Water Supply and Sewerage Network

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Design of Water Distribution System

- *Hazen-William Equation*

$$Q = 0.849\, C\, A\, R^{0.63}\, S^{0.54} \qquad \textit{SI Units}$$

$$S = \frac{h_f}{L}$$

C … $Hazen\, William\, Coeff.$

$$Q = 1.318\, C\, A\, R^{0.63}\, S^{0.54} \qquad \textit{US Units}$$

The velocity of water (0.6-1.5) m/s or (2-5) ft/s

When C of the pipe is not equal to 100

$$Q_C = Q_{100} \frac{C}{100}$$

$$D_C = D_{100} \left(\frac{100}{C}\right)^{0.38}$$

$$S_C = S_{100} \left(\frac{100}{C}\right)^{1.85}$$

Typical Values of the Hazen-Williams Constant

Material	Minimum Value	Maximum Value
Polyvinyl chloride (PVC)	150	150
Fiber reinforced plastic (FRP)	150	150
Polyethylene	140	140
Cement, Mortar Lined Ductile Iron Pipe	140	140
Asbestos, cement	140	140
Copper	130	140
Cast iron – new	130	130
Galvanized iron	120	120
Cast iron – 10 years	107	113
Concrete	100	140
Steel	90	110
Cast iron – 20 years	89	100
Cast iron – 30 years	75	90
Cast iron – 40 years	64	83

Example:

Find the Head losses for 1000m length of pipe if D=500mm and the flow Q=0.25 m^3/s

C=130

$$S = \frac{h_f}{L} \qquad Q = 0.849\, A\, R^{0.63}\, S^{0.54} \qquad Q = 0.278\, C\, D^{2.63}\, S^{0.54}$$

$$0.25 = 0.278 * 130 * (0.5)^{2.63}\, S^{0.54}$$

$$S = 0.0029244 \qquad h_f = S * L = 0.0029244 * 1000 = 2.924m$$

$\underline{\boldsymbol{Using\ Monograph}}$

$$S_{100} = 2.8 * 10^{-3}$$

$$S_{130} = S_{100}\left(\frac{100}{130}\right)^{1.85} = 4.8 * 10^{-3}\left(\frac{100}{130}\right)^{1.85} = 2.95 * 10^{-3}$$

$$h_f = S * L = 1.73 * 10^{-3} * 1000 = 2.95\ m$$

Distribution Storage

Its purpose is to provide continuous water. Water tanks are storage containers for water, these tanks are usually storing water for human consumption. Water tanks exist in many forms and a variety of materials. Water tanks provide for the storage of drinking water, & fire fighting. The size of service reservoirs depend on the population served, but they must provide storage for at least 24-36 h. Such tanks must be watertight and sealed to ensure quality is protected. Each service reservoir serves a water supply zone, which can supply a maximum of 50000 people.

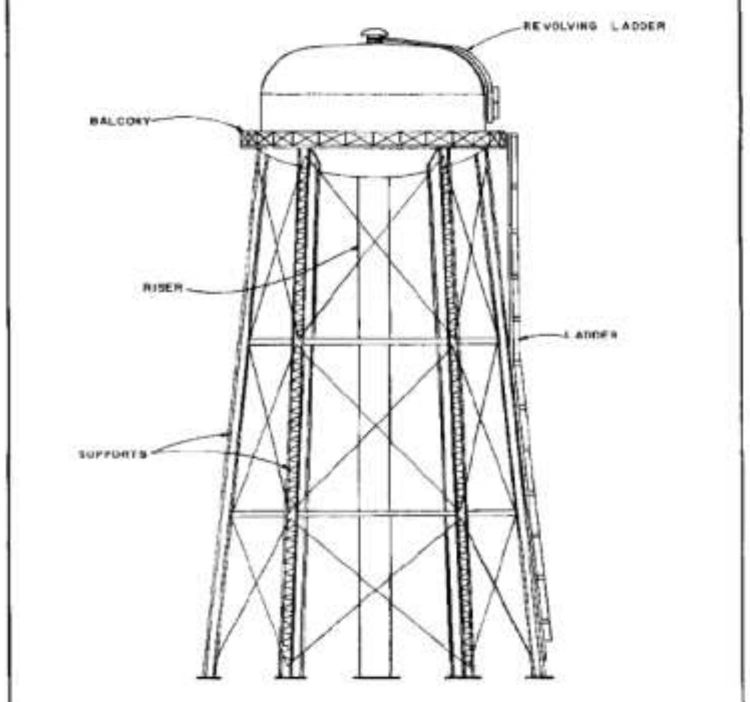
Storage Advantages

1. Demands on source, treatment, transmission & distribution are equal.
2. Reducing needed sizes & capacities.
3. Stabilized system pressure.
4. Control emergency, i.e. fire fighting & repairs.

❑ Elevated Tanks

Steel or Concrete, Capacity = 200–12,000 cubic meter, Provide pressure
Steel tanks exterior painted & need cathodic protection for interior.

Elevated tanks create a distribution pressure at the tank outlet of 1 psi per 2.31ft (0.7m) of elevation, thus a tank elevated to 70ft (21m) creates about 30 psi of discharge pressure, 30 psi is sufficient for most household requirements.



ELEVATED STORAGE TANK
U. S. Army Corps of Engineers

Stand Pipes

Steel, Above ground

Capacity ≈ 20,000 cubic meter

Height > diameter

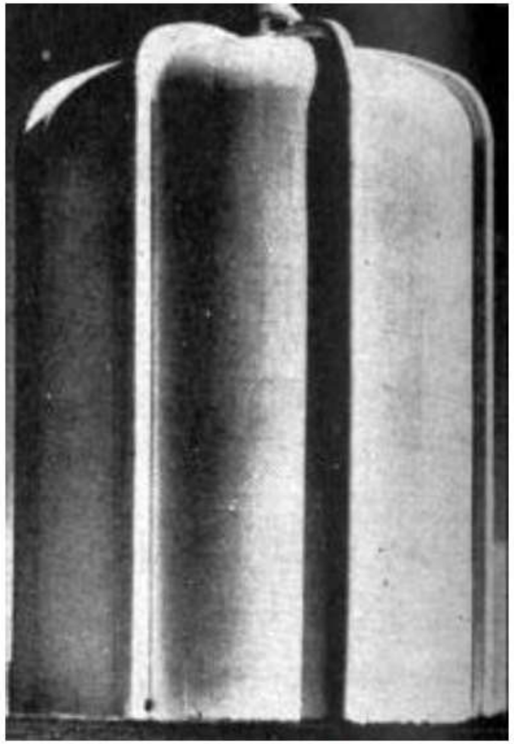
Underground or above ground basins

Concrete, Diameter > Height.

Choice between elevated & ground storage

1. Topography
2. Community size
3. Economics.

Underground basin



Stand pipe

Factors of storage design

The type of material used, and the design of the tank will be dictated by the following variables:

1. Location of the water tank (elevated or underground) Inside the city → elevated, Outside the city → above ground

2. What the water will be used for? e.g. Drinking need large storage, Gardens irrigation needs small storage.

3. How is the water to be delivered to the water tank? e.g. by gravity or pump.

4. Wind and Earthquake design considerations allow water tanks to survive seismic events) e.g. High wind → ground type, Earthquake zone → small volume & ground type

5. Volume of water tank will need to hold e.g. Large volume → ground, Small volume → elevated

Design of storage capacity

Example: Hourly demands on the day of maximum water consumption are given in Table below (Cols.1 & 2). Fire flow requirements are 190L/s for duration of 3h. *Plot the hourly water consumption rates. Calculate the distribution storage needed for both equalizing demand & fire reserve*.

Solution:

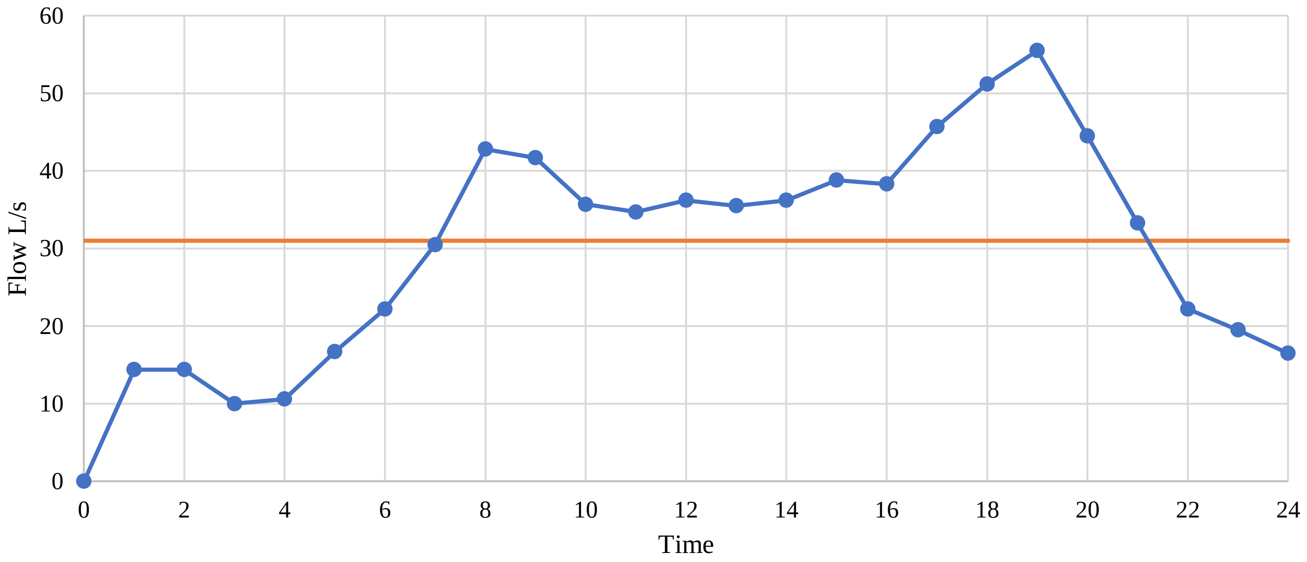
From the Table (Col.1-Col.2) → Plot Time-Consumption.

Average hourly consumption Pumping rate = 31L/s

If consumption < 31L/s → reservoir is filling

> 31L/s → emptying.

Storage volume with 31L/s pump rate = Area under the emptying or filling curve.



Time	Hourly Consumption		Cumulative Consumption
	L/s	L	L
0	0	0	0
1	14.4	51840	51840
2	14.4	51840	103680
3	10	36000	139680
4	10.6	38160	177840
5	16.7	60120	237960
6	22.2	79920	317880
7	30.5	109800	427680
8	42.8	154080	581760
9	41.7	150120	731880
10	35.7	128520	860400
11	34.7	124920	985320
12	36.2	130320	1115640
13	35.5	127800	1243440
14	36.2	130320	1373760
15	38.8	139680	1513440
16	38.3	137880	1651320
17	45.7	164520	1815840
18	51.2	184320	2000160
19	55.5	199800	2199960
20	44.5	160200	2360160
21	33.3	119880	2480040
22	22.2	79920	2559960
23	19.5	70200	2630160
24	16.5	59400	2689560
Average	31		

These areas are difficult to measure, so a mass diagram is used. … First, make Col.3& Col.4

From Table (Col.1-Col.4) → Plot Cumulative flow.

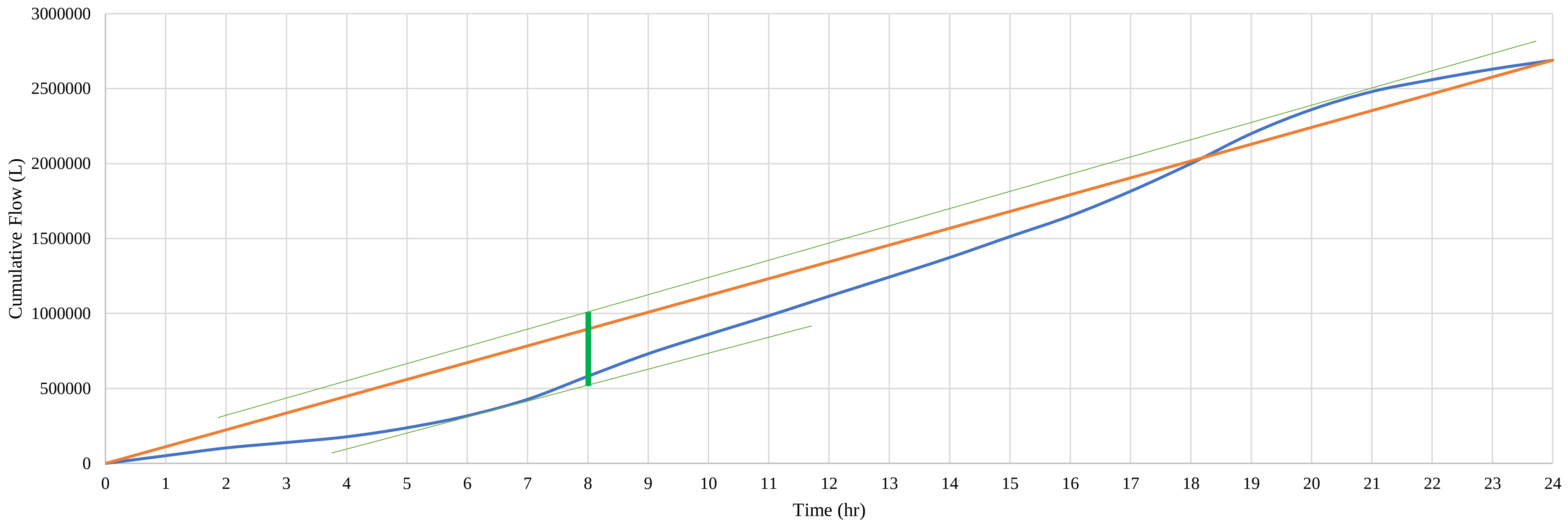
Plot a straight line connecting the origin & final point (cumulative pumping).

Construct lines parallel to cumulative pumping rate tangent to mass curve at high & low point.

Any vertical distance between these two parallel = storage capacity = 500m^3.

Fire storage = 190L/s × 3h * (3600s/1h) × (m^3/1000L) = 2050m^3.

Total storage capacity (24h pumping) = 500 + 2050 = 2550m^3.



Evaluation of a main pipe in network with and without Storage Tank

Design Example

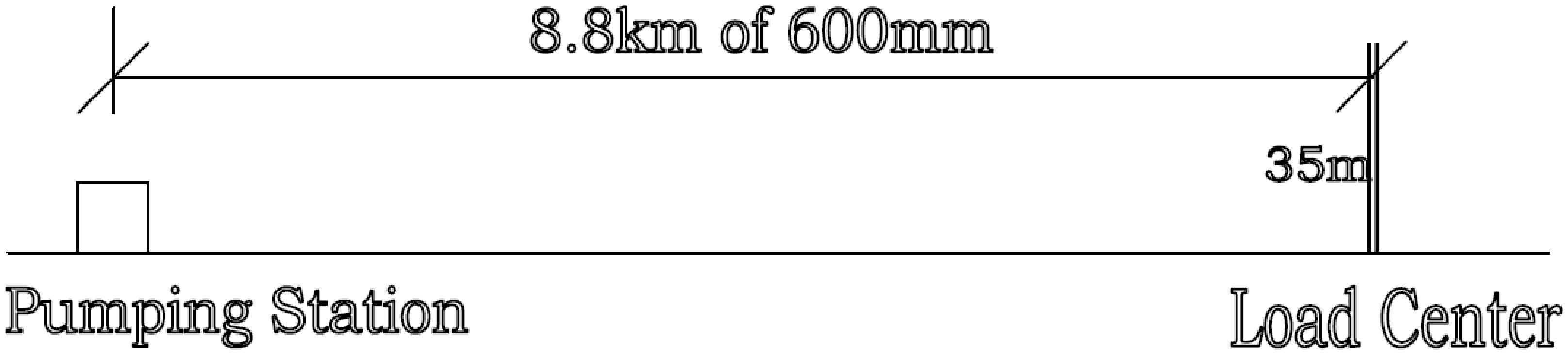
Consider a water supply system serving a city with:

- Average daily demand = 180L/s
- Max. daily demand = 270L/s
- Peak hourly demand = 405L/s.
- Required fire flow 320L/s resulting in a max. 5h rate of 590L/s (max. daily demand + fire flow).

The required min. pressure in the main city center is 35m (343kPa) except during fire flow & peak hourly. The piping system diameter is 600mm with Hazen Williams coefficient, C = 100. Distance between pumping station and city center is 8.8km.

a) Consider the system without storage

b) With storage beyond load center. Use storage = 3800m^3, with elevation = 36.5m, at 3km beyond load center & 11.8km from pumping station.



Solution

- *Without Storage:*

To find headloss in a pipe use Hazen-Williams formula, $Q = 0.278\,C\,D^{2.63}\,S^{0.54}$

Or use Nomograph for Hazen Williams Formula, ….. With Q & dia. → head loss.

- <u>At average daily demand (180L/s)</u>

Pumping head = 35 + (1.1 × 8.8) = 44m.

- <u>At max. daily demand (270L/s)</u>

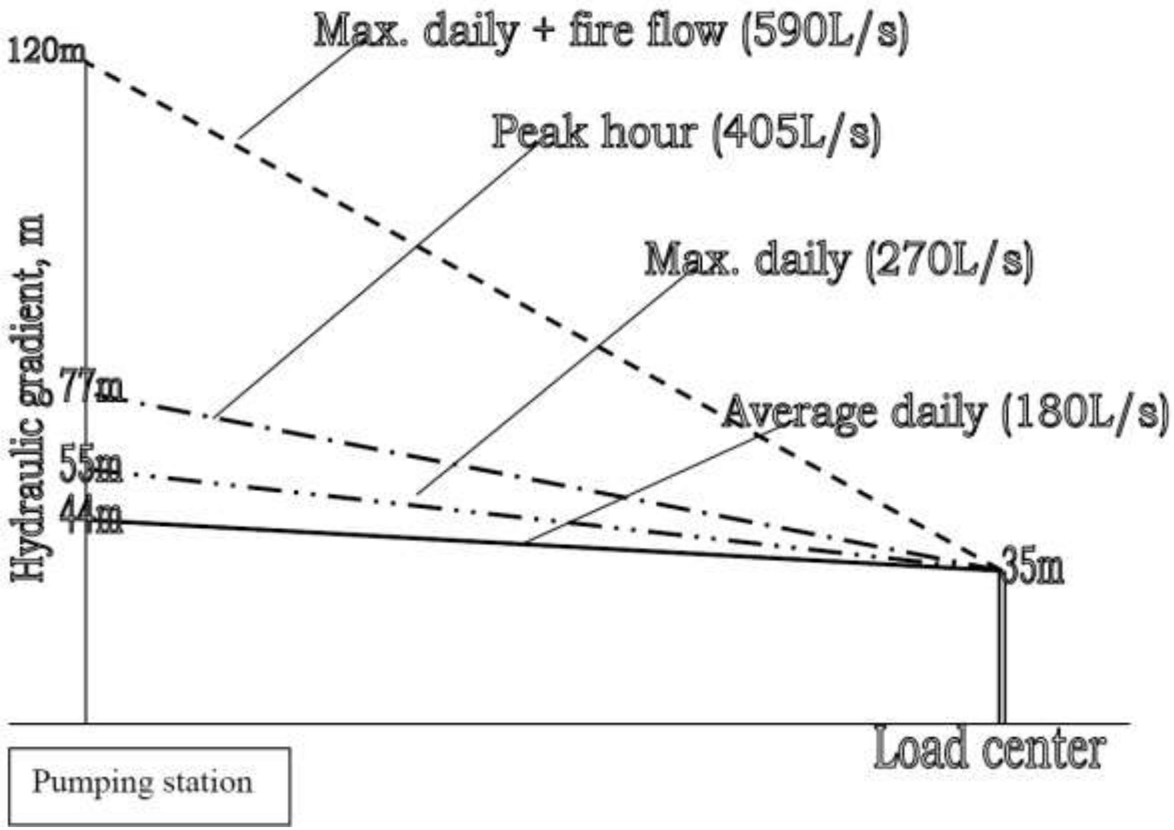
Pumping head = 35 + (2.3 × 8.8) = 55m.

- <u>At peak hourly demand (405L/s)</u>

Pumping head = 35 + (4.8 × 8.8) = 77m.

- <u>At max. daily demand + fire flow (590L/s)</u>

Pumping head = 35 + (9.6 × 8.8) = 120m.



- *With storage beyond load center:*

- ✓ **When no water is taken from storage:**

Pumping head = head at tank + head losses between pump & center.

- ✓ **When water is taken from storage:**

Pumping head = head at load center + head losses between pump & center.

- Average daily demand (180L/s)

Pumping rate = 180L/s with no water from storage

H.G.L at load center = H.G.L. at storage = 36.5m.

Pumping head = H.G.L. at load center + head losses in 8.8km = $36.5 + (1.1 \times 8.8) = 45$m.

- Max. daily demand (270L/s)

Pumping rate = 270L/s with no water from storage

Pumping head = H.G.L. at load center + head losses in 8.8km = $36.5 + (2.3 \times 8.8) = 57$m.

- Peak hourly demand (405L/s) > max. daily demand

Pumps design on max. day = 270L/s.

Pump rate = 270L/s. ……. 405 – 270 = 135L/s, taken from storage.

H.G.L. at load center = H.G.L. at tank – head losses in 3km pipe with Q = 135L/s.

$= 35 - (0.6 \times 3) = 33.2$m < 35m (only during peak hourly).

Pumping head = $33.2 + (2.3 \times 8.8) = 53$m.

Note: How to not be lower than 35m always?

- In case of fire (max. daily + fire flow) > max. daily demand

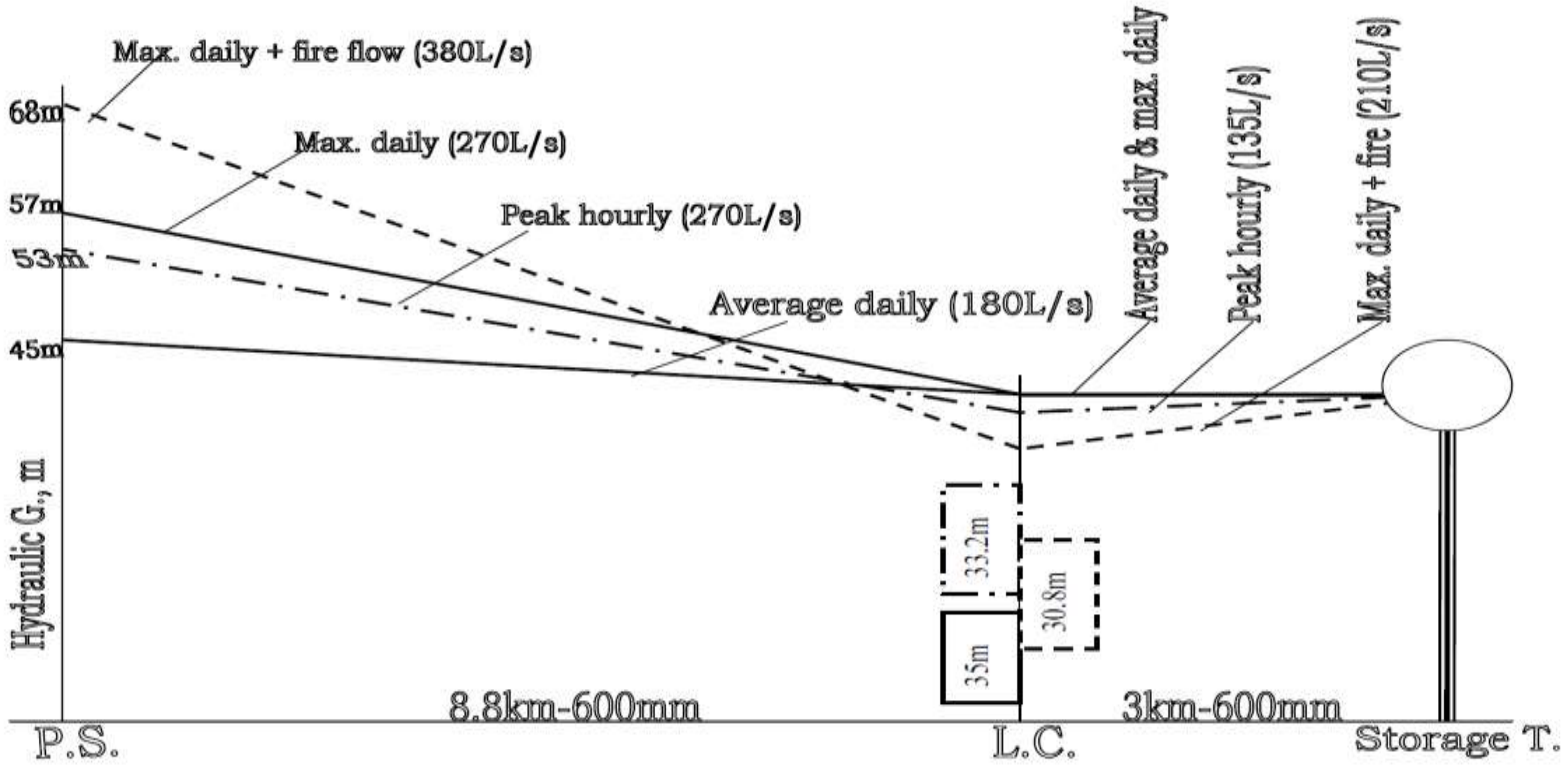
Discharge from storage = ($3800m^3$/ 5h)(1h/3600s)($1000L/m^3$) = 210L/s.

H.G.L. at load center = 35 – (1.4 × 3) = 30.8m < 35m (only during max. day + fire)

Pump rate = 590 – 210 = 380L/s > 270L/s. ….. Therefore, increases pump capacity to 380L/s.

Pumping head = 30.8 + 4.3 × 8.8 = 68m.

Or increase storage capacity to get 320L/s from storage.



Discussion: if we did not use storage, then high pumping head (120m) is required.

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