LECTURE 23

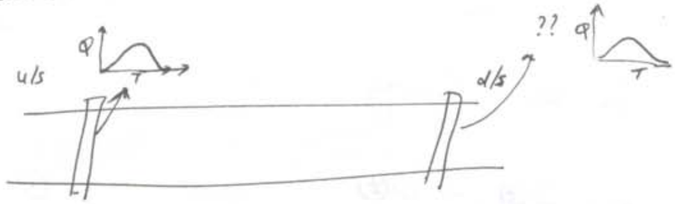
08- MARCH - 2013

LUMPED FLOW ROUTING

In the last classes we discussed on unit hydrograph. UH is a linear system model. It is a characteristic of a watershed.

Moreover, UH is a deterministic lumped steady state hydrological model.

→ As a hydrologist one of the important works you need to carry out could be predicting the discharge of water at various locations in a watershed or a channel, etc.

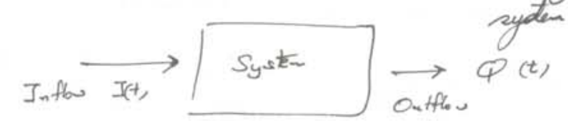


→ You may be given the inflow hydrograph at u/s and may be asked to determine the outflow hydrograph at d/s.

→ This process is called Flow Routing.

(If the inflow is some sort of flood, then it is flood routing.)

Routing is nothing but the system process. if you give input.



→ If in the hydrologic system considered, if you compute outflow discharge only w.r.t time — then it is hydrologic routing.

→ If the routing is done both w.r.t space and time, then it is called hydraulic routing.

So the first one is lumped in space.

The Lumped System Routing

$$I(t) \longrightarrow \boxed{\quad \Omega \quad} \longrightarrow Q(t)$$

We have for the hydrologic system:

$$\frac{dS}{dt} = I(t) - Q(t) \qquad \rightarrow (1)$$

Q: Do you think that eq. (1) can be solved directly?

Ans. Here S and Q are unknowns to the system. Only I is given.

→ You need to incorporate storage function for relation

$$S = f\left(I, \frac{dI}{dt}, \frac{d^2I}{dt^2}, \ldots, Q, \frac{dQ}{dt}, \frac{d^2Q}{dt^2}, \ldots \right) \rightarrow (2)$$

→ In the last chapter we discussed on how S can be linearly related w.r.t inputs and its derivatives as well as output and its derivatives.

⇛ For lumped flow routing we will discuss:

(i) Reservoir routing by level pool method
(Here $S = f(Q)$ and non-linear function of Q)

(ii) Muskingum method for flow routing in channels
where $S = aI + bQ$ linearly related to I & Q

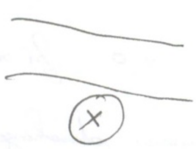
(iii) Several linear reservoirs serially connected.

⇛ In hydrology, you need to understand the relationship between outflow and storage.

* Usually in reservoirs storage is a function of elevation of water.

* The relationship between outflow and storage can be <u>invariable</u> or <u>variable</u>.

→ If there is horizontal water surface that means that water is getting stored. The release Q from the reservoir is controlled.



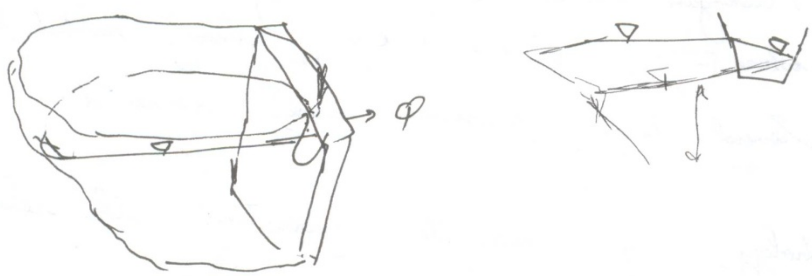
→ Such reservoirs – pool is wide and deep compared to length in direction of flow

~~Here~~ $S = f(Q)$ → 3

Note that inflow velocity to such wide pools are mostly negligible.

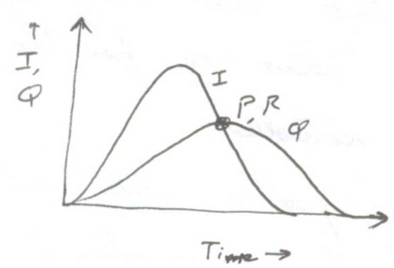
Therefore, mostly storage in such reservoirs are functions of water elevation

IIIly outflow discharge from reservoir can also be function of water elevation or head, etc.



→ Due to these features reservoir storage and discharge related by invariable function $S = f(Q)$.

→ So if in such reservoir and pond for each elevation of water there will be particular value of storage. Similarly there will be particular value of outflow.



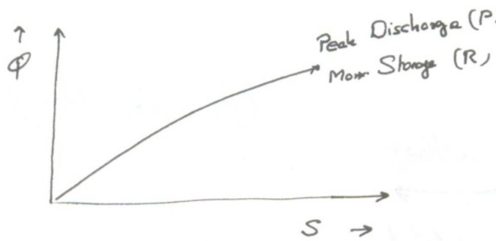
Outflow will be maximum when storage is maximum.

As $S = f(Q)$

and $\frac{dS}{dt} = I - Q = 0$ for max.

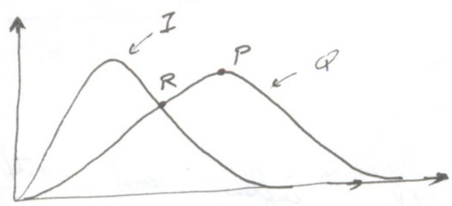
i.e. $I = Q$ at max. discharge location.

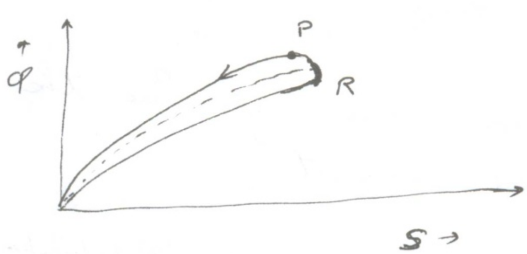
∴ Peak of outflow coincides with inflow hydrograph. P.



(For invariable relationships)

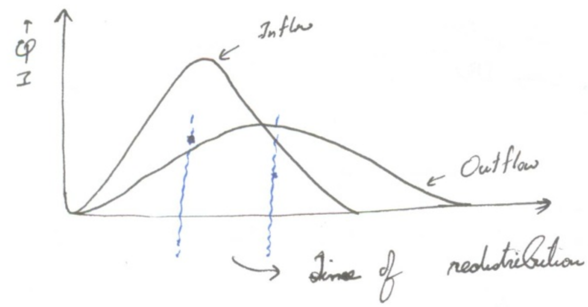
⇒ In a variable storage - outflow cases
- mostly long narrow reservoirs, open channels etc
the water surface may be not horizontal.
(Recall Open Channel Hydraulics — GVF, RVF, etc.)
uniform flow





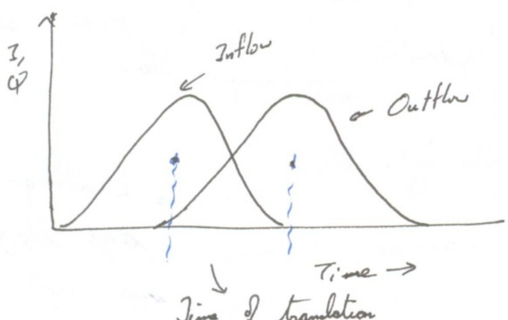
→ Discharge and storage may not be single valued.
i.e. for ~~discharge~~ same storage you may have different discharge.

⇒ So what does this type of routing do!
(i.e. both invariable and variable)
→ The storage in both the cases redistribute the hydrographs of inflow and outflow.



(Invariable Case)

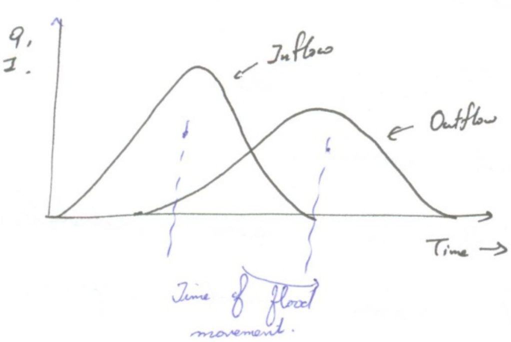
If you compare the centroids of inflow hydrograph and outflow hydrograph, they are displaced (or shifted) by a certain time. This is time of redistribution.



(Long Narrow Channels.)

In long channels, the inflow and outflow hydrographs may look like this.

In general for variable cases, you have the combined time of flood movement



→ Redistribution modifies shape of hydrograph

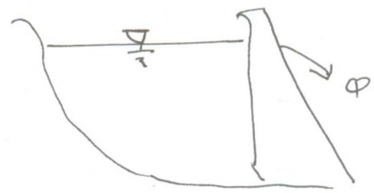
→ Translation changes the position of hydrograph.

Level Pool Routing

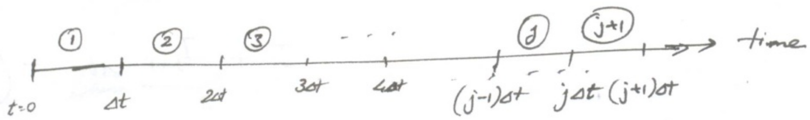
→ To calculate outflow hydrograph from a reservoir with horizontal water surface.

You know

$$\frac{dS}{dt} = I - Q$$



→ The entire time scale is discretised into intervals Δt.



In the $(j+1)^{th}$ time interval

$$\int_{S_j}^{S_{j+1}} dS = \int_{j\Delta t}^{(j+1)\Delta t} I(t)\,dt - \int_{j\Delta t}^{(j+1)} Q(t)\,dt$$

→ Inflow hydrograph is given to you.
The inflow hydrograph values are considered to be in every Δt time step.

→ We need to find Q_1, Q_2, Q_3 ... Q_j, Q_{j+1} ...

→ Inflow to the system here is not pulse data.

We have now

$$S_{j+1} - S_j = \frac{I_j + I_{j+1}}{2} \Delta t - \frac{Q_j + Q_{j+1}}{2} \Delta t$$

Beginning from $t=0$, i.e. S_0, I_0, Q_0 should be given or provided.

Then when $j=1$,

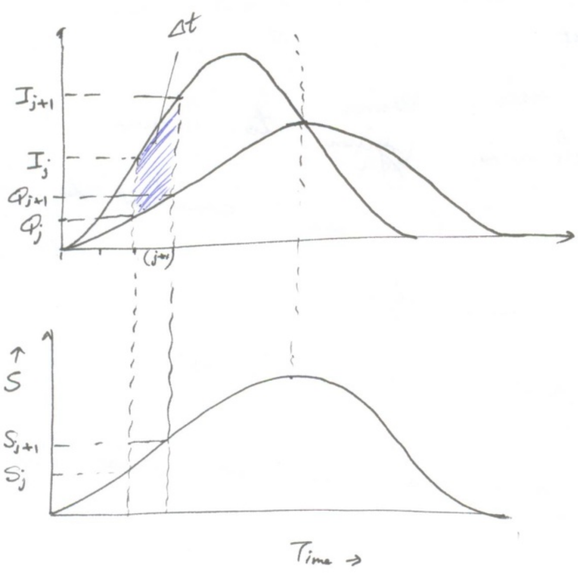
$$S_1 - S_0 = \frac{I_0 + I_1}{2} \Delta t - \frac{Q_0 + Q_1}{2} \Delta t$$

where S_1 and Q_1 are unknowns

1ly go to next time step; $j = 2$.

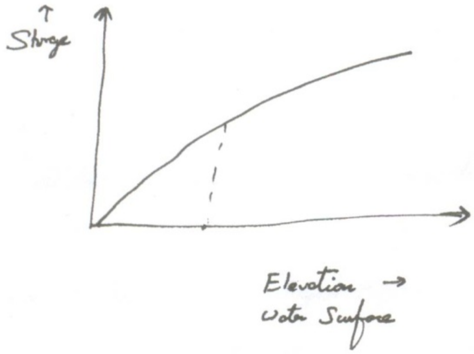
i.e. $$\left(\frac{2 S_{j+1}}{\Delta t} + Q_{j+1} \right) = \frac{I_j + I_{j+1}}{2} \Delta t - \left(\frac{2 S_j}{\Delta t} + Q_j \right)$$

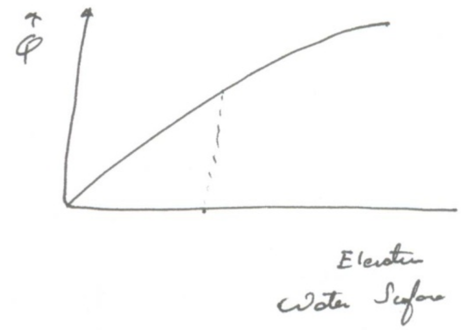
This is level pool routing relation.



To solve level pool routing equation you require relation between storage and outflow.

You have studied Survey. From surveying one can interpret the land terrain details. Also from hydrographic survey and all you can get





From hydraulic structure and corresponding relation, you get

From those you can develop