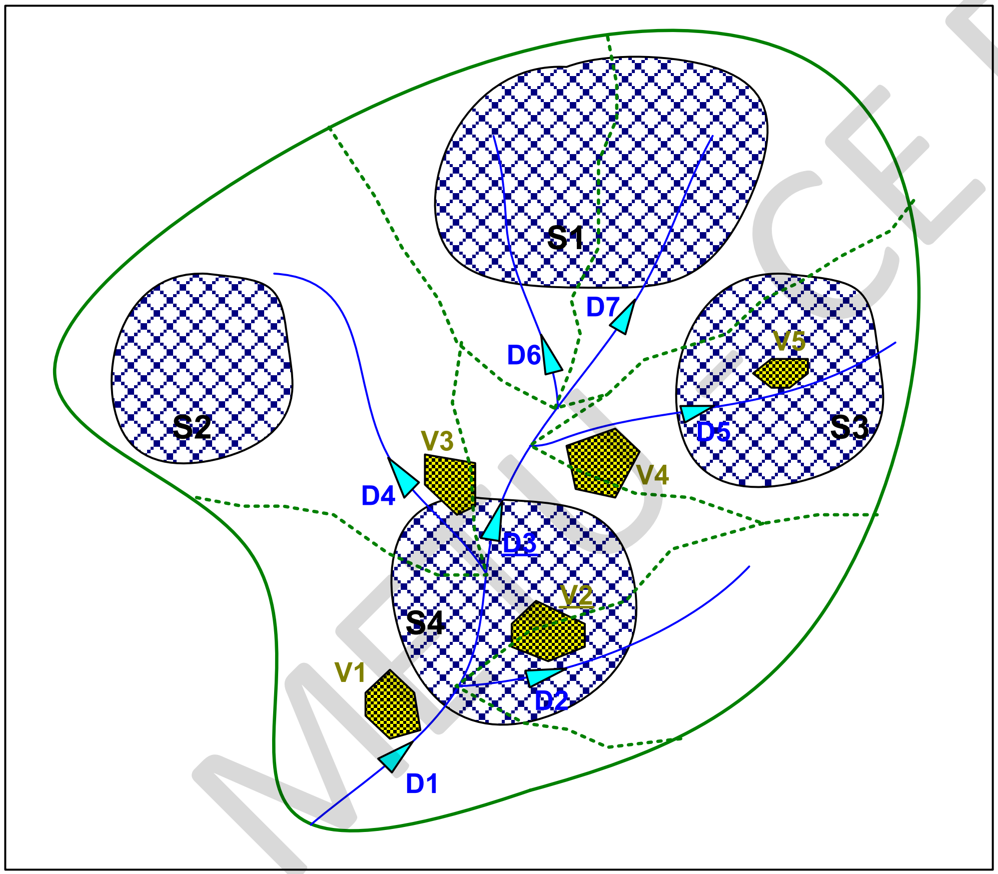
Chapter 4

Reservoir Routing

Flood routing is the determination of flood discharge with time at a downstream point using the data at an upstream point.

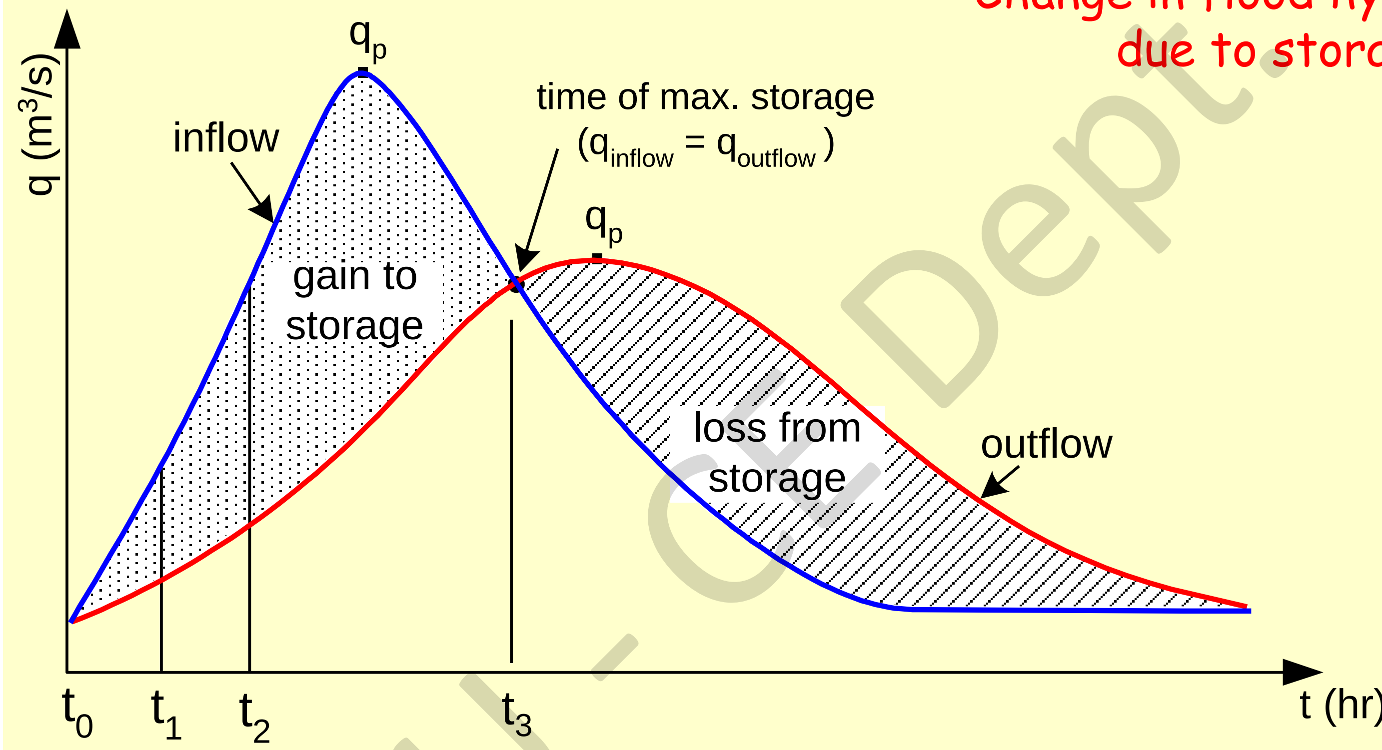


V: village
D: dam
S: storm

Flood Routing

- Unsteady Flow
- Different velocities at different points along flood wave
- Flow additions from tributaries
- Variations in channels or reservoirs

Change in flood hydrograph due to storage



Between t_0 and t_1:

inflow	outflow	storage
$\int_{t_0}^{t_1} I\,dt$	$\int_{t_0}^{t_1} Q\,dt$	$\int_{t_0}^{t_1} (I - Q)\,dt$

or $\Delta S = \Sigma\,(I - Q)\,\Delta t$

Storage (Continuity) Equation

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

$$\bar{I} - \bar{Q} = \frac{\Delta S}{\Delta t} = \frac{S_2 - S_1}{\Delta t}$$

$\bar{I}$: average inflow, $(I_1 + I_2) / 2$, during Δt,

$\bar{Q}$: average outflow, $(Q_1 + Q_2) / 2$, during Δt,

S_1 , S_2 : storage values at the beginning & at the end of the time interval Δt.

$$\frac{I_1 + I_2}{2} - \frac{Q_1 + Q_2}{2} = \frac{S_2 - S_1}{\Delta t}$$

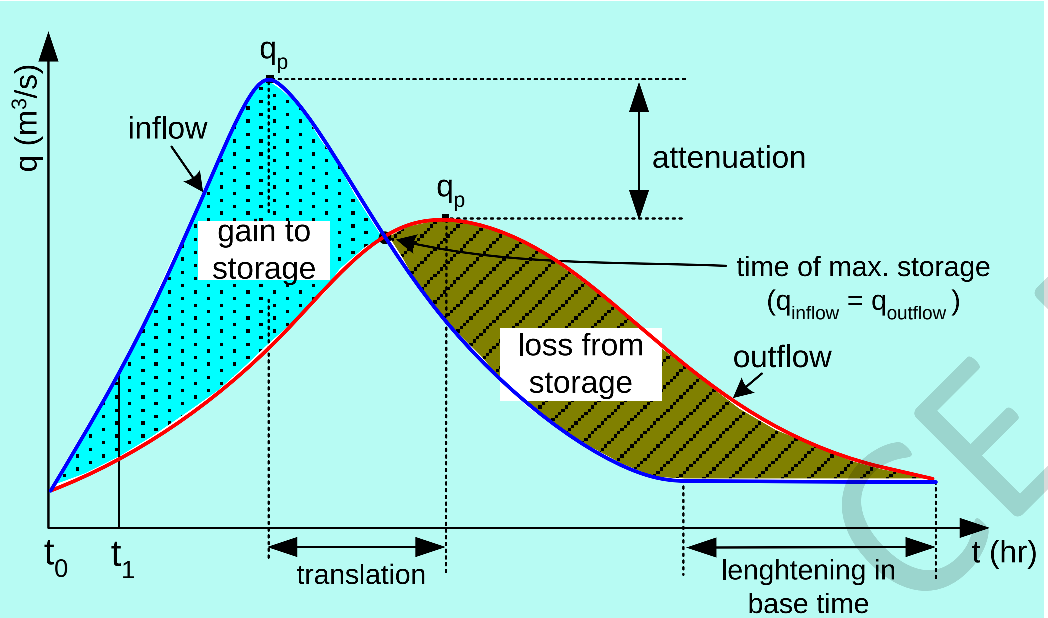


Figure 8.1 Change in flood hydrograph due to storage

Attenuation

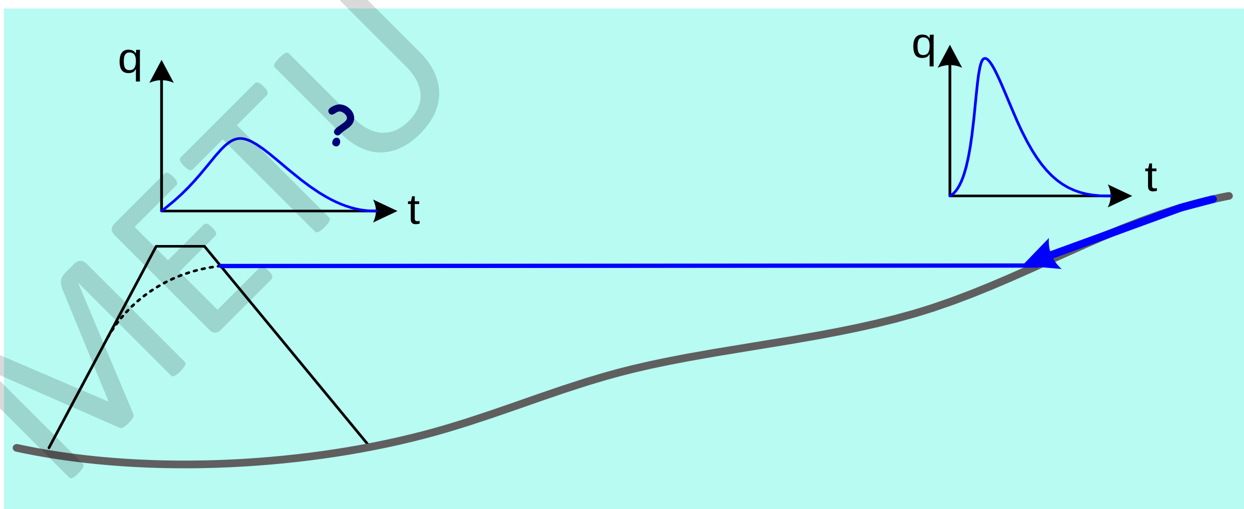
Translation

Lengtening in base time

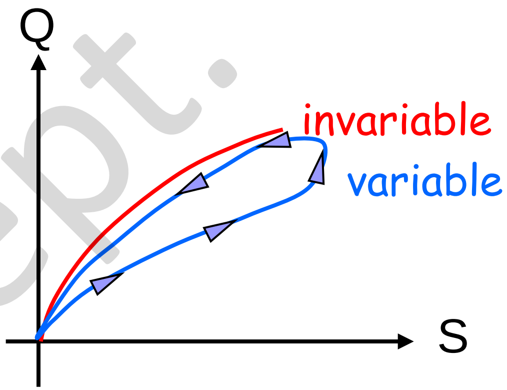
- Although the storage equation is correct & simple, the movement of a flood wave in a river channel or in a reservoir is unsteady flow.
- Therefore some assumptions are required for the development of a practical procedure for flood routing.

Reservoir Routing

- Reservoir is an enlarged channel → modifies flood wave more than a channel
- Routing is necessary for design & planning (location and capacity of reservoir, size of outlets,...).
- After construction, routing is necessary for operation of reservoir.



Reservoir Routing



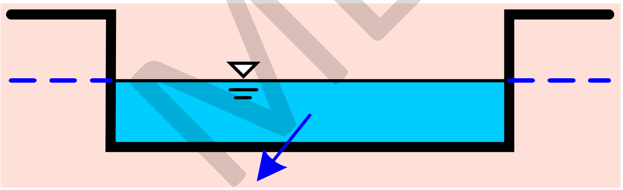
$S = f(Q)$

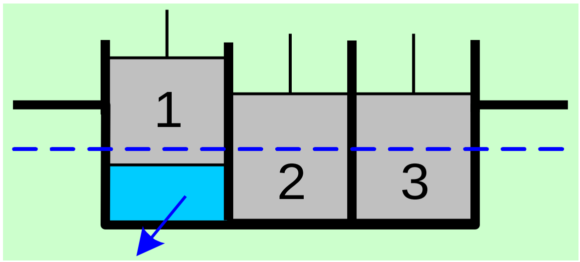
Assumptions:

- Invariable discharge – storage relationship
- Water surface is horizontal

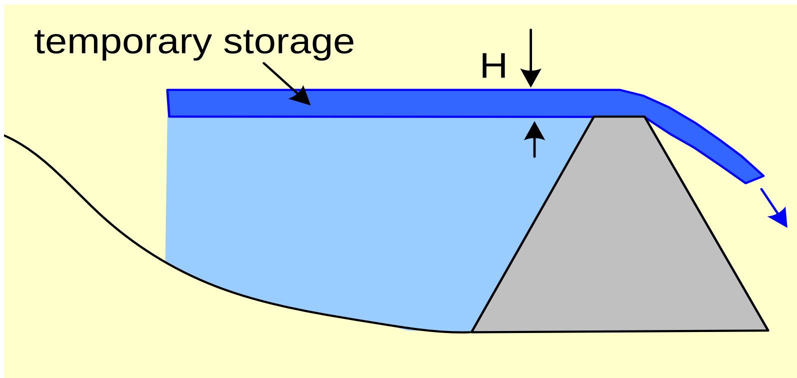
Uncontrolled reservoir → no gates, outflow is a function of reservoir level

Controlled reservoir → outflow is controlled by gates (not a function of level)





Routing in Uncontrolled Reservoirs
Temporary Storage



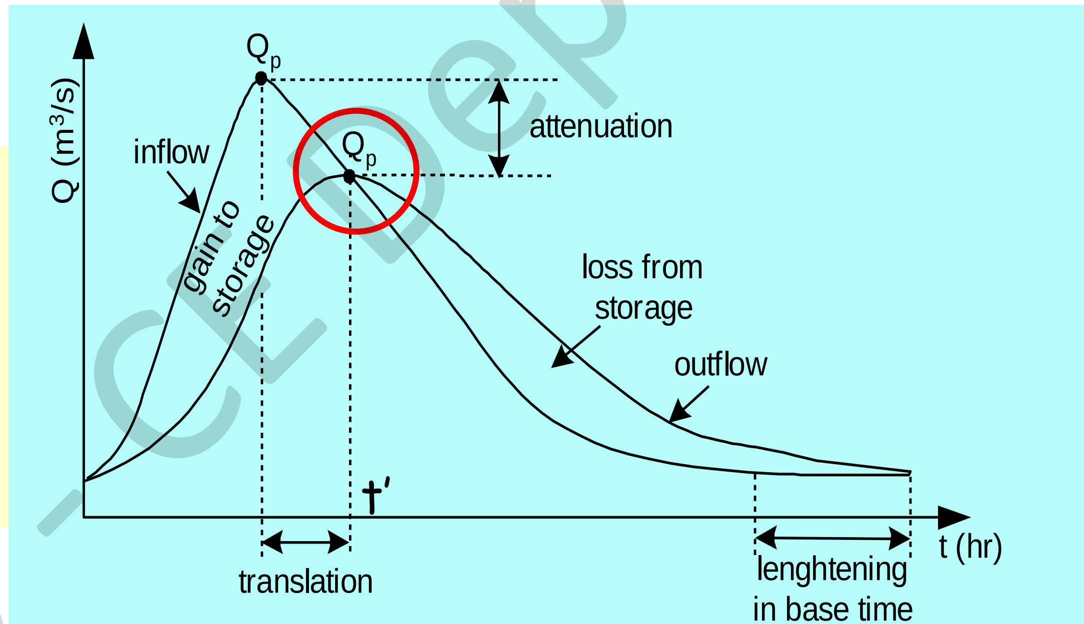


Figure 8.3 Change in flood hydrograph due to storage in the reservoir

- Temporary storage, S = f(H)
- Discharge from spillway, Q = f(H)

- Storage is a function of outflow, S = f(Q)

The peak of outflow hydrograph occurs at the intersection of inflow & outflow graphs (t').

up to t' → storage increasing

at t' → I = Q

dS/dt = 0

head → max, S → max, Q → max

after t' → storage decreasing

$$\bar{I} - \bar{Q} = \frac{\Delta S}{\Delta t}$$

$$\frac{I_1 + I_2}{2} - \frac{Q_1 + Q_2}{2} = \frac{S_2 - S_1}{\Delta t}$$

$$(I_1 + I_2) + (\frac{2S_1}{\Delta t} - Q_1) = (\frac{2S_2}{\Delta t} + Q_2)$$

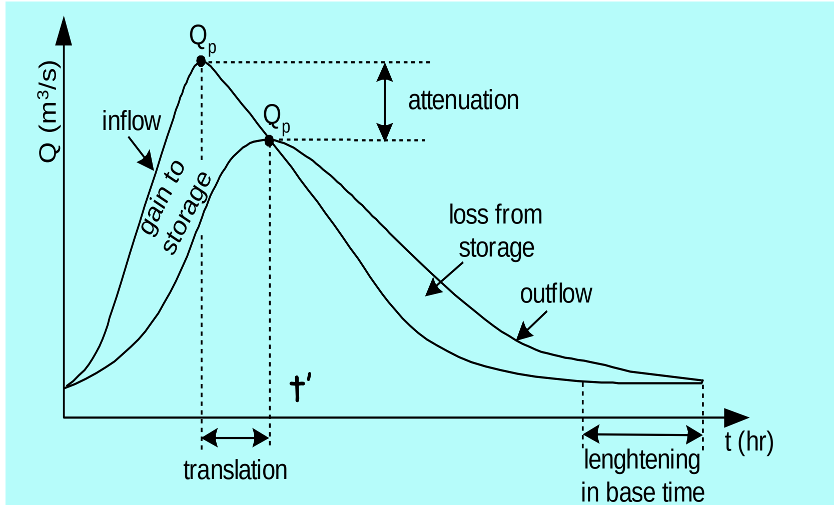
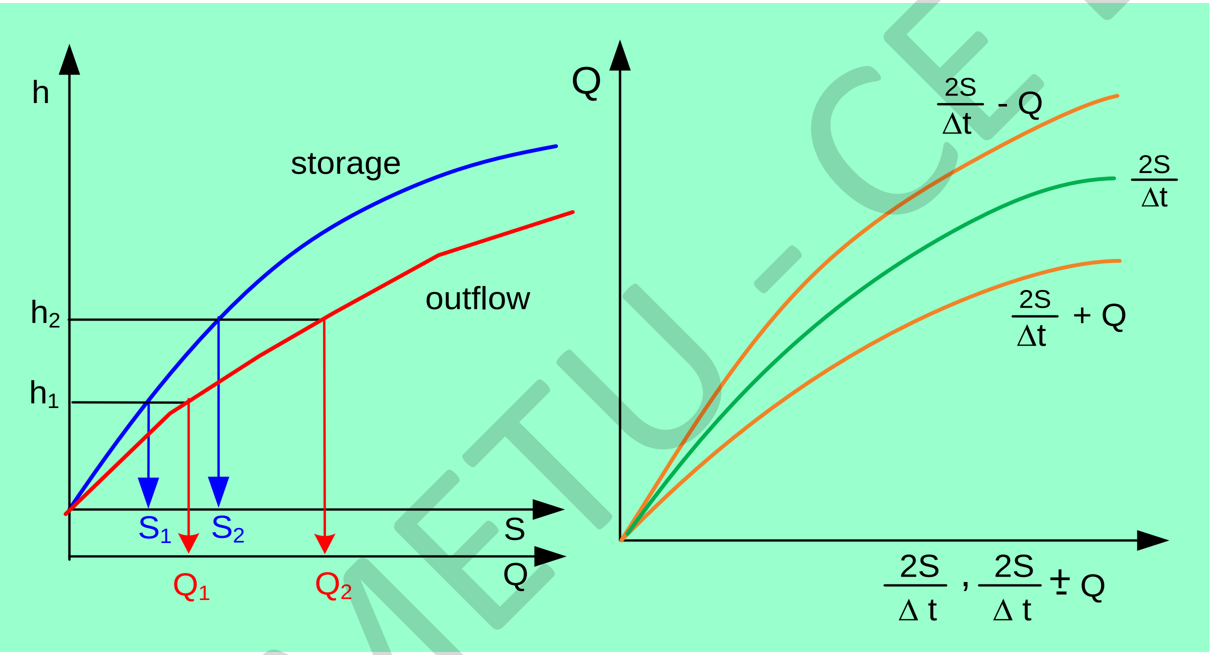


Figure 8.3 Change in flood hydrograph due to storage in the reservoir

$$(I_1 + I_2) + \left(\frac{2S_1}{\Delta t} - Q_1\right) = \left(\frac{2S_2}{\Delta t} + Q_2\right)$$

One equation with two unknowns (Q_2, S_2)

One more relationship is necessary!



$$\left.\begin{aligned} S &= f_1(h) \\ Q &= f_2(h) \end{aligned}\right\} \quad S = f_3(Q)$$

$$Q \text{ vs} \left(\frac{2S}{\Delta t}\right)$$

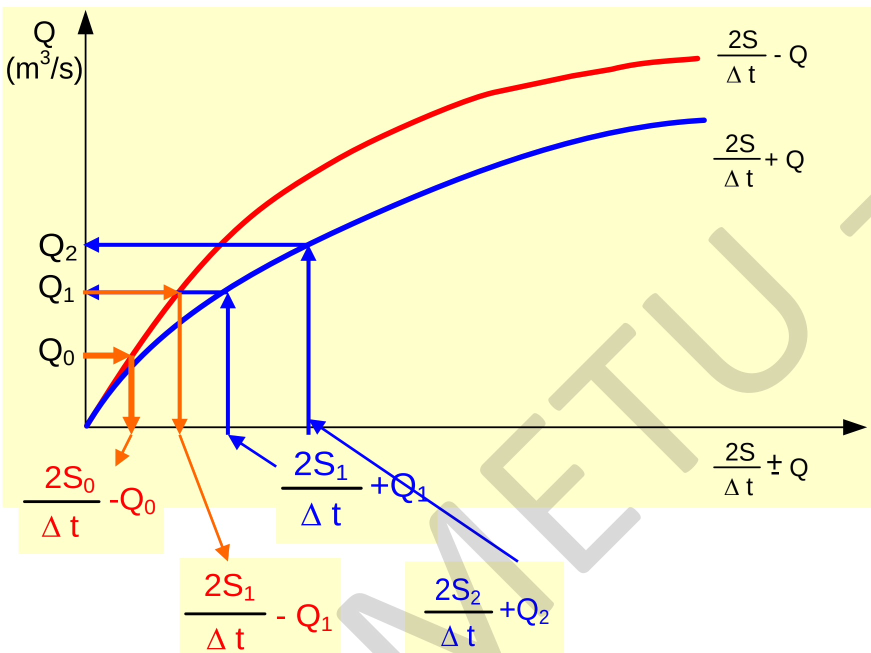
$$Q \text{ vs} \left(\frac{2S}{\Delta t} \pm Q\right)$$

$\boxed{\begin{array}{l} \text{h vs S} \\ \text{h vs Q} \end{array}}$ $\xrightarrow[\text{from}]{\text{derived}}$ physical characteristics of the reservoir.

Given : Inflow hydrograph & first outflow value

Asked : Outflow hydrograph

$$(I_i + I_{i+1}) + \left(\frac{2S_i}{\Delta t} - Q_i\right) = \left(\frac{2S_{i+1}}{\Delta t} + Q_{i+1}\right)$$



t (hr)	I (m^3/s)	I_1+I_2 (m^3/s)	$\left(\frac{2S_1}{\Delta t} - Q_1\right)$	$\left(\frac{2S_2}{\Delta t} + Q_2\right)$	Q_2 (m^3/s)
t_0	I_0				Q_0
t_1	I_1	I_0+I_1	$\left(\frac{2S_0}{\Delta t} - Q_0\right)$	$\left(\frac{2S_1}{\Delta t} + Q_1\right)$	Q_1
t_2	I_2	I_1+I_2	$\left(\frac{2S_1}{\Delta t} - Q_1\right)$	$\left(\frac{2S_2}{\Delta t} + Q_2\right)$	Q_2
t_{n-1}	I_{n-1}	$I_{n-2}+I_{n-1}$	$\left(\frac{2S_{n-2}}{\Delta t} - Q_{n-2}\right)$	$\left(\frac{2S_{n-1}}{\Delta t} + Q_{n-1}\right)$	Q_{n-1}
t_n	I_n	$I_{n-1}+I_n$	$\left(\frac{2S_{n-1}}{\Delta t} - Q_{n-1}\right)$	$\left(\frac{2S_n}{\Delta t} + Q_n\right)$	Q_n

Routing in Controlled Reservoirs

- If outflow from spillway or sluiceway is controlled by gates or valves, the relation of Q vs S will not be unique.
- There will be a different set of curves for Q vs ($2S/\Delta t \pm$ Q) relationships, depending on the number of open gates.

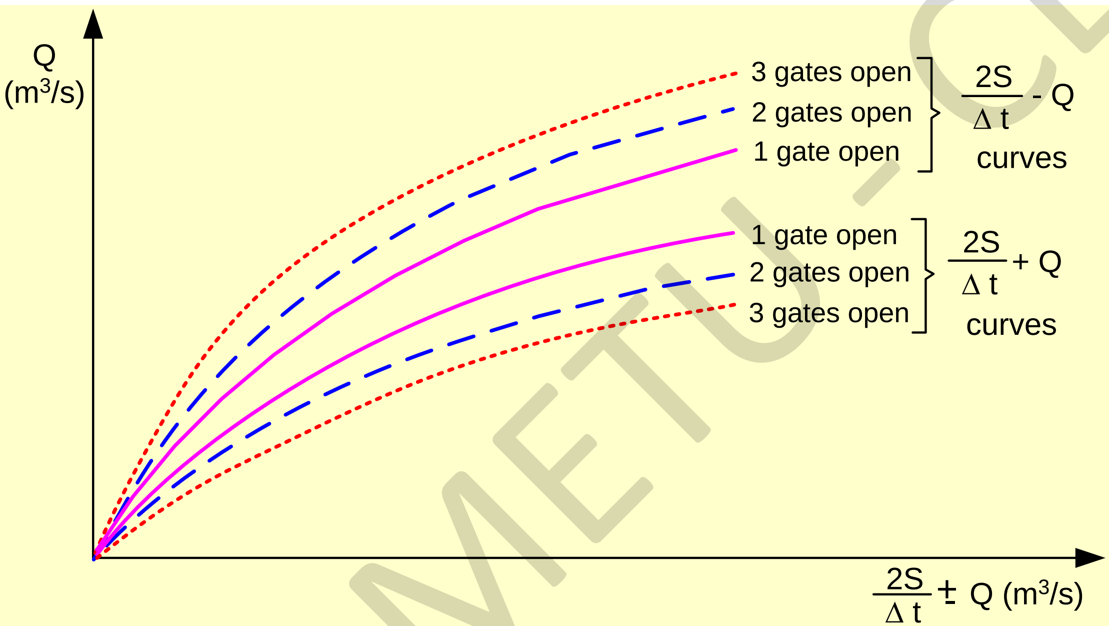
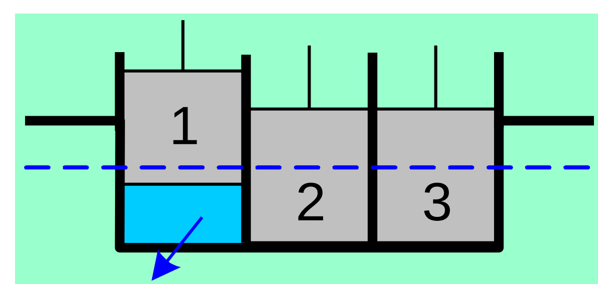


Figure 8.6 Curves for controlled reservoir

After deciding on the # of open gates, then the procedure is exactly the same as before.



Example 10

Determine the peak discharge and base time of the outflow hydrograph of a reservoir which a storage-outflow relationship ($S = 2Q\Delta t$) for the given inflow hydrograph.

Time (hr)	0	3	6	9	12	15	18	21	24
Inflow (m^3/s)	200	620	1250	1080	870	610	505	390	200

Solution

$$(I_1 + I_2) + (2S_1 / \Delta t - Q_1) = (2S_2 / \Delta t + Q_2)$$

$S = 2\,Q\,\Delta t$

$2S = 4\,Q\,\Delta t$

$2S / \Delta t = 4Q$

$2S / \Delta t - Q = 3Q$

$2S / \Delta t + Q = 5Q$

Time (hr)	Inflow (m^3/s)	I_1+I_2	$2S/\Delta t - Q = 3Q$	$2S/\Delta t + Q = 5Q$	Outflow, Q
0	200				200
3	620	820	600	1420	284
6	1250	1870	852	2722	544
9	1080	2330	1633	3963	793
12	870	1950	2378	4328	866
15	610	1480	2597	4077	816
18	505	1115	2446	3561	712
21	390	885	2137	3032	606
24	200	590	1819	2409	481
3	200	400	1444	1844	369
6	200	400	1107	1507	301
9	200	400	904	1304	261
12	200	400	783	1183	237
15	200	400	710	1110	222
18	200	400	666	1066	213
21	200	400	639	1039	208
24	200	400	624	1024	205
3	200	400	615	1015	203
6	200	400	609	1009	202
9	200	400	606	1006	201
12	200	400	603	1003	200

$Q_p = 866\ m^3/s$ $t_p = 12$ hr $t_{base} = 2.5$ days