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HYDROLOGICAL MODELLING OF RIVER SARADA USING TANK MODEL

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PREFACE

Hydrological modelling of streamflow is very important to ascertain, to forecast and to distribute the riverflows properly, optimally and judiciously. It has become an inevitable tool in water resources engineer's hand since the water nowadays gained the distinction of scarce commodity. Also it is the tool to warn about the flood disaster, when it is linked to a good forecasting and warning system.

This report presents a modelling study taken up for the first time on Eastern ghats by the Institute. Tank model developed in Japan by Sugawara in 1967 to simulate runoff of a basin is applied to an Eastern ghats river Sarada having an area of about 1980 sq.km upto Anakapalli. The basin is treated as a humid basin in the present study and the final parameters are arrived at after trail and error method. Though this modelling was done on VAX-11/780 Computer, the model can suitably be implemented on the personal computers as well.

This report entitled 'Hydrological Modelling of River Sarada using Tank Model' is part of the work programme of Deltaic Regional Centre of the Institute. This study is carried out by Shri S V Vijaya Kumar, Sc'B' and assisted by Shri S M Saheb, SRA and Shri U V N Rao, RA. While Shri R D Singh, Sc'E' supervised, Dr P V Seethapathi, Sc'F', Head & Coordinator DRC, guided the case study.

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LIST OF SYMBOLS

α	=	Decreasing ratio
T	=	Time constant
X	=	Storage
Y	=	Discharge
E	=	Evapotranspiration
Ao	=	Coefficient of discharge of bottom outlet of top tank (measure of infiltration rate from top strata)
A1,A2	=	Coefficient of discharge of first and second side outlets of top tank (measure of surface runoff rate from top tank)
Bo	=	Coefficient of discharge through bottom outlet of second tank (measure of percolation)
B1	=	Coefficient of discharge through sid outlet of second tank (measure of intermediate flow)
Co	=	Coefficient of discharge through bottom outlet of third tank (measure of deep percolation)
C1	=	Coefficient of discharge through side outlet of third tank (measure of sub-base flow)
D1	=	Coefficient of discharge through side outlet of fourth tank (measure of base flow)
HA1,HA2	=	Head for first and second side outlets of top tank (measure of initial losses)
PS	=	Saturation value of primary soil moisture
SS	=	Saturation value of secondary soil moisture

XP	=	Initial storage of primary soil moisture
XS	=	Initial storage of secondary soil moisture
XA,XB,XC,XD	=	Initial storage of top tank, second tank, third tank and fourth tank of each zone
T1	=	Transfer velocity of water from lower strata to fulfil the primary soil moisture under capillary action
T2	=	Transfer velocity of water from primary to secondary soil moisture
Y1,Y2,Y3,Y4	=	Discharges respectively from top tank, second tank, third tank and fourth tank
Cp	=	Weightage of precipitation
We	=	Weight of discharge

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ABSTRACT

Hydrological modelling is very important for the management of the available water resources. In these days where water is recognised as scarce resource, simulating streamflow is inevitable. In this report an attempt has been made to model river Sarada in Eastern ghats so that one will be in a position to apply the results for better management of streamflow in the region. Keeping in view the limited data available, Tank Model was selected for modelling the river Sarada which has a catchment area of 1980 sq.km upto Anakapalli in the Eastern ghats.

The Sarada river gathers its head waters in the high mountains of Eastern Ghats and flows from north to south for over a length of 140 km., receiving a few tributaries and finally joins the Bay of Bengal 60 km. southeast of Visakhapatnam without any delta. The general drainage pattern is of dendritic type.

From the results, it is observed that the Tank model is well suited for hydrological modelling of the streamflow of river Sarada. It can be reasonably used for continuous streamflow simulation purpose. Total flows can also be simulated acceptably. In any case one should be cautious in using Tank model for simulation of individual events.

1.0 INTRODUCTION:

Hydrological modelling is very important for the management of the available water resources. In these days where water is recognised as scarce resource, simulating streamflow is inevitable because of its applicability in extending streamflow records; in flow forecasting; in watershed experimentation; in designing urban drainage, highway structures, reservoirs etc., in developing water supply; in flood mitigation; in drought management and in irrigation planning and management (Singh, 1988). In the present study an attempt has been made to model an Eastern Ghats Stream so that one will be in a position to apply the results for better management of streamflows in the region.

A number of rainfall-runoff models are in use in India for simulation of daily runoff. Keeping in view the limited data available, Tank Model was selected for modelling the river Sarada which has a catchment area of 1980 sq.km upto Anakapalli in the Eastern Ghats. In this study, Sarada basin is treated as a humid basin and the entire catchment is treated as single unit.

The Tank model was first introduced by Sugawara in 1961 and has since undergone a number of revisions until its final version reported by Sugawara et.al.(1984). The model has the capacity to simulate both flood and daily runoff. Among others the representation of zonal structure of ground water is the main idea in this model. The Tank model has been applied to model many watersheds in Japan and elsewhere. The results were encouraging for both forecasting and simulation. The model parameters can be estimated either by trial and error or by an automatic optimization. In this study parameters were estimated by trial and error. The model considers total rainfall as input and estimates runoff. Observed flow are also supplied as input for comparision purpose.

The salient features of tank model, modelling of river Sarada upto Anakapalli and the performance of the model are described in the following sections.

2.0 DESCRIPTION OF THE STUDY AREA

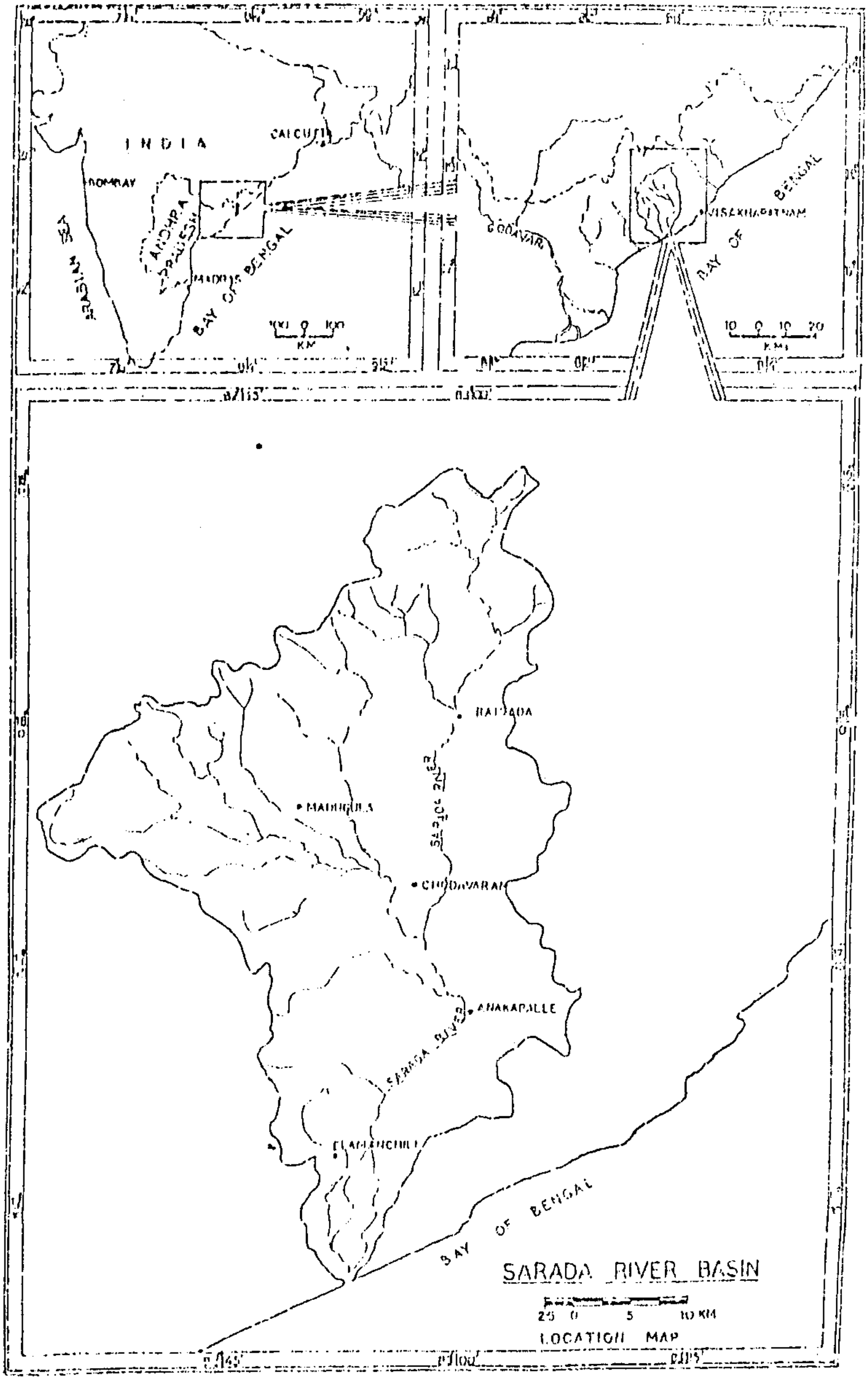
2.1 Sarada Basin

The Sarada river basin forms a part of Survey of India toposheets Nos.65 0/1,2,3 and 6 and 65 K/13,14,15. It extends from latitudes 17 25'to 18 17'N and longitudes 82 30'to 83 07' E. The total area of the basin is around 2590 sq.kms. It is one of the minor watersheds lying between the Eastern Ghats and the Eastern coast line (Figure 1).

Around 70,000 hectares is the ayacut in the Sarada river basin. Agriculture is the principal occupation. Paddy, jowar, bajra, maize, groundnut, blackgram, horsegram and sugarcane are the main crops in the basin.

The Sarada river gathers its head waters in the high mountains of Eastern Ghats and flows from north to south for over a length of 140 kms. receiving a few tributaries and finally joins the Bay of Bengal, 60 kms southeast of Visakhapatnam without any delta. The general drainage pattern is of dendritic type.

Topographically the basin can be divided into mountains, hills and ridges and plains. The northern and northeastern parts of the basin have mountains with a maximum relief of 1620 metres. Down south the hills and ridges are at an altitudinal range of 150 to 600 metres. In general, the plains are rolling excluding those built by the river aggredation. Small hillocks and mounds in the altitudinal range of 30 to 150 metres lie scattered in the plains.



LOCATION MAP - SARADA RIVER BASIN
Fig. 1

2.2 Drainage:

The main Sarada river originates at about 1448 metres above mean sea level (MSL) in the hill range of Ananthagiri mandal of Visakhapatnam district of Andhra Pradesh. Many hill streams join the river and the river flows for a distance of about 45 kms. with rapid falls in a short distance. After 45 kms. it flows almost in a plain country. The bed level at 45 kms. is about 106 metres above MSL. At 45 kms. of its traverse one major stream originating in Madugula hill ranges, joins Sarada river. Near this confluence another stream Isukagedda flowing in a southeastern direction joins the Sarada river. At 77 kms further downstream another major stream Padderru joins the river from the east side at about bed level of 36 meters above MSL. Thus the average fall in bed level works out to 3 mts/km. After flowing further in Chodavaram mandal upto 78.8 kms. it enters Anakapalli mandal and flows for a length of about 19.3 kms. The average fall of bed level in this mandal is about 1.5 mts/km.

Pedderu river rises in G.Madugula mandal at a height of +1143.3 mts. and flows eastwards. The pedderu traverses for a length of about 27.35 kms. in Madugula and Buchiyyapet mandals and enters Chodavaram mandal. It has two major hill streams, Chittigedda and Tacheruvagu, as its tributaries. The Chittigedda joins pedderu on the right side and Tacheruvagu on the left side near Vaddadi. After the confluence with Bodderu, it joins Sarada river after traversing about 72 kms. from its source.

Bodderu river rises in Paderu mandal in Madugula Zamindari hill ranges at level +457.3 mts. and flows southwards in the

Chidikada mandal. The river flows for a length of about 56.3 kms. and joins pedderu at about 4.83 kms. from Chodavaram.

Main tributaries of the Sarada river basin in the study area are 1) Upper Sarada, 2) Bodderu river, 3) Tacheru and Pedderu rivers, 4) Vedurla Gedda and 5) Lower Sarada (Figure 2).

Out of the total area nearly 60% forms the plains (below 80 mts. MSL) and it is under extensive cultivation.

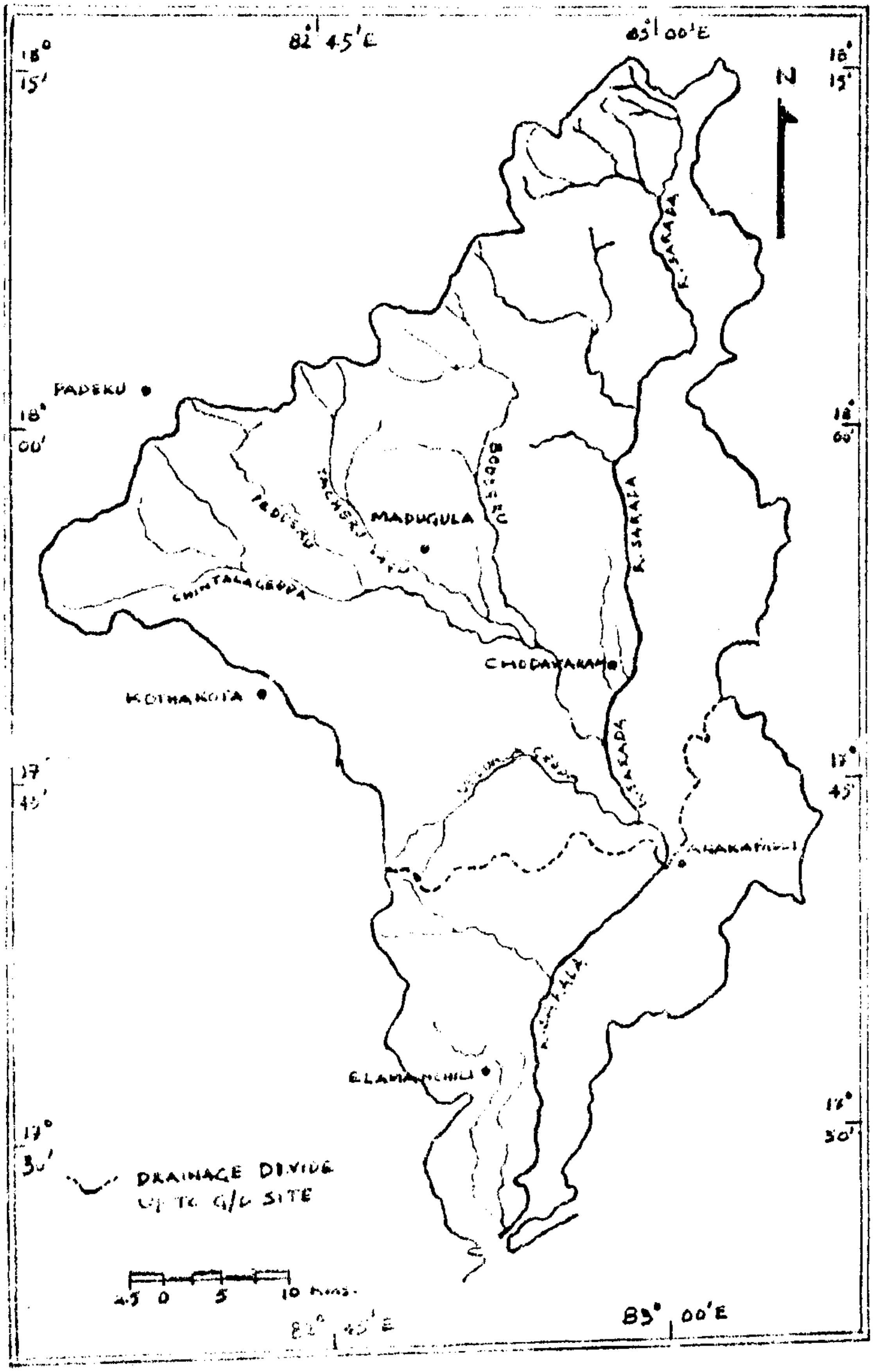
2.3 Soils :

Residual soils are of common occurance on the hills whereas transported soils are present in the plains. Sandy soils characterise quartzitic terrains while clayey soils are on charnockite and gneissic regions. The sandy soils are usually brick red in colour, ill sorted and coarse. The clayey soils have a colour which ranges from black to grey.

The soil cover of the basin could be classified into four types - 1) Sandy soils, 2) Loamy soils, 3) Clay loamy soils and 4) Clayey soils.

2.4 Land use/land cover:

The total area of the basin is 2590 sq.kms, spread over 19 administrative mandals of Visakhapatnam district and one mandal of Vizianagaram district. Out of the basin area 25.3% is under forest cover and 13.7% is barren land. The area under current fallow and other fallows together constitute 7.4% of the total basin area.



MAP OF SARADA BASIN
Fig. 2

The total cropped area of the basin is 42.6%, of which 45.4% is under irrigated area; and the area irrigated more than once is 28.2% of the total irrigated area.

2.5 Climate:

The Sarada river basin falls under two types of climate. The area between the coast and the foothills of the Eastern Ghats enjoys semi-arid climate and the upper reaches fall under the dry sub-humid type of climate.

The average climate of the year is characterised by four distinct seasons. They are

1. Winter season (December to February)
2. Hot weather season (March to May)
3. South West monsoon season (June to September)
4. Post monsoon season (October and November)

2.6 Temperature :

May is the hottest month with a mean monthly maximum temperature of 36.9 C and mean monhtly minimum temperature of 17.5 C at Anakapalli (Visakhapatnam district). December is the coldest month and the highest mean daily minimum temperature is 17.4 C in January.

2.7 Evaporation :

Evaporation plays an important role in the water balance studies. The daily evaporation varies from 3.2mm.(January) to 7.9mm (April). The maximum evaporation has been recorded during the month of April. From May onwards evaporation gradually decreases with the onset of monsoon (INCOR,1986).The daily mean monthly evaporation at Anakapalli is given in Table 2.1.

Table 2.1: DAILY MEAN MONTHLY EVAPORATION AT ANAKAPALLI
(5 years average 1981-1985)

MONTHS	EVAPORATION (mm)
January	3.2
February	5.3
March	6.5
April	7.9
May	7.6
June	6.7
July	5.1
August	4.8
September	4.3
October	4.4
November	4.0
December	4.0

3.0 DATA USED IN THE STUDY

Following data of Sarada basin are used for calibration and testing of the Tank model and simulation of daily runoff.

i) Basin map of River Sarada collected from A.P Irrigation Department.

ii) Daily rainfall data of six staions namely Anakapalli, Chodavaran, Kothakota, Madugula, Paderu and Elamanchili from 1981 to 1986 obtained from Bureau of Economics and Statistics,Hyderabad.

ii) Daily discharge data of river Sarada at Gudari anicut near Anakapalli for the period 1981 to 1986 as observed at 0600 hrs everyday, provided by Deputy Director (gaugings), A.P Irrigation Department.

iii) Monthly mean of daily evaporation values of at Anakapalli Agricultural Farm from January to December.

4.0 METHODOLOGY

4.1 General Description :

The structure of the Tank model and the method of its application to different types basins is described in the following sections.

4.1.1 For humid basin :

The Tank model is a simple conceptual rainfall-runoff model developed by Sugwara(1967) to simulate the runoff of a basin. The Tank model, which was used by Sugwara for daily flow analysis, is composed of several tanks laid vertically in series representing soil moisture and groundwater in different soil strata of the basin as shown in figure 3. Each tank has oneside outlet and one bottom outlet except the top tank which has two side outlets and the bottom tank which does not have any bottom outlet. The top tank corresponds to structure of ground surface and the discharge through side outlets (Y1=YA1+YA2) represents the surface flow, while the discharge through bottom outlet represents infiltration. Similarly, discharges through side outlets of second, third and fourth tanks represent interflow (Y2), subsurface flow (Y3) and base flow (Y4) respectively. The sum of outflows through side outlets of four tanks (Y=Y1+Y2+Y3+Y4) represents total runoff from the basin. The HA1 and HA2 represents the heads (threshold levels) of two side outlets of top tank and are measures of initial losses. Similarly, HB and HC are heads (threshold levels) of side outlets of second and third tanks respectively. A1,A2,B1,C1 and D1 are discharge coefficients of bottom outlets of top, second and third tanks respectively.

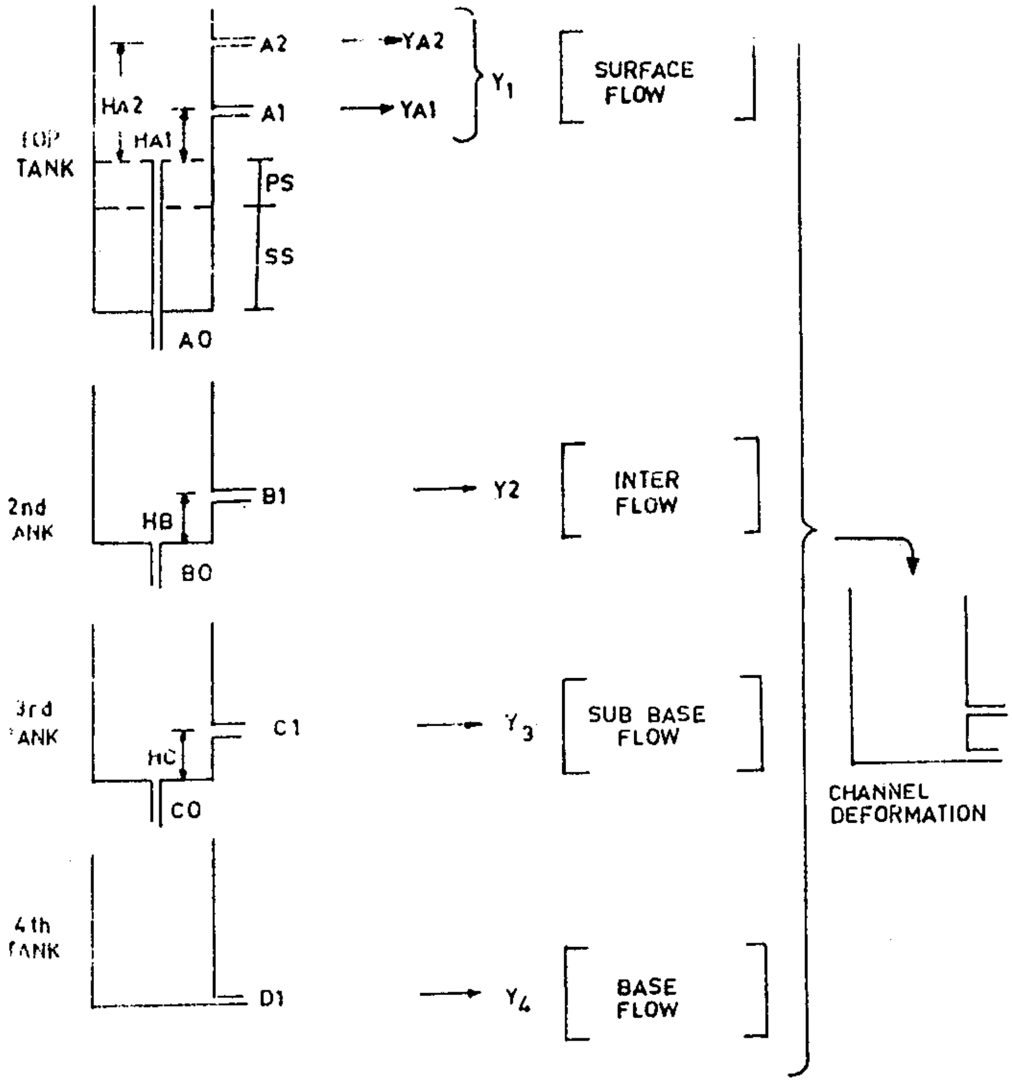


Fig.3- TANK MODEL STRUCTURE

Rainfall is the input to the top tank. Water in all the three tanks from top moves both horizontally and vertically. Discharges through bottom outlet of top tank is the inflow to the second tank. Similarly, discharges through bottom outlets of second and third tanks are the inflows to the third and fourth tanks respectively. The model is based on the assumption that the runoff at any instant from each tank depends on the storage in the tank at that instant and follows an exponential function.

<u>4.1.2</u> <u>For</u> <u>Non-humid</u> <u>basin</u> :

For non humid basins which experience long dry periods, the 4 X 4 Tank model is used for daily rainfall-runoff analysis. Some part of such basins remain dry while the area near the such basins do not remain constant all throughout the year. As the dry season continues, the percentage of dry area to the whole basin area continues to increase. When the rainy season begins, the wet area that remained near the river courses at the end of dry period starts to increase and continues to grow till the rainy season contiues. Surface runoff occurs only in wet area while in dry area all the rainfall gets absorbed as soil moisture. Evaporation from the basin also varies depending on the variation of wet area. To take into account such variations, the basin is divided into number of zones and variation is accounted in steps. Generally the basin is divided in four zones, S1,S2,S3, and S4 as shown in Figure 4. For each zone four linear tanks in series are considered to represent surface flow, intermediate flow, sub-base flow and base flow. Schematically, 4 X 4 Tank model structure along slopping ground of a basin is shown in

Figure 5. Left side is the mountain side and right side is the river side. Details of 4 X 4 Tank model structure is shown in Figure 6. Each zone is represented for simulation by series of four tanks laid vertically with soil moisture structure at the bottom of the tank. Series of four tanks of first zone S1 is in parallel with that of the other three zones S2,S3,S4. The top tank of four zones are of identical structure, similarly structure of all seccond tanks, structure of all third tanks, structure of all fourth tanks are identical. The only difference in the structure of four zones that may occur is in the structure of soil moisture (PS and SS values may be different) and zonal areas.

In this model free water moves in two directions; horizontally and vertically. Each tank receives water from the upper tank of the same zone or from the mountain side tank of the same strata and transfer water to the lower tank of the same zone or to the river side tank of the same strata. The top tank of each zone receives rainwater as input. Another important water trasnfers to soil moisture from lower free water by capillary action.

When the dry season comes, free water of the highest zone decreases faster than that of the other zones due to water transfer to lower zones. After depletion of free water, soil moisture begins to decrease. Due to these depletions, the highest becomes dry earliest and then the second zone, the third zone and fourth zone. When the rainy season starts, in the opposite way the lowest zone becomes saturated first and then the second zone, the third zone and the fourth zone.

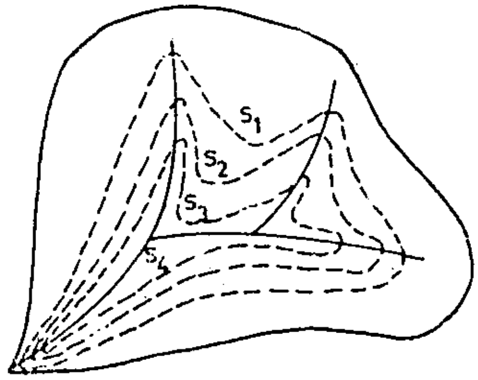


Fig. 4 - NON-HUMID BASIN DIVIDED INTO FOUR ZONES

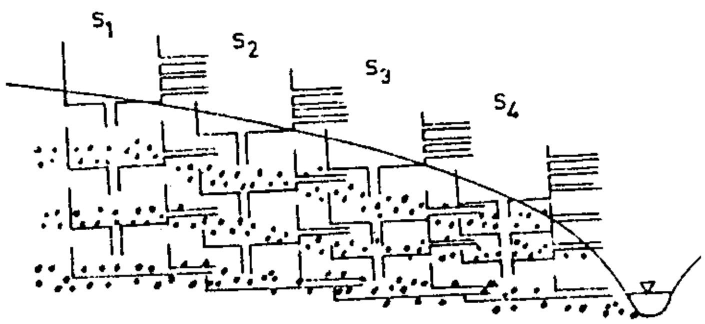


Fig.5 - 4 X 4 TANK MODEL ALONG A SLOPING GROUND OF A BASIN

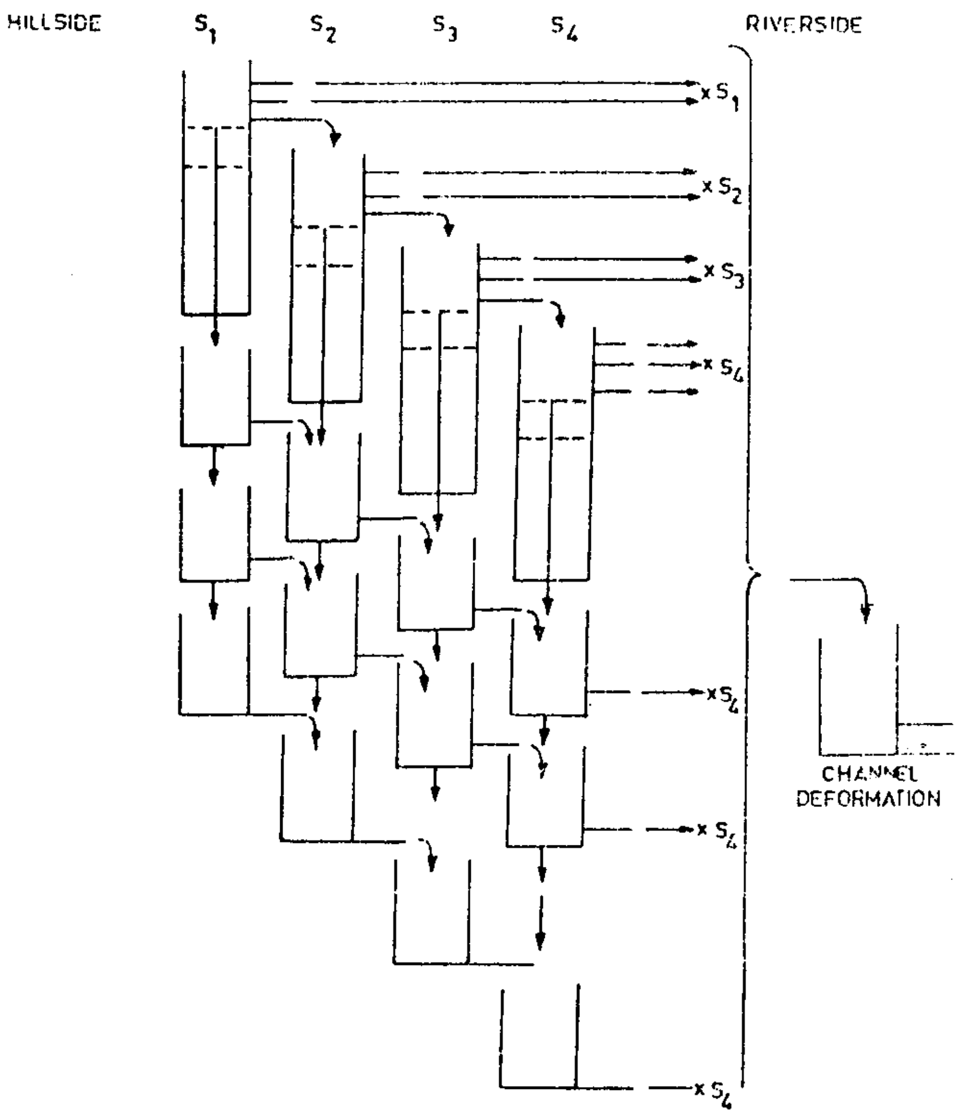


Fig.6 - 4 X 4 TANK MODEL STRUCTURE FOR NON HUMID BASIN

Areal ratio of zones S1:S2:S3:S4 is an important paramater in this model. These ratios can be determined if the detailed information regarding hydrological, topographical and geological characteristics of the basin are available. If no such information is available, the ratio can be determined by trial and error method.

4.1.3 Soil Moisture :

Tank model for daily discharge analysis consists of four tanks laid vertically in series as shown figure 3. The daily analysis model also includes a structure of soil moisture at the bottom of the top tank.

When rain starts after a long dry period, value of primary soil structure (XP) goes on increasing till it reaches saturation value (PS), after this water becomes free water in the top tank. This free water partly infiltrates to the lower tank and partly discharges as surface runoff. Water gradually goes from from primary soil moisture to secondary soil moisture at a transfer velocity T2 which can be given as:

$$T2 = C0+C(1-XS/SS) \qquad \text{.............(1)}$$

Where

C0 and C = Constants

XS = Secondary soil moisture

SS = Saturation capacity of secondary soil moisture

When dry season starts, evaporation first takes place from free water, at a certain stage free water of the top tank becomes zero and evaporation starts to take place from primary soil moisture. When primary soil moisture is not in saturated condition and free water is available in the lower tank, water goes up by capillary action at a transfer velocity T1 which can be given as:

$$T1 = b0+b(1-XP/PS) \quad ....(2)$$

Where

b0 and b = Constants

XP = Primary soil moisture

PS = Saturation capacity of primary soil moisture

The ratios (XP/PS) AND (XS/SS) represent moisture status and can be regarded as relative humidity of primary and secondary soil moisture.

4.2 Data Requirements :

Following inputs are necesary for running the computer programme of daily analysis model.

(a) Data for the storm

(1) Year and month of begining and end of data number of rainfall stations.

(2) Catchment area in sq. km.

(3) Name of basin

(4) Observed descharge value of first year

(5) Daily evapotranspiration data of first year (If option IEVAP=1)

(6) Observed precipitation values for first year for first station, second station and so on. Serial (4),(5) anhd (6) are repeated for subsequent years.

(7) Monthly mean of daily evapotranspiration value (If option IEVAP=0)

(b) Initial Parameter Values

(1) Primary and secondary soil moisture depths (PS & SS)

(2) Coefficient of discharge and initial loss heads of top tank, second tank, third tank and fourth ttank.

(3) CP, WE and LAG of each rainfall station.

(4) Transfer velocity of water T1 and T2

(5) Initial storage for each tank.

(c) Following are to be identified for the output

(1) Number of graphs to be plotted, number of scale points, range of plot, maximum and minimum value to be plotted.

(2) Scale points to define

(3) Output format to be supplied.

4.3 Analysis :

4.3.1 Daily analysis procedure using Tank Model

Following are the main points to be followed for analysis and selecting initial parameter values for first trail run to start the calibration process of the Tank model for daily analysis.

(1) Length of data- A minimum of three to four years continuous daily discharge, rainfall and evapotranspiration are necessary.A period of ten years continuous data containing both wet year and dry year is a good choice.

(2) Hydrograph plotting- observed discharge data are plotted in logatithmic scale against time in natural scale. A rough estimation of time constant of runoff, TC, is made from recession slope of the flow hydrographs.

(3) Initial Tank model parameters- Decreasing ratio α is calculated as 1/TC. From the value of a the discharge

coefficients and initial losses are calculated for top tank, second tank and third tank using the equations :

$$A0 = A1 = A2 \;\ldots\ldots\; = \alpha/2$$

$$B0 = B1 = \alpha/10$$

$$C0 = C1 = \alpha/50$$

The values of initial losses are selected from the following ranges

HA1 = 0 - 15 (mm), HA2 = 15 - 49 (mm)

HA3 = 40 - 60 (mm), HB = 5 - 15 (mm)

HC = 5 - 15 (mm)

(4) Input precipitation- weighted mean values of the rainfall stations for the basin are generally considered. For simplicity simple mean of rainfall stations may also be considered.

(5) Time Lag (LAG) - Unit of time lag is one day. Initial time lag is considered to be zero.

(6) Evapotranspiration (E) - If observed evaporation data are available from number of stations within the basin or near the basin, then mean daily evapotranspiration values are computed and used for analysis. If no such data are available for the period under consideration monthly mean of daily evapotranspiration values for that region may be used.

(7) Initial storage (XA,XB,XC,XD) - Initial amount of storage of the fourth tank can be decided from long duration of dry period. For first trial, initial value of storage for other tanks may be set to zero.

(8) Correction Factor for precipitation - For initial trial, the values of correction factors (CP & WE) are usually considered as 1.0

4.3.2 Calibration :

Main steps to be followed in calibration are as follows:

(i) Observing and comparing the calculated and observed hydrographs, if it is found that nth runoff component takes the main part then the parameter of nth tank is adjusted.

(ii) If the parameter of side outlet is increased and that of bottom outlet is decreased of the nth tank keeping their sum unchanged then the amount of discharge increase without changing the form of the hydrograph and vice versa.

(iii) If both the parameters of side outlet and bottom outlet of nth tank are increased then the recession slope corresponding to nth tank becomes steeper.

(iv) Ifthe parameter of top side outlet of top tank is decreased and that of lower outlet is increased then hydrograph of large flood becomes steeper whereas for smaller flood it becomes smoother.

(v) The positions of the side outlets, determined by the parameters HA1,HA2,HA3,HB and HC, are useful for representing initial losses of surface flow, interflow and baseflow.

(vi) After obtaining fairly good result by adjusting the above stated parameters, calibration of the weights of rainfall station begins.

(vii) When there are no. of rainfall stations and data of each rainfall stations are considered as a part of the input, then on comparing the simulated hydrograph with observed one suitable time lags are provided to the stations depending on the distance of rainfall stations from the observed discharge site.

(viii) Usually same amount of initial storages are considered but depending on antecedent rainfall and soil moisture condition different initial storages may be considered subject to further adjustment.

(ix) Correction factor for the precipitation is provided when the depth of calculated discharge differs considerably from the observed one. Generally same value of correction factor is provided to all precipitation stations. But in some cases, it becomes necessary to provide different correction factors to different precipitation stations depending on its topographic location, orographic effect etc.

(x) Correction factor for channel deformation is also provided depending on the situation. (Channel deformation is not considered in this programme).

(xi) During calibration it is very important to keep in mind that parameters are to be changed and adjusted one by one in successive trials. Usually it is better to adjust the top tank first, then the second tank, the third tank and so on. But in case of significant difference between calculated and acutal base discharge, the parameter corresponding to fourth tank requires to be adjusted first.

(xii) It is important to make a well balanced general outline first and then fine adjustments are to be made.

5.0 RESULTS AND DISCUSSIONS :

Daily discharge and rainfall data from 1981 to 1984 have been used for calibration of the Tank model and that for the years 1985 and 1986 are used independently for validation of the parameters calibrated. The data used are given in detail in Section 3.0

Average daily rainfall values of the basin are calculated using Thiessen weights for six stations namely Anakapalli, Chodavaram, Kothakota, Madugula, Paderu and Elamanchili.

5.1 Calibration of Tank model :

The entire catchment of 1983.23 sq.km area upto Anakapalli is assumed as single unit. The top tank with two outlets is considered. The Tank model parameters are calibrated using 4 year data from 1981 to 1984

The calibrated parameters values of the Tank model for Sarada basin are given in Appendix-I. The method of conducting calibration in a systematic manner is described in detail in section 4.3.2. The observed and estimated hydrographs along with the Rainfall histigrams for 1981 to 1984 are shown as figures 7 and 8. The monthwise mean daily flows from the Tank model over the 4 year period are given in Appendix-II.

It is to be noted that in the modelling the flows as observed at 0600 hrs are used as observed discharges. It is observed from the monthwise mean daily flows given in Appendix-II for the

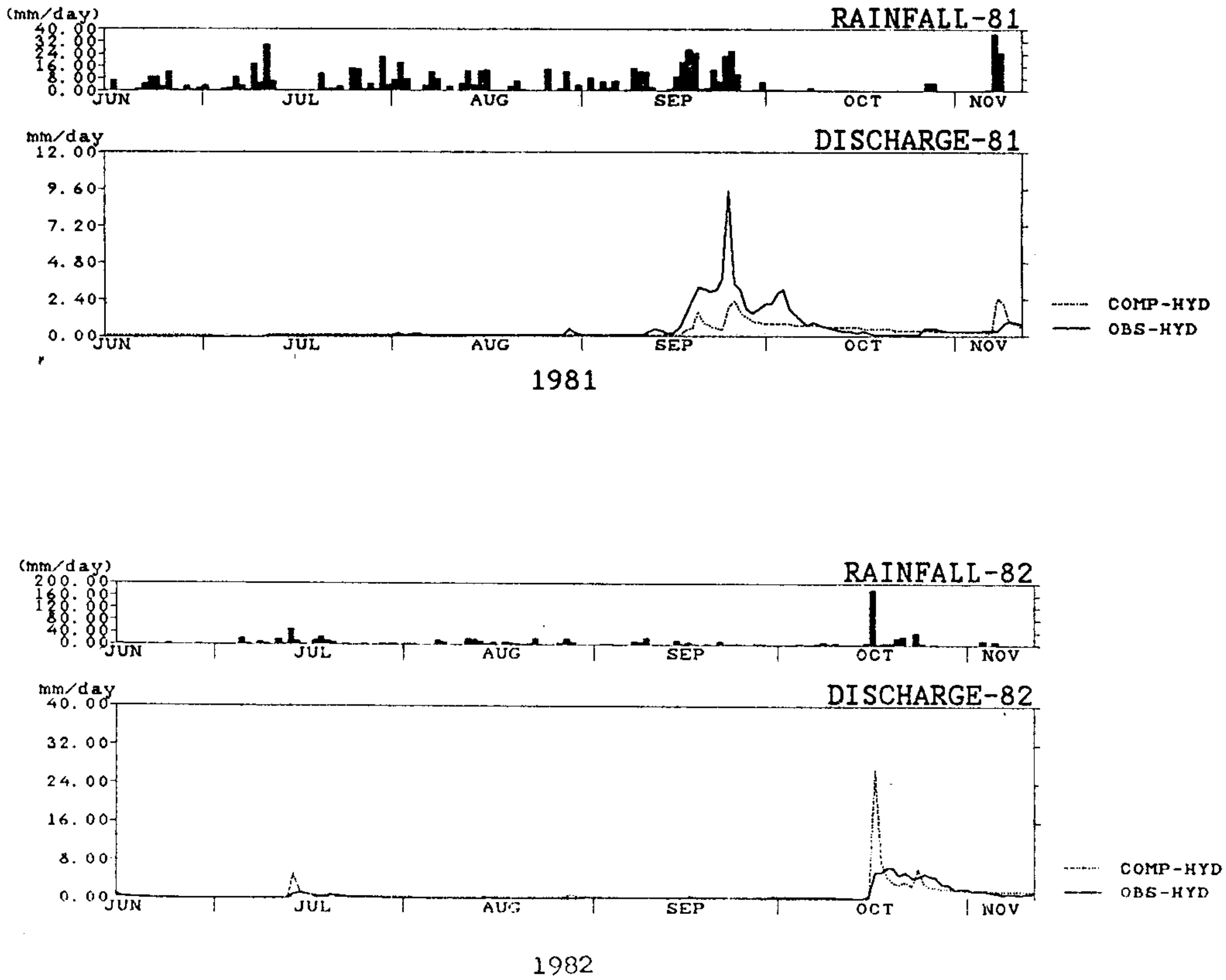


Fig. 7 Hydrograph for 1981 and 1982 with rainfall histogram

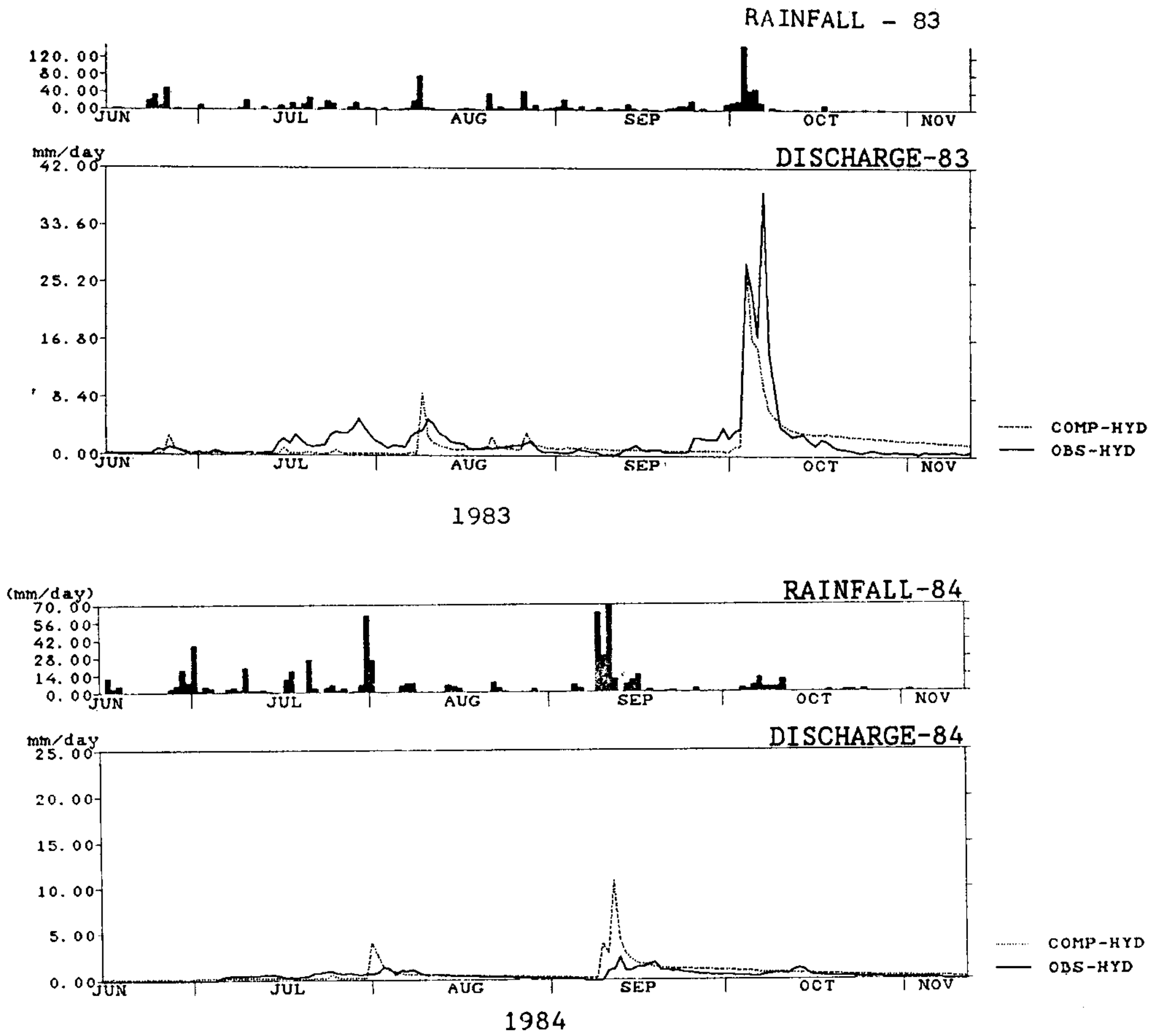


Fig. 8 Hydrograph for 1983 and 1984 with rainfall histogram

calibration period that the total mean daily flows for 1981 and 1983 are under estimated and for 1982 and 1984 are over estimated slightly to the observed flows. This may be because the simulation is unable to exactly simulate the rising limb in 1981 and 1983, and so the estimated hydrograph is lying below the observed one in this portion. Whereas in 1982 and 1984 the total monthly mean daily flows are over estimated since the calibration is unable to exactly simulate the recession side of the hydrograph and estimated values are lying slightly above the observed values. It is important to note that the peak estimates are immediately reacting to the precipitation whereas in the real case the observed peaks are rather delayed, which is natural. The simulation is unable to take care of the lag properly may be because the input is lumped daily rainfall. Had it been hourly rainfall the simulation could have been rather close to the observed peaks.The peak discharges estimated using the model are matching with observed peaks in most of the events. Except on two occasions i.e., 4th Oct 1981 and 7th Oct 1983, on all other occasions the model predicted peak flows on the higher side. The estimated monthly total mean daily flows over the four year period are 22.64 mm/day. It is excess by 2.7% over the observed values. It was felt that the calibraton was in acceptable stage and the calibrated parameters are used for the validation of the model for 1985 and 1986 independently.

5.2 Validation of the Tank model :

The observed flows in 1985 and 1986 are of good contrast. Both the years were tested independently and the hydrographs for observed and estimated flows, with rainfall histograms are presented as figure 9 and figure 10 for 1985 and 1986 respectively.The year 1985 had low flows whereas the year 1986 recorded good flows with two strong peaks some time in the middle of August and in the beginning of October because of intense rains in the catchment. The monthly mean daily flows for the two years are given in Appendix-II. It is found from the results that in both the years the estimated monthly mean daily flows over the year are on the higher side by 18.8% in 1985 and 6.0% in 1986. The estimated total monthly mean daily flows for the two year period of 1985 and 1986 are exceeding the observed flows by 8.5%. It is observed that the estimated hydrographs for 1985 and 1986 have matched reasonably well with the observed hydrographs.

5.2.1: Comparison of results:

The results obtained from Tank model for 1985 and 1986 are compiled for monthly flows and are presented along with the results obtained from statistical methods for the same period in Table 5.1. The Bi-variate and Multi-variate regression equations developed for an adjacent Yeleru river basin are applied for Sarada in the absence of such relation for Sarada (NIH,1986).

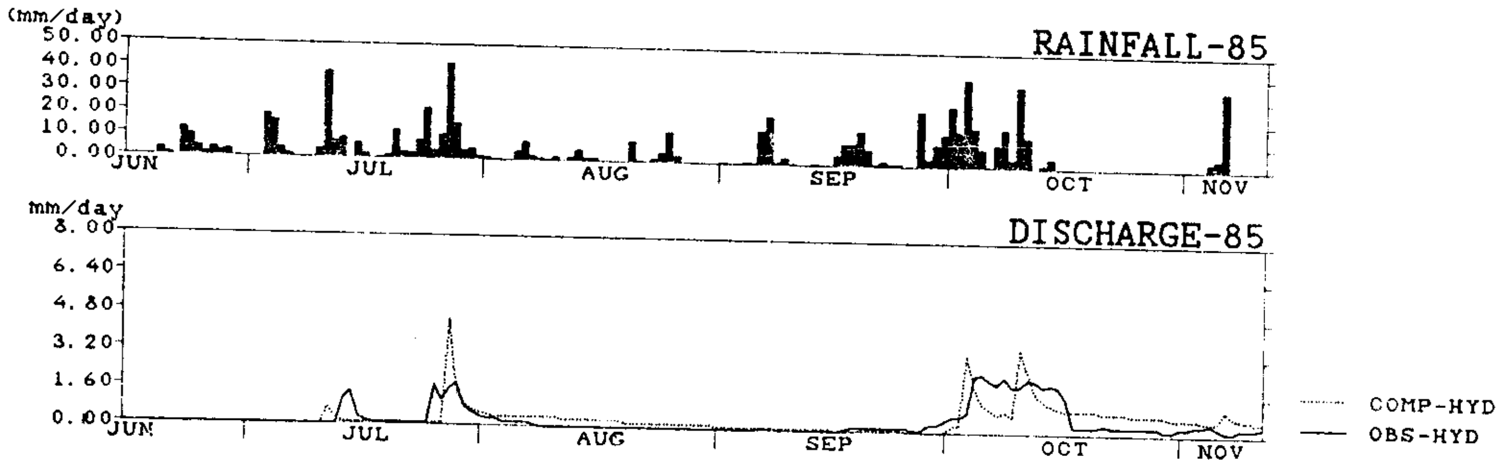


Fig. 9. Hydrograph for 1985 with Rainfall histogram

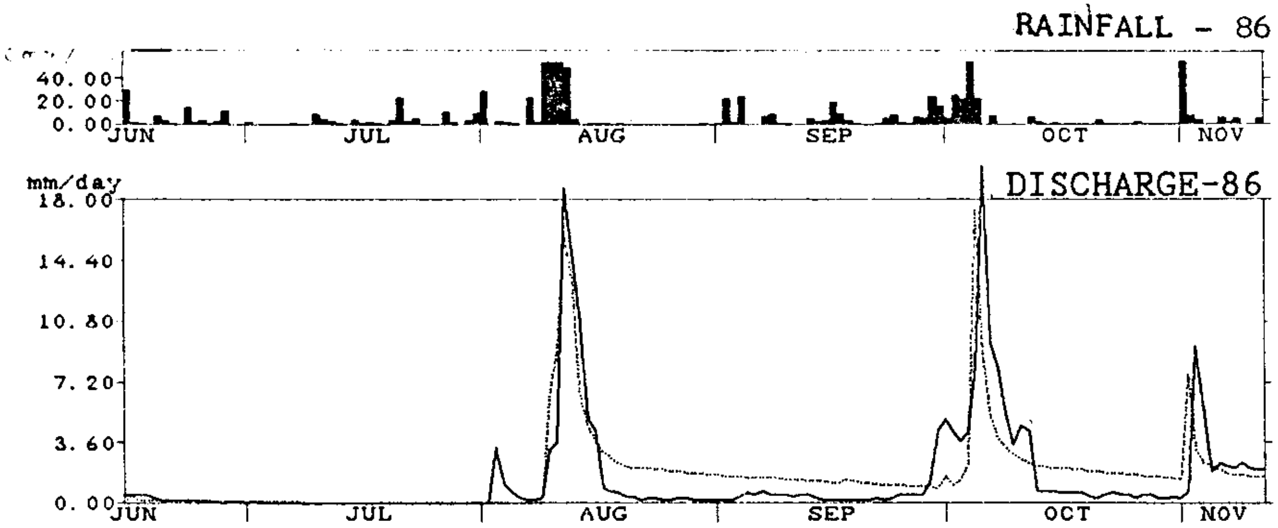


Fig. 10 Hydrograph for 1986 with Rainfall histogram

Table 5.1: Comparison of monthly and seasonal flows (mm) from Tank model and statistical methods.

MONTH	1985			OBSERVED DISCHARGE	1986			OBSERVED DISCHARGE
	STATISTICAL METHOD		TANK MODEL		STATISTICAL METHOD		TANK MODEL	
	BI-VARIATE	MULTI-VARIATE			BI-VARIATE	MULTI-VARIATE		
JUN	9.40	8.64	0.0	0.0	19.81	19.81	4.20	6.0
JUL	24.39	20.83	9.30	11.16	0.0	18.03	0.93	0.62
AUG	27.94	21.08	9.61	2.17	78.23	66.29	91.14	72.85
SEP	29.97	18.29	2.10	3.0	47.24	108.20	39.00	15.30
OCT	66.04	69.34	35.65	34.72	67.06	69.09	88.04	90.52
NOV	8.64	19.56	16.80	12.30	7.87	21.84	51.60	55.50
SEASONAL	166.37	157.74	73.40	63.35	220.21	303.26	274.91	241.39

From the table it can be seen that the estimated monthly flows from Tank model are close to the observed flows than the other statistical estimates. Except in Aug'85, in other cases the estimated flows are nearer to the observed flows. The estimated flows from Tank model are mostly on the higher side of the observed flows by a small margin compared to other statistical estimates. Seasonal flows are also estimated in a better way by Tank model than by other methods. The seasonal flows are predicted on the higher side to the observed flows 16% in 1985 and 14% in 1986.

6.0 REMARKS AND CONCLUSIONS :

It is observed that the performance of the Tank model is satisfactory. The monsoon flows were estimated reasonably well. The testing of the model for 1985 and 1986 showed good performance especially 1985 being low flow year and 1986 having good flows. The limitation of Tank model in its present application to Sarada basin is that the entire catchment is considered as humid and treated as single unit.

From the results, it is observed that the Tank model is well suited for hydrological modelling of the streamflow of river Sarada. It can be reasonably used for predicting the flows for for continuous streamflow simulation purpose. Total flows can also be simulated acceptably. In any case one should cautious in using Tank model for simulation of individual events.

The Tank model has simple structure and data requirement is far less than that required for other conceptual and physical models that are available. Though this modelling was carried on VAX-3200, the programme can be implemented on the latest versions of Personal Computers that are available in market. It is important that Tank model required expertise to get a good calibration because the structure and parameters of the model must be determined subjectively by the analyst.

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2. Deputy Director,Gaugings,Irrigation Department, Govt. of A.P., Hyderabad for making available Discharge data of Sarada River at Gudari Anicut, near Anakapalli.

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APPENDIX -I

VALUES OF PARAMETERS USED IN THE MODEL FOR CALIBRATION

FYEAR	FMONTH	LYEAR	LMONTH	NP	ISNOW	IEVAP	AREA
1981	1	1984	12	6	0	0	1983.23

S1	S2	HA1	HA2	A0	A1	A2
40.	120.	15.	30.	0.8000	0.1000	0.0015

HB1	B0	B1	HC1	C0	C1	HD1	D0	D1
10.	0.6000	0.0850	5.	0.3000	0.0650	0.	0.0000	0.0200

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
E	3.20	5.30	6.50	7.90	7.60	6.70	5.10	4.80	4.30	4.40	4.00	4.00

K1	K2
0.4	15.0

CP					
1.00	1.00	1.00	1.00	1.00	1.00

WE					
0.04	0.27	0.11	0.48	0.09	0.01

LAG					
0	0	0	0	0	0

XA	XS	XB	XC	XD	SNOW
0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	

MONTHLY MEAN DAILY FLOWS IN MM/DAY

A : CALIBRATION

YEAR	MONTH	OBSERVED	ESTIMATED
1981	JAN	0.00	0.00
	FEB	0.00	0.00
	MAR	0.00	0.33
	APR	0.00	0.09
	MAY	0.00	0.03
	JUN	0.00	0.18
	JUL	0.05	0.02
	AUG	0.13	0.08
	SEP	1.48	0.51
	OCT	0.73	0.56
	NOV	0.38	0.54
	DEC	0.09	0.11
	TOTAL	2.86	2.45
1982	JAN	0.05	0.00
	FEB	0.00	0.00
	MAR	0.00	0.03
	APR	0.00	0.04
	MAY	0.00	0.01
	JUN	0.11	0.11
	JUL	0.33	0.51
	AUG	0.12	0.35
	SEP	0.24	0.25
	OCT	2.42	2.49
	NOV	1.01	1.39
	DEC	0.38	0.59
	TOTAL	4.66	5.77
1983	JAN	0.20	0.15
	FEB	0.01	0.02
	MAR	0.00	0.00
	APR	0.00	0.02
	MAY	0.00	0.09
	JUN	0.44	0.26
	JUL	1.74	0.41
	AUG	1.92	1.40
	SEP	1.14	0.96
	OCT	5.80	5.01
	NOV	0.65	1.68
	DEC	0.30	0.72
	TOTAL	12.21	10.71

1984	JAN	0.07	0.20
	FEB	0.00	0.01
	MAR	0.00	0.00
	APR	0.00	0.02
	MAY	0.00	0.01
	JUN	0.00	0.05
	JUL	0.48	0.19
	AUG	0.52	0.74
	SEP	0.73	1.61
	OCT	0.42	0.67
	NOV	0.08	0.19
	DEC	0.01	0.01
	TOTAL	2.31	3.71
	TOTAL	22.04	22.64

B : VALIDATION

YEAR	MONTH	OBSERVED	ESTIMATED
1985	JAN	0.00	0.01
	FEB	0.00	0.00
	MAR	0.00	0.01
	APR	0.00	0.09
	MAY	0.00	0.00
	JUN	0.00	0.00
	JUL	0.36	0.30
	AUG	0.07	0.31
	SEP	0.10	0.07
	OCT	1.12	1.15
	NOV	0.41	0.56
	DEC	0.16	0.15
	TOTAL	2.23	2.65
1986	JAN	0.05	0.00
	FEB	0.13	0.04
	MAR	0.06	0.02
	APR	0.02	0.00
	MAY	0.05	0.02
	JUN	0.20	0.14
	JUL	0.02	0.03
	AUG	2.35	2.94
	SEP	0.53	1.30
	OCT	2.92	2.84
	NOV	1.85	1.72
	DEC	0.97	0.64
	TOTAL	9.15	9.69
	TOTAL	11.38	12.34

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