Forcemains and Wells

Recap Previous Lecture: Bernoulli and Hazen-Williams

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$h_f = \frac{10.675 \cdot L \cdot Q^{1.85}}{C^{1.85} \cdot D^{4.8655}}$$

Recap: Pressure

- The atmosphere contains gases that have a mass and therefore have weight.
- The total weight of the atmosphere exerts pressure on every surface with which it comes in contact with.
- At sea level, under normal conditions, the atmospheric pressure is approximately equal:

$$1.014 \times 10^5 \text{ N/m}^2 \text{ or Pa} = \underline{101{,}400 \text{ N/m}^2 = 14.7 \text{ lbs/in}^2}$$

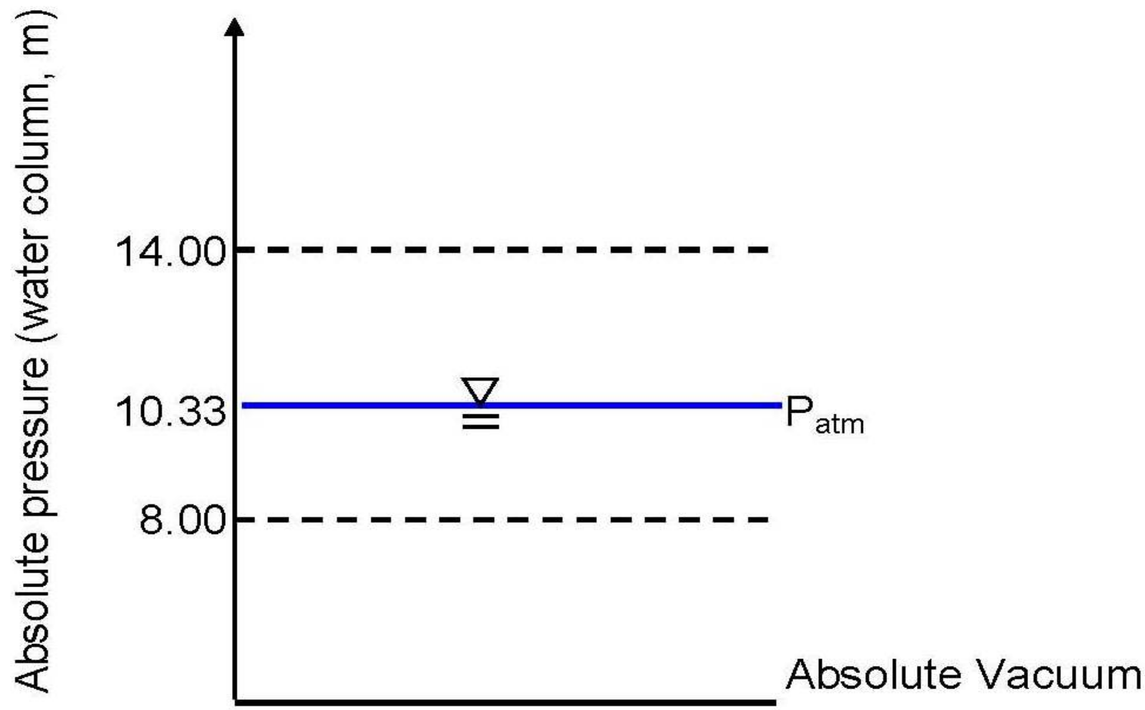
- A water surface in contact with the atmosphere (open vessel or lake) is subjected to atmospheric pressure. The pressure is equal to 10.33 m height of water at sea level. In water, any object below the water surface is subjected to a pressure greater than atmospheric pressure.
- One atmosphere can support a column of water 10.33 m high.
- The difference in pressure between two points in still water is always equal to the product of the specific weight of water and the difference in elevation between the two points:

$$\Delta P = \Upsilon h \ 101.234$$

Recap: Pressure Continued

- Pressure is defined as force per unit of area.
- For an object sitting on a surface, the force pressing on the surface is the weight of the object.
- Pressure (P) = Force (F) / Area (A)
- Pressure (P) = Energy / Volume

Pressure (Absolute)



- Pressure gauges are usually designed to measure pressures above or below the atmospheric pressure. (atmospheric pressure is the base)

Recap Continued

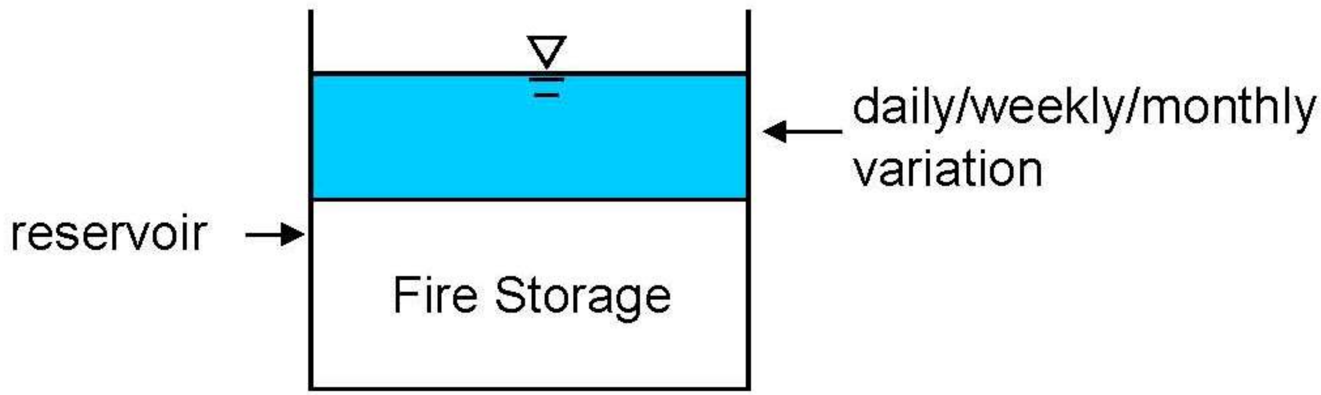
- *What is head? Why does it have units of length?* Head is energy per unit weight of fluid (i.e. Force x Length/Weight = Length).
- *Why is Pressure = 0 for a reservoir?* A reservoir is open to the atmosphere, so its gage pressure is zero.
- *Why is Velocity = 0 for a reservoir?* This is a common assumption in fluid mechanics and is based on the fact that a reservoir has a large surface area. Therefore, the water level drops very little even if a lot of water flows out of the reservoir. A reservoir may physically be a lake or a large diameter tank.
- *What is a "main" and a "lateral"?* A "main" is a large diameter water supply pipe that has many smaller diameter "laterals" branching off of it to supply supply water to individual residences, businesses, or sub-divisions. In fluid mechanics, we set V=0 for the main since it has a large diameter (relative to the lateral) and thus a very small velocity. To further justify the V=0 assumption, the main's pressure is typically high, so the velocity head in the main is negligible. The main is drawn such that it is coming out of your computer monitor.
- *What are minor losses?* Minor losses are head (energy) losses due to valves, pipe bends, pipe entrances (for water flowing from a tank to a pipe), and pipe exits (water flowing from a pipe to a tank), as opposed to a major loss which is due to the friction of water flowing through a length of pipe.

Storage, Fire Flow, Dry Wells, Wet Wells, and Forcemains

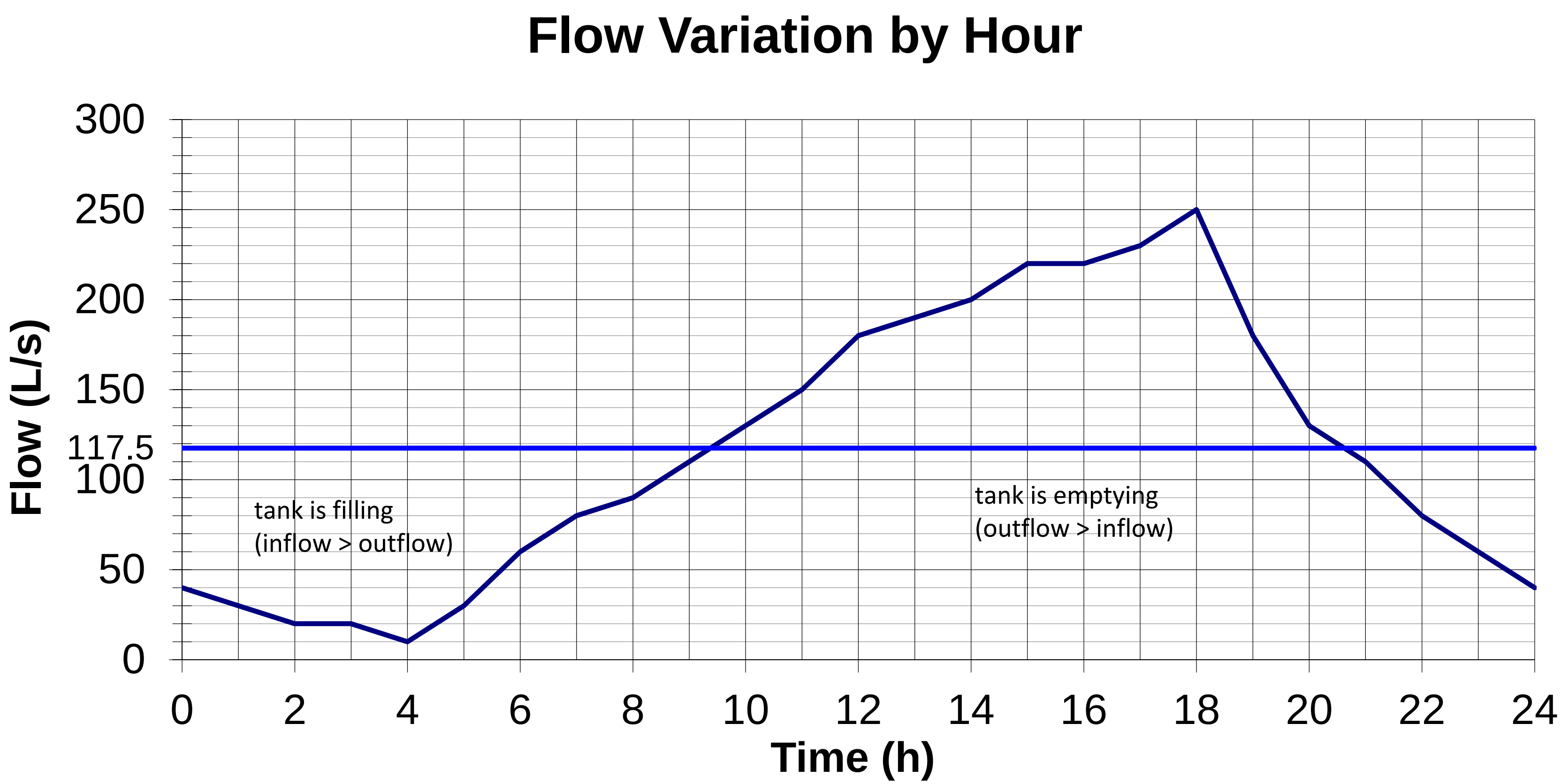
Storage

Reservoir

- Storage volume within a reservoir will vary due to daily/weekly/monthly variations in flow.
- majority of tank is actually for fire fighting flow



Flow and Storage Variation



Notice at approx. 9:20 am the tank is beginning to empty.

It continues to empty until approx. 8:40 pm when it starts to fill again.

Storage Calculation Example

Time h	Flow L/s	Flow m^3/h	Total m^3
0	40		
1	30		
2	20		
3	15		
4	10		
5	40		
6	70		
7	80		
8	100		
9	120		
10	135		
11	150		
12	180		
13	195		
14	210		
15	225		
16	240		
17	250		
18	265		
19	220		
20	180		
21	140		
22	80		
23	60		
24	40		

Town uses water at the rates shown. Determine the following:

a. Storage required for average daily use (based on population)

b. The average pump rate, L/s (24hr)

c. Approximate population

d. Fire Flow (L/s) and storage

Notes:

- population Consumption = 290 L/c/d
- Need 10 hours of storage for F.F.

Storage Calculation Example

Time	Flow	Flow	Total
h	L/s	m^3/h	m^3
0	40	0	0
1	30	126	126
2	20	90	216
3	15	63	279
4	10	45	324
5	40	90	414
6	70	198	612
7	80	270	882
8	100	324	1206
9	120	396	1602
10	135	459	2061
11	150	513	2574
12	180	594	3168
13	195	675	3843
14	210	729	4572
15	225	783	5355
16	240	837	6192
17	250	882	7074
18	265	927	8001
19	220	873	8874
20	180	720	9594
21	140	576	10170
22	80	396	10566
23	60	252	10818
24	40	180	10998

Solution:

a. Storage required for average daily use from the chart

b. The average pump rate (based on a 24 hour period)

- 10998 m^3 x 1000 / (24*60*60) = 127.3 L/s

c. Using a rate of 290 L/c/d

- 10998 m^3 =/ 0.290 m^3/cap/day
- Population = 37924 people

d. Fire Flow (L/s) and storage

- F.F. = 65√P(1.0 - 0.01√P)
- F.F. = 65 √ 37.92 x (1.0 - 0.01 √ 37.92)
- F.F. = 375.6 L/s
- F.F. = 0.376 m^3/s since
- Storage = 0.3763 m^3/s * 60 * 60 * 10 hours
- Storage = 13523 m^3

Fire Flow

- There are many equations for calculating fire flow:

$$F.F. = 65\sqrt{P} * (1 - 0.01\sqrt{P})$$

where: F.F. = Fire Flow (L/s)

P = population (in 1000's)

<u>Example</u>:

What would the Fire Flow be if Population is 2000 people?

$$F.F. = 65\sqrt{2} * (1 - 0.01\sqrt{2})$$

F.F. = <u>90.6</u> L/s

Forcemains

- Sanitary sewage pumping systems range in size from the small single pump private home unit to the pumping station serving small or medium size areas up to the main installation pumping all of the Municipality's sewage to a sewage treatment plant.
- Storm water pumping systems generally have high volume pumping capability and usually do not involve forcemains. These systems are usually located adjacent to a receiving stream or trunk gravity sewer conduit.
- The common applications:
  a) The pumping of sewage from a low area over a height of land to existing gravity mains.
  b) Raising of sewage from gravity mains whose outlets are below the receiving waters.
  c) Raising the sewage to provide a head of gravity flow through sewage treatment plants.

What is a force main?

a) Sewage is forced along a sewer pipe by the action of a pump.

b) The pipe must be below frost line

c) pipe is sized for a minimum velocity 0.8 m/s

d) max velocity 4.0 m/s

e) the forcemain should discharge into a manhole at the point of highest elevation of the forcemain and be drained by gravity flow.

Forcemains Cont’d

- If the power goes out then the sewage may overflow into a dry area or into a stream. To overcome this problem, there **<u>must</u>** be an additional source of power.
- Alternatives:
  - built in backup generator (gas/diesel operated)
  - ability to hook up a portable generator
  - pump sewage into truck and haul to another point into the gravity system

<u>Site Selection</u> What determines where a pumping station will be located?

a) Accessibility - must be close to the street with adequate parking for inspection and maintenance

b) Drainage - graded to ensure that surface drainage does not become a problem

c) Soil conditions - consider water table location - will it cause flooding, and is there bedrock because it is expensive to excavate

d) Power - must be available with an alternative during blackouts

e) Appearance - must fit into neighbourhood

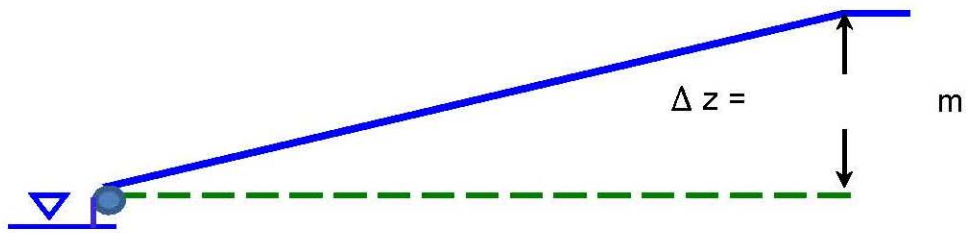
<u>Pump Design</u>

a) There must be 2 pumps.

b) Each pump alone must be capable of pumping the maximum flow. This allows for 1 pump to fail or be removed for repairs without any overflow issues.

c) Pump capacity required is based on peak flows, length of pipe and type of pipe used to calculate friction loss and pipe fittings losses.

Forcemain Example



- If a pump is located at elevation 151.0m and the outlet is at elevation 182.2m what is the static head (lift)?
- Static head = 182.2m – 151.0m = 31.2 m

Dry Well

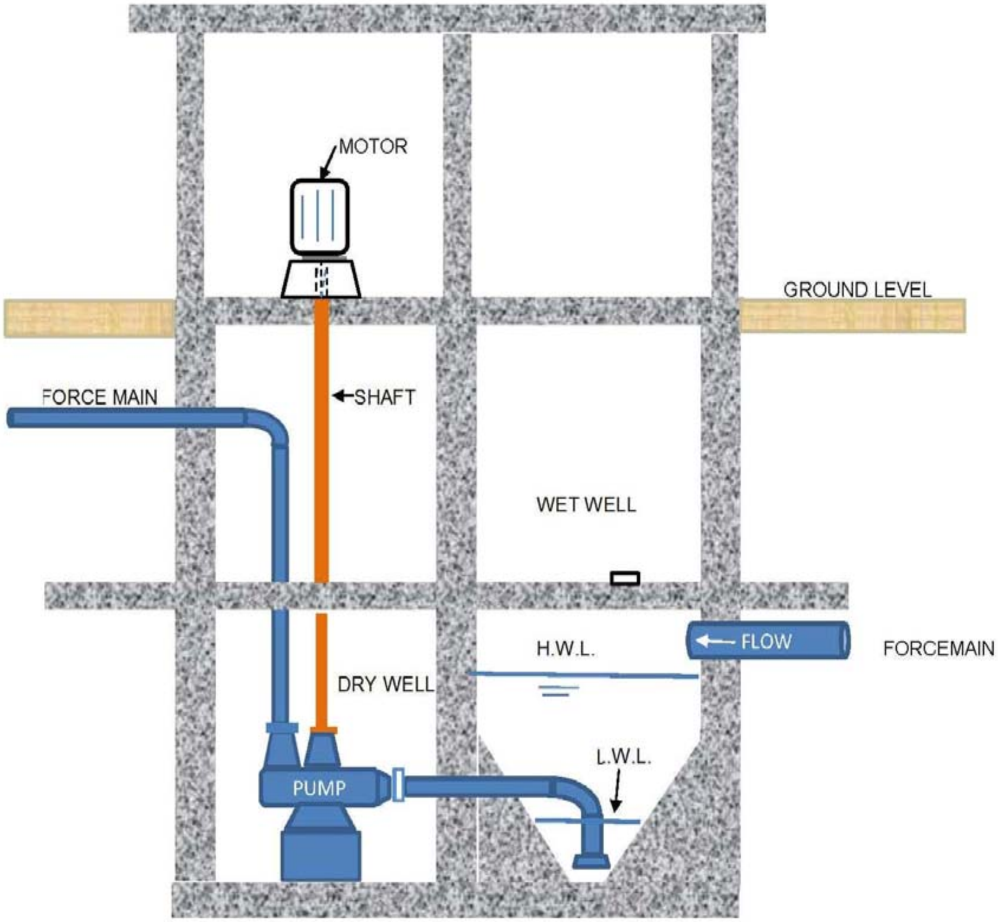


FIGURE 2: WET WELL/ DRY WELL

- sewage is collected in a separate well or pit from where the pumps, motors and controls are located.
- The two portions are isolated so that the only the connection is through the inlet pipes.

Wet Well

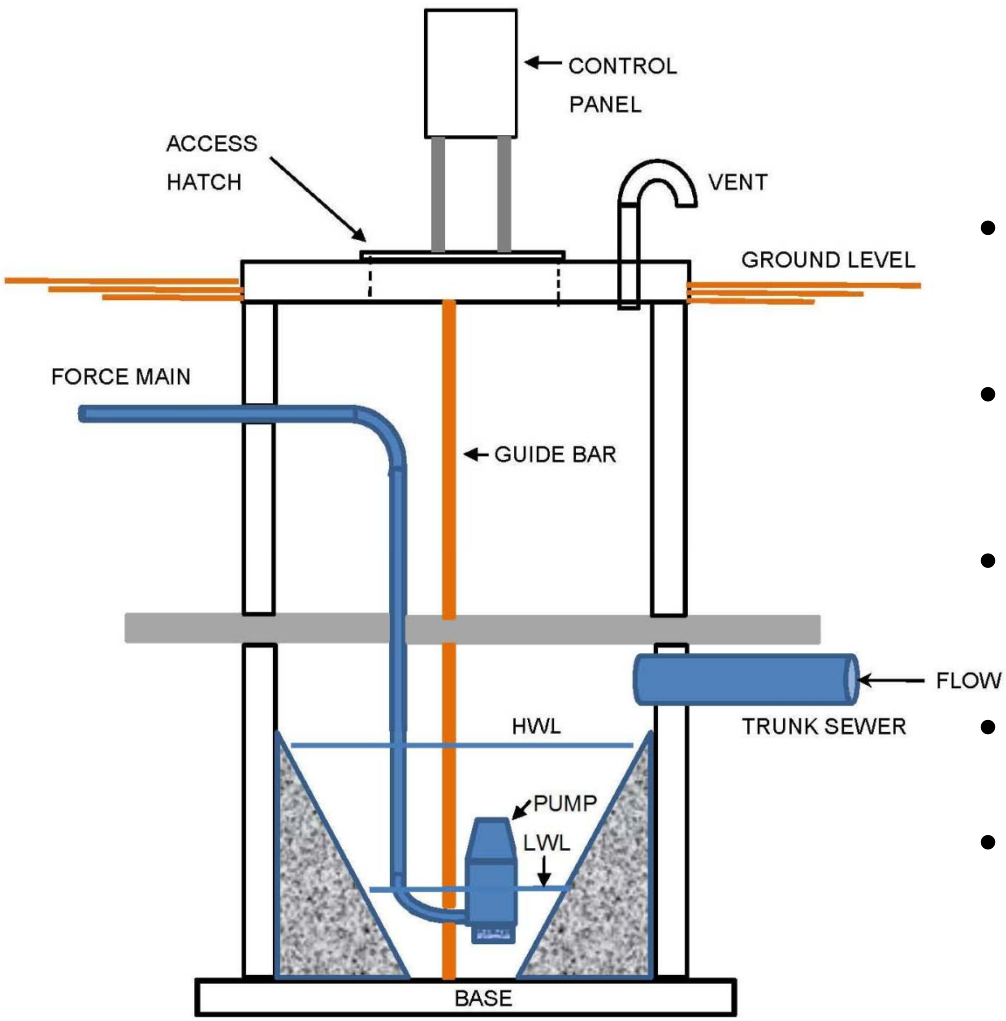


FIGURE 1: PRECAST WET WELL WITH SUBMERSIBLE PUMP

- pumps and motors are located in the same chamber into which the sewage flows.
- In some cases the motor is above the pump and drives the pump with a long shaft.
- submersible pump is more common (pump and motor in one sealed unit)
- usually used for small to medium type flows
- pumps and motors have to be lifted out for the inspection and maintenance

What is this?

Water Pumping Station in Ranleigh, North Carolina

Features:

- No driveway / parking
- No mailbox
- No garage

- Windows are blocked
- Lights never turn on
- Fake Air Conditioner

Uses sound dampening materials to mask noise