4 THE TANK MODEL

Tank Model was originally developed by M. Sugawara of Japan in 1967 keeping in view the hydrological condition of the Japan. In Japan evapotranspiration values are not high, basins are small in size, river gradients are steep and time of concentration is small. So the original model developed was consisting of three tanks laid vertically in series. Later on Sugawara suggested m x n structure of model for non-humid basins. Application of Tank Model is not much found in India and only few cases of such studies are found so far. Among these studies study of Ekbote and V.G. Bhave (1982), study of Bhaskar Dutta and S.M. Seth (1983) and study of K.S. Ramasastri are important. Here Tank Model has been developed for the Machhan River Basin by making appropriate changes and corrections to suit the characteristics and properties of the area.

4.1 Concept of Tank Model

The model is based on the hypothesis that the runoff at any instant from each tank depends on the storage in the tank at that instant and follows an exponential function.

The 4x4 Tank model is used for non-humid regions or the basins which experience long dry periods. Some part of such basins remains dry while the area near the river remains wet. Percentage of dry area and wet area of such basins do not remain constant through-out 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 so long the rainy season continues. 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 with the variation of the wet area. To take into account such variations, the basin is divided into four zones. Therefore, a non-humid basin contains 4x4 = 16 tanks.

Each zone is represented by series of four tanks laid vertically with soil moisture structure at the bottom of the top tank. Series of four tanks of first zone is in parallel with that of the other three zones. The top tanks of four zones are of identical structure. Similarly, structures of all second tanks, of all third tanks and 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.

Tank Model has a non linear structure caused by setting the side outlets somewhat above the bottom of each tank except the lowest tank. The concept of initial loss of precipitation is not necessary because its effect is included in the non-linear structure of the tank model. If the output Y(t) is maintained at its initial value at t= 0, then the storage in the tank will disappear after T = 1/k. This is concept of time constant.

If we consider the time constant for each tank of the four tank model by moving the side outlet or outlets to the bottom level then the top tank should have a time constant about a day or few days, the second tank should have it a week or ten days or so, the third tank a few months or so and the fourth tank should have a time constant of years. (Reference : Dutta Bhaskar et. al. "Simulation of Daily Runoff of Two Sub-basins of River Narmada Using Tank Model").

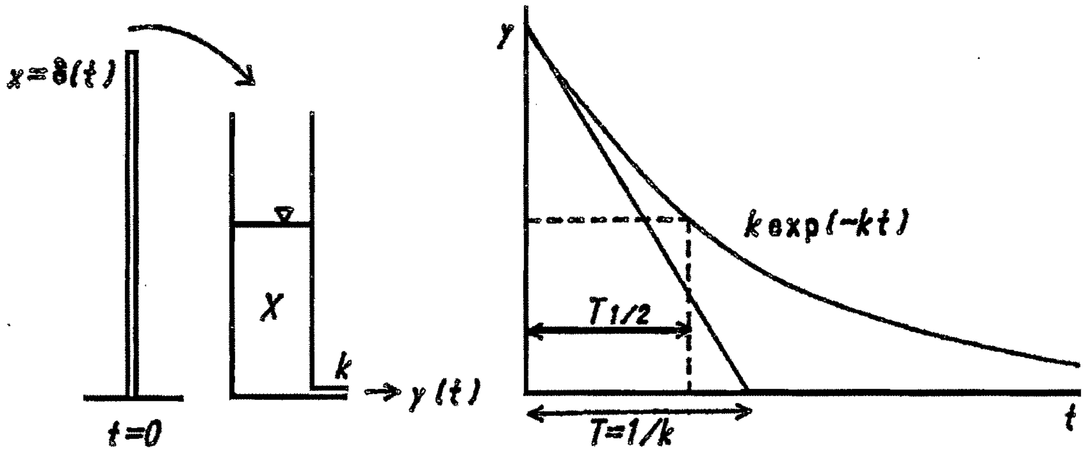


Figure 4.1: Concept of Tank Model

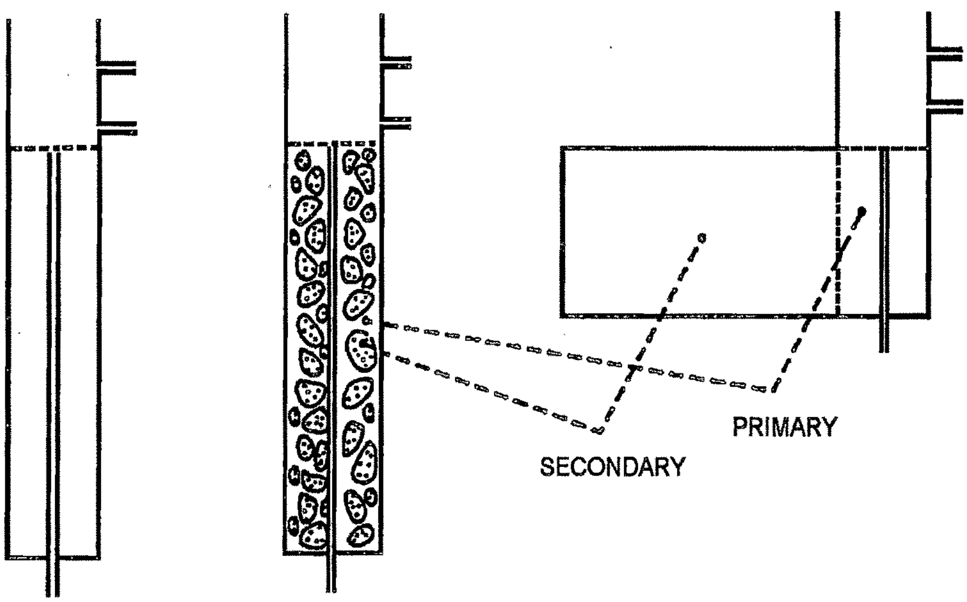
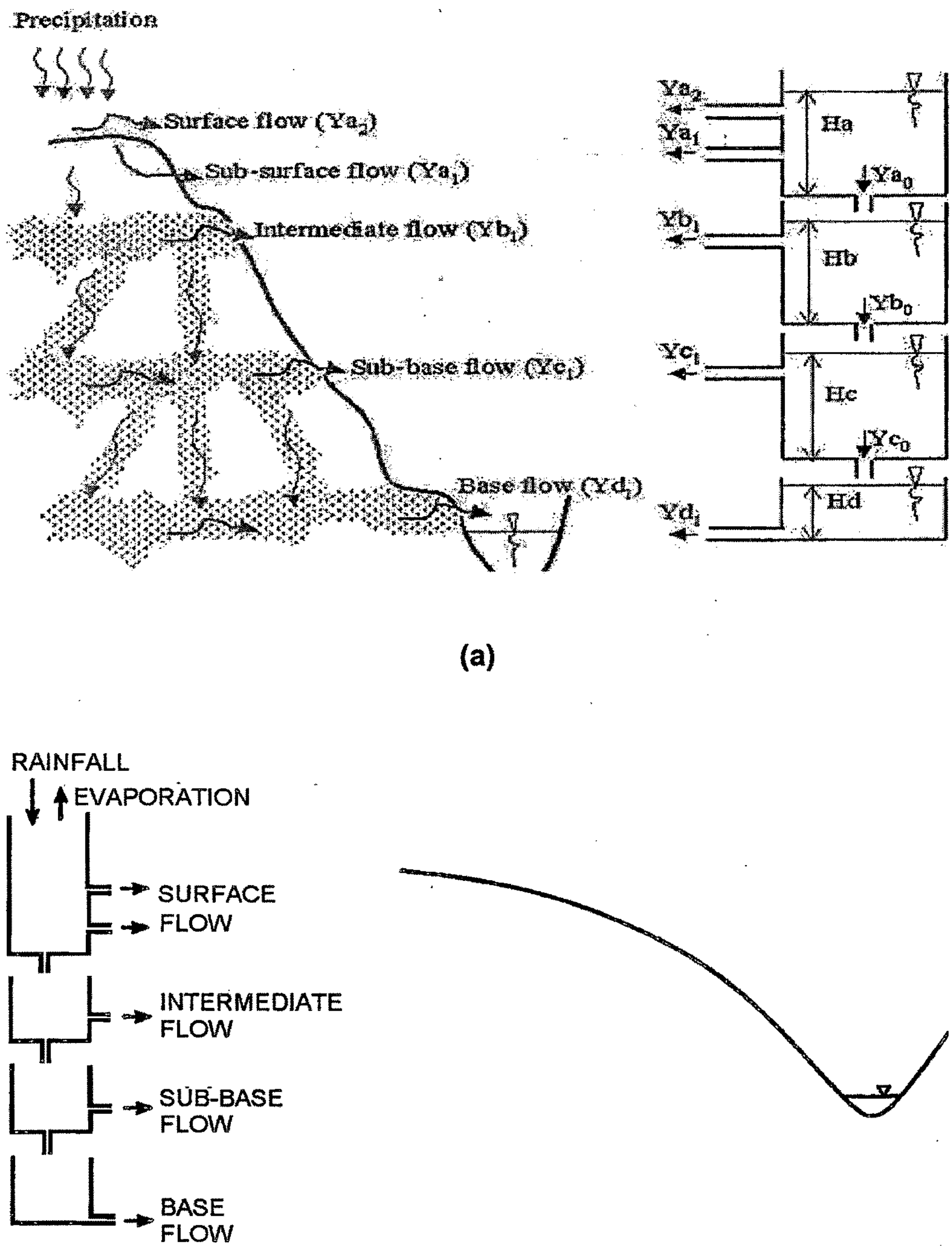


Figure 4.2 : Soil Moisture Structure in Tank Model

4.2 Structure of 4X4 Tank Model

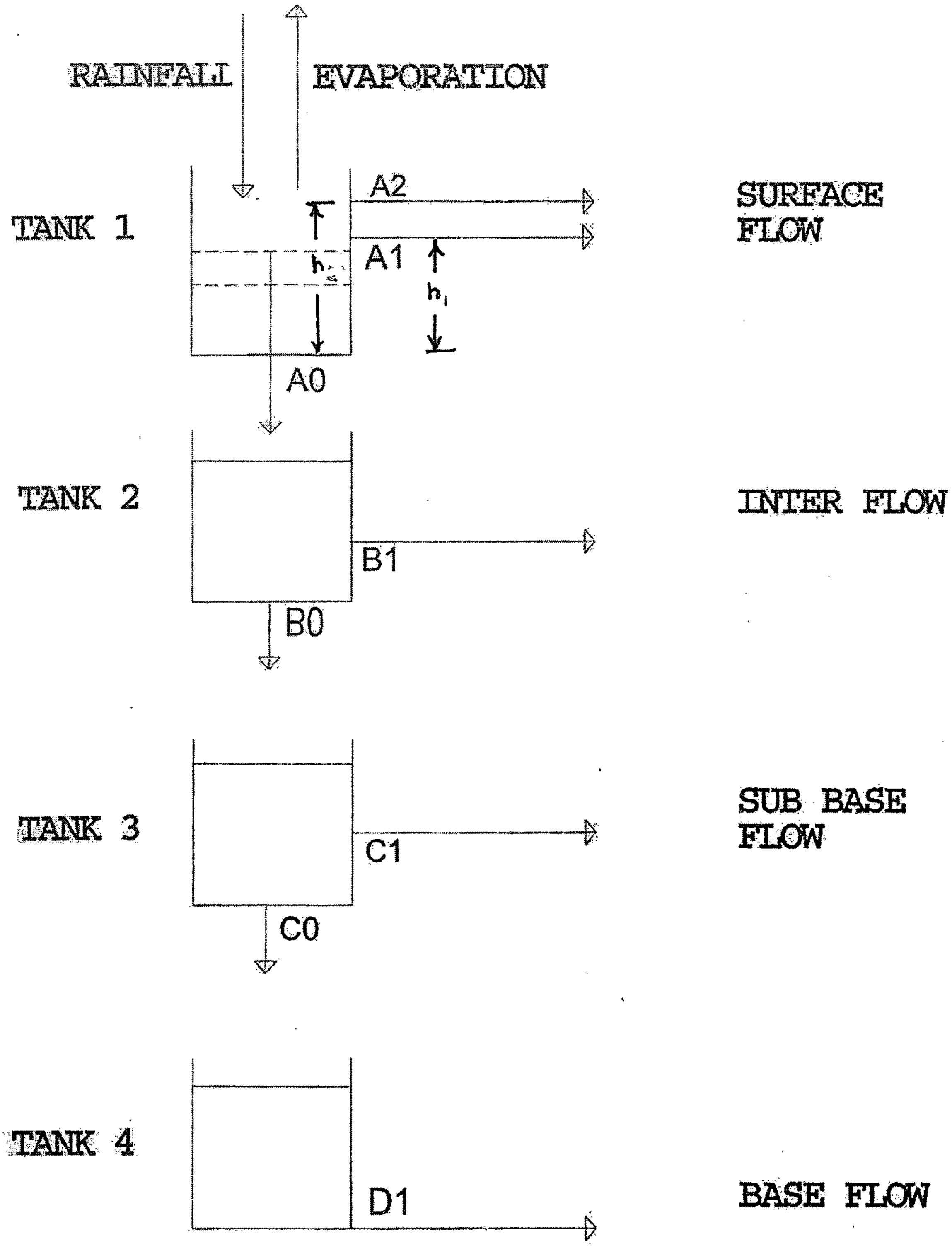
Tank model for stream flow analysis of non-humid basin, the basin is generally divided into four zones and for each zone four tanks are considered in series and the model is known as 4x4 Tank model. The model consists of four tanks horizontally and four tanks vertically thus forming 4x4 tanks structure. Each four tank in vertical series represents one zone. Top tank includes a structure of soil moisture at the bottom. Soil moisture is composed of two components viz; primary soil moisture and secondary soil moisture.

The outer most zone represents hill side of the basin while inner most zone represents river side. Each tank has side outlet. Except Last or bottom most tank in vertical series each of three tank consists bottom outlet. Outflow from side outlets represents surface runoff, inter flow, sub base flow and base flow respectively. Out flows from the bottom outlets represents interception, infiltration and deep percolation.



(b)

Figure 4.3 : Schematic Tank Model



A0,A1,A2,B0,B1,C0,C1,D1 ARE DISCHARGE COEFFICIENTS

Figure 4.4 : Basic Structure of the Tank Model

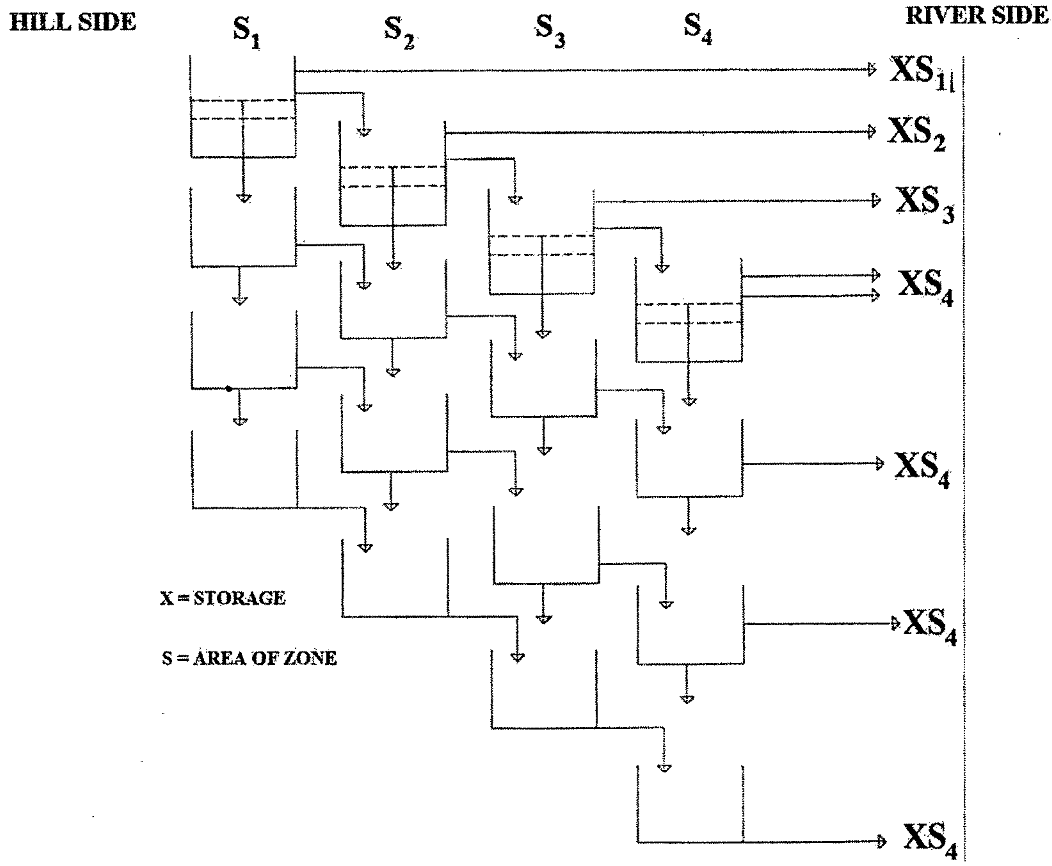


Figure 4.5 : Structure of 4x4 Tank Model

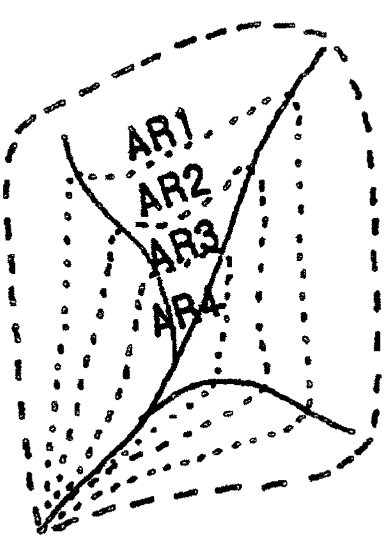


Figure 4.6: Zonal Structure of Tank Model

4.3 Working of Tank Model

Rainfall is Input to the first tank. Outputs from each zone tanks are carried forward as input to the next zone. Water in all the three tanks from top moves to both horizontally and vertically. Discharge through bottom outlet of the 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 uses total rainfall as input and gives total runoff as output along with values of different components viz; surface flow, inter flow, sub-base flow and base flow separately. It simulates outflow hydrographs. Simulated discharges related to various components of the total runoff viz; surface runoff, interflow, and base flow are obtained. Observed runoff is compared with simulated runoff. Also results from the model with varying numbers of check dams etc. are obtained. Calibration of the parameters is done by trial and error.

4.4 Water Movements in 4x4 Tank Model

In this model free water moves in two directions, horizontally and vertically. Each tank receives water from the upper tanks of the same zone or from the mountain side tank of the same strata and transfers 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 rain water as input. Another important water transfer is transfer to soil moisture from the lower free water surface by capillary action.

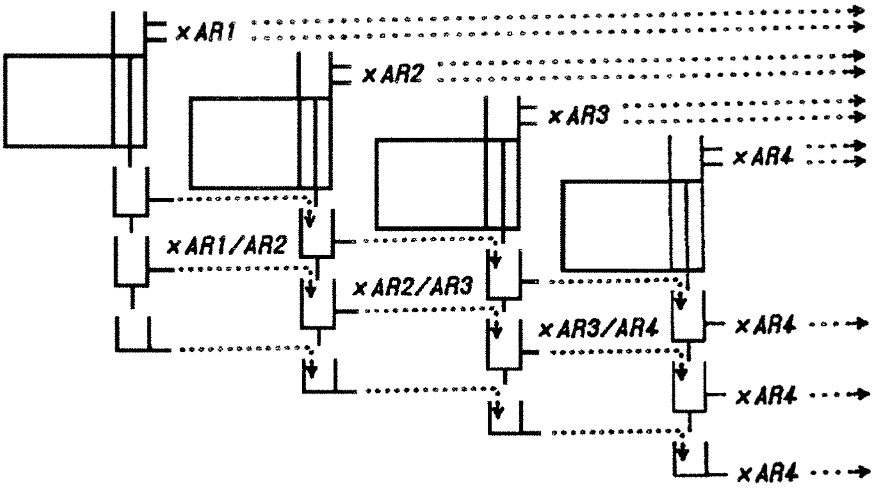


Figure 4.7 : Water Movements In 4x4 Tank Model

When rain starts after a long dry period, primary soil moisture (XP) goes on increasing till it reaches saturation value (PS), after this it 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 primary soil moisture to secondary soil moisture at a transfer velocity T_2 given as

$$T_2 = C_0 + C\ (1\text{-}XS/SS)$$

where C_0 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; when free water of the top tank becomes zero, evaporation starts 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 T_l given as

$$T_1 = b_0 + b\,(1\text{-}XP/PS)$$

where b_0 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.

As the dry season begins, free water of the topmost zone decreases at a faster rate than that of the other zones. After the depletion of free water, the soilmoisture begins to decrease. During depletion, the top-most zone is the first to become dry followed in succession by the second, the third and the fourth zone from the top. When rainy season comes, the lowest zone becomes saturated first followed in succession by the second, the third and the fourth zone from the lowest zone.

4.5 Effect of Irrigation and Check Dams

In cases where irrigation is practiced and check dam is constructed on river their effect becomes essential to be considered. As suggested by Sugawara, it is easy to consider effect of irrigation water intake and storage due to check dams etc. Let the amount of irrigation water intake is 'Z'. This Z is subtracted from the output of the tank model. However considering the fact that the irrigation water is not lost but infiltrates from fields and adds to the ground water so 'Z' is put back in to the third tank. In case of check dams effect of additional storage created by check dams is added to the top tank.

4.6 Advantages of the Tank Model

1. It is simple and to some extent it has reasonable physical meaning corresponding to the zonal structured of groundwater,
2. It can represent the non-linear character of surface runoff,
3. it can represent several components of runoff.
4. Input (rainfall) is distributed to each of the components automatically by its non-linear structure,
5. Runoff components from lower tanks are smoothened in shape and the time-lags are given automatically,
6. Data requirements are comparatively small, and
7. The model can also be suitably modified to basins experiencing snowmelt runoff.

4.7 Capability of the Model to Pickup Parameters from Physical Consideration

Discharge is the macroscopic physical response of the basin and it is the only measurable integral value of the basin. There are many hydrological data and most of them are measured at some points, such as precipitation, evaporation, level of water table etc. Of course, there are many areal values, such as mean areal precipitation, total actual evapo-transpiration of the basin, total amount of groundwater storage in the basin, etc. However, these values are estimated ones. Among such estimated areal values, there is one measured integral value over the basin, the discharge, the macroscopic physical response of the total basin. Coefficients of the tank model are determined by the comparison of its output time series with the observed discharge hydrograph, the time series of the macroscopic physical response of the basin.

4.8 Explanation of the Model

4.8.1 Tank Model with Two Side Outlets and One Bottom Outlet.

This model works with parameters like Initial Storage, Time of concentration, Decreasing ratio, Discharge coefficients of bottom as well as side outlets and heights of the side outlets. There are three possible conditions considered in this model

1. $x(i) < h_1$
2. $h_1 <= x(i) <= h_2$
3. $x(i) > h_2$

If storage is more than second side outlet (top side outlet) then side flow occurs from both the side outlets. When storage is between h_1 and h_2 outflow occurs only from first side outlet. When storage is less than h_1 there does not occur any outflow from any of the side outlet.

h_1 and h_2 are the heads of the side outlets in the top tank

4.8.2 Tank Model with Sequential Input

Time of concentration 'T_C' is the most important variable in this model. It is calculated using decreasing ratio alpha α. Other parameters used in the model are initial storage and initial runoff.

4.8.3 Linear Tank Model in Series

This model describes 'Linear Tanks in Series' laid vertically. First two tanks have outlets on side as well as at bottom whereas third tank has only a side outlet. Side flow from the first tank is surface runoff, from the second tank is inter flow and from third tank is base flow. The parameters associated in working of this model are Net Storage, Surface Flow, Infiltration, Inter Flow, Percolation and Base Flow.

4.8.4 General Symbolization

Storage	X
Runoff (Outflow From Side Outlet)	Y
Outflow From Bottom Outlet	Z
First Tank	A
Second Tank	B
Third Tank	C
Fourth Tank	D

4.8.5 Parameters of Tank Model

There are number of parameters in tank model. Broadly they can be classified as:

- General parameters (like rainfall, evaporation, area of zone etc.)
- Outlets of tanks
- Constants in equations and
- Soil moisture parameters

Movement of water in tank model is described by T_1 and T_2. T_2 is downward velocity (rate) of water and T_1 is upward velocity. These are similar to infiltration and capillary rise. The concept behind time constant T_c is similar to the lag referred in a traditional manner. In an attempt to understand T_c behaviour of a linear reservoir is considered. This is typical reservoir where outflow is proportional to storage. This requires setting of a constant to account for units between storage and outflow. On plotting the behaviour of this reservoir, it is found a straight line and slope of the line have units of time. This slope is considered as time constant.

Primary Soil Moisture refers to moisture in top surface layer of soil that can be extracted by plants for their growth and other activities. Soil moisture that can be extracted by the plants for their growth is called Field capacity. We take Primary soil moisture as Field Capacity from the Detailed Soil Survey Report of study area. Secondary Soil Moisture refers to the soil moisture in a layer adjacent to soil containing primary soil moisture, such that water can be transferred to the layer temporarily up to saturation capacity for transfer to upper layer. Initial losses (Side outlets of first tank) refers to the fraction of rainfall required to saturate the soil layers after which horizontal flow would commence. Height of outlet above base represents the losses from components of runoff viz surface, inter and base flow.

For basins in non-humid regions or the basins which experience long dry periods some part of the basin remain dry while the area near the river remains wet. Percentage of dry area and wet area of such basins do not remain constant 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 so long the rainy season continues. 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 with the variation of the wet area. To take into account such variations, the basin is divided into four zones S_l, S_2, S_3 and S_4.

As the dry season begins, free water of the top-most zone decreases at a faster rate than that of the other zones. After the depletion of free water, the soil moisture begins to decrease. During depletion, the top-most zone is the first to become dry followed in succession by the second, the third and the fourth zone from the top. When rainy season comes, the lowest zone becomes saturated first followed in succession by the second, the third and the fourth zone from the lowest zone. So areal ratio of zones S_l:S_2:S_3:S_4 is another important parameter in this model. Table 4.1 lists different parameters of the tank model.

Table – 4.1 Parameters of Tank Model

Sr. No.	Name of Parameter	Tank	Symbol
1	Decreasing ratio	------	α
2	Time constant	------	Tc
3	Coefficient of discharge of first side outlet	First	A1
4	Coefficient of discharge of second side outlet	First	A2
5	Coefficient of discharge of third side outlet	First	A3
6	Coefficient of discharge of side outlet	Second	B1
7	Coefficient of discharge of side outlet	Third	C1
8	Coefficient of discharge of side outlet	Fourth	D1
9	Coefficient of discharge of bottom outlet	First	A0
10	Coefficient of discharge of bottom outlet	Second	B0
11	Coefficient of discharge of bottom outlet	Third	C0
12	Head for side outlet	First	HA
13	Head for side outlet	Second	HB
14	Head for side outlet	Third	HC
15	Rate of water transfer (Capillary action)	2nd to 1st	T1
16	Rate of water transfer (Infiltration)	1st to 2nd	T2
17	Initial storage in first tank	First	XA
18	Initial storage in second tank	Second	XB
19	Initial storage in third tank	Third	XC
20	Initial storage in fourth tank	Fourth	XD
21	Primary Soil Moisture Depth	------	PS
22	Secondary Soil Moisture Depth	------	SS
23	Initial storage of primary soil moisture	------	XP
24	Initial storage of secondary soil moisture	------	XS
25	Evapotranspiration	------	E
26	Areal ratio of tank 1:2:3:4	------	SI:S2:S3:S4

4.8.6 Assumptions / Considerations in Tank Model

In order to conceptualize tank model for region under study following considerations have been made:

1. Aquifer is unconfined.
2. Basin is behaving as if it is tank i.e. response of the basin is like tank.
3. Initial conditions at the beginning of monsoon are zero.
4. There is only one input to the system, rainfall.
5. Second layer is thicker and to refine time lag we consider it to be composed of two similar tanks representing inter flow and sub-base flow respectively.
6. The sum of discharge coefficients on side and base does not exceed unity for keeping the proper balance of inflow and outflow.
7. The discharge coefficient value reduces as we go downwards.
8. Values of Primary and Secondary Soil Moistures, PS and SS are same for all zones.

4.8.7 Calibration of Tank Model

4.8.7.1 Concept of calibration

Calibration of parameters is done by trial and error method. Value of each parameter is successively changed and from comparison of fit of simulated hydrograph with observed one, best fit parameter value is ascertained. In this way parameters are calibrated leading to final model structure. Comparison is done by human judgment. Three main characteristics that are mainly looked into for comparison peak flow value, time to peak, recession slopes of hydrographs but importance is given to overall fit of the simulated hydrograph with observed one.

There are number of parameters in tank model. Broadly they are divided in to three categories as

(a) Outlets of tanks
(b) Constants in equations and
(c) Soil moisture parameters.

Coefficients of the tank model are determined by the trial and error method starting from some initial model and adjusting the working model. Adjustments are made in two ways for each tank, quantitatively and qualitatively. These adjustments are some sort of physical consideration and so they are very effective.

During calibration it is very important to remember 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 actual base discharge, the parameter corresponding to fourth tank requires to be adjusted first. Table 4.2 lists initial values of some basic parameters suggested by Sugawara to start with the calibration trials.

4.8.7.2 Data Necessary for Calibration

(i) Daily rainfall values of number of rain-gauge stations within and near the basin.
(ii) Daily discharge values at the outlet of the basin.
(iii) Daily mean evaporation value for the basin. If observed evaporation values are not available for the period under consideration, monthly mean of daily evapo-transpiration values may be considered from the tables provided by IMD.
(iv) Catchment area.
(v) Topographic and geo-morphological map of the basin.

Table – 4.2 Initial Values of Parameters Suggested by Sugawara

Parameter Name	Symbol	Parameter Value		
		Initial	Minimum	Maximum
Discharge coefficient for bottom outlet of first tank	A_0	0.2	0	1
Discharge coefficient for first side outlet of first tank	A_1	0.1	0	1
Discharge coefficient for second side outlet of first tank	A_2	0.1	0	1
Discharge coefficient for bottom outlet of second tank	B_0	0.06	0	1
Discharge coefficient for side outlet of second tank	B_1	0.03	0	1
Discharge coefficient for bottom outlet of third tank	C_0	0.012	0	1
Discharge coefficient for side outlet of third tank	C_1	0.006	0	1
Discharge coefficient for side outlet of fourth tank	D_1	0.001	0	1
Head of first side outlet in top tank	HA_1	15	5	15
Head of second side outlet in top tank	HA_2	25	25	60
Head of side outlet in second tank	HB_1	15	0	30
Head of side outlet in Third tank	HC_1	15	0	60

(Reference :Setiawan, Fukuda & Nakano, 2003)

4.8.8 Results from Tank Model

The model simulates outflow hydrographs. Different hydrographs can be plotted simultaneously the observed discharge Q_o. Three Graphs are plotted as below

1. Comparison of Observed and Calculated Runoff verses Time.
2. Inter Flow Vs Time
3. Base Flow Vs Time

4.9 Mathematical Formulation of Tank Model

4.9.1 Simple Tank Model

4.9.1.1 Simple Tank Model With One Side Outlet

Let

X_0 = Initial Storage.

$\propto$ = Discharge Coefficient.

X = Storage at any time t.

Rate of change of storage = Rate of discharge.

$$\therefore \quad \frac{dX}{dt} = -y \quad \text{(Negative sign indicates decreasing rate)}$$

$$\therefore \quad \frac{dX}{dt} = -\propto X$$

$$\therefore \quad \frac{dX}{X} = -\propto dt \quad \text{(Separable variable method for solving O.D.E.)}$$

Integrating on both the sides, we get

$$\therefore \quad \int \frac{dX}{X} = \int -\propto dt$$

$$\therefore \quad \log X = -\propto \int dt = -\propto t + C, \text{ where 'C' is integration constant.}$$

$$\therefore \quad \log X = -\propto t + C$$

$$\therefore \quad X = e^{-\propto t + C} \qquad (1)$$

When t = 0 ; X = X_0 (Initial Condition)

$$X_0 = e^{-\propto(0)+C}$$

$$\therefore \quad X_0 = e^{C} = C_1$$

$$\therefore \quad X_0 = C_1$$

$$X = e^{-\propto t} . e^{C}$$

$$X = X_0 . e^{-\propto t}$$

$$Y = \propto X$$

$$\frac{dY}{dt} = \frac{d}{dt}(\propto X) = \propto \frac{d}{dt}X, \text{ Where } \frac{dY}{dt} \text{ is rate of discharge}$$

But, $\frac{dX}{dt} = -Y$

$$\therefore \frac{dY}{dt} = -\propto Y$$

$$\therefore \frac{dY}{Y} = -\propto dt$$

$$\therefore \int \frac{dY}{Y} = \int -\propto dt = -\propto \int dt$$

$\therefore \log Y = -\propto t + C'$, Where C' is integration constant

$$Y = e^{-\propto t + C'} = e^{-\propto t}.e^{C'}$$

$$Y = e^{-\propto t}.e^{C'} \qquad \text{——————} \quad (2)$$

When $t = 0$; $Y = Y_0$ (Initial Discharge)

$$Y_0 = e^{-\propto(0)}.e^{C'}$$

$$\therefore Y_0 = e^{C'}$$

From equation (2), $Y = e^{-\propto t}.e^{C'}$

$$Y = e^{-\propto t}.Y_0$$

4.9.1.2 Simple Tank Model With Rainfall Output

$$P = p(t)$$

Rate of change of storage = Input – Output

$$\frac{dX}{dt} = p - Y = p - \propto X$$

$$\frac{dX}{dt} + \propto X = p \qquad \text{(Linear differential equation)}$$

$$\text{I.F.} = e^{\int p dt}$$

$$= e^{\int \propto dt}$$

$$= e^{\propto \int dt}$$

$$= e^{\propto t}$$

Multiply both the sides of equations (1) by I.F.,

$$e^{\propto t}\left(\frac{dX}{dt}+\propto X\right)=e^{\propto t}.p$$

$$\frac{dX}{dt}(X.e^{\propto t})=e^{\propto t}.p$$

Integrating on both the sides, we get

$$\int\frac{dX}{dt}(X.e^{\propto t})dt=\int e^{\propto t}.p\,dt$$

$$=p\left(\frac{e^{\propto t}}{\propto}\right)-\int\left(p'\frac{e^{\propto t}}{\propto}\right)dt+c$$

$$Xe^{\propto t}=p\left(\frac{e^{\propto t}}{\propto}\right)-\int\left(p'\frac{e^{\propto t}}{\propto}\right)dt+c$$

$$X(t)=Ce^{-\propto t}+e^{-\propto t}\int_0^1 e^{\propto s}p(s)\,ds \qquad (1)$$

Rate of discharge = Input-Output

$$\therefore \quad \frac{dX}{dt}=p-Y$$

$$\therefore \quad \frac{dX}{dt}+Y=p$$

Integrating Factor $= e^{\int P dt} = e^{\int 1 dt} = e^{t}$

$$e^{t}\left(\frac{dX}{dt}+Y\right)=e^{t}p$$

$$\frac{d}{dt}(Y.e^{t})=e^{t}.p$$

$$\int\frac{d}{dt}(Y.e^{t})=\int e^{t}.p\,dt$$

$$Y.e^{t}=pe^{t}-\int(p^{t}e^{t})\,dt$$

$$Y=p-\int p^{t}\,dt \qquad (2)$$

4.9.1.3 Simple Tank Model With Sequential Input

Initial storage is X_0

Decreasing at the rate of $X_0\,e^{-\propto t}$

$\therefore$ After unit time step (i.e. t=1) initial storage decreases to

$$X_0\,e^{-\propto(1)}$$

$$=X_0\,e^{-\propto}$$

$$\therefore \begin{pmatrix}\text{Run off in unit}\\ \text{time step (Y)}\end{pmatrix} = (\text{Initial storage}) - \begin{pmatrix}\text{Storage in tank after}\\ \text{unit time step}\end{pmatrix}$$

$$\therefore Y = X_0 - X_0\, e^{-\alpha}$$

$$Y = X_0 (1 - e^{-\alpha})$$

$$Y = a.X_0$$

$$a = 1 - e^{-\alpha}$$

$$e^{-\alpha} = 1 - a$$

In the 2nd time step storage $X_0\, e^{-\alpha}$ (storage after 1st unit time step) decrease to $X_0.\, e^{-\alpha}.e^{-\alpha} = X_0.e^{-2\alpha}$ and so on. (Because $e^{-\alpha}$ is the decreasing rate of storage).

$$X_0, X_0 e^{-\alpha}, X_0\,.e^{-2\alpha}, X_0.\ e^{-3\alpha} \dots\dots\dots$$

Let, r = common ratio = $e^{-\alpha}$ = 1-a.

$\therefore$ In terms of geometrical progression

Storage (X_i) : X_0, $X_0.r$, $X_0.r^2$.......

Runoff (Y_i) :$a\ X_0$, $aX_0.r$,$a\ X_0.r^2$....... Runoff (Because $Y = aX_0$)

$\therefore$ Storage X_i is obtained by

$X_i = X_{i-1}.r + p_i$ ______________________ (1)

$Y_i = a.X_i$ $\leftarrow$ Runoff. (Discharge) ____________ (2)

$\therefore$ The remaining storage X_{i-1} is

$X_{i-1} = X_{i-1} - Y_{i-1}$ ______________________ (3)

4.9.2 Tank Model With One Side Outlet and One Bottom Outlet

Let the discharge coefficients in this case are for side outlet and for bottom outlet. Initial storage is X. If at different time step t = 1,2,3,.... rainfall inputs are P_1,P_2,.... and evaporations are E_1, E_2,.... then calculation of storage (X), surface runoff (Y) and infiltration (Z) can be done at different time step as shown in table 4.3

Table – 4.3 Formulas for Different Parameters of Tank Model

Parameter	At first time step	At second time step
Storage at beginning of time step	X	X
Precipitation	P_1	P_2
Evaporation	E_1	E_2
Net Storage	$X+P_1-E_1$	$X^1+P_2-E_2$
Surface Flow (Y)	$(X+P_1-E_1)\ \beta_{11}$	$(X^1+P_2-E_2)\ \beta_{11}$
Infiltration (Z)	$(X+P_1-E_1)\ \alpha_{11}$	$(X^1+P_2-E_2)\ \alpha_{11}$
Total outflow from Tank (Y+Z)	$(X+P_1-E_1)\ (\alpha_{11}+\beta_{11})$	$(X^1+P_2-E_2)\ (\alpha_{11}+\beta_{11})$
Storage remained at the end of time step	$(1-(\alpha_{11}+\beta_{11}))\ (X+P_1-E_1)$	$(1-(\alpha_{11}+\beta_{11}))\ (X^1+P_2-E_2)$

4.10 Computer Program for the Tank Model

A computer program for the tank model incorporating concept described above, is developed using software MATLAB. Working of the program can briefly be explained as follows:

1. Program starts working with initialization of the parameters. All the necessary parameters like T_c, a, PS, SS, area ratio, h_1,h_2 are initialized by trial value or reference value.
2. The program then check for the free water, Pi, with reference to XP, XS, PS and SS and calculates T_2 and T_1.
3. Program then calculates net storage, surface flow and infiltration.

4. Parameters b_0, b_1, c_0, c_1, a and r are calculated from alpha α.
5. Conditions are applied; storages are determined at each time step and updated. Effect of lift irrigation and additional storage due to check dam is applied. Output of one zone is transferred to next zone.
6. Various outflows are calculated. Graphs are plotted and Root Mean Square Error (RMSE) is worked out.

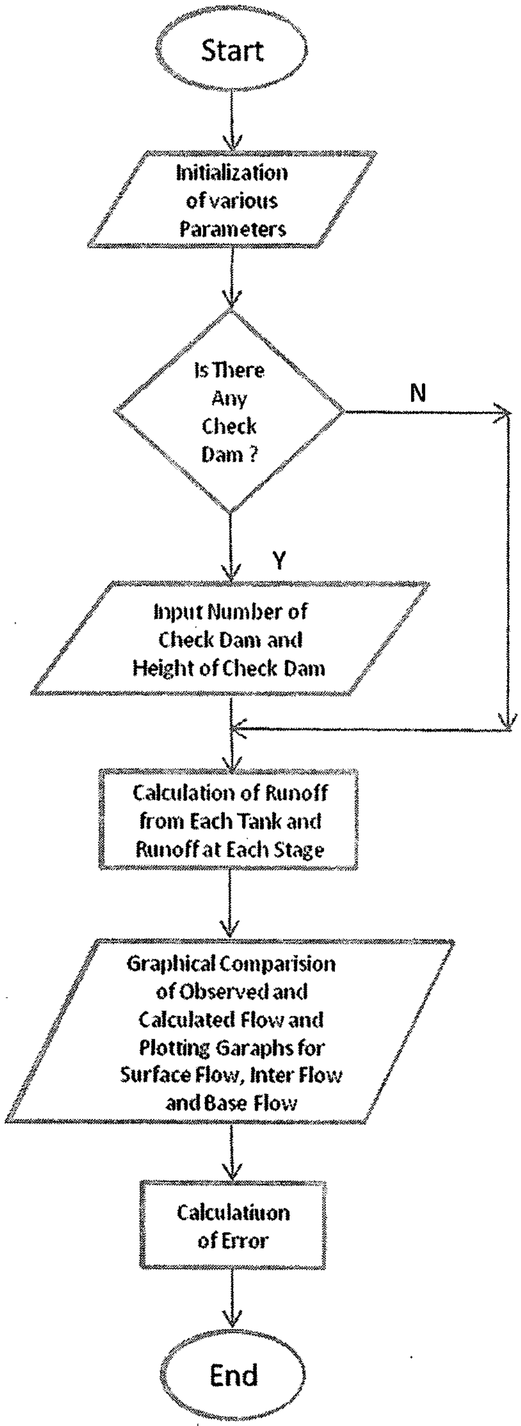


Figure 4.8 : Flowchart of The Model