FAQ

This document intends to provide basic knowledge on topics dealt with in the course, and some modelling software tips.

Q: *What is the difference between pressure and head?*
A: Pressure is defined as force per unit area and is expressed as:

$$\Delta P = \rho g \Delta y \tag{1}$$

Where ΔP is increase of pressure, ρ is density of fluid, g is gravitational acceleration, and Δy is increase in depth.

At any section of the flowing fluid total energy consists of potential (usually elevation and pressure terms) energy and kinetic energy. The most common way to express total energy (a.k.a. the hydraulic head) is given by the Bernoulli equiation for inconmpressible fluids:

$$H = z + \frac{P}{\rho g} + \frac{v^2}{2g} \tag{2}$$

Where H is total (hydraulic) head, z is elevation head, $\frac{P}{\rho g}$ is pressure head, and $\frac{v^2}{2g}$ is velocity head. The concept is presented in Figure 1.

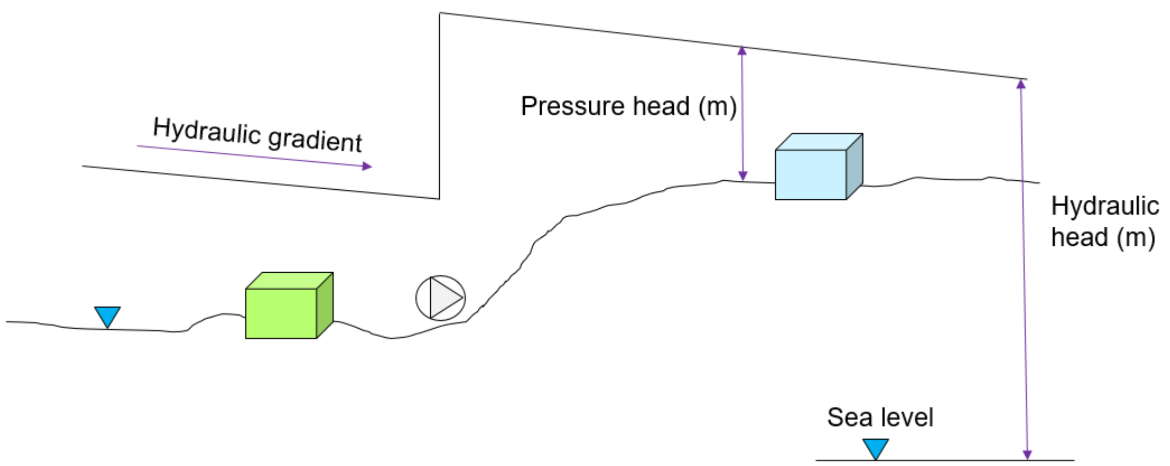

Figure 1: Concept of hydraulic head.

Q: *What is the difference between pressure and pressure head?*
A: Pressure head due to static pressure is a component of hydraulic head. It expresses the internal energy of a fluid as height of a water column that exerts pressure on the bottom of its container, and is expressed as:

$$\psi = \frac{P}{\gamma} = \frac{P}{\rho g} \tag{3}$$

Where ψ is pressure head (usually in meters), P is fluid pressure (force per unit area), γ is specific weight, ρ is density of fluid, and g is gravitational acceleration.

Q: *What is a head loss?*
A: When a liquid flows in pipes, some energy (head) is dissipated:

$$H_1 - h_L = H_2 \tag{4}$$

or

$$z_1 + \frac{P_1}{\rho g} + \frac{v_1^2}{2g} - h_L = z_2 + \frac{P_2}{\rho g} + \frac{v_2^2}{2g} \tag{5}$$

Energy losses include friction losses caused by forces between liquid and pipe solid boundary and local losses caused by disruptions of flow due to bends and changes in cross-section. Estimation of friction losses is important in hydraulic design, and it can be done using Darcy-Weisbach equation:

$$h_f = f \frac{L}{D} \frac{v^2}{2g} \tag{6}$$

Where h_f is head loss due to friction, f is friction factor, L is pipe length and D is pipe diameter. The term $\frac{h_f}{L}$ is the hydraulic gradient, which describes the direction of flow. The Manning equation, the Darcy-Weisbach equation, and the Kutter-Chézy equation are the most commonly used methods for computing head losses in sewers. Slope and energy relationship are depicted in Figure 2.

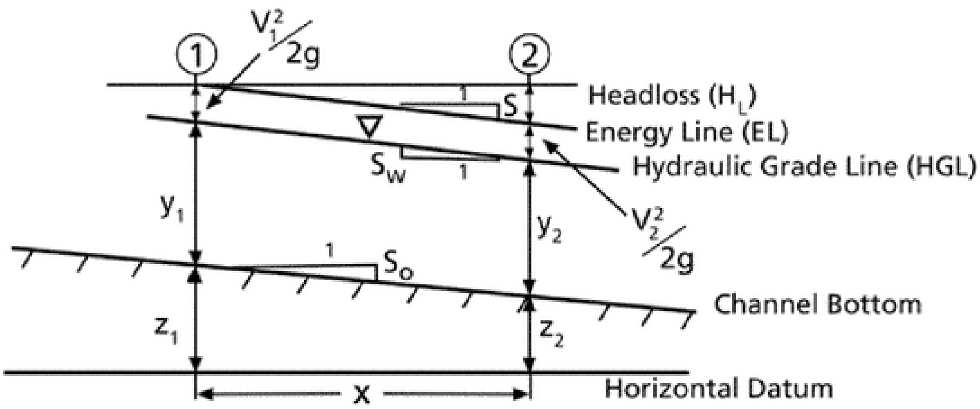

Figure 2: Slope and energy relationships for open-channel flow.

Q: *What is the difference between absolute and gauge pressure?*
A: Absolute pressure is the pressure measured with absolute zero (a perfect vacuum) as its datum, i.e. absolute pressure is relative to a vacuum. Gauge pressure is the pressure measured with ambient atmospheric pressure as its datum, i.e. gauge pressure is relative to atmospheric pressure. The two are related by $P_{abs} = P_{gauge} + P_{atm}$. Gauge pressure is used in most hydraulic calculations.

Q: *What is roughness?*
A: In turbulent flow, velocities are rather similar across most of the cross-section. However, in the zone very near the pipe wall, velocities fall rapidly and a boundary layer with laminar conditions occur: *a laminar sub-layer*. Frictional losses are affected by the thickness of the laminar sub-layer relative to the roughness of the pipe wall, which is measured in terms of equivalent sand roughness size (k_s). Roughness values are related to pipe type and age. The term k_s/D denotes relative roughness, which is used for determination of friction factor from the Colebrook-White equation:

$$\frac{1}{\sqrt{f}} = -2\ log\left(\frac{k/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right) \tag{7}$$

Q: *What is wetted perimeter and hydraulic radius?*
A: Wetted perimeter is a portion of the flow area's perimeter that is in contact with the channel. Hydraulic radius R_h is defined as the ratio of area A (cross-sectional area of flow) to wetted perimeter P for the cross section (for full circular pipes):

$$R_h = \frac{A}{P} = \frac{\pi D^2/4}{\pi D} = \frac{D}{4} \tag{8}$$

Q: *What do pressure zones mean?*
A: Water distribution systems work best with minimal fluctuations in pressure. Requirements determine the maximum and minimum ground elevations that can be supplied. The minimum pressure establishes the highest ground elevation that can be supplied, and the maximum pressure defines the lowest ground elevation. The former criterion ensures that the highest customers will be supplied with at least the minimum pressure, while the latter ensures that the lowest customers will not experience objectionably high pressures (Figure 3).

To supply water at acceptable pressure, the distribution system is thus divided into a number of distinct pressure zones. The maximum change in elevation across each zone is determined by the difference between the maximum and minimum design pressure values. Adding new pressure zones or adjusting existing pressure zone boundaries is needed when pressure differentials are outside their desirable values. Pressure zone boundaries are delineated through the use of closed valves.

To improve reliability, pressure-regulating valves (or pumps) are normally installed between the zones (along the pressure zone boundaries), and stretches of new pipe are added to eliminate dead ends. Proper design of pressure zones reduces leakage and pipe breaks, and pumping costs.

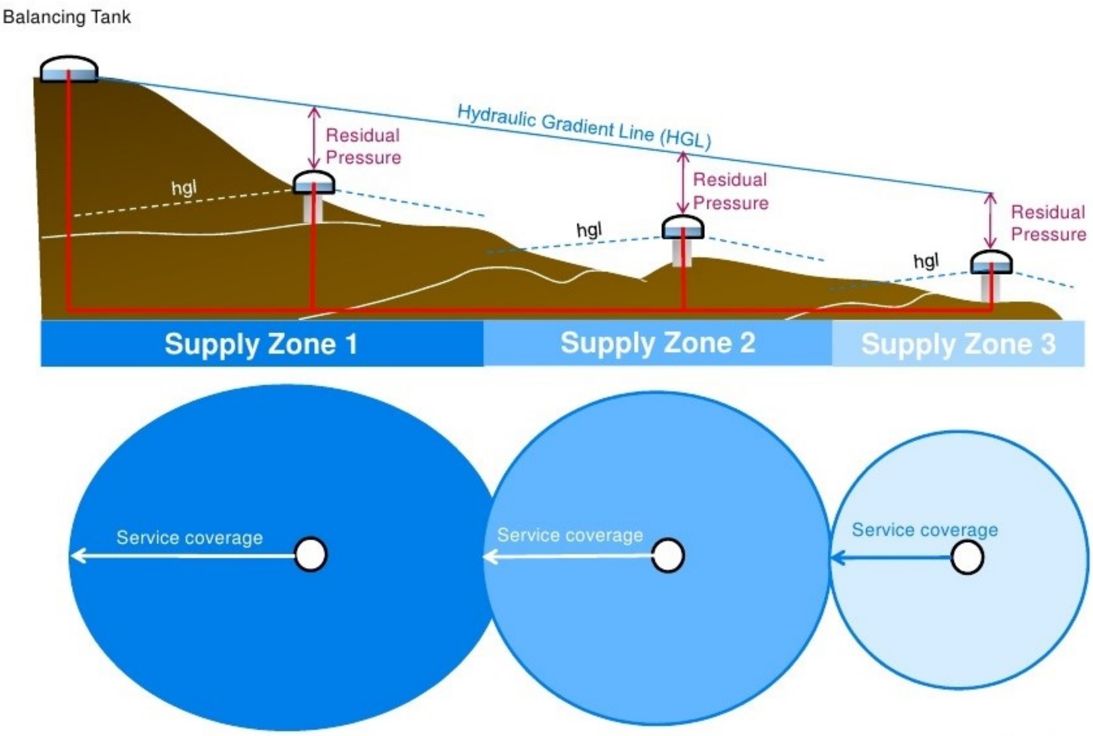

Figure 3: Pressure zones.