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ESTIMATING HYDROLOGICAL PARAMETERS FOR WATER BALANCE STUDIES IN TAMBARAPARNI RIVER BASIN, TAMIL NADU

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Abstract

A study has been conducted to do the water balance of the Tambaraparni river basin, Tamilnadu. Various components of water balance have been estimated and presented in this report. To estimate these components, the process estimating module of SWRRB, a model developed by USDA has been employed. The model was used to assess the futuristic scenario of water availability in the basin by simulating the water balance components. A weather generator model has been used for simulating the components. The study provided some insight into the hydrology of the basin and assessment of different water balance components of the one of the sub basins, Pachaiar of Tamabaraparni river basin, having an area of 246.21 sq. km. The estimated values of various hydrological processes in the basin would be useful for planning better management practices in the basin.

Chapter 1

Introduction

It is becoming readily apparent to third world countries and to their donor agencies who supply technical and economical assistance for increasing food and fibre production that their focus must turn more and more towards rainfed agricultural projects rather than to large scale irrigation projects. The river basin sites where irrigation diversion can take place are becoming fewer in number and more complex and costly to develop.

To improve the present practices, it is important to know the availability of the water in any basin. Water balance studies are conducted to assess the quantity of water available in a region. It is defined as the systematic presentation of data on the supply and use of water within a geographical region for specific periods. The water balance of any basin establishes that all water entering the basin during any given period of time must either go into storage within the boundaries, be consumed or flow out during that period. Clearly, the items of inflow and outflow can include a number of components depending on the geographical and hydrological features of the basin. This can be done in a conventional manner, but recent advances in process hydrology has led to development of various computer models and handbook procedures which allow quantification of hydrological processes. These computer models had been widely accepted by researchers to estimate various components of water balance.

Tamilnadu, being predominantly an agricultural state, the state government induced the conjunctive use practice in many of the basins in the state. Presently this practice is unplanned by the use of ground water through construction of wells, private shallow wells and deep state tube wells. A realistic assessment of the water resources in these basins would be required for proper planning and management. Keeping the above aspects in mind it was intended to take up the water balance study in the Tambaraparani River basin of Tamilnadu state. This study involves a series of steps viz. collection and processing of data, identification of the various physical features of the hydrological system involved, their hydraulic characteristics and hydraulic interrelationships and finally estimation of various components of water balance equation. In the present study the process estimating module of SWRRB model (USDA, 1980) has been employed to quantify various hydrological processes in the basin. The Study has been confined to a sub basin of the Tambraparani river basin due to limited availability of data.

Chapter 2

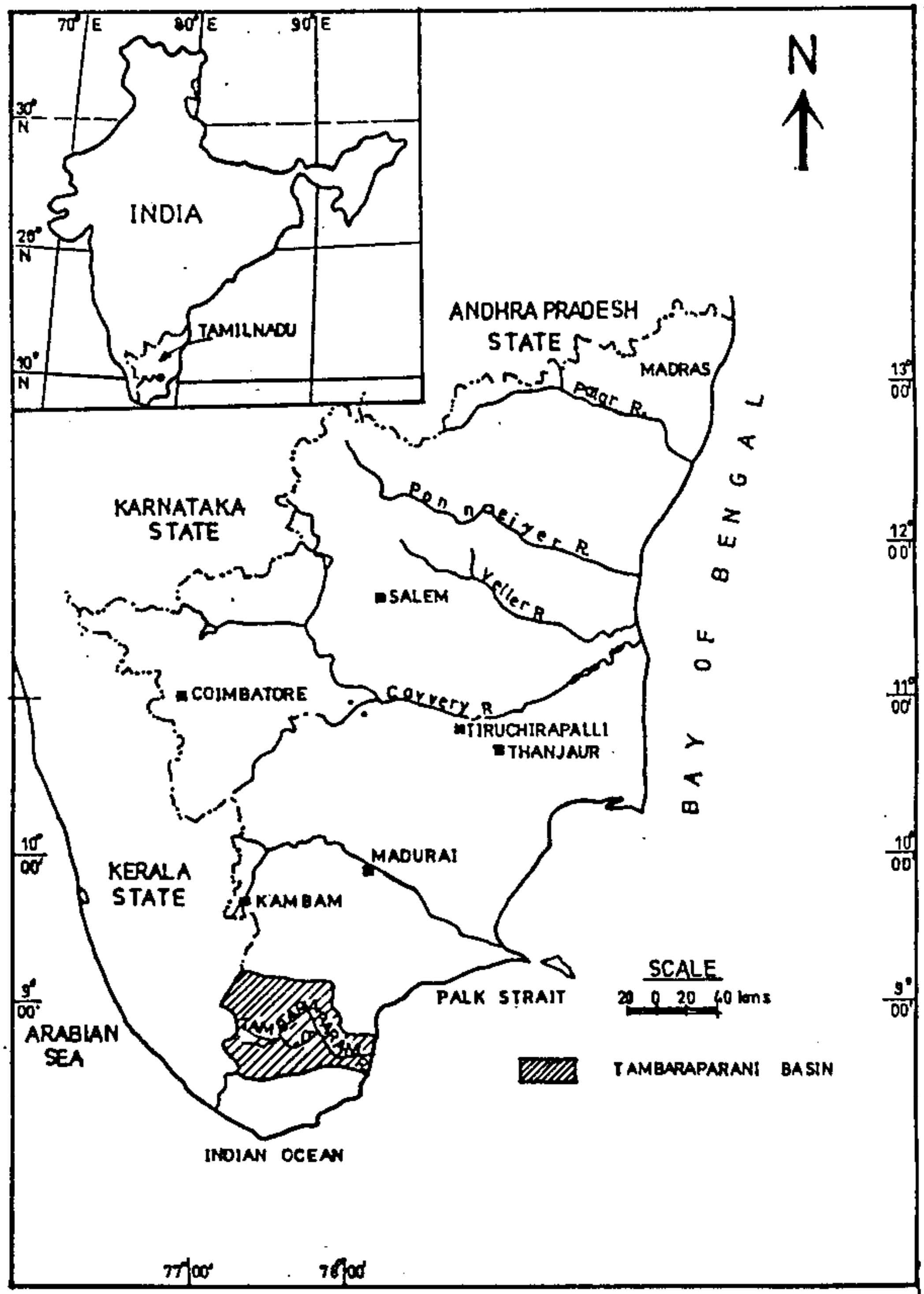
Study Area

2.1 General

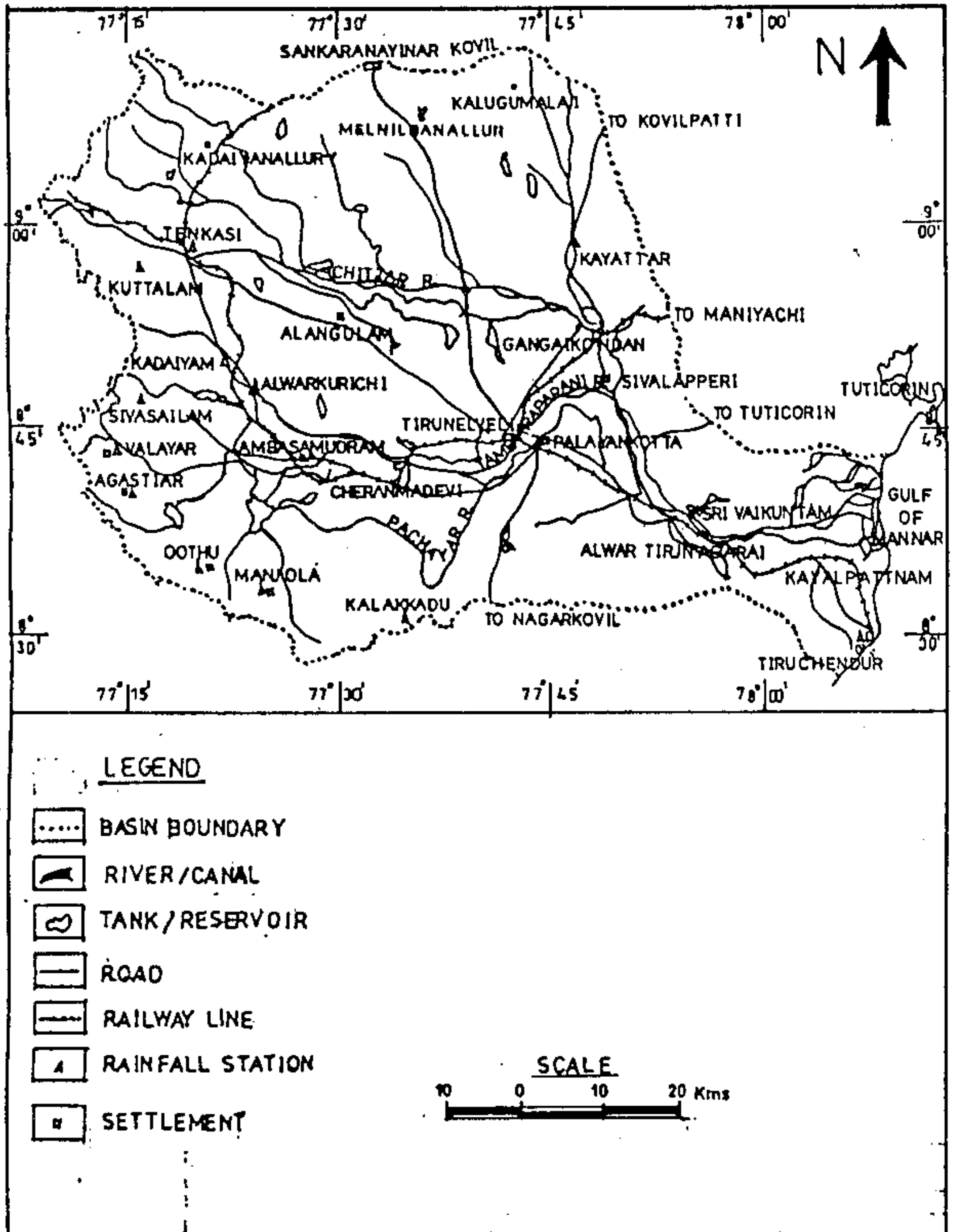
The river Tambaraparani originates at Pothigai hills in Tamilnadu state on the eastern slopes of the Western Ghats at an altitude of 2000m and it confluence's with the Bay of Bengal at gulf of Mannar. The total area of the basin is 5969 sq. Km. The basin lies between $8^0\ 26'\ 45''$ to $9^0\ 12'\ 00''$ north latitude and $77^0\ 69'\ 00''$ to $78^0\ 08'\ 30''$ east longitude. The index map of the basin is presented in Figure 1. The length of the basin is about 120 km and its width varies from 25 to 35 km. Generally the gradient of the entire Tambaraparni from eastern side of western ghats to Bay of Bengal on the East is about 4.5m per kilometer. The basin map of the Tambaraparni river basin is depicted in Figure 2.

2.2 Drainage

The Tambaraparni with its tributaries is the main river of the basin. More than twelve tributaries join the river as it runs down, of which Servelar, Manimutar, Gadana Aru, Pachaiyar and Chittar can be termed as major ones. Tambaraparni after traversing a distance of 22 km from its origin is joined by its tributary Sarvalar. The Manimuthar originates from Mukkuttukal and confluence with Tambaraparni at its 36th km. The Gadana Aru joins Tambaraparni on it's left at the 43rd km. The river flows past Saranma Devi town and takes its tributary Pachaiar on its right. The Chittar confluences with it at a distance of 75 km from its origin. From this point, river flows southward and then eastward and at its 96th km the Srivaikundam anicut spans across the river. Then the river Tambaraparni after traversing another 30 km drains into the Gulf of Mannar.



LOCATION MAP OF TAMBARAPARANI BASIN



BASIN MAP OF TAMBARAPARANI RIVER

2.3 Climate

2.3.1 Rainfall

The basin has a monsoonic climate, as it lies within the tropical monsoon area of Asia. During the monsoon period (June to December) which lasts for about seven months the South west monsoon has influence over the months of June to September, while the north east monsoon is effective during the months of October to December. The monsoon period causes heavy rainfall and consequent stream flows in the basin and therefore this period is hydrologically significant for any water resources analysis. The long term aerial rainfall in the basin for different season is presented in Table 1. The non monsoon period is from January to May with winter falling during the months of January and February. Table 2 depicts the normal values of mean monthly rain fall.

2.3.2 Humidity

The humidity observed in the basin does not show wide variation, when mean monthly average values are considered. The variation is in the range of 50% to 80%. However, the daily variation of humidity is considerable. The humidity appears to be generally little higher during the North east monsoon period. The mean annual humidity works out to be 60%. The mean monthly values of humidity at a representative station in the basin are furnished in Table 3.

2.3.3 Temperature

The region shows little variation in temperature, similar to the areas situated in the same temperate to tropical latitudes. The variation in mean monthly temperature ranges from 24^0 C to 34^0 C in the full year. The temperature is higher during the months of April to June and lower during the months of December to February. The fluctuation of temperature in a single day is large with the temperature reaching as high as 40^0 C and as low as around 20^0 C. The mean yearly temperature is around 29^0 C. The mean monthly temperature values along with annual values are furnished in Table 4. The variations in

Table 1. The Long term areal rainfall in the basin for different seasons . (Rainfall in mm)

		Southwest Monsoon	Northeast Monsoon	Winter & Sumer	Annual
01.	Rainfall	233.00	565.00	284.00	1082.00
02.	% Component of rainfall	21.53	52.22	26.25	100%

Table 2. Normal Valuse of mean monthly rainfall of Tambaraparni River Basin

	Jan	Feb	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Normals	41.0	23.0	41.0	63.0	34.0	9.0	15.0	20.0	25.0	170.0	176.0	109.0

Table 3. Mean monthly values of humidity for Tambaraparni River Basin

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean
1973	-	-	71.19	70.27	64.81	62.70	Nil	60.23	60.16	59.02	63.37	38.14	54.99
1974	78.61	38.36	77.55	70.67	62.29	57.57	63.23	71.32	67.17	22.47	65.83	63.47	61.55
1975	63.52	66.30	65.03	66.83	56.24	63.03	62.89	64.50	65.13	64.06	74.60	66.95	64.92
1976	62.53	57.74	53.58	58.70	53.29	52.45	53.66	56.77	57.90	66.18	75.35	75.40	60.30
1977	65.48	66.34	67.00	64.75	67.82	64.00	65.20	58.76	64.65	80.74	82.53	68.54	67.98
1978	64.19	66.50	65.68	59.02	60.27	54.95	56.05	58.13	53.52	70.32	74.38	79.27	63.52
1979	66.80	69.20	62.40	55.80	56.30	58.60	63.10	61.00	67.00	77.00	85.00	77.40	66.63
1980	62.40	63.13	66.50	74.87	64.29	73.07	68.69	59.82	57.70	72.00	77.57	73.18	67.76
1981	68.60	63.07	63.27	62.55	64.87	67.67	59.32	60.13	64.33	69.58	71.12	70.77	65.44
1982	65.85	61.55	64.95	62.07	63.68	57.70	55.06	58.15	53.12	61.55	79.87	70.23	62.73
1983	64.48	67.13	60.48	64.25	63.11	63.63	57.13	70.19	64.03	67.39	70.38	79.10	65.94

Table 4. Mean monthly temperature values of Tambaraparni River Basin

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean
1973	-	-	29.70	31.00	32.20	31.10	30.30	30.30	30.60	28.80	27.40	24.90	26.65
1974	24.40	25.20	28.00	30.30	31.20	31.40	30.60	30.40	29.70	28.70	27.80	25.70	28.62
1975	25.70	27.80	28.50	30.30	31.10	30.20	29.60	29.90	29.70	29.40	26.90	24.60	28.64
1976	24.99	26.04	28.39	30.27	32.78	32.22	31.61	31.27	31.23	29.09	27.22	25.99	29.26
1977	24.87	27.63	29.10	30.79	29.45	31.74	31.20	31.28	31.10	26.93	27.10	25.78	28.86
1978	25.76	27.49	29.18	31.40	31.78	30.62	30.63	30.66	31.08	29.11	26.84	25.81	29.21
1979	26.20	28.00	29.00	31.60	32.40	32.06	31.10	30.70	28.70	27.90	25.80	25.80	29.11
1980	25.10	26.40	28.50	29.90	32.34	31.04	30.52	30.72	30.98	28.80	26.45	26.15	28.91
1981	25.84	26.06	29.12	31.27	31.73	30.20	30.87	30.66	29.70	28.83	27.13	25.51	28.91
1982	25.54	26.60	29.35	31.11	32.05	31.88	31.67	32.37	32.84	30.17	27.50	26.56	29.80
1983	27.81	30.62	32.54	34.07	34.40	33.44	32.76	32.58	32.29	30.86	28.75	26.93	31.42

temperature are only for the plain regions of the basins. The major portion of the basin experiences considerably high temperature and it may be a little lower in the hilly regions.

2.3.4 Sunshine and Wind

The sunshine hours have been observed since 1977 in the basin. The values of mean monthly sunshine hours are furnished in Table 5. The variation of percentage of sunshine hours ranges from 35% to 60% during October and November and 70 % to 90% in the months of January to April. Being situated in tropics, the lengths of day and night are more or less equal in the basin.

The basin experiences strong winds during the southwest monsoon period and low winds prevail during the months of October to April. There is a large variation in the values of wind velocity from a meagre value of 0.5 kmph to around 25 kmph.

2.3.5 Evaporation

Evaporation measurements have been made by pan evaporimeter in the basin at various observation stations. The monthly total evaporation values are furnished in Table 6 along with the annual total values. In the basin there is a wide variation in evaporation ranging from 100mm to 450mm. The evaporation is considerably high during the months of June to August and lower during the months of November and December. The average monthly potential evaporation values for the basin are furnished in Table 7. It may be noted that the annual potential evaporation value is higher than the annual rainfall in the major portion of the basin area particularly in the plains indicating overall water deficit in the region.

The influence of evaporation in a region is particularly important as it greatly affects the water balance of the area. In tropical areas and that too in agricultural predominant region the loss is considerable. The estimation of evaporation rate becomes significant in the computation of water resources utilisation and loss from the basin. It is a controlling factor in the computation of water balance with the evaporation taking place from the soil surface, cultivated areas , forest areas, water bodies etc.

2.4 Geology and Soil

The major soil in the basin belongs to vertisol, alfisol, inceptisol and entisol. The major soil types found in different taluks of the basin are given in Table 8. Tambaraparni river basin comprises of crystalline rocks of archean age on the western portion and sedimentary rocks of terirtiary age and quartineary age on the eastern coastal area.

2.5 Agriculture

The main crop in the Tambaraparni basin is paddy. As the flow is perennial about 95% of the paddy crop areas have two crops. The first crop season is synchronised with the south west monsoon between June and September called Kar and the second crop is synchronised with north east monsoon called Pishanam (October and February). Since there is considerable flow in the main river particularly in the lower down or tail end reaches due to summer rains and also due to the return flow during April and July some area there is summer paddy crop during April and July which is advance Kar.

2.6 Hydrological Zones

The basin has been divided into four zones and numbered as IA, IB, II and III for water balance studies. The division of these zones are governed by the existence of control structures (anicuts). For the present study Pachair subbasin in the zone II is considered. This area has been selected since sufficient amount of data was available for the subbasin.

Table 5. Mean monthly sunshine hours of Tambaraparni River basin

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
1977	9.54	8.16	8.93	7.81	7.87	8.57	6.17	8.50	7.79	4.38	5.68	7.24	7.55
1978	9.35	9.50	9.20	8.92	8.71	5.80	7.51	6.22	7.57	5.27	7.50	5.26	7.57
1979	9.78	9.10	9.43	9.60	8.53	7.85	8.20	8.08	7.65	6.30	4.41	6.89	7.99
1980	10.15	10.30	10.06	7.71	9.11	7.88	8.11	8.39	8.88	6.81	5.99	7.51	8.40
1981	8.61	9.72	9.98	8.59	8.10	5.93	6.93	7.73	7.14	6.51	6.47	8.03	7.81
1982	9.42	10.89	10.35	8.76	8.12	7.31	7.30	7.64	8.35	5.99	4.57	6.26	7.91
1983	9.23	9.91	10.37	9.71	8.72	6.48	6.71	6.58	7.11	6.84	7.43	4.65	7.81

Table 6. Monthly total evaropation values of Tambaraparni River Basin

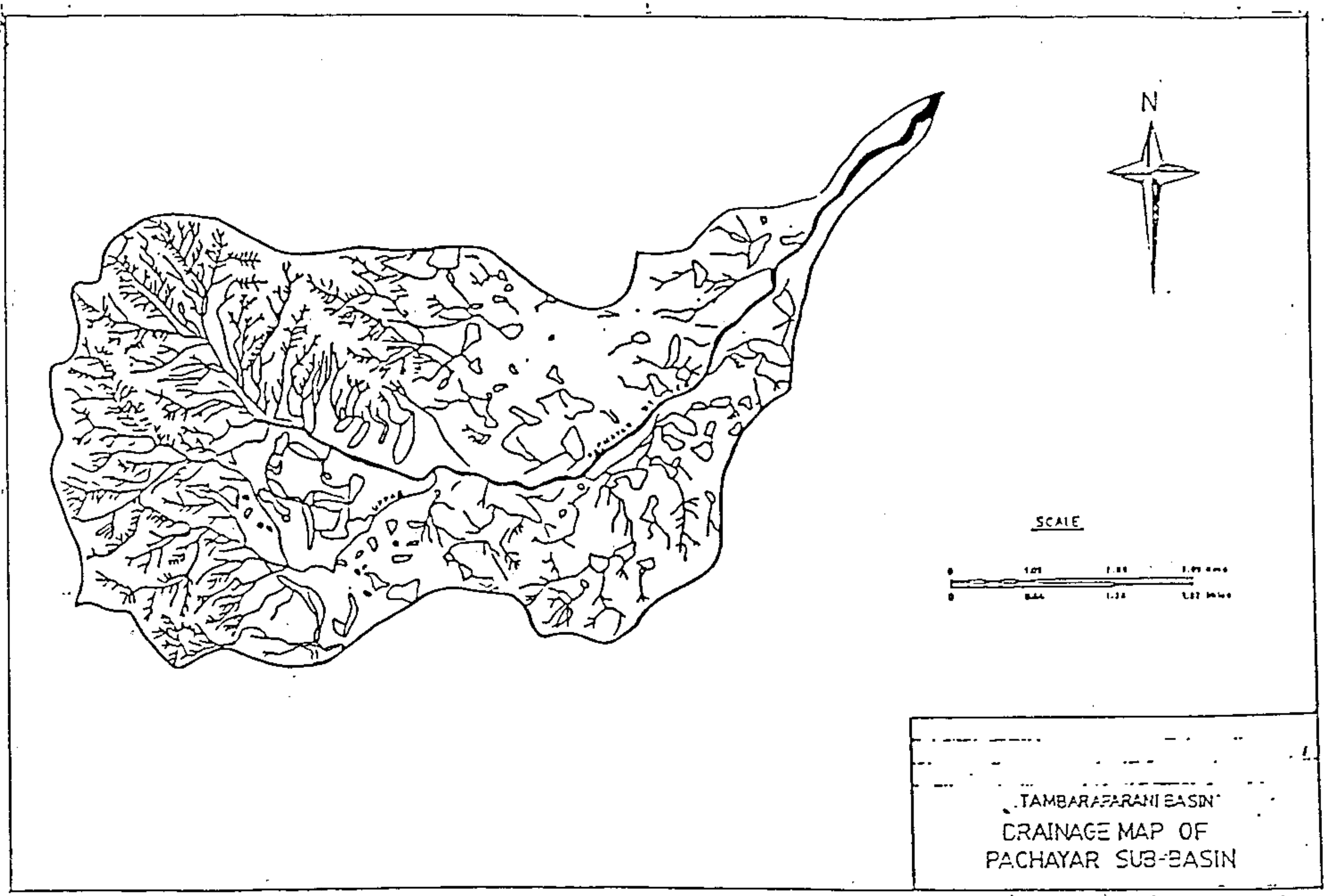
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1973	-		214.00	189.00	291.00	334.00	296.00	325.00	261.00	125.00	120.00	113.00	2268.00
1974	155.00	175.00	197.00	185.00	282.00	388.00	400.00	435.00	290.00	324.00	159.00	202.50	3192.50
1975	220.00	189.00	232.00	212.00	281.00	455.00	404.00	391.00	293.00	282.00	245.00	154.00	3358.00
1976	212.00	210.00	224.00	194.00	293.60	410.90	478.50	406.50	334.50	194.00	84.80	111.60	3155.80
1977	157.70	147.00	182.30	183.00	242.70	201.50	418.30	403.50	334.70	89.40	82.90	142.30	2585.30
1978	159.00	164.20	197.40	137.00	286.70	373.00	387.00	439.00	373.00	195.10	137.20	99.20	2948.50
1979	146.50	156.20	207.00	263.50	287.00	310.90	405.10	423.00	216.15	184.50	81.70	113.50	2500.05
1980	186.00	167.50	215.00	153.50	246.50	323.00	347.50	362.00	307.30	175.00	126.50	151.90	2761.70
1981	194.70	230.70	279.00	251.50	247.70	258.00	264.90	355.00	257.00	225.50	226.90	199.50	2990.40
1982	250.50	245.00	245.50	242.00	257.40	291.00	306.00	284.50	282.00	195.50	132.50	168.80	2900.70
1983	176.00	242.50	297.00	345.50	334.40	332.40	313.00	394.00	283.00	258.50	155.80	144.00	3186.10

Table 7. Average Potential Evaporation (mm) of Tambaraparni River Basin

Month Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Potential Evaporation	179.61	175.35	206.71	202.89	243.40	275.20	276.73	284.78	238.30	168.05	133.10	137.91

Table 8. Soil Classification of the Tambarapami River Basin

Sl.No.	Name of District	Taluk Name	Major Soil Great Order	Type Found Sub Group
1.	Chidambaranar	Kovilpatti	Vertisol	Typic Chromusterts
			Alfisol	Typic Haplustalfs
		Ottapidaram	Vertisol	Typic Chromusterts
			Alfisol	Typic Haplustalfs
		Srivaikundam	Inceptisol	Typic Ustropepts
			Entisol	Paralithic Ustropepts
			Inceptisol	Fluventic Ustropepts
			Vertisol	Typic Chromusterts
			Entisol	Typic Ustipsamments
			Alfisol	Typic Hapluscalfs
			Alfisol	Fluventic Haplustalfs
			Alfisol	Aquic Haplust
			Inceptisol	Vertic Haplustalfs
			Alfisol	Vertic Haplustalfs
		Thiruchendur	Alfisol	Udic Rhodustalfs
			Alfisol	Typic Haplustalfs
			Inceptisol	Fluventic Ustropepts
			Alfisol	Vertic Haplustalfs
			Alfisol	Aquic Haplustalfs
			Inceptisol	Typic Ustrorepts
		Tuticorin	Vertisol	Typic Chromusterts
			Entisol	Typic Ustipsamment
02.	Thirunelveli Kattabomman	Shencottai	Inceptisol	Typic Ustropepts
			Alfisol	Udic Rhodustalfs
			Alfisol	Aquic Haplustalfs
			Alfisol	Udic Haplustalfs
			Alfisol	Typic Haplustalfs
			Entisol	Paralithic Ustorthents
		Sankarankovil	Inceptisol	Typic Ustropepts
			Entisol	Paralithic Ustrothents
			Alfisol	Udic Rhodustalfs
			Inceptisol	Vertic Ustropepts


N
SCALE
TAMBARAPARANI BASIN
DRAINAGE MAP OF
PACHAYAR SUB-BASIN

The map of the sub basin is presented in Figure 3. Pachaiar river originates from Kalakkadu reserve forest at an altitude of about 1300m. This river joins the main river Tambaraparani at its 61st km near Gopalasamundram village on the right flank through Palayam channel in which an outlet is provided. All the data considered for the present study are pertaining to this region.

Chapter 3
Methodology

A simulation model reproduces the physical relations among the elements of water resources system (various hydrological processes) and describes the outcome of the system under a given set of inputs and operating assumptions. Successive and systematic runs of the model can evaluate the response to the variations in the input or operating conditions.

3.1 Process Simulating Models

The process simulating models are the ones that shall simulate the yield of the basin under varying climate conditions as well as with respect to the man made changes brought about to introduce a diversion cycle within the basin. This would be helpful in evaluating the effect of any man made changes, as changing the input to the model can do it. It represents all the constituent processes of the water balance of the basin, e. g. the surface and sub surface flow of water, evaporation from the land and water bodies, evapotranspiration from various land usage, infiltration, ground water flow etc. Such models shall be conceptual, continuous emulating models that shall be simulating the various natural processes prevalent in the basin in continuos manner. The major attributes, which such a model should possess, are given below. The model should be

- physically based and should use only readily available data
- capable of taking care of the variable land use in the basin.
- capable of continuous simulation.

A model called SWRRB (Simulator for Water resources in Rural basins) was found to satisfy the above attributes. This model has been developed by the U. S. Department of Agriculture (Williams *et. al.*, 1985). The objective of this was to predict and evaluate the effect of management decisions on water and sediment yield for the basins in United States. The hydrological process estimation module of this model, with some variations in some of the processes, has been adopted for the present study. As such, this model has been formulated by adopting some good representations for various hydrological processes, from literature.

3.2 The SWRRB Model

SWRRB includes five major components: weather, hydrology, sedimentation, nutrients, and pesticides. Processes considered include surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, sedimentation, and crop growth. A weather generator allows precipitation, temperature, and solar radiation to be simulated when measured data is unavailable using long term statistical parameters. The precipitation model is a first-order Markov chain model, while air temperature and solar radiation are generated from the normal distribution. SWRRB allows for simultaneous computations on each subbasin and routes the water, sediment, nutrients, and pesticides from the subbasin outlets to the basin outlet.

The SWRRB Model operates on a daily time step, and daily weather can be input or generated. SWRRB is not limited by drainage area since it has a provision for subdividing basins and since each subbasin can use a different raingauge. The subbasins can be subdivided to account for differences in soils, land use, crops, topography, rainfall, temperature, etc. SWRRB can handle a maximum of ten subbasins. The vertical direction of the model is capable of working with any variation in soil properties - - the soil profile is divided into a maximum of ten layers (the top layer thickness is set at 10 mm and all other layers may have variable thickness).

3.3 Hydrology Model Description

Surface runoff volume is predicted using the SCS curve number (USDA, 1972) as a function of daily soil moisture content. Return flow is calculated as a function of soil water content and return flow time. Return flow travel times can be calculated from soil hydraulic properties or user-inputs.

The percolation component uses a storage routing model combined with a crack-flow model to predict flow through the root zone. Evapotranspiration is estimated using Ritchie's ET model. Transmission losses in the stream channel are calculated as a function of channel dimensions, flow duration, and effective hydraulic conductivity of the channel bed. Pond storage is based on a water balance equation that accounts for inflow, outflow, evaporation, and seepage. The reservoir water balance component is similar to the pond component except that it allows flow from the principal and emergency spillways.

Some of the major hydrological processes incorporated in the model and expressions used for their representations are briefly described below. All these variables/hydrological processes are estimated to perform the water balance of the basin.

3.4 Surface Runoff Volume

The SCS (Soil Conservation Service) curve number technique (USDA, 1972) has been used to complete the surface runoff using daily rainfall using the following equation.

$$Q = \frac{(R - 0.2s)^2}{(R + 0.8s)} \qquad (1)$$

where

Q	-	daily runoff
R	-	daily rainfall
s	-	retention parameter

The retention parameter s is related to soil water content through the equation

$$s = s_1\left(1 - \frac{SW}{SW + \exp[w_1 - w_2(SW)]}\right) \qquad (2)$$

where

SW	-	soil water content in root zone
w_1, w_2	-	are the shape parameters
s_1	-	value of s corresponding to the 1 (dry) moisture condition curve number CN_1

Values for w_1 and w_2 are obtained from a simultaneous solution of the above equations assuming that $s=s_1$ at the wilting point and $s=s_3$ at the field capacity. At saturation the equation allows s to approach its lower limits of zero giving CN → 100.

3.5 Percolation

The percolation component uses storage routing technique to predict flow through each soil layer in the root zone. The flow from a soil layer occurs when the soil water content in the rootzone exceeds field capacity. Hence downward flow from the soil layer occurs when the field capacity is exceeded and the layer below the considered layer is not saturated. Upward flow occurs when lower layer exceeds field capacity. The soil water to field capacity ratios of the two layers regulates movement from lower layer to adjoining upper layer. Thus the daily percolation is computed using the equation

$$O_i = SW_0\left[1 - \exp\left(\frac{-\Delta t}{TT_i}\right)\right] \qquad (3)$$

O_i	-	percolation rate through layer (mm/day)
SW_0	-	soil water content at the beginning of the day (mm)
t	-	travel interval (24 hour)
TT_i	-	travel time through the soil layer i (hour)

The travel time TT_i is computed for each soil layer with the linear storage equation

$$TT_i = \frac{SW_i - FC_i}{H_i} \qquad (4)$$

where

H_i	-	hydraulic conductivity (mm/s) for the i^{th} layer
Fc_i	-	field capacity water content (mm) for the i^{th} layer

The hydraulic conductivity varies from the saturated hydraulic conductivity value at saturation to near zero at field capacity and is computed using the equation

$$H_i = SC_i \left(\frac{SW_i}{UL_i} \right)^{\beta} \qquad (5)$$

where

SC_i	-	saturated hydraulic conductivity for the layer i (mm/hour)
UL_i	-	soil porosity (mm)
β	=	The parameter that causes H_i to approach zero as SW_i approaches FC_i.

A saturated lower soil layer may reduce flow through a soil layer. If the layer immediately below the layer being considered is saturated no flow can occur regardless of the results from the percolation equation. Hence the effect of lower layer water content is expressed in the equation

$$O_{ci} = O_i \sqrt{1 - \frac{SW_{i+1}}{UL_{i+1}}} \qquad (6)$$

where

O_{ci}	-	percolation rate for layer i (mm/day) corrected for layer (i+1) water content.
O_i	-	percolation computed with the original equation.

3.6 Lateral Subsurface Flow

The lateral subsurface flow is calculated simultaneously with percolation. Lateral flow occurs when the storage in any layer exceeds the field capacity after percolation. The lateral flow function is expressed in the equations

$$QR_i = (SW_i - FC_i)\left[1 - \exp\left(\frac{-\Delta t}{TT_{Ri}}\right)\right] \qquad (7)$$

$$TT_{Ri} = \frac{1000CLA}{CLA + \exp(10.047 - 0.148CLA)}$$

where

i	-	lateral flow rate for soil layer i (mm/day)
TTR_i	-	Lateral flow travel time (days) (Time required for subsurface flow to travel a distance equal to the land surface slope length)
CLA	-	clay content in the soil layer (%)

Evapotranspiration

The Ritchie's evapotranspiration model (Ritchie, 1972) has been used for estimating the evapotranspiration from the basin. Potential evaporation rate is estimated using the equations

$$E_0 = \left[\frac{1.28RA(1-AB)}{58.3}\right]\frac{\delta}{\delta + 0.68} \qquad (8)$$

$$\delta = \frac{5304}{T_k^2}\left[\exp(21.255 - \frac{5304}{T_k})\right] \qquad (9)$$

where

E_0	-	potential evaporation rate (mm/day)
RA	-	Daily solar radiation (ly)
AB	-	the albedo
δ	-	slope of the saturation vapour pressure curve at the mean air temperature
T_k	-	daily average air temperature ^0K

The albedo is evaluated by considering the soil, crop and snow cover. If a snow cover exists with 5 mm or greater water content, the value of albedo is set to 0.6. If the snow cover is less than 5 mm and no crop is growing, the soil albedo is the appropriate value. When considering the cultivable land use, albedo is determined using the equation

$$AB_s = 0.23(1 - EA) + (AB_s)(EA) \qquad (10)$$

$$EA = \exp[2.9 * 10^{-5}(CV)] \qquad (11)$$

where

AB_s	-	Soil albedo (0.23 is the albedo for plants)
EA	-	Soil cover index (The value of EA ranges from 0 to 1.0)
CV	-	Sum of the above ground biomass and crop residue (kg/ha)

The model computes soil and plant evaporation separately. Actual soil evaporation is computed in two stages. First stage is the constant rate stage and the second one is the falling rate stage. In the first stage, the soil is sufficiently wet for the water to be transported to the surface at a rate at least equal to the evaporation potential. The soil evaporation is limited only by energy available at the surface. In the stage two, soil evaporation is predicted with a square root function of time.

Plant transpiration is computed as linear function of leaf area index (LAI) and E_0 upto a LAI value of 2.7. Beyond LAI equal to 2.7 the plant transpiration is equal to E_0. If LAI is less than 2.7 the plant transpiration is estimated using the equation

$$EP = E_0(-0.27 + 0.7\sqrt{LAI}) \tag{12}$$

where

EP	-	plant transpiration (mm)
E_0	-	potential evaporation (mm)
LAI	-	Leaf area index.

The upper limit of 2.7 for LAI is to be an apparent threshold representing the minimum LAI necessary to constitute an apparent 'full coverage canopy'.

The SWRRB model operates on a continuous time scale and allows for subdivision of basins to account for differences in soils, land use, rainfall, etc. SWRRB has been tested on 11 large watersheds from eight Agricultural Research Service (ARS) locations throughout the United States. The results show SWRRB can realistically simulate water and sediment yields under a wide range of soils, climate, land-use, topography, and management conditions (Arnold and Williams, 1987). SWRRB should provide a versatile and convenient tool for use in planning and designing water resource projects.

Chapter 4
Results and Discussions

There is an abundance of literature concerning water-balance modeling. However, most of these studies assume there are plentiful data, either hourly or daily, for precipitation, potential evaporation, and stream flow. In addition, soil types, land use, and vegetative cover are usually known and, in some cases, even the sate of the soil moisture is known. This is certainly not the case with the present study area. Only monthly values of the precipitation etc. were available. Potential evapotranspiration data exist only as long term monthly averages, and soil water data are non existent. In the present study, the various components of the water balance technique are either estimated or simulated from existing data.

4.1 Data Availability

It is well established that the climate of the region is variable in both time and space. Drought to flood conditions can occur in a very short interval of time. Historical hydrometeorological records often do not include these extremes and any subsequent analysis based on this incomplete record may be misleading. To avoid this, previously developed techniques (Williams *et. al.*, 1985) or generating a synthetic time series of daily precipitation and temperature are used.

The SWRRB model, which has been used for simulating various components of water balance, requires daily precipitation and daily temperature data. Since these data were not readily available, the required data has been generated using 'WXGEN' program of the EPIC (Environmental Policy Integrated Climate model developed by USDA, 1980), which require only long term statistical parameters of both precipitation and temperature. To validate the performance of WXGEN model, the data for a station, out side the basin under consideration, where daily data were readily available have been used. The resulted mean monthly rainfall from the WXGEN model is compared with the actual monthly rainfall for the station in the year 1995 in Fig. 4. The results of the model agree with the actual data for most of the months except

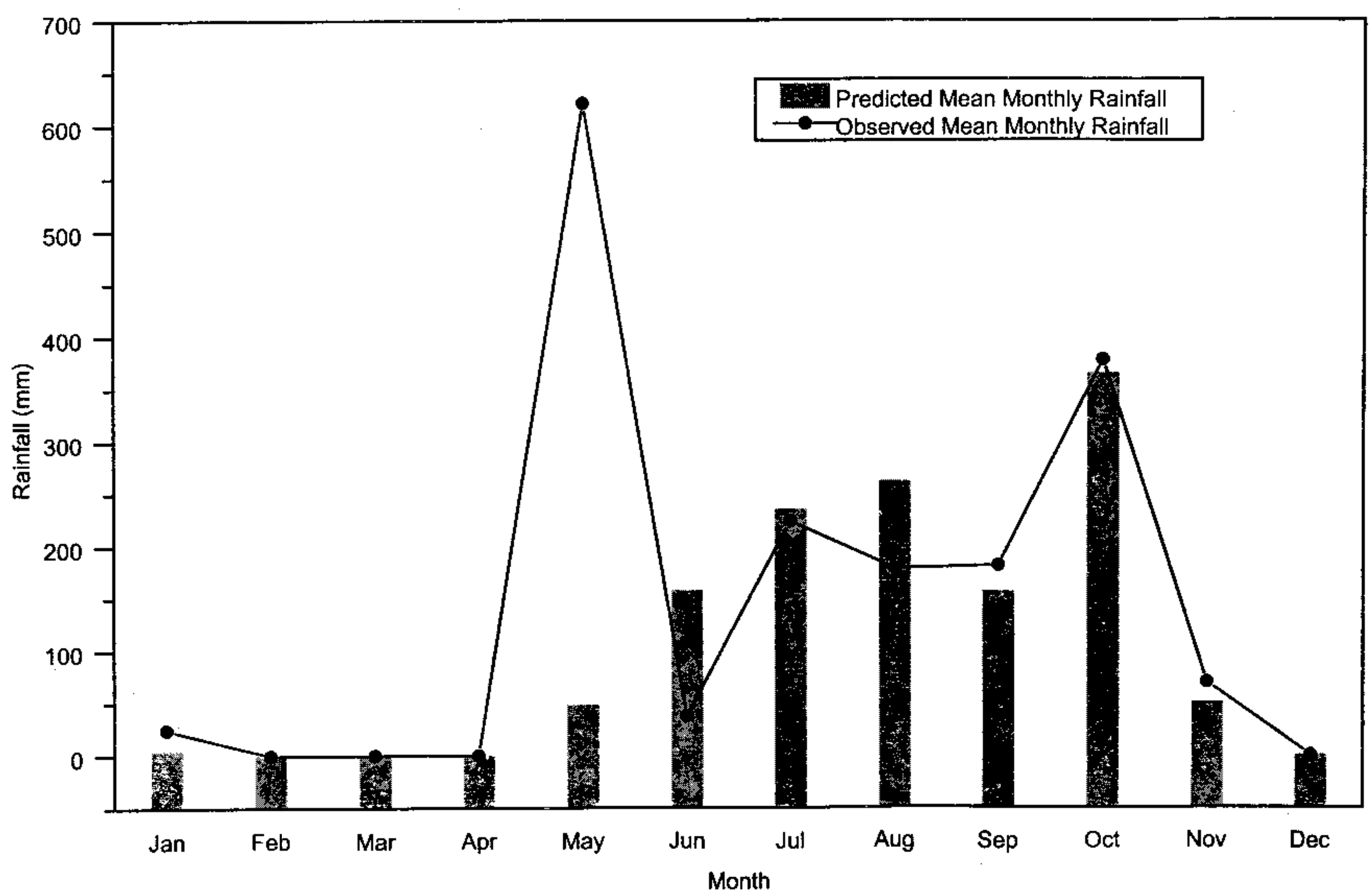


Fig. 4 The validation plot of weather generator model

in the month of May. This may be due to the cyclonic storm occurred during May 1995 (559 mm in three days), which the model was not able to account for. There are many sources of error in the results obtained from any model. The precipitation record could be erroneous from which the statistical parameters have been derived. This would affect the estimated precipitation for the entire basin under consideration. Generally the cyclonic storms are not very common in all the years and hence the statistical analysis of the long term data will not reflect it and hence these minor errors. Since the weather generator model was found performing satisfactorily well, the WXGEN model is used for generating the weather data for the Pachaiyar Sub basin from long term statistical values. The long term statistical data used for the model are presented in Table 9. The other data used in the study are collected from Tamilnadu State Govt. agencies and also from various literatures.

Table 9. The statistical parameters of the weather data for Pachaiyar Sub basin, of Tamilnadu

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Max. Temp.	31.3	32.3	36.4	37.4	38.3	34.9	35.3	34.5	34.7	34.9	33.3	31.5
Min. Temp	22.0	23.7	25.8	26.7	26.1	27.1	26.5	25.8	26.4	25.7	24.8	22.7
Mean monthly rainfall	37.2	34.0	38.9	62.9	40.9	08.7	06.7	20.2	33.8	144.9	197.0	93.4
Std. Deviation of rainfall	16.22	1.97	3.75	5.43	64.34	23.22	11.96	11.11	11.63	21.24	50.66	6.78
Skewness of rainfall	2.48	0.96	0.00	1.33	2.68	3.09	2.15	1.76	1.34	2.64	3.30	1.84
Prob.W/D	0.046	0.024	0.011	0.017	0.093	0.268	0.378	0.429	0.314	0.284	0.073	0.011
Prob.W/D	0.273	0.200	0.00	0.00	0.375	0.559	0.750	0.647	0.590	0.655	0.621	0.500
Number of rainy days	1.83	0.83	0.33	0.50	4.00	11.33	18.67	17.00	13.00	14.00	4.83	0.67
Radiation	267.7	333.0	363.3	380.4	367.8	219.1	135.4	154.1	183.9	209.0	236.4	251.9

Note : Prob W/D - Probable wet day after a dry day; Prob. D/W - Probable dry day after a wet day.

The total area of the Pachaiar sub basin is 246.21 sq. Km. This sub basin has been divided into 8 sub divisions to account for difference in land use, channel properties, topography etc. The details of the sub divisions are depicted in Table 10.

Table 10. The numbers of sub basins and their area and main channel length.

Sub-Basin No.	Area (Km^2)	% Area	Length of Main Channel (Km)
01	31.88	12.95	4.26
02	43.22	17.55	11.71
03	14.24	5.78	4.26
04	43.22	17.55	8.16
05	28.10	11.41	6.57
06	30.62	12.44	3.90
07	44.48	18.07	14.55
08	10.46	4.25	8.52

The direct run off from the basin has been computed using the equation presented in the last chapter. The curve number for the basin has been selected from the recommended values given in various literatures. Since paddy was the major crop in the basin, it was expected that a major portion of the rainfall would attribute to run off. The results of the rainfall-runoff relationship for the sub basin during 1975-1979 are depicted in Fig. 5. It can be observed from the plot that the relation of rainfall runoff is almost constant in every year. The simulated runoff resulted from simulated rainfall for the period, for the year 1981, 1989 and 1995 are presented in Fig. 6,7,8 respectively.

The evapotranspiration is estimated using Ritchie's model discussed elsewhere in this report. The estimated evapotranspiration for the years 1975-1979 is graphically represented in Fig. 9. The figure follows the trend observed by various researchers that the evapotranspiration during a rainstorm may be quite high (Jarvis, P. G *et. al.,* 1979; McNaughton, K. G. *et. al.*, 1983). The subsurface flow is estimated using the model described in the last chapter. Subsurface flow is computed as a property of the soils water holding capacity like field capacity and wilting point. Rao (1989) has presented a generalised procedure for determining the soil hydraulic properties and the values reported by Rao (1989) have been selected for the study. The values as reported for Indian soils by Rao (1989) are presented in Table 11.

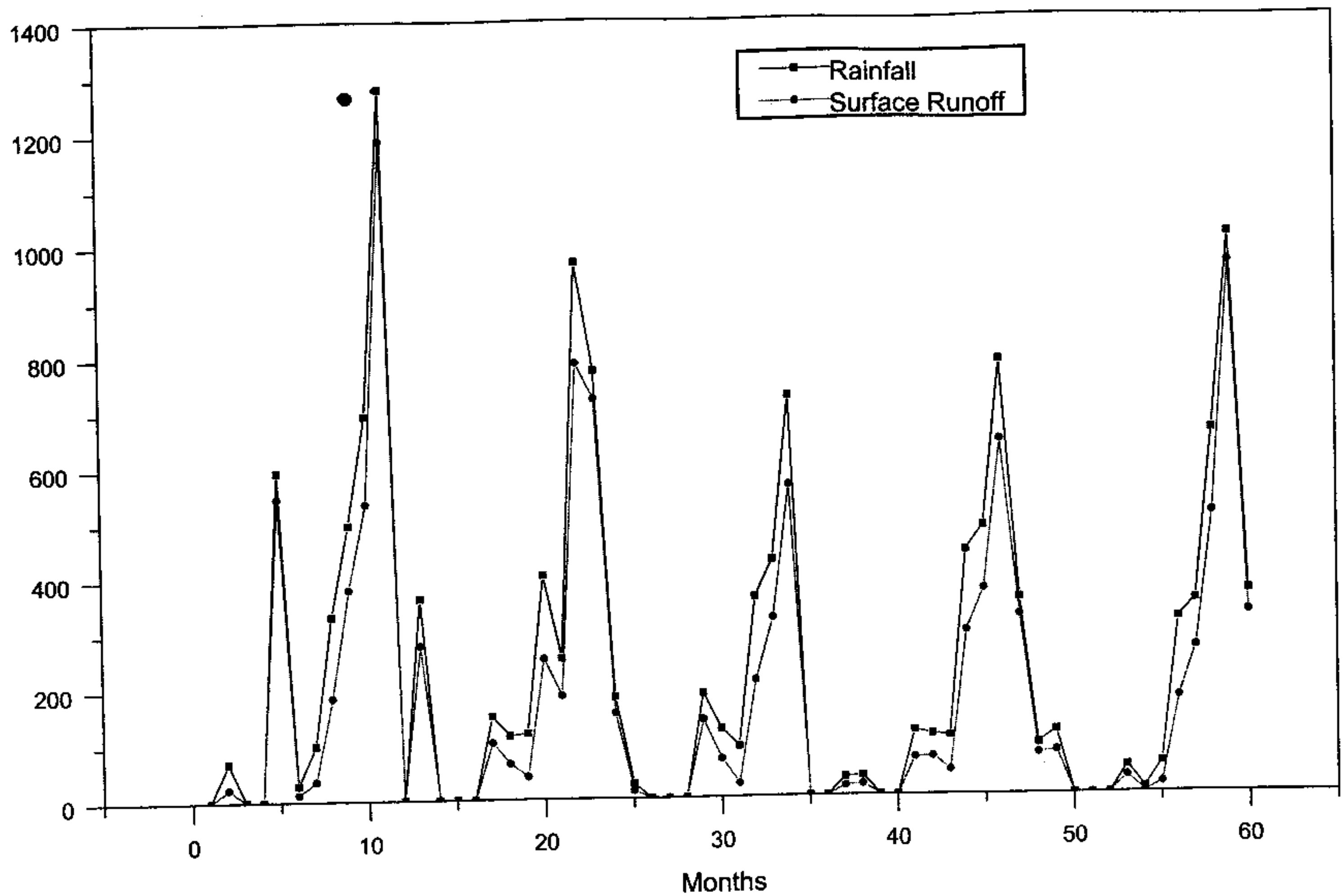


Fig. 5 Rainfall - Runoff (estimated) relationship for Pachaiyar Subbasin, Tamilnadu (1975-1979)

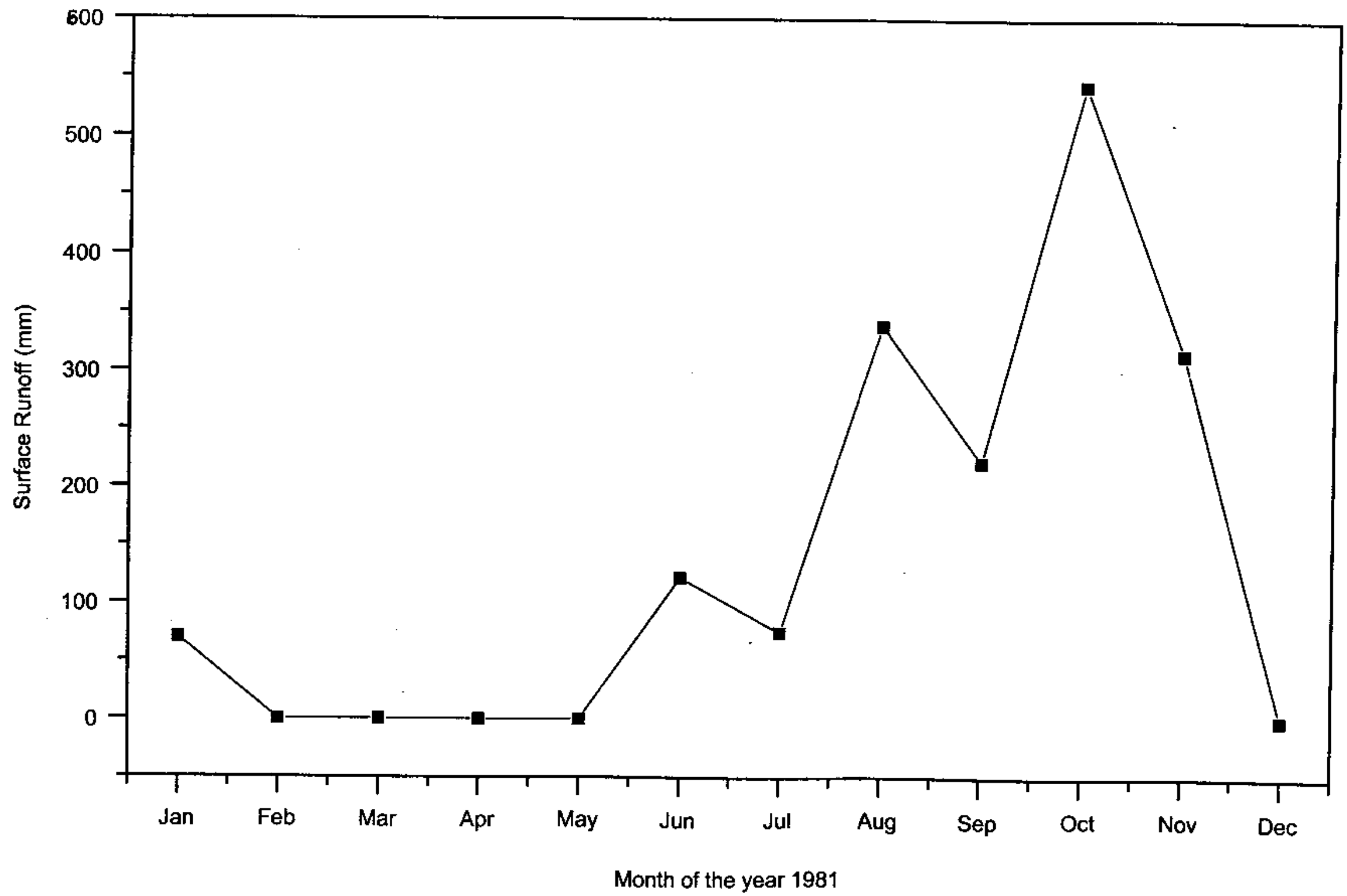


Fig. 6 Estimated Runoff for the year 1981

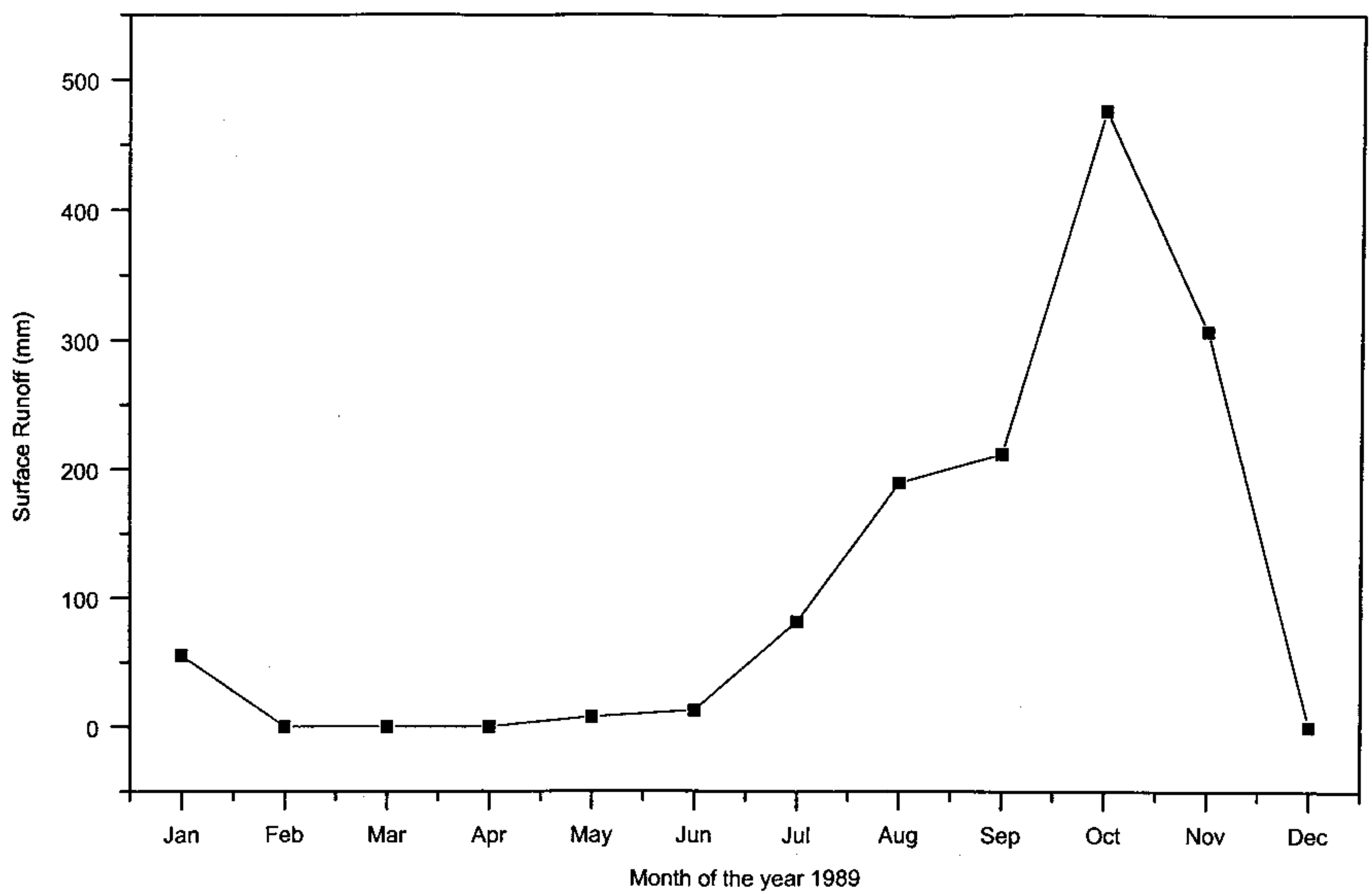


Fig. 7 Estimated Runoff for the year 1989

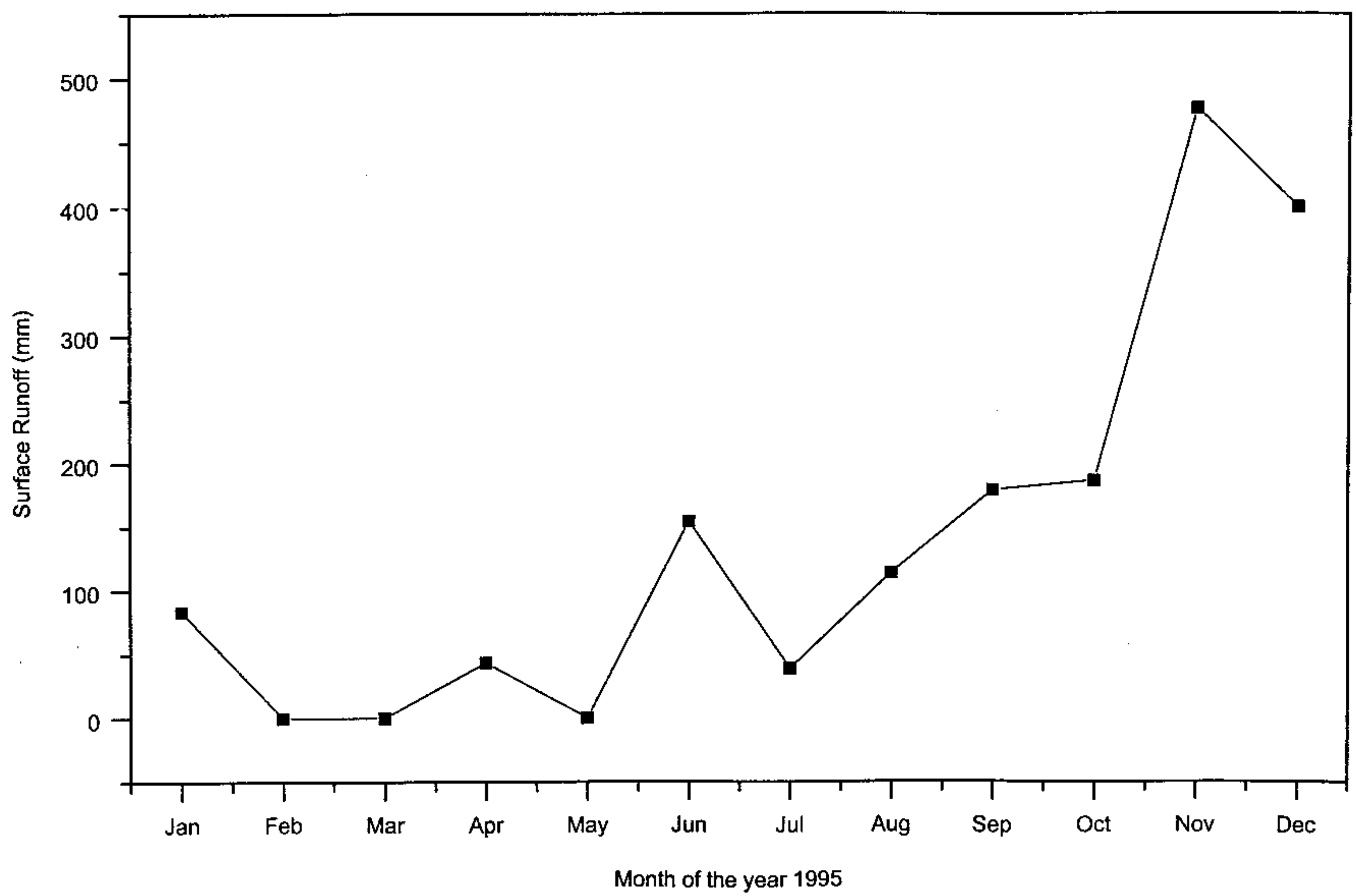


Fig. 8 Estimated Runoff for the year 1995

Table 11. Average soil hydraulic properties for Indian soils (Rao, 1989)

Soil	Profile Texture	(% v/v)	PWP (% v/v)
Alluvial Soil	Coarse to medium (loamy sand to sandy loam) Medium (sandy loam to loam) Medium to fine (loam to clay loam) Fine (clay Loam)	14 ± 3 21 ± 3 30 ± 3 37 ± 3	5 ± 2 9 ± 3 10 ± 3 12 ± 3
Black Soil	Medium black soil (clay loam) Deep black soil (clay loam to clay) Deep black clays	39 ± 3 48 ± 4 53 ± 4	20 ± 3 25 ± 3 36 ± 4
Red Soils	Coarse to medium (loamy sand to sandy loam) Medium (sandy loam to loam) Medium to fine (loam to clay loam) Fine (clay Loam)	17 ± 2 24 ± 4 34 ± 4 44 ± 4	6 ± 2 14 ± 4 17 ± 4 27 ± 3

The total basin yield has been considered to be constituted by three components viz. surface runoff, subsurface runoff and base flow. These components have been estimated individually, and summed up to result the total basin yield or the flow at the basin outlet. This basin yield would be of use in reducing flood hazards, inundation etc. The total basin yield and the corresponding values of its components considered are depicted in Fig. 10.

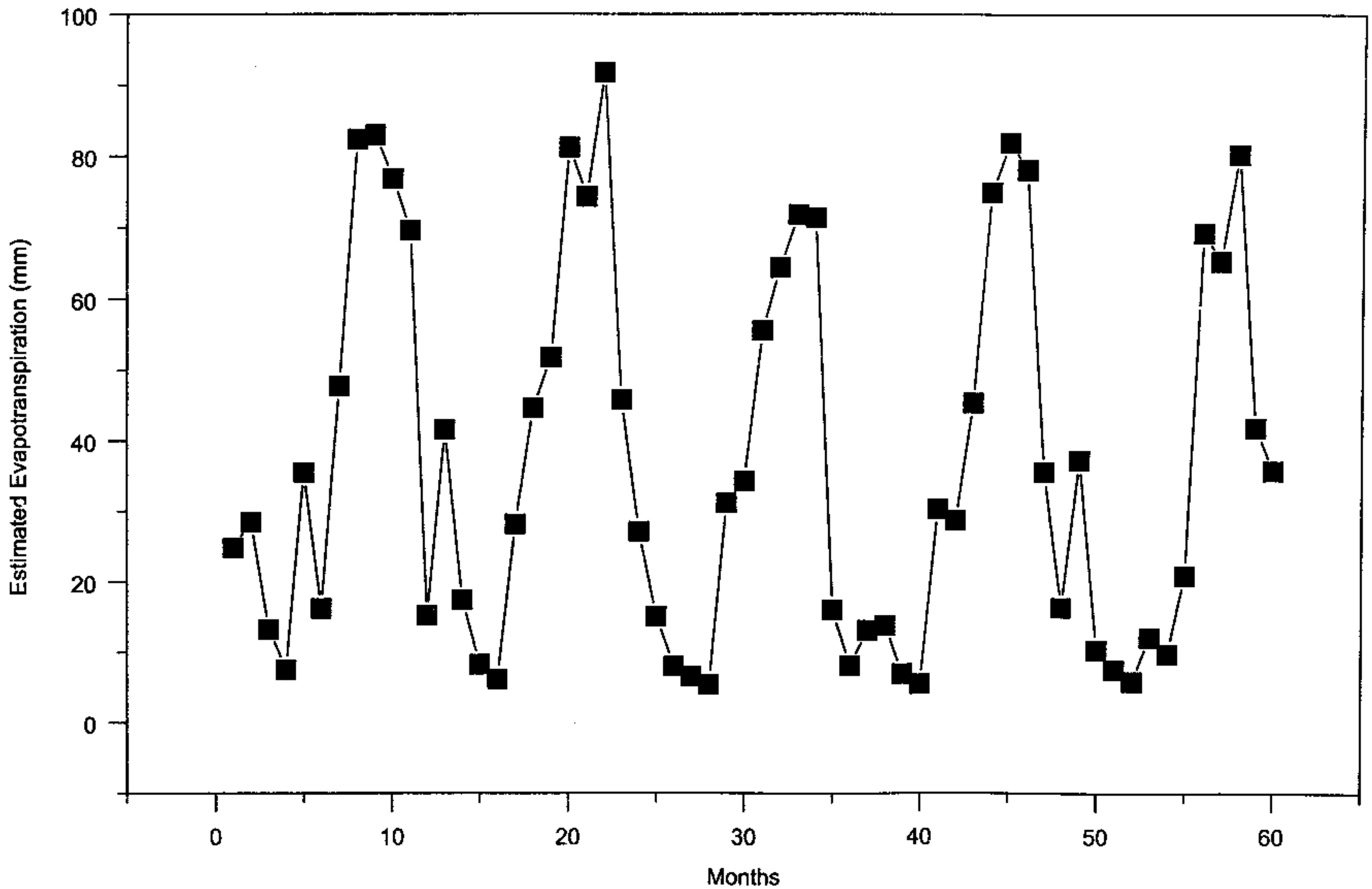


Fig. 9 Estimated evapotranspiration for Pachaiyar Subbasin, Tamilnadu (1975-1979)

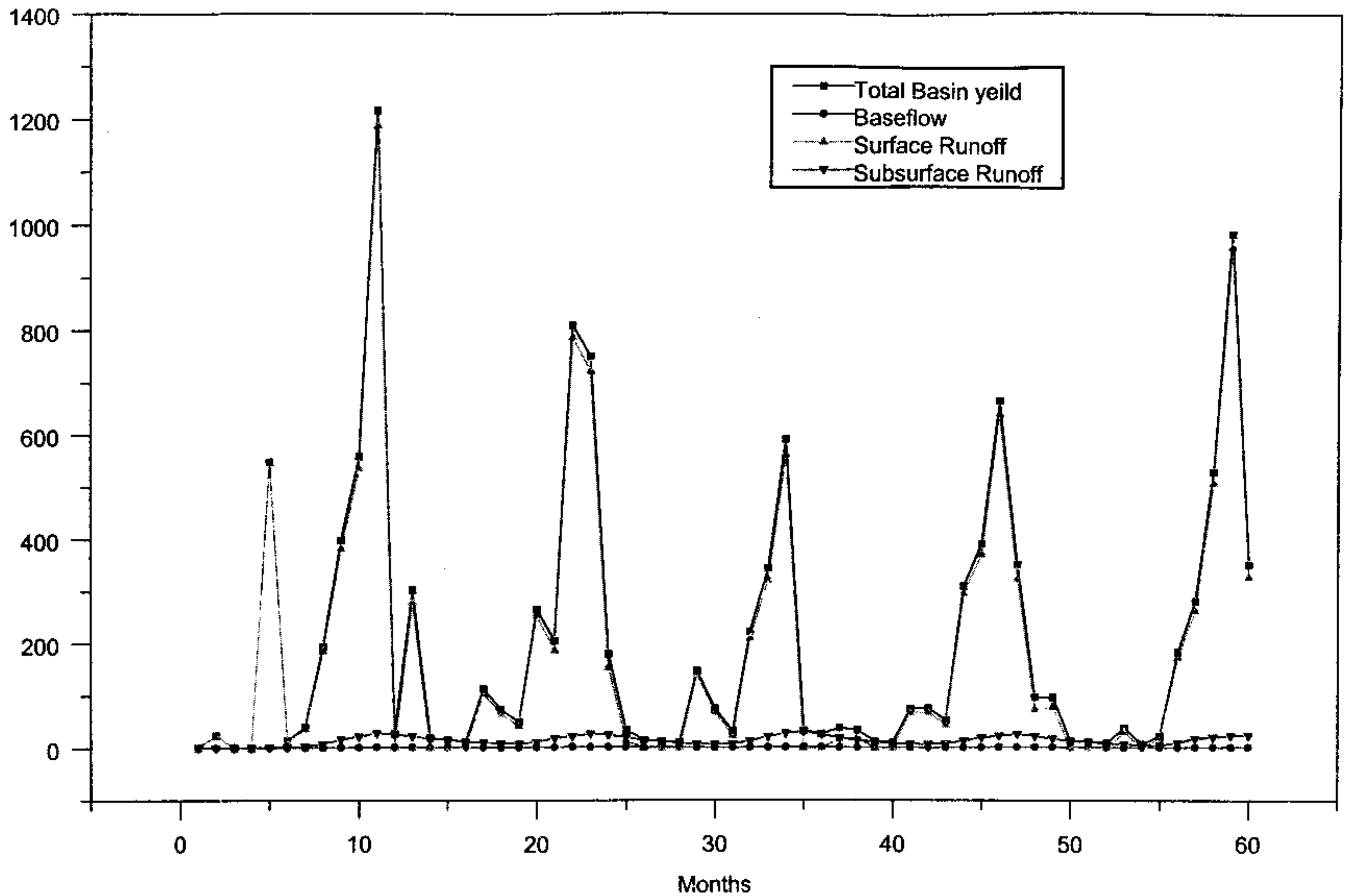


Fig. 10 Estimated components of basin yield for Pachaiyar Subbasin, Tamilnadu (1975-79)

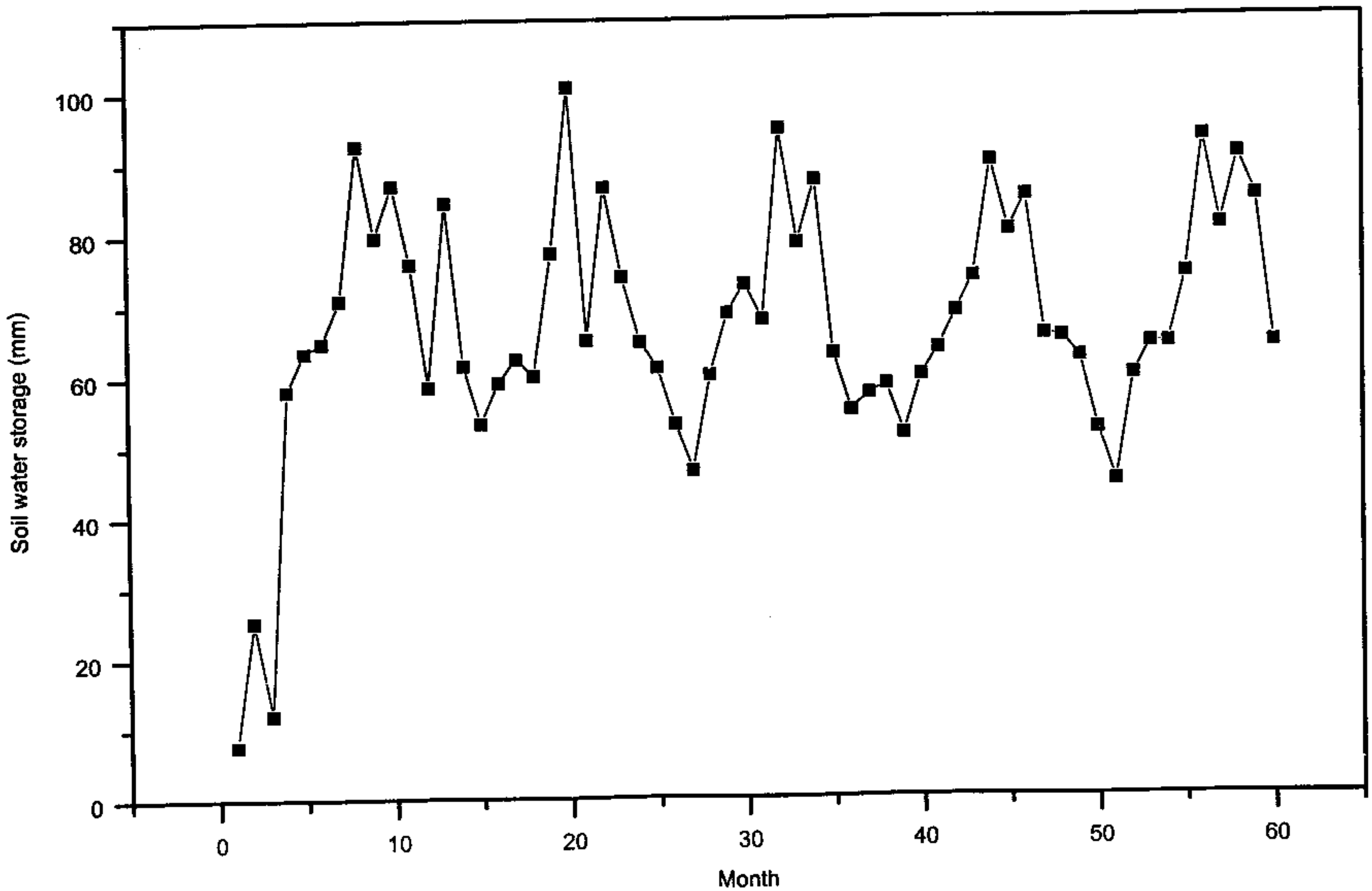


Fig. 11 Estimated soilwater storage (1975-79)

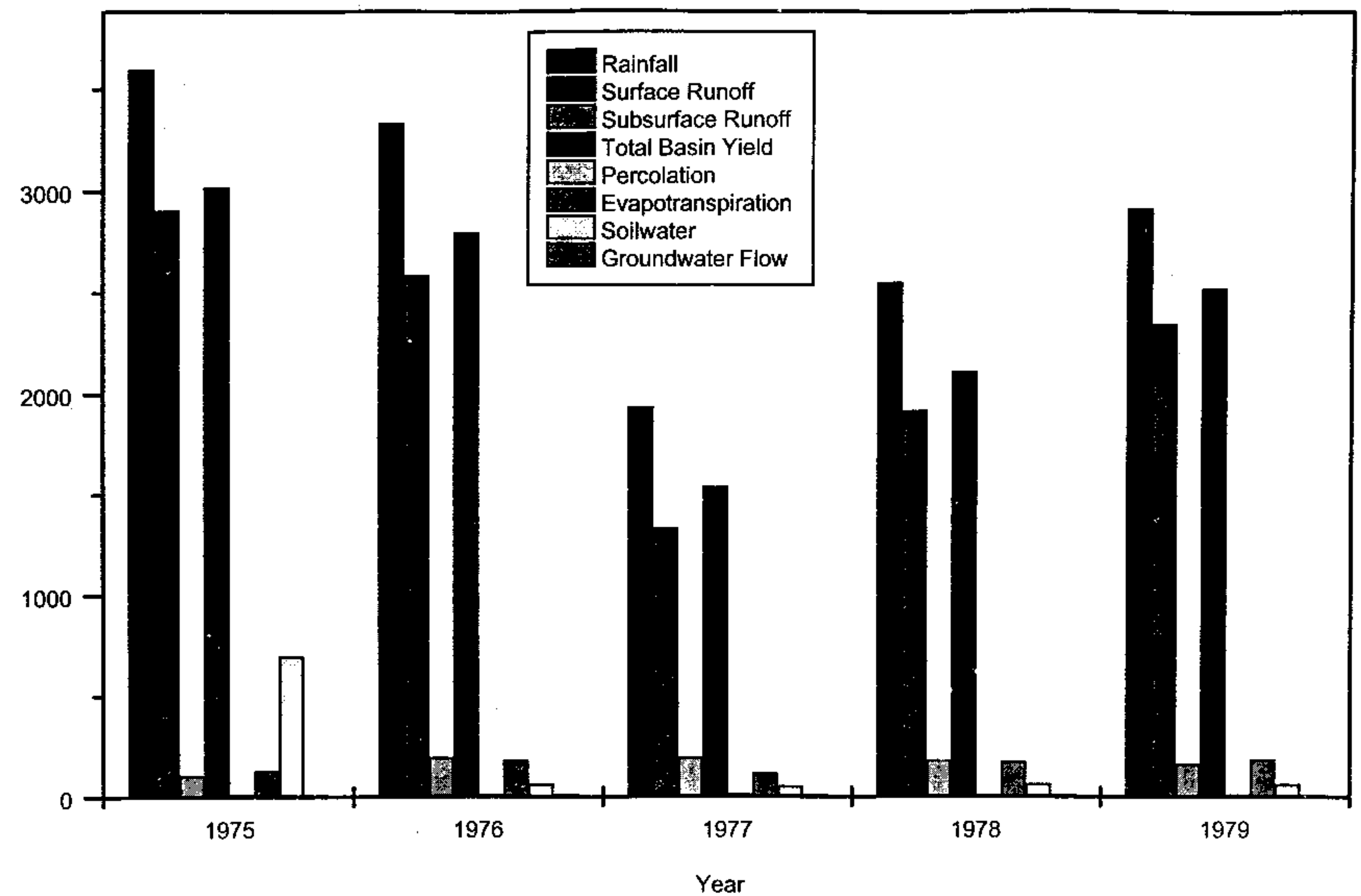


Fig. 12 The annual water balance components (1975-79)

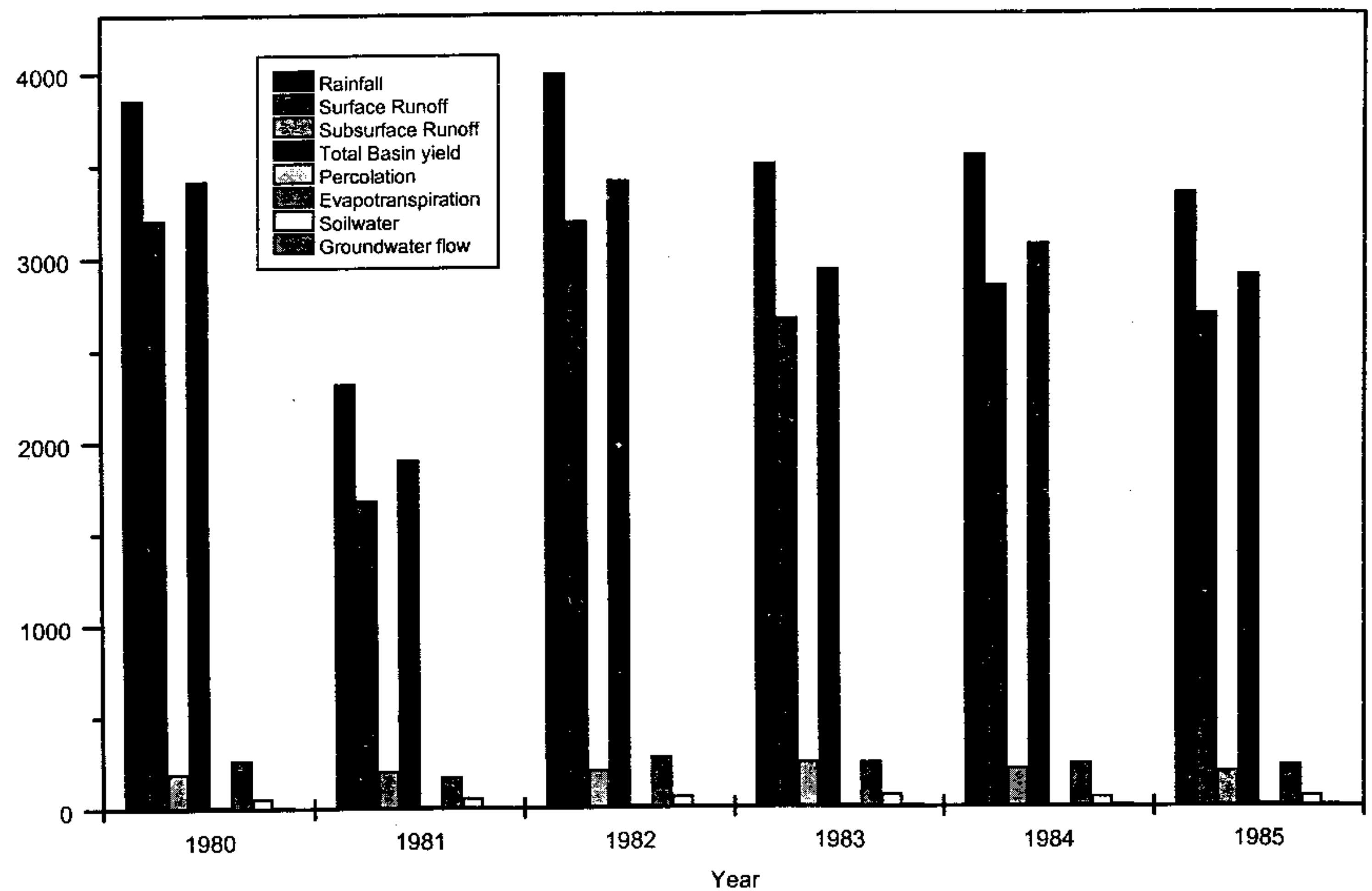


Fig. 13 The projected water balance components (1980-85)

The water balance was done to account the soil moisture storage in the basin. The general water balance equation is (Gupta, 1989)

$$P + Q_{SI} + Q_{GI} - E - Q_{SO} - Q_{GO} - \Delta S = 0$$

where

P	-	precipitation
Q_{SI}	-	surface inflow
Q_{GI}	-	ground water inflow
E	-	Evapotranspiration
Q_{SO}	-	surface outflow
Q_{GO}	-	groundwater outflow
ΔS	-	change of storage volume within the boundary.

Over a long period of time (*i. e.* annually), the transfer of ground water across boundaries can be neglected (Gupta, 1989). Hence the water balance has been employed to compute the change in soil water storage. The resulted change in soil water content is presented in the Fig. 11. The annual values of components of water balance for the Pachaiyar sub basin is depicted in Fig. 12 for the period 1975-79. The model has been run to simulate various components for a future period and the results (for years 1980-85) are presented in Fig. 13. This would be of help to plan better management practice. Attempt to validate this simulation was not made due to lack of availability of data.

Chapter 5

Summary and Conclusions

The Tambraparani river in Tamilnadu has a drainage area of 5969 Sq. Km. Relatively few analysis have been conducted on this river basin. A study has been conducted on the waterbalance of one of the sub basins (Pachaiyar) of Tambraparani. This study has been initiated with a request from Director, Institute for Water Studies, Chennai.

The study employed the process generating module of the SWRRB model developed by USDA, the performance of the model has been validated internationally by various researchers. Since the model required continous weather data, a time series of weather data has been generated using another model. The efficiency of this model has been checked for a meteorological station outside the basin, whose data were readily available.

The analysis resulted that the basin experiences 18.47 water stress days annually, which is a very low figure, indicating there is sufficient water available in the basin for agricultural purposes. This emphasis the need for proper development and management of the water resources for better production.

The present study has provided insight into the hydrology of Tambraparani river basin through the use of monthly water balance. Since Pachaiyar is the source of a large portion of the main Tambraparani river, it is important to have an understanding of the rainfall runoff relationship for forecasting purposes. The results of this project are useful for forecasting flows into downstream reservoirs. The water balance studies can also be used to determine the effect of global climatic changes on the volumes of water that is cycled under various hydrological processes in the basin. Such an analysis could be valuable toward water resources planning and management of the reservoirs along the river.

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