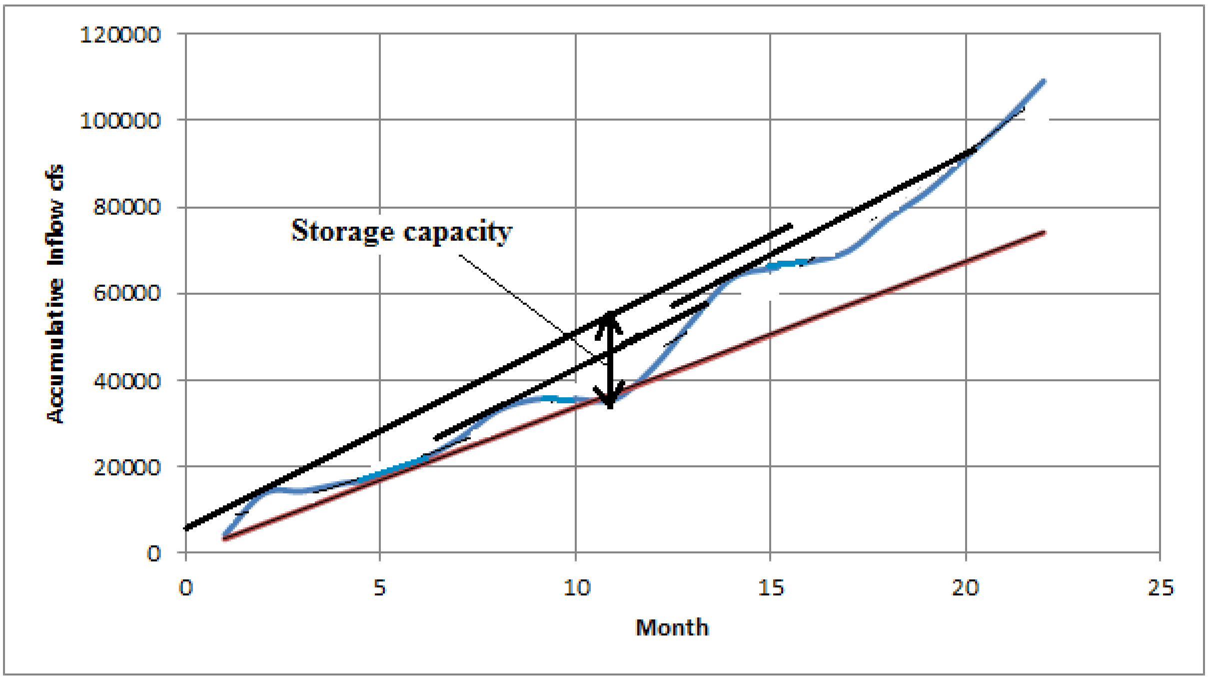
Example (2): determine the storage capacity for a reservoir according to the data in table, the uniform release is 18 cfs and average evaporation is 2 cfs (use TP or mass curve method)?

Month	Inflow (cfs)	Outflow (cfs)
Apr.	141	90
May	310	92
Jun	18	92
Jul	56	93
Aug	40	90
Sep	135	90
Oct	160	90
Nov	221	89
Dec	85	89
Jan	0	89
Feb	0	91
Mar	241	90
Apr	359	90
May	312	92
Jun	75	92
Jul	50	93
Aug	82	93
Sep	247	90
Oct	198	90
Nov	268	90
Dec	266	89
Jan	305	89

Sol:

Month	Inflow (cfs)	Outflow (cfs)	total outflow (cfs)	Inflow volume, It(cfs-day)	Outflow volume Ot(cfs-day)	Cumulative inflow ∑It (cfs-day)	Cumulative outflow ∑Ot (cfs-day)	Difference ∑It- ∑Ot (cfs-day)
Apr.	141	90	110	4230	3300	4230	3300	930
May	310	92	112	9610	3472	13840	6772	7068
Jun	18	92	112	540	3360	14380	10132	4248
Jul	56	93	113	1736	3503	16116	13635	2481
Aug	40	90	110	1240	3410	17356	17045	311
Sep	135	90	110	4050	3300	21406	20345	1061
Oct	160	90	110	4960	3410	26366	23755	2611
Nov	221	89	109	6630	3270	32996	27025	5341
Dec	85	89	109	2635	3379	35631	30404	5227
Jan	0	89	109	0	3379	35631	33783	1848
Feb	0	91	111	0	3108	35631	36891	-1260
Mar	241	90	110	7471	3410	43102	40301	2801
Apr	359	90	110	10770	3300	53872	43601	10271
May	312	92	112	9672	3472	63544	47073	16471
Jun	75	92	112	2250	3360	65794	50433	15361
Jul	50	93	113	1550	3503	67344	53936	13408
Aug	82	93	113	2542	3390	69886	57326	12560
Sep	247	90	110	7410	3300	77296	60626	16670
Oct	198	90	110	6138	3410	83434	64036	19398
Nov	268	90	110	8040	3300	91474	67336	24138
Dec	266	89	109	8246	3379	99720	70715	29005
Jan	305	89	109	9455	3379	109175	74094	35081

Uniform release + evaporation=20 cfs



Storage Capacity=7068-(-1260)=8328cfs.day or 16490 acre.ft

Example (3): The following is a record of the mean monthly discharges of a river in a dry year. The available fall is 80 m. Determine

(1) The minimum capacity of a reservoir if the entire annual inflow is to be drawn off at a uniform rate (with no flow going into waste over the spillway).

(2) The amount of water must be initially stored to maintain the uniform draw off.

(3) The uniform power output assuming a plant efficiency of 70%.

(4) If the amount of water initially stored is 125 Mm3, the maximum possible draw off rate and the amount of water wasted over the spillway (assuming the same reservoir capacity determined in (i) above.

(5) If the largest reservoir that can be economically constructed is of capacity 125 Mm3, the maximum possible output and the amount of water wasted over the spillway.

(6) The capacity of the reservoir to produce 22.5 megawatts continuously throughout the year.

Month	*Mean flow (cumec)*	*Month*	*Mean flow (cumec)*
Jan.	29.7	July	68.0
Feb.	75.3	Aug.	50.2
March	66.8	Sept.	74.5
April	57.2	Oct.	66.8
May	23.2	Nov.	40.5
June	26.3	Dec.	26.3

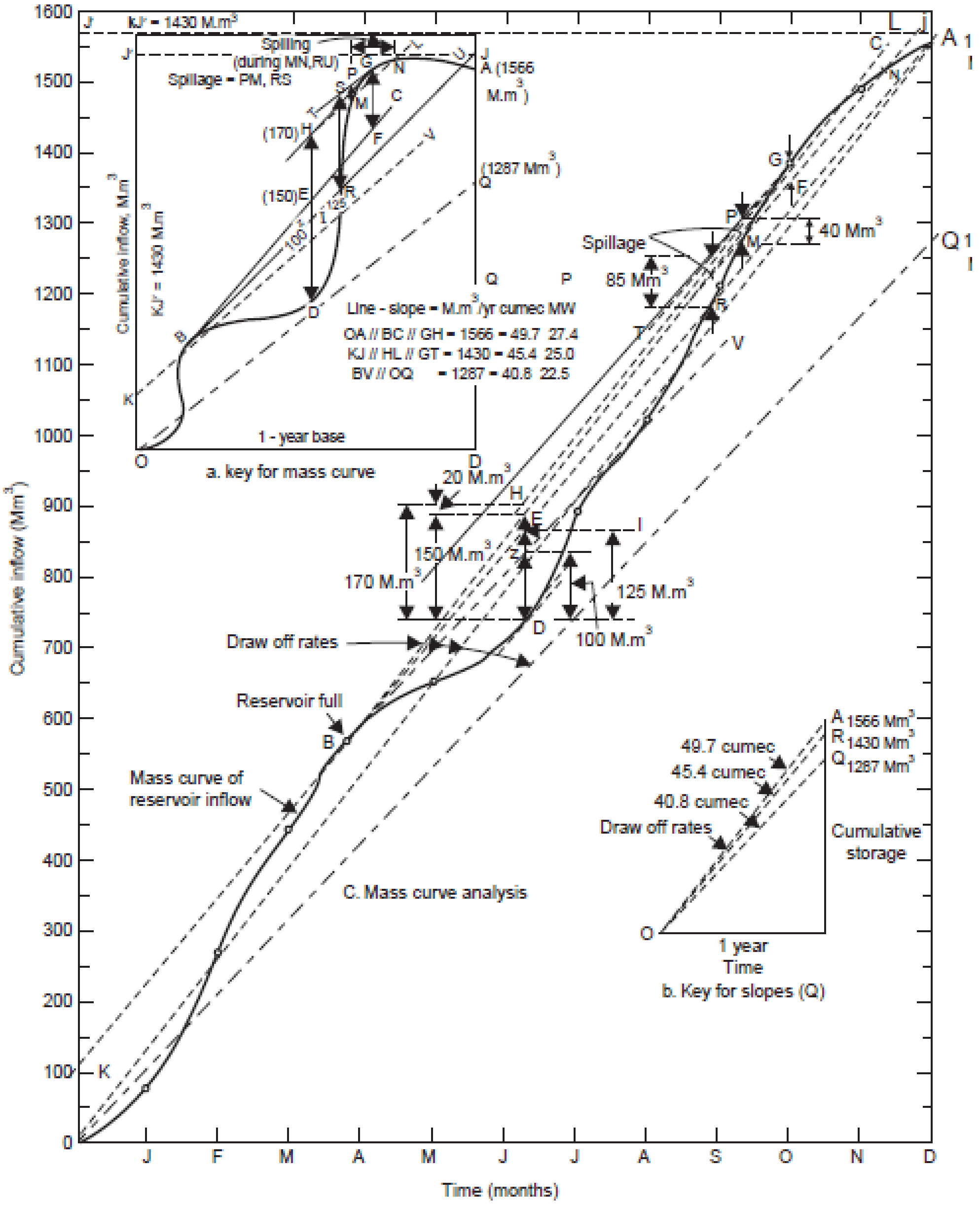
Sol:

Take each month as 30 days for convenience; 1 month = 30 days × 86400 sec = 2.592 × 106 sec. Inflow volume in each month = monthly discharge × 2.592 Mm3; and monthly inflow and cumulative inflow are tabulated in Table below:

Cumulative inflow into reservoir

Month	*Mean flow (cumec)*	*Inflow volume (Mm^3)*	*cumulative inflow (Mm^3)*	*Month*	*Mean flow (cumec)*	*Inflow volume (Mm^3)*	*cumulative inflow (Mm^3)*
Jan.	29.7	77	77	July	68.0	176	897
Feb.	75.3	195	272	Aug.	50.2	130	1027
Mar.	66.8	173	445	Sept.	74.5	193	1220
April	57.2	148	593	Oct.	66.8	173	1393
May	23.2	60	653	Nov.	40.5	105	1498
June	26.3	68	721	Dec.	26.3	68	1566

Plot the mass curve of flow as cumulative inflow vs month as shown in Fig. below.



Mass curve studies in reservoir design (Example 1)

1. Join *OA* by a straight line; the slope of *OA*, *i.e.*, 1566 Mm3/yr or (1566 × 106) m^3/ (365 × 86400)

2. sec = 49.7 cumec is the uniform draw off throughout the year with no spill over the spillway. Draw *BC* || *OA*, *GH* || *OA*, *B*, *G* being the crests of the mass curve; *EH* = *FG*

   Minimum capacity of reservoir = *DE* + *EH* = 150 + 20 = **170 Mm3**

Note: If the capacity is less than this, some water will be wasted and if it is more than this, the reservoir will never get filled up.

3. Amount of water to be initially stored for the uniform draw off of 49.7 cumec = DE = 150 Mm^3
4. Continuous uniform power output in kW, $P = \frac{\rho_w g Q H}{1000} * \eta_o$

Where
ρw = mass density of water, 1000 kg/m3
Q = discharge into turbines
H = head on turbines (≈ available fall)
η0 = overall or plant efficiency

$$P = \frac{\rho_w g Q H}{1000} * \eta_o \Rightarrow P = \frac{1000 * 9.81 * 49.7 * 80}{1000}$$
$$= 27400 kW$$
$$= 27.4 MW$$

5. If the amount of water initially stored is only 125 M.m^3, measure *DI* = 125 M.m^3, join *BI* and produce to *J*. The slope of the line *BJ* is the maximum possible draw off rate. Let the line *BJ* intersect the ordinate through *O* (*i.e.*, the cumulative inflow axis) at *K*. The vertical intercept *KJ′* = 1430 Mm^3 and the slope of this line = 1430 Mm^3/yr = 45.4 cumec which is the maximum possible draw off rate. To maintain the same reservoir capacity of 170 M.m^3, draw the straight line HL || KJ intersecting the mass curve of flow at M and N. Draw the straight line GT || HL. The vertical intercept PM gives the amount of water wasted over the spillway (during the time period MN) which is 40 Mm^3.

6. If the reservoir capacity is limited to 125 M.m3 from economic considerations, the line KJ intersects the mass curve of flow at R. Let the vertical at R meet the line GT (GT || KJ) at S. In this case the amount of water wasted over the spillway = RS = 85 Mm3. The maximum possible output in this case for a uniform draw off rate of 45.4 cumec is

$$P' = 27.4 \frac{45.4}{49.7} = 25 MW$$

7. For a continuous power output of 22.5 MW the uniform draw off rate can be determined from the equation

$$22500 kW = \frac{1000 * 9.81 * Q * 80}{1000} * 0.7$$
$$= 40.8 cumec$$

Which can also be calculated as 49.7 ×(22.5/27.4)= 40.8 cumec = 40.8 (365 × 86400 sec) = 1287 Mm^3/yr. On the 1-year base, draw the ordinate at the end of December = 1287 M.m3 and join the line OQ (dashed line). The slope of this line gives the required draw off rate (40.8 cumec) to produce a uniform power output of 22.5 MW. Through B and D, i.e., the crest and the trough draw tangents parallel to the dashed line OQ (BV || OQ). The vertical intercept between the two tangents DZ gives the required capacity of the reservoir as 100 Mm3.

Reservoir Water Level:

- **For short, deep reservoir, the reservoir water surface is level representing a reasonable assumption.**
- **If flow is passing the dam, there must be some slope to the water surface to cause this flow. When the cross sectional area of the reservoir is large compared with the rate of flow, the velocity will be small and the slope of the hydraulic grade line will be very flat.**
- **The computation of the water surface profile is an important part of reservoir design since it provides information on the water level at various points along the length of the reservoir from which the land requirements for the reservoir can be determined.**

Acquisition of land or flowage rights over the land is necessary before the reservoir can be built. Docks, houses, storm drain outlets, roads, and bridge along the bank of the reservoir must be located above the maximum water level expected in the reservoir.

Recently, computer programs are widely used in reservoir and river modeling such as HEC-RAS, MIKE11, and MIKE21 as well as the geographic information system (GIS).

Storage in reservoir subject to marked backwater effects cannot be related to water surface elevation alone. A second parameter such as inflow rate or water surface elevation on a gage near upper end of the reservoir must also be used. Storage volume under each profile can be computed from cross sections by the methods used for earthwork computations.