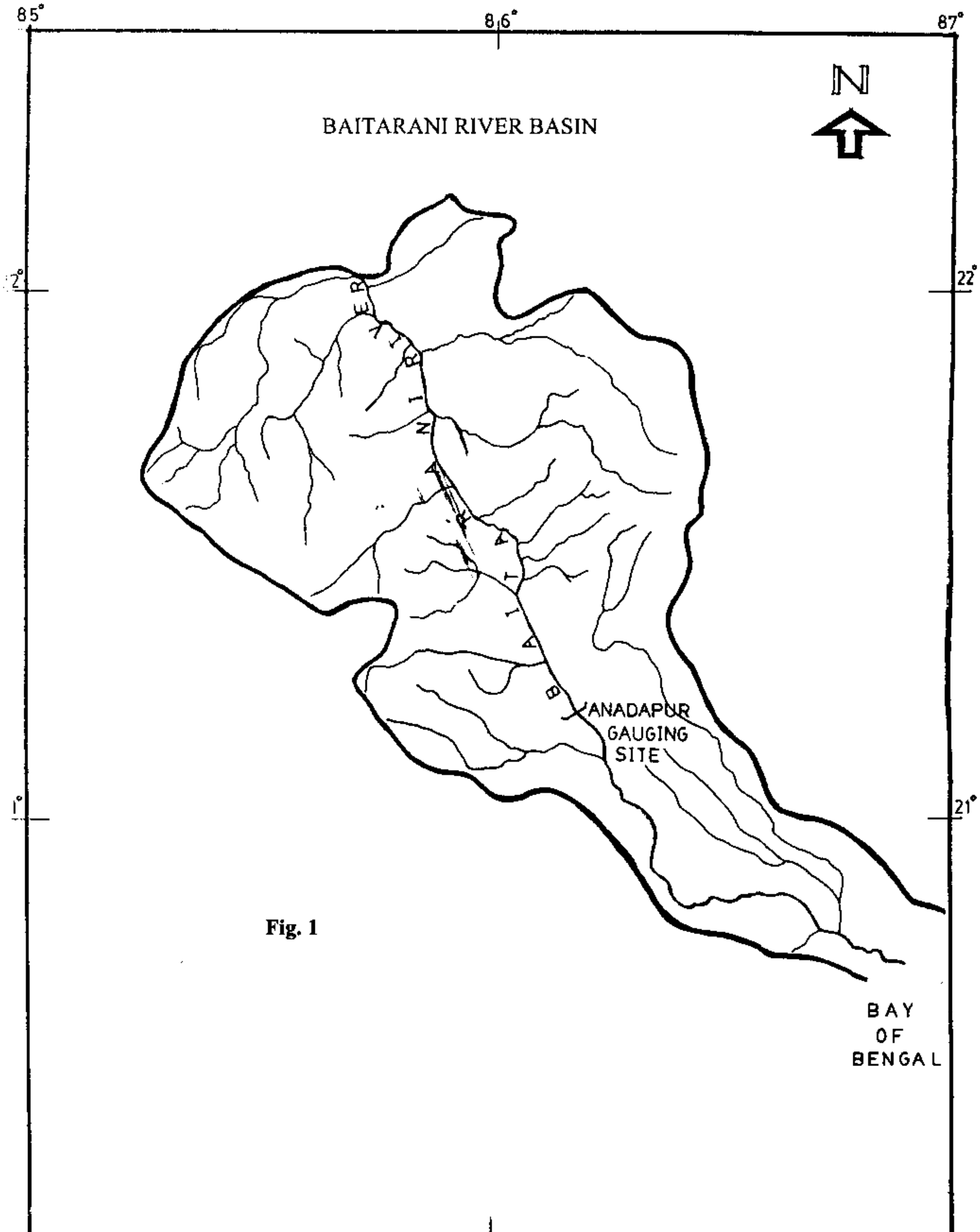

BAITARANI RIVER BASIN
N
85°
86°
87°
22°
21°
BAITARANI RIVER
ANADAPUR
GAUGING
SITE
BAY
OF
BENGAL

Fig. 1

present there is no flood moderating arrangement/ any project completed in the Baitarani main stream. Only there are a few major and medium project have been completed. These are Salandi, Kanjhari, Remal and Akhuapada projects having total command area 1,32,294 hectares. In addition to above, the ongoing projects are Kanupur and Deo considering a command area of 39,478 hectares. There are some proposed projects and Bhimkund project at Udaipur has been identified as one of the important major project that is in stage of investigation.

1.2 BASIN CHARACTERISTICS

The Baitarani river basin may be classified as Upper, Middle and Lower Baitarani based on topography and hydrometeorology.

A) Upper Baitarani

The upper Baitarani covers an area of 5792 sq. Km. in which 736sq. Km. lies in Bihar. This is mostly mountainous and rocky and lies in higher altitude. The upper portion of this basin is in the northern plateau and eastern ghats. The rock of the basin belongs to iron ore series of the upper Dharwar system of the eastern archear group. The major tributaries are Khairi-Bhandan, Deo that joins Baitarani in the sub-basin.

B) Middle Baitarani

The middle Baitarani with an area of 4333 sq. Km. cover the entire state of Orissa. This portion is partly hilly and partly plain area. The major tributaries are Kanijhari, Kushei, Kantamuli and Sim in the middle basin.

C) Lower Baitarani

The lower Baitarani covering an area of 4093 sq. Km. mostly consisting of Salandi and Matai river basin, physiographically the sub-basin is in the deltaic region and situated in fertile plain of Cuttack and Balasore district. Major portion of the sub-basin is made of alluvial soil. The basin receives most of its rainfall from southwest monsoon during June to October.

1.3 GEOLOGICAL FEATURE

The geological feature in and around upper Baitarani are of two main series, the iron ore series and younger Kolhan series. The Iron ore series are represented by mica, hornblende, schist, hornblende, gneiss, phyllite, chert and jasper which alongwith Singhbhum granite constitute the surrounding Country rock. The Kolhan series comprises mainly flat-bedded Kolhan, sand stone and conglomerate. The sand stone usually from the flat tapped hills over the peneplained granite terrain in this area. The generalised geological setup for whole of south Singhbhum and Keonjhar district is i) New Dolerite ii) Kolhan series iii) Singhbhum series iv) Iron Ore series.

1.4 CLIMATE

The Baitarani basin is an ovalshaped basin having 14218 sq.Km. drainage area. The basin consists of Singhbhum district of Bihar and Keonjhar, Dhenkanal, Mayurbhanj, Sundergarh, Cuttack and Balasore districts of Orissa. The upper Baitarani is about 700m. above mean sea level and therefore the Climate of upper Baitarani is of extreme in nature. The middle Baitarani is partly hilly and partly plain, and the lower Baitarani is in Coastal area. The effect of the sea is very much felt in lower basin of Coastal plain.

1.4.1 TEMPERATURE

The maximum recorded temperature of Keonjhar district in summer days is 48.5^0 Centigrade and minimum in winter days is 6^0 Centigrade.

1.4.2 RAINFALL

The rainfall receives in the basin is mostly from south- west monsoon and lasts from June to October. About 80% of the annual precipitation occur during these months. The rainfall caused mostly by depression in Bay of Bengal. About 80% of the annual precipitation occurs during these months. The annual rainfall varies from a maximum 1595mm to a minimum 745mm and average rainfall is 1187mm.

1.4.3 RELATIVE HUMIDITY

The relative humidity is minimum in the month of April and May and maximum in the month of August and September. All maximum and minimum humidity is of the order of 83.08% and 39.63% respectively.

1.4.4 WIND VELOCITY

The mean monthly wind velocity values of IMD stations at Cuttack and Balasore apart of which lies in Lower Baitarani Basin, contributes to the climatic factor of Lower Baitarani Basin. As per IMD station at Keonjhar the minimum and maximum wind speed are 5Kmph. and 75Kmph respectively.

1.4.5 CLOUD COVER

The maximum cloud cover is observed in the month of June and July where as minimum is in the month of December and January.

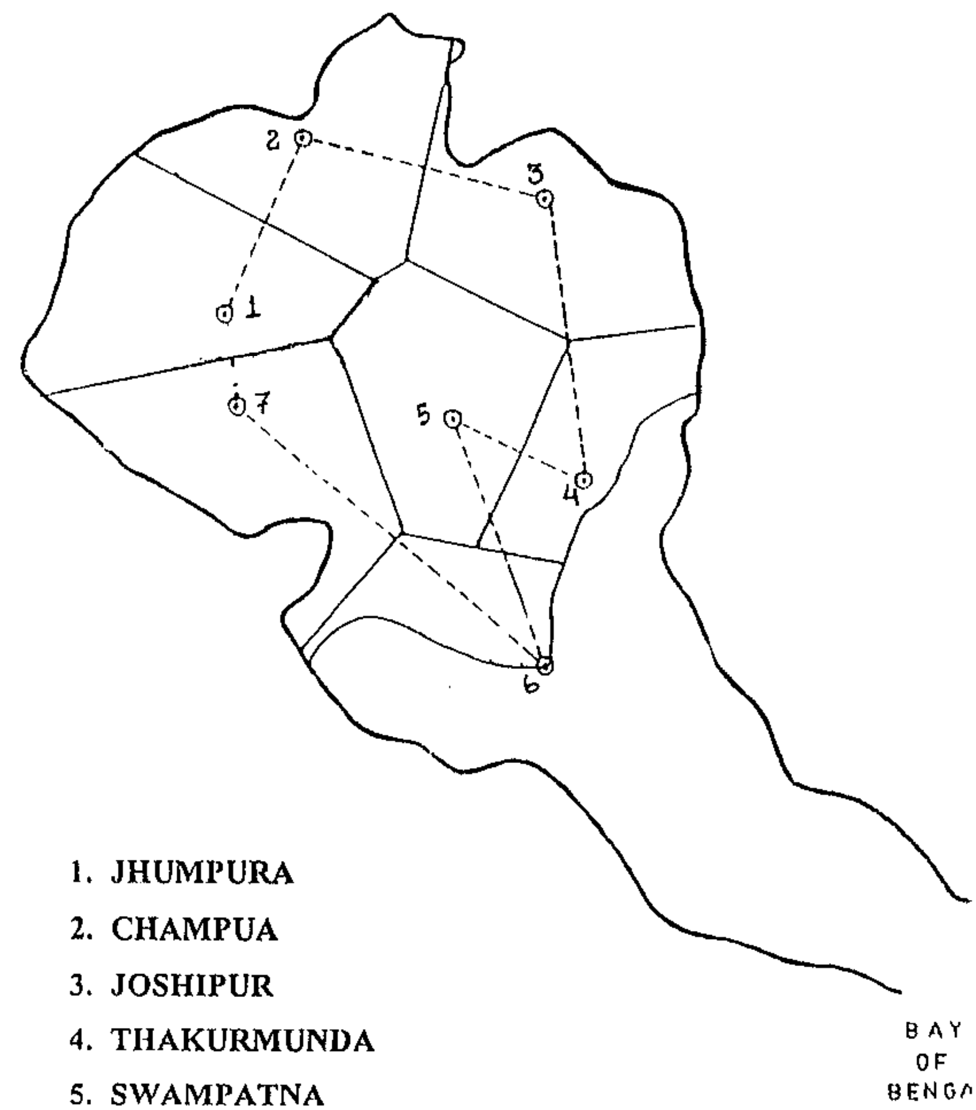
For the present study, the input data collected and processed for Rainfall-Runoff simulation using HEC-1 for Baitarani Basin upto Anandapur gauging site, are as described bellow.

2.1 RAINFALL DATA

There are seven rainfall stations located in the basin upto-gauging site. The rainfall stations are Jhumpura, Champua, Joshipur, Thakurmunda, Swampatna, Anandapur, and Keonjhar. Out of these seven rainfall stations, hourly rainfall data was available only at Champua and Swampatna SRRG stations. Indian Meteorological Department (IMD), Bhubaneswar, maintains all the raingauge stations. Hourly discharge data collected for year 1991 to 1994 was available with Central Water Commission, Bhubaneswar and has been collected. Due to non-availability of data in all rain gauge stations during 1991 to 1994, only five storm events were used as input for HEC-1 program. Hourly rainfall data of Champua and Swampatna stations were utilised for converting the daily rainfall of others stations into hourly data, using standard procedures (Jha, 1995). Out of five events, three events were selected randomly and were used for calibration and the other two events were used for validation.

The Theissen polygon technique was applied to compute mean areal precipitation of Baitarani basin upto Anandapur (Fig. 2). The Theissen weights for each raingauge stations calculated are given in Table-1.

THEISSEN POLYGON FOR ORG AND SRRG STATIONS



1. JHUMPURA
2. CHAMPUA
3. JOSHIPUR
4. THAKURMUNDA
5. SWAMPATNA
6. ANADAPUR
7. KEONJHAR

FIG.2.

Table 1: Thiessen weights for ORG and SRRG stations

Raingauge Stations	Area in Sq. Km.	Thiessen Weight
Jhumpura (ORG)	1696.86	0.198
Champua (SRRG)	1328.35	0.155
Joshipur (ORG)	1636.87	0.191
Thakurmunda (ORG)	822.72	0.096
Swampatna (SRRG)	1182.66	0.138
Anandapur (ORG)	394.22	0.046
Keonjhar (ORG)	1508.32	0.176

2.2 GAUGE AND DISCHARGE DATA

During the collection of data from 1991 to 1994 hourly runoff data was available in CWC, Bhubaneswar. Gauging site is located in Anandapur in Keonjhar District of Orissa. These data are reliable and of good quality used in preparation of Bhimkund and Kanupur project by Department of Water Resources, Govt. of Orissa (OWPO, 1998). The mode of observation is current meter.

2.3 TOPOGRAPHIC DATA

The topographic data, salient features of the study area, land use and soil information were obtained from Secha Sadan, Govt. of Orissa and IMD, Bhubaneswar.

3.1 OVERVIEW OF PROGRAM

HEC - 1 is a computer model for rainfall - runoff analysis developed by the Hydrologic Engineering Centre of the U.S.Army Corps of Engineers. This program develops discharge hydrographs for either historical or hypothetical events for one or more locations in a basin. The basin can be subdivided into many subbasins. Uncontrolled reservoirs and diversions can also be accommodated.

The available program options include the following: calibration of unit hydrograph and loss-rate parameters, calibration of routing parameters, generation of hypothetical storm data, simulation of snowpack processes and snowmelt runoff, dam safety applications, multiplan/ multiflood analysis, flood damage analysis, and optimization of flood-control system components.

HEC-1 allows a wide variety of options for specifying precipitation, losses, base flow, runoff transformation, and routing. A description of these options are presented below.

3.2 PRECIPITATION

Spatially averaged precipitation can be determined externally and supplied as program input. As an alternative, precipitation for individual recording and non-recording gauges can be specified, along with weighting factors to calculate the average precipitation for each subbasin. The basin - average precipitation can be further adjusted if the gauges from which it is determined have a normal annual rainfall systematically different from the basin as a whole, for example. if the gauges are in the valleys and the precipitation is greater in the hills.

3.3 LOSSES

Losses can be computed from:

1. An initial loss and constant loss rate
2. A four-parameter exponential loss function unique to HEC-1.
3. The Soil Conservation Service (SCS) curve number (with an optional initial loss)
4. The Holtan formula
5. The Green and Ampt method

3.4 RAINFALL EXCESS TO RUNOFF TRANSFORMATION

Precipitation excess can be transformed to direct runoff using either unit hydrograph or kinematic wave techniques. Several unit hydrograph options are available. A unit hydrograph may be supplied directly or the unit hydrograph may be expressed in terms of Clark, Snyder, or Soil conservation Service unit hydograph parameters. The kinematic wave options permits depiction of subbasin runoff with elements representing one or two overland-flow planes, one or two collector channels, and a main channel.

3.5 BASE FLOW CALCULATIONS

Base Flow is specified by means of three input variables

1. a starting discharge at the beginning of the simulation
2. an exponential recession rate term, and
3. a recession threshold discharge for the recession limb of the hydrograph.

Once the discharge drops below this threshold, the discharge is based solely on the recession rate.

The base flow part of the model uses a logarithmic decay function. Equation (1) defines the parameters that are used in the model, in which the recession flow threshold Q_R and the decay constant RTIOR must be specified by the user.

$$Q = Q_R (RTIOR)^{-n\Delta t} \quad (1)$$

where

Q = recession flow rate at end of $n \Delta t$ (cumec),

Q_R = flow rate at beginning of recession (cumec)

RTIOR = ratio of recession flows $n \Delta t$ increments apart.

3.6 PARAMETER CALIBRATION CAPABILITIES

A very useful option of HEC-1 is the ability to employ an automatic parameter calibration procedure for single basin (basins that are not subdivided) when both discharge data and precipitation data are available for historical flood events. Using a univariate gradient procedure unit hydrograph and loss-rate parameters can be optimized.

The optimisation involves an objective function for which a minimum value is sought, subject to certain constraints (ranges) on the parameters. The function takes the form

$$STDER = \sum_{i=1}^{N} (QOBS_i - QCOMP_i)^2 \ (WT / N) \quad (2)$$

where STDER is the error index; $QOBS_i$ is the observed hydrograph ordinate for time i; $QCOMP_j$ is the computed ordinate for time i from HEC-1; N is the total number of hydrograph ordinates and WT is a weighting function that emphasizes accurate reproduction of peak flows. The parameter values are bounded by upper and lower values. A more detailed description of this method is available in the HEC-1 user's manual (Hydrologic Engineering Centre, 1990).

3.7 CAPABILITIES OF HEC-1 PROGRAM

The capabilities of HEC-1 program includes

1. Hypothetical Storm Generation
2. Snowpack / Snowmelt Simulation

3. Dam Safety Applications
4. Multiplan / Multiflood Analysis
5. Flood Damage Analysis
6. Optimization of the Size of Flood Control System Components
7. Routing through Stream Channels
8. Reservoir Routing

3.8 OUTPUT DATA OVERVIEW

Most of the HEC-1 output can be controlled by the user, and a variety of summary outputs can be printed easily. The data used in each hydrograph computation can be printed along with hydrographs, rainfall, storage, and other data as needed. This is generally controlled by specific commands in the input file. The output control provides an echo of input data, which should be used to check actual input data (Bedient and Huber 1989).

Hydrographs may be printed as tables or graphed as a printer plot. Rainfall, losses, and net rainfall are included in the table and the plot. Inflow and outflow hydrographs are printed and plotted along with storage for each routing step. A list of error messages may be printed that may or may not stop execution of the program. Output should always be checked for possible errors or warnings.

In the present study, the following methods were used for rainfall-runoff simulation of Baitarani river basin using HEC-1 model.

4.1 TIME AREA CURVE DEVELOPMENT

For the development of Time -area curve, the time of concentration (Tc) was calculated for all the streams of the basin. The time of concentration (Tc) of the basin is the travel time of the waterway in the watershed and was determined by the following empirical equation in the present study (Kirpich, 1940).

$$Tc = 0.0195 \text{ X } L^{0.77} \text{ X } S^{-0.385} \quad (3)$$

Where,

L = the main stream length (m) and

S = the equivalent mean slope of the main stream. S for the watershed was determined by an empirical equation proposed by Wu (1964).

$$S = \forall \left[N / \{ 1/\forall s1 + 1/\forall s2 + \ldots\ldots\ldots\ldots + 1/\forall sn \} \right] \quad (2)$$

Where

N = Total number of observations and

s1, s2, sn = slopes at various distance

Time of concentration of the main stream using equation (3)

$$Tc = 0.0195 \text{ X } 232^{.77} \text{ X} (4.677 \text{X} 10^{-3})^{-0.385}$$

=10.2 Say 11hours.

Based on computed time of concentration, isochrones (area of equal travel time) of 1 hour interval were plotted for the study area (Fig. 3) and further a time area curve representing the percent of the travel time and cumulative area contributing to the outlet was developed (Fig. 4). The tme area curve developed was used for computation of outflow hydrograph by Clark unit hydrograph method.

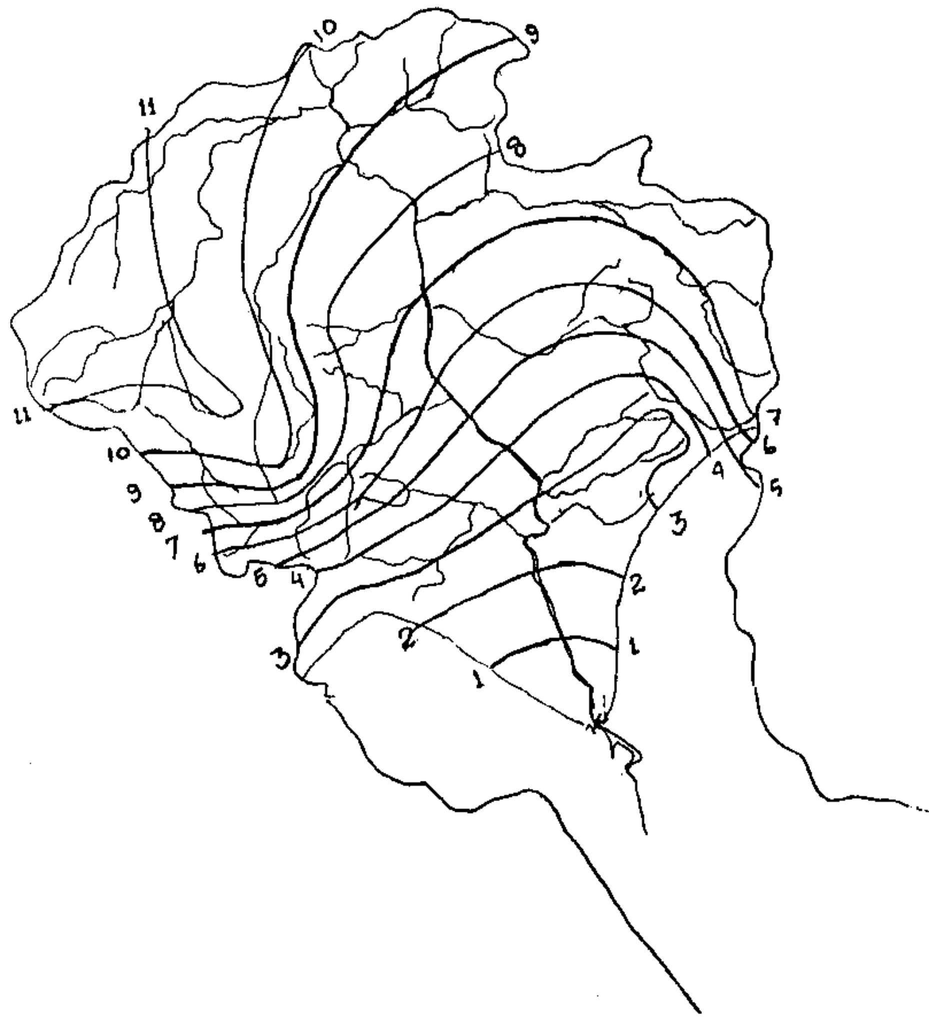


Fig. 3 COMPUTED ISOCHRONES OVER BAITARANI BASIN

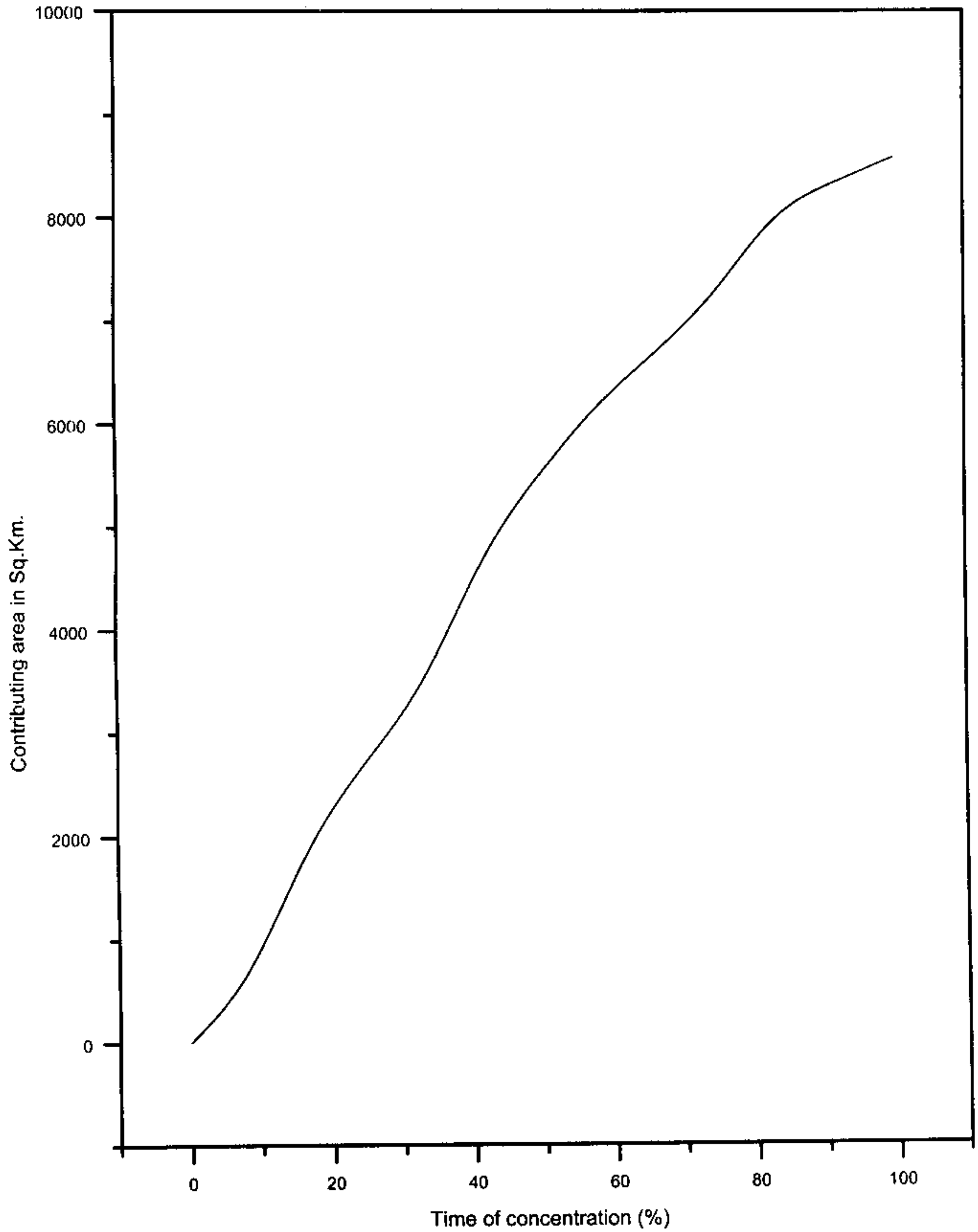


Fig. 4 Time area curve

4.2 BASE FLOW SEPARATION

In the Hec-1 model the base flow in the streamflow hydrograph is a function of three input parameters. These are STRTQ, QRCSN, and RTIOR, where STRTQ represents the initial flow in the river. The STRTQ is different for different storm event on long term contribution of groundwater releases in the absence of precipitation and antecedent condition. The QRCSN indicates the flow at which an exponential recession begins on the receding limb of the computed hydrograph. The RTIOR is equal to the ratio of a recession limb flow to the recession flow occurring one hour later. Details of these parameter calculations are explained in HEC-1 manual.

4.3 CLARK UNIT HYDROGRAPH

The Clark method requires three parameters to calculate a unit hydrograph, these are Tc, time of concentration for a basin, R, a storage coefficient and time area curve. In the present study, all these parameters were computed, optimised and calibrated using the HEC-1 Program and it's capabilities.

4.4 INITIAL AND CONSTANT LOSS RATE COMPUTATION

There is no data available for the computation of losses for this basin. Value of -1 was given for both losses in the input file so that the program will assume a starting value and then optimise.

4.5 CALIBRATION OF THE MODEL

In the present study three storm events were randomly considered from the period 1991 to 1994 and were used for the calibration of the model parameter (Table-2). To gain initial estimates of different parameter for initial runs of the models, the parameters T_c, R and initial constant loss rates were optimised using automatic parameter optimisation capability of the model. The input format used for automatic optimisation is shown in Appendix-I. The following procedure was adopted for optimisation.

Table No.2. Storm events used for calibration and validation of the model.

Sl.No	Storm events used for calibration runs	Storm events used for validation
01.	12 August, 1991	02 August, 1994
02.	15 July, 1993	13 July, 1994
03.	28 June, 1994	

1. Initially T_c, R initial and constant loss rate values were kept to be -11, -11, -1 and -1 respectively for optimisation.

2. After first run the computed T_c and R for storm events were averaged and then fixed to be 13.53 and 16.96 respectively. The initial and constant loss rates were kept for optimisation in second run.

3. After the second run, the computed values of initial loss and coastal loss rate for all storm events were averaged and fixed to 13.66 and 2.16. The T_c and R were kept for optimisation in third run.

4. After third run, the computed value of Tc and R for all storm events were averaged then fixed to be 14.25 and 17.02 respectively. The initial and constant loss rate were kept for optimisation in the fourth run.

5. After the fourth run, initial losses and constant loss rate for all storm events were averaged and values are 14.17 and 3.39 respectively. For the validation of the model the parameter T_c and R initial loss and constant loss were kept as 14.25, 17.02, 14.17 and 3.39 respectively. The result showing change in volume, depth percentage even for all

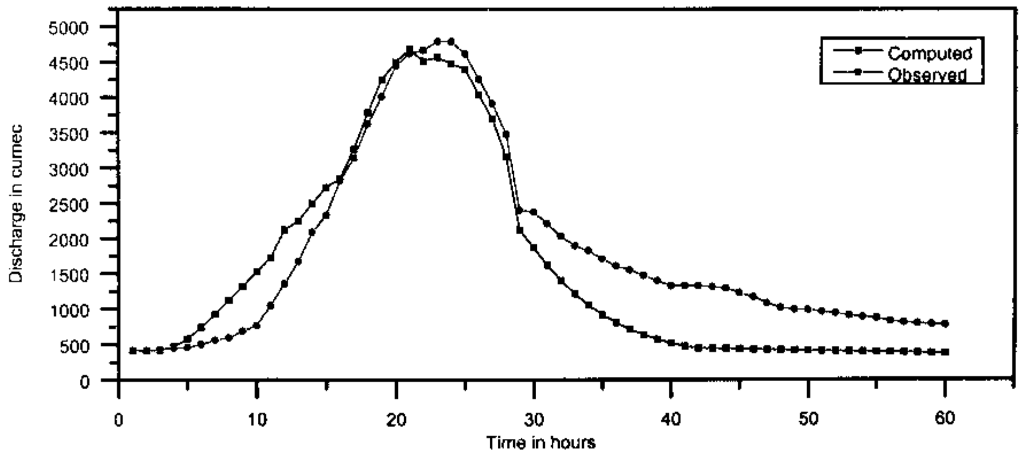


Fig. 5(a) Computed and observed hydrograph for the storm 28 June 1994.

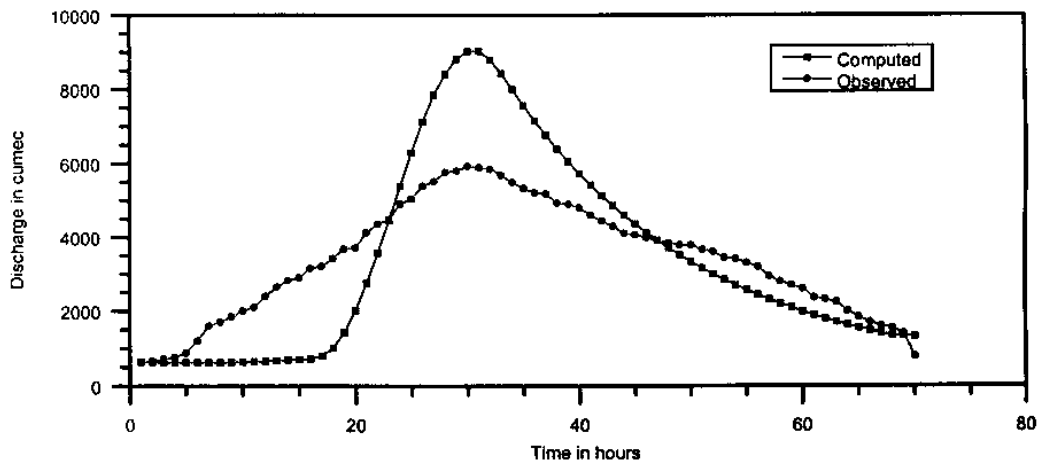


Fig. 5(b) Computed and observed hydrograph for the storm 12 Aug. 1991.

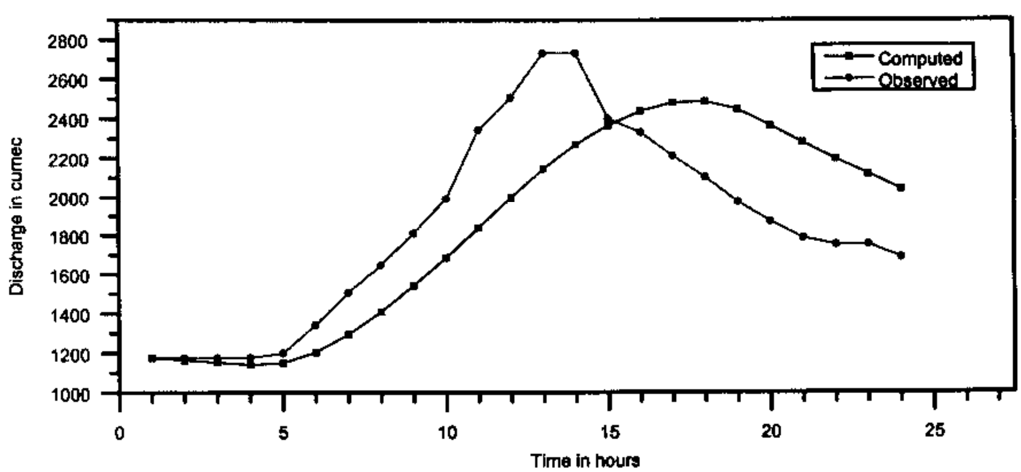


Fig. 5(c) Computed and observed hydrograph for the storm 15 July 1993.

Hydrographs for calibration run

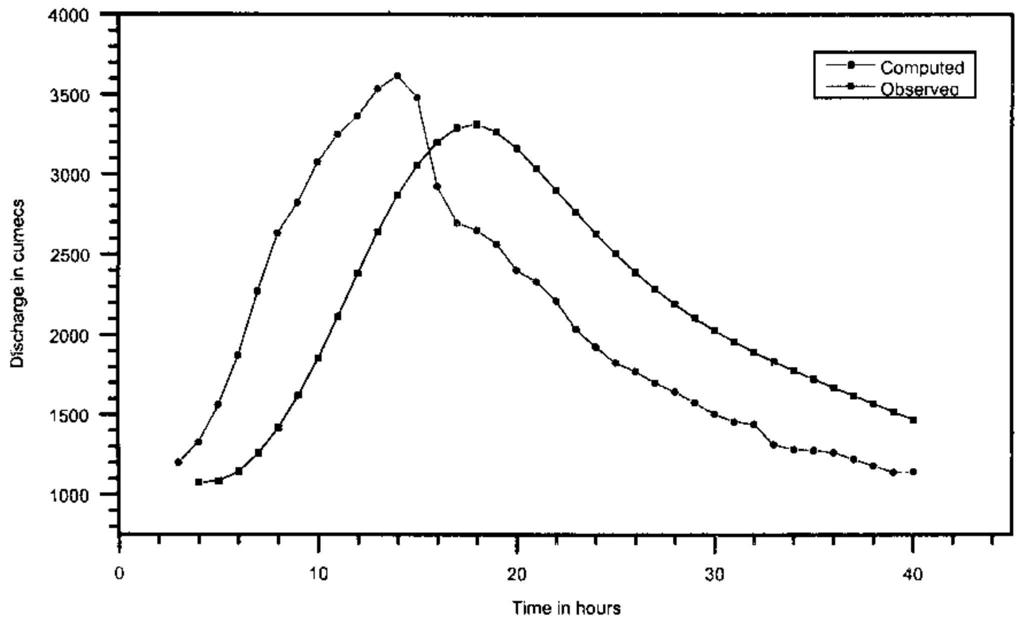


Fig. 6(a) Computed and observed hydrograph for the storm of 13 July 1994.

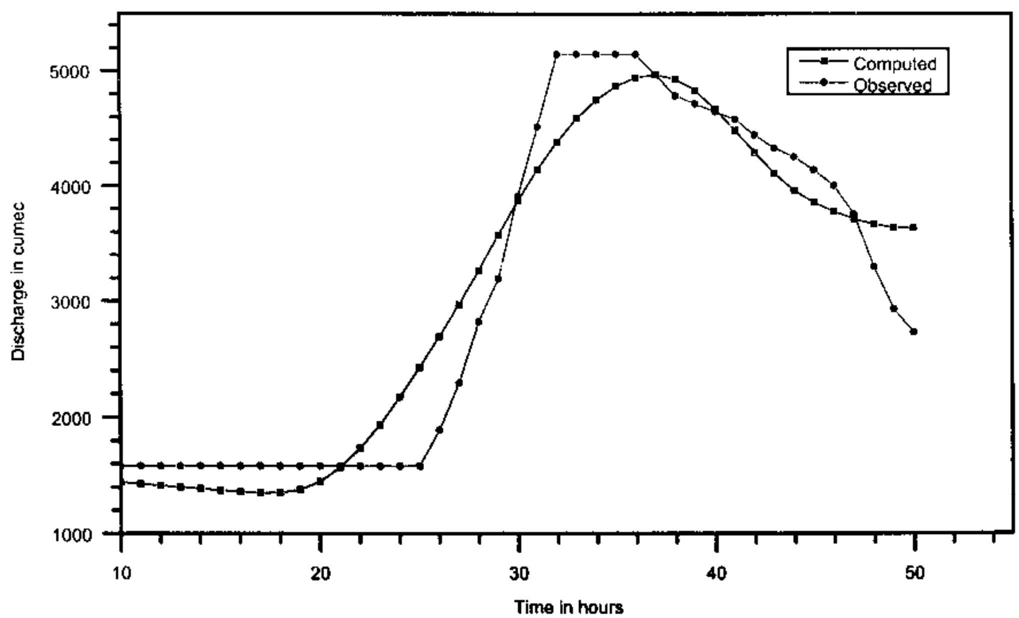


Fig. 6(b) Computed and observed hydrograph for the storm of 02 Aug. 1994

Hydrographs for the validation runs.

calibration runs are presented in Appendix -II. The computed and observed hydrographs are plotted (Fig. 5 (a), (b), and (c)).

4.6 VALIDATION

In the present study the model parameters T_c and R initial constant loss rate were optimised and calibrated to be 14.25,17.02, 14.17 and 3.39 respectively. For validation of the model parameters only two single peaked observed hydrograph were used. Considering all optimised and calibration parameters computed hydrograph were compared with observed hydrographs (Fig.6 (a) and (b)). It is observed that the HEC-1 simulated hydrograph is performing well.

Conclusions

Based on the present HEC-1 model application, the following conclusions have been drawn.

1) HEC-1 model has been successfully used for modelling rainfall-runoff simulation of Baitarani basin upto Anandapur with the constraints of data availability. The simulation shows a good reproduction of stream flow, volume, peak and hydrograph.

2) In the present model application raingauge network is not adequate and it is also not well distributed within the catchment. Only two recording raingauge stations are available, which are not adequate for achieving good results.

3) Hec-1 needs extensive input data, which is not available for this basin. Due to non-availability of sufficient data, some of the input data were assumed based on the available information. For better results it needs sufficient number of storm events for calibration and validation of the model parameters, which is not sufficient for this basin.

4) The model parameters that have been calibrated and subsequently validated may be used for rainfall-runoff simulation and flood estimation in Baitarani basin upto Anandapur.

REFERENCES

1. Hydrologic Engineering centre. September 1990. "HEC-1, Flood Hydrograph package" User's Manual, US Army Corps of Engineering.

2. Bedient, Philip B. and Huber, Wayne C. 1989 "Hydrology and Flood Plain Analysis" Addison-Wesley Publishing Company.

3. Jha, Ramakar and Arora, Monohar., 1995. HEC-1 Application to Hamidnagar site. NIH report, No CS(AR)-188.

4. Jain, M. K., 1991, 'Application of HEC-1 to Hemavati (upto Sakleshpur) basin, NIH report, No CS-55.

5. 'Report on Basin planning of Baitarani Basin (second spiral study)' June 1998, Orissa Water Planning Organisation, Govt. Orissa, Bhubaneswar.

ID	RAINFALL RUNOFF SIMULATION
ID	BAITARANI BASIN UPTO ANANDAPUR
ID	UNIT GRAPH AND LOSS RATE OPTIMIZATION
IT	TIME INTERVAL INFORMATION
IO	
OU	
IM	
IN	
PG	1
PI	INCREMENTAL PRECIPITATION OF NON RECORDING RAINGAUGE
PG	2
PI	INCREMENTAL PRECIPITATION OF NON RECORDING RAINGAUGE
IN	
PG	3
PI	INCREMENTAL PRECIPITATION OF RECORDING RAINGAUGE
IN	
PG	4
PI	INCREMENTAL PRECIPITATION OF NON RECORDING RAINGAUGE
PG	5
PI	INCREMENTAL PRECIPITATION OF NON RECORDING RAINGAUGE
IN	
PG	6
PI	INCREMENTAL PRECIPITATION OF RECORDING RAINGAUGE
IN	
PG	7
PI	INCREMENTAL PRECIPITATION OF NON RECORDING RAINGAUGE
KK	A
KM	RUNOFF CALCULATION FOR A
IN	
QO	HOURLY DISCHARGE
BA	BASIN AREA
BF	BASE FLOW PARAMETERS
PR	1 2 3 4 5 6 7
PW	WEIGHTED FOR GAUGES (BASIN AVERAGE)
UC	UNIT HYDROGRAPH
LU	LOSS RATE
ZZ	

APPENDIX-II

RESULT OF FIRST CALIBRATION RUN

Date	Tc	R	R/(Tc+R)	Strtl	Cnstl
12.08.91	22.96	10.16	.31	12.0	1.32
28.06.94	9.5	29.52	.76	18.92	1.6
15.07.93	8.12	11.21	.53	14.86	1.46
Average	**13.53**	**16.96**			

RESULT OF SECOND CALIBRATION RUN

Date	Tc	R	R/(Tc+R)	Strtl	Cnstl
12.08.91	13.53	16.96	.56	23.29	0.18
28.06.94	13.53	16.96	.56	13.51	3.45
15.07.93	13.53	16.96	.56	4.19	2.85
Average				**13.66**	**2.16**

RESULT OF THIRD CALIBRATION RUN

Date	Tc	R	R/(Tc+R)	Strtl	Cnstl
12.08.91	25.20	6.42	.2	13.66	2.16
28.06.94	7.82	364	.82	13.66	2.16
15.07.93	9.73	8.25	.46	13.66	2.16
Average	**14.25**	**17.02**			

RESULT OF FOURTH CALIBRATION RUN

Date	Tc	R	R/(Tc+R)	Strtl	Cnstl
12.08.91	14.25	17.02	.59	20.13	4.36
28.06.94	14.25	17.02	.59	14.27	1.75
15.07.93	14.25	17.02	.59	8.11	4.06
Average				**14.17**	**3.39**

COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPH FOR 12TH AUGUST, 1991

Sl. No.	Details of Hydrograph	Sum of Flows (m^3/s)	Equiv. Flow	Mean flow (m^3/s)	Time to centre of mass	Lag C.M. to C.M.	Peak flow (m^3/s)	Time of peak (hr)
01.	Observed	236811	99.477	3383	35.91	20.17	5920	29
02.	Computed (1st run)	235673	98.99	3367	38.61	20.94	6106	26
03.	Computed (2nd run)	236991	99.553	3386	36.86	19 12	7493	29
04	Computed (3rd run)	215867	99.679	3084	38.67	21.38	6275	25
05.	Computed (4th run)	236931	99.528	3385	37.15	19.38	9018	30

COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPH FOR 28TH JUNE, 1994

Sl. No.	Details of Hydrograph	Sum of Flows (m^3/s)	Equiv. Flow	Mean flow (m^3/s)	Time to centre of mass " (hr)	Lag C.M. to C.M.	Peak flow (m^3/s)	Time of peak (hr)
01.	Observed	109042	45.805	1817	28.14	20.77	4790	22
02.	Computed (1st run)	109038	45.804	1817	26.36	20.99	4003	22
03.	Computed (2nd run)	109048	45.808	1817	27.61	19.75	3464	17
04	Computed (3rd run)	92290	38.768	1538	24.82	20.23	3604	21
05.	Computed (4th run)	109053	45.81	1818	27.73	20.07	3481	17

COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPH FOR 15TH JULY, 1993

Sl. No.	Details of Hydrograph	Sum of Flows (m^3/s)	Equiv. flow	Mean flow (m^3/s)	Time to centre of mass (hr)	Lag C.M. to C.M.	Peak flow (m^3/s)	Time of peak (hr)
01.	Observed	44355	18.623	1848	13.43	7.17	2730	12
02.	Computed (1st run)	44149	18.543	1840	13.48	7.23	2597	12
03.	Computed (2nd run)	44343	18.627	1848	14.08	8.81	2482	16
04	Computed (3rd run)	43363	18.215	1807	13.34	7.54	2598	13
05.	Computed (4th run)	44347	18.629	1848	14.16	8.85	2484	17

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