LANDING

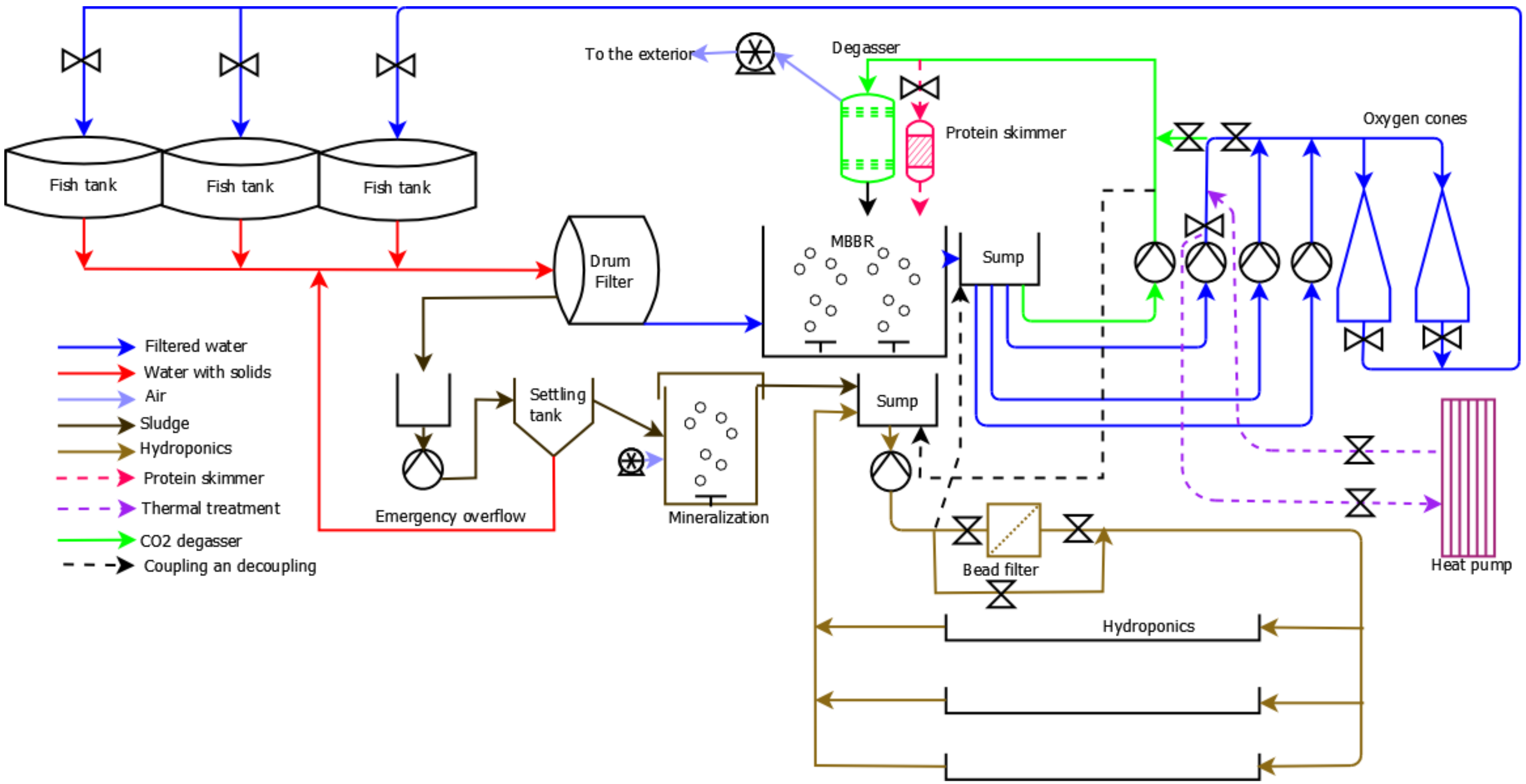
AQUACULTURE

WHAT WILL YOU TAKE HOME:

- How water moves in an aquaponic system
- What can we use to move water around
- How to calculate energy losses in pipes
- Basic design and engineering considerations

LANDING AQUACULTURE

...FROM YESTERDAY



LANDING AQUACULTURE

MOVING WATER AROUND

- By gravity
  - No electricity required
  - Head needed (elevation so water can run "down")
  - Gentle on solids in the water – no pumps grinding things down
  - …at some point, you need to lift the water again and start over

- By pumping
  - Uses electricity
  - You can lift of water as much as you need
  - Flexible for water treatment that requires pressure
  - Breaks down solids

LANDING AQUACULTURE

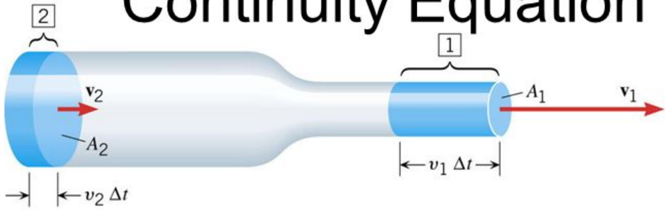
WATER PROPERTIES

- Subject to pressure (bar, PSI)
- Fluid mechanics = statics (water without motion
- Fluid dynamics= water in motion
- An incompressible fluid

Property	H_2O	D_2O
Molecular mass	18.015	20.028
Melting Point (K)	273.2	276.8
Boiling-Point (K)	373.2	374.4
Temperature of Maximum Density (K)	277.1	284.4
Maximum Density ($g\ cm^{-3}$)	1.000	1.106
Density ($g\ cm^{-3}$)	0.997	1.104
Heat of Vapourization (373 K) (kJ/mol^{-1})	40.66	41.61
Heat of Fusion ($kJ\ mol^{-1}$)	6.01	6.28
Specific Heat ($J\ g^{-1}\ K^{-1}$)	4.177	------
Ionization Constant, $[H^+][OH^-]$ ($mol^2\ L^{-2}$)	1.008×10^{-14}	1.95×10^{-15}
ΔH_f° $kJ\ mol^{-1}$)	- 285.9	-294.6

LANDING AQUACULTURE

Continuity Equation



$$\rho_2 A_2 v_2 = \rho_2 A_1 v_1$$

Same, incompressable, fluid so roe drops out!

$$A_1 v_1 = A_2 v_2$$

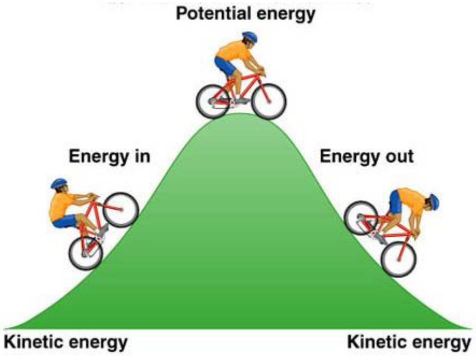
- Applied to pipes:
- Q=VA
- Where
- Q= flow (m3/s)
- V= velocity (m/s)
- A= cross sectional area of the pipe

$$A = \pi r^2$$

FROM THE LAW OF CONSERVATION OF ENERGY:

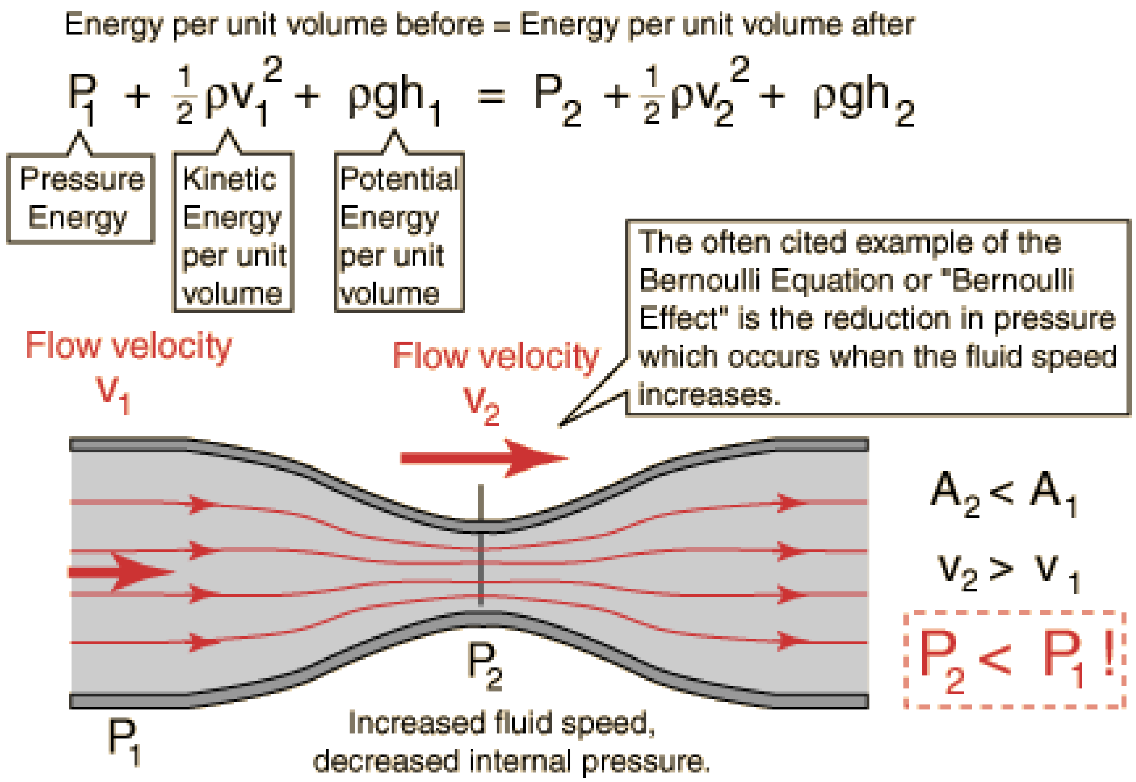
- Three main energy components:

1. Potential energy due to elevation
2. Potential energy due to pressure
3. Kinetic energy due to movement



LANDING
AQUACULTURE

THE BERNOULLI EQUATION



LANDING AQUACULTURE

LAW OF CONSERVATION OF ENERGY

$$E_1 + E_{added} = E_2 + E_{lost} + E_{extracted}$$

E_{lost} = energy lost due to the friction of the water rubbing against the pipe walls.

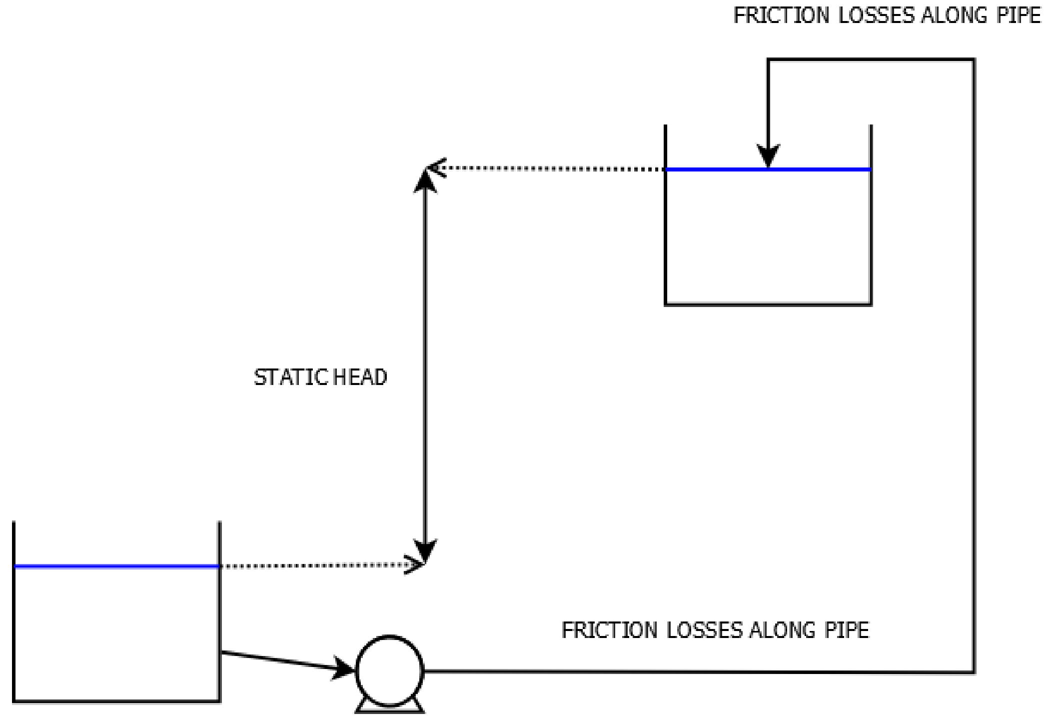
“Lost” actually means converted to heat due to friction

LANDING AQUACULTURE

- The pumps add energy:

1. Pressure and velocity
2. Elevate the water

- Friction subtracts energy



WE KNOW HOW HIGH WE WANT TO PUMP…SO HOW DO WE COMPENSATE FOR FRICTION?

$$h_{\mathrm{m}} = \frac{fLV^2}{2gd}$$

f	Friction coefficient (pipe material specific)
L	Length of pipe
V	Velocity in pipe
g	Acceleration due to gravity
d	Pipe diameter

Darcy – Weisbach equation for pipelines

LANDING AQUACULTURE

Calculate the head loss in an old PE pipe with Internal diameter of 110 mm (0.11 m). The length of the pipe is 500 m and the velocity in the pipe is 1.5 m/s; the friction coefficient is 0.030.

$$h_m = \frac{fLV^2}{2gd}$$

$$h_m = \frac{0.030 \times 500 \times 1.5^2}{2 \times 9.81 \times 0.11}$$

$$h_m = 11.47\,\text{m}$$

….BUT PIPE SYSTEMS HAVE BENDS AND TURNS

$$H_t = kV^2/2g$$

k Friction coefficient (fitting-idependent)

V Velocity in pipe

g Acceleration due to gravity

Water must flow through a 90° elbow: either two 45° elbows or one 90° elbow with k values of 0.26 and 0.9, respectively, can be used to achieve this. The flow velocity is set to 1.5 m/s. Calculate the head loss in the two cases.

For the two 45° elbows:

$$H_t = \Sigma k V^2 / 2g$$
$$H_t = \left(2 \times 0.26 \times 1.5^2\right) / 2 \times 9.81$$
$$H_t = 0.06\,\text{m}$$

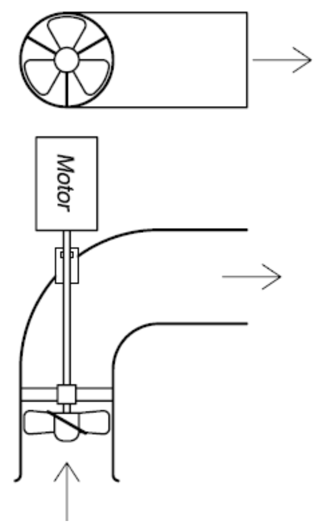
For the 90° elbow:

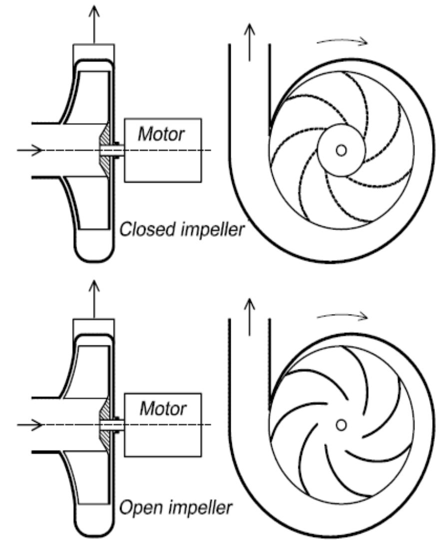
$$H_t = k V^2 / 2g$$
$$H_t = \left(0.9 \times 1.5^2\right) / 2 \times 9.81$$
$$H_t = 0.10\,\text{m}$$

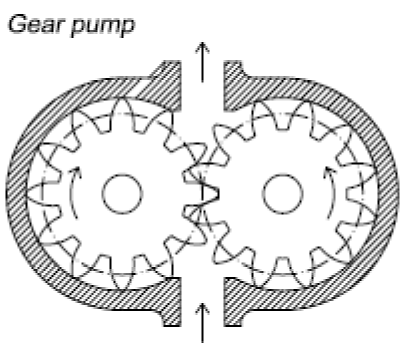
PUMPS

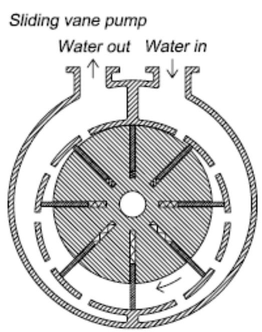
- Remember: pumps add energy

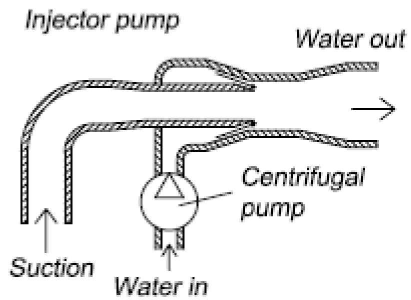
1. Pressure and velocity
2. Elevate the water

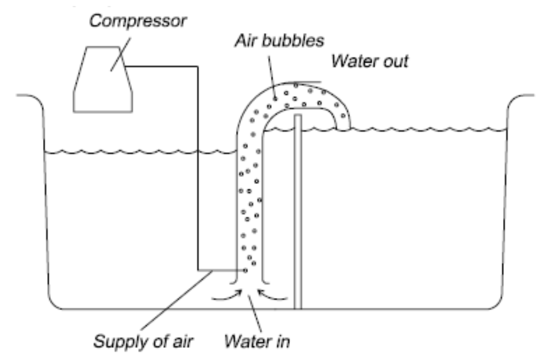




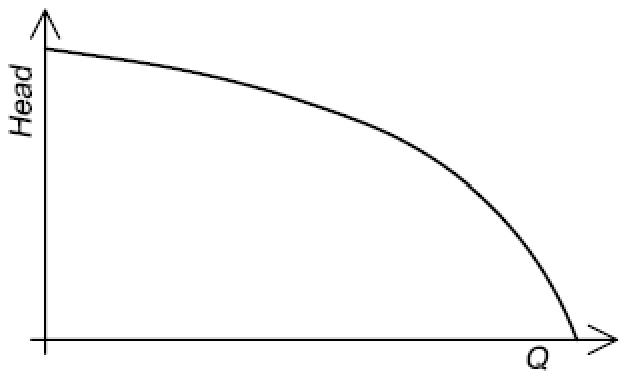


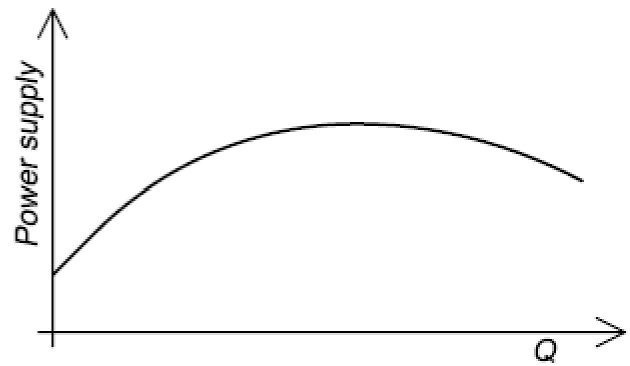


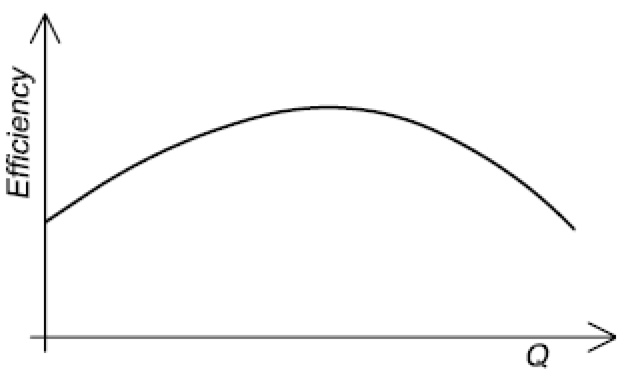


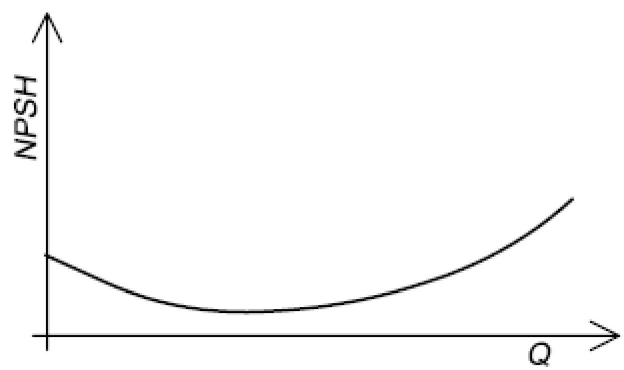


PUMP PERFORMANCE

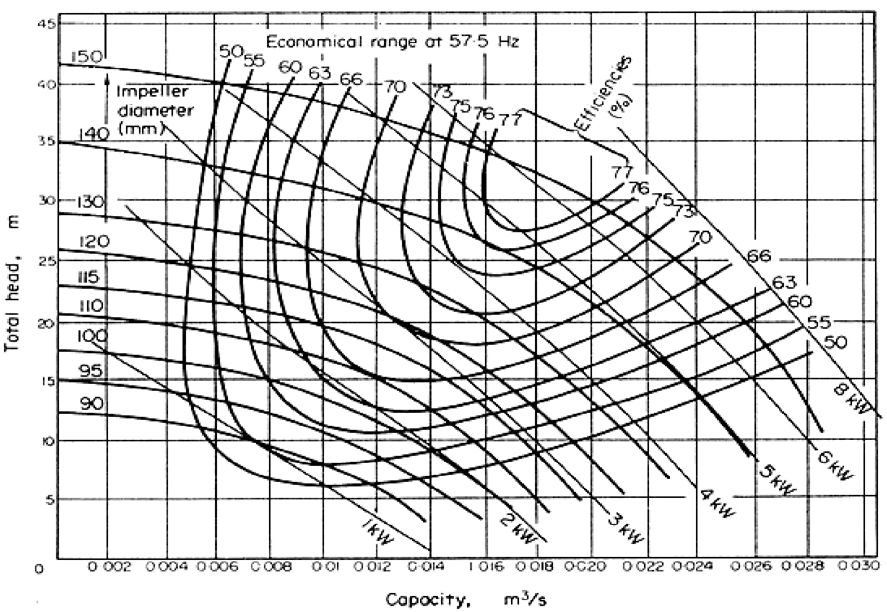


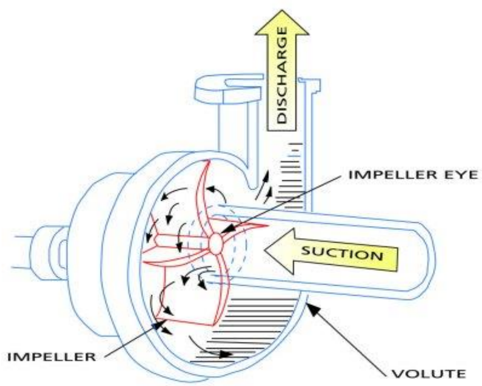


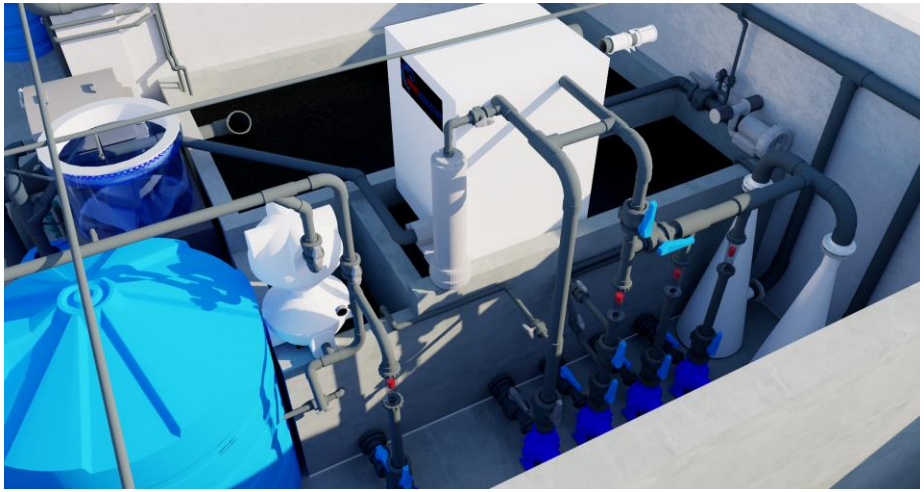


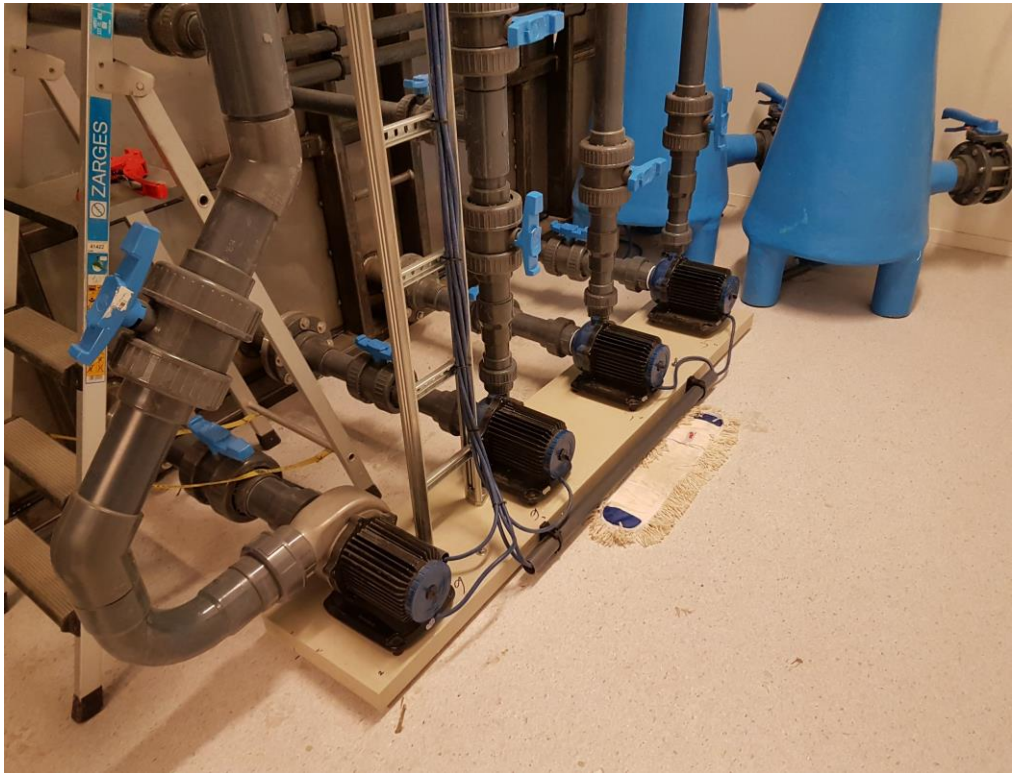


IN AQUAPONICS, MOSTLY CENTRIFUGAL PUMPS









LANDING
AQUACULTURE

DESIGN ADVICE FOR SMALL SYSTEMS

Decide your flows

- 1-2 system volumes per hour, normally
- If you want to be more accurate, do a mass balance

Decide how high you want to pump

- Make some drawings and sketches
- Take measurements
- Remember: pumping height is from the water level at the pump reservoir to the highest water level in the system
- Calculate your head losses for pipes and fittings

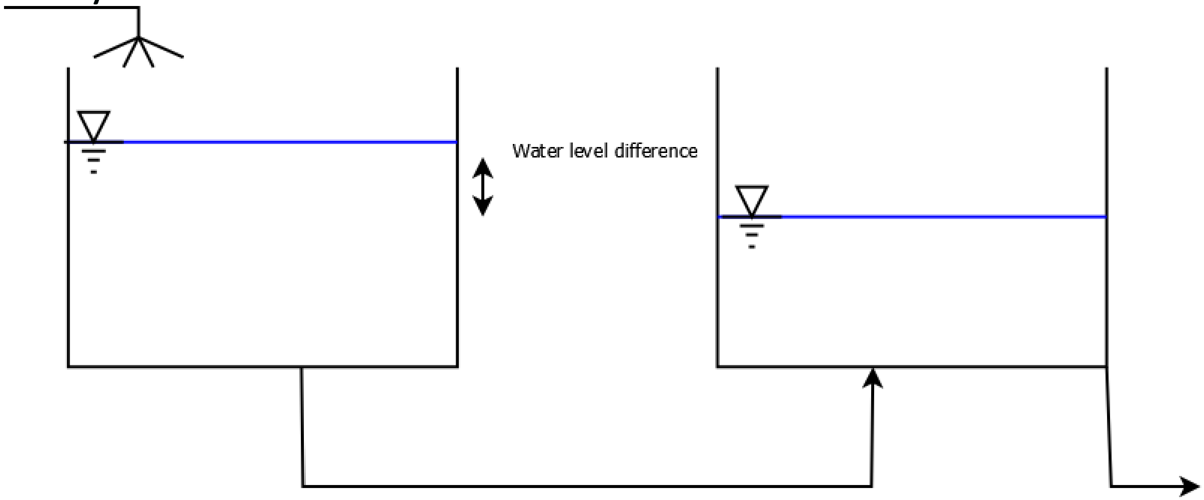
Flow velocity guidelines (remember the continuity equation!)

1. For gravity flows, water velocities between 30 cm per second and 100 cm per second are useful.
2. For pumped flows, water velocities between 100 cm and 200 cm per second are enough.

LANDING AQUACULTURE

DESIGN ADVICE FOR SMALL SYSTEMS

Gravity flow and water levels – connected tanks



The water level difference = the friction losses in the pipe connecting the two tanks

- More water level difference = more velocity = more flow
- More velocity = more friction, but generally not so important if pipes are not long
- More flow = more velocity = more friction = more water level difference

LANDING AQUACULTURE

DESIGN ADVICE FOR SMALL SYSTEMS

Gravity flow and water levels – connected tanks

To find how flow changes as you increase head (or level difference)

$$V\left(\frac{m}{s}\right) = \left(\frac{Available\ Head(cm) * 2 * 9.81\ (\frac{m}{s^2})}{100 * Dynamic\ heads\ required\ (unitless)}\right)^{0,5}$$

Assume 1 fitting = 1 dynamic head, then:

Continuity equation:

- Q=VA

- Where
- Q= flow (m3/s)
- V= velocity (m/s)
- A= cross sectional area of the pipe

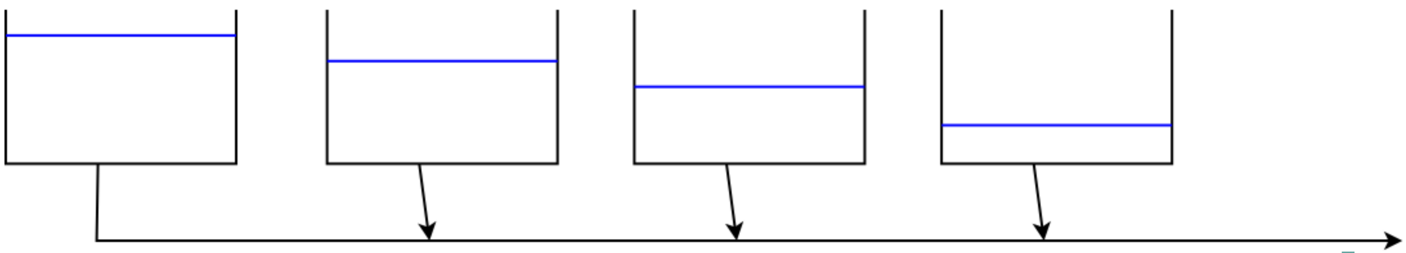
$$\boldsymbol{A = \pi r^2}$$

LANDING AQUACULTURE

DESIGN ADVICE FOR SMALL SYSTEMS

Interconnected tanks – implications

Flow added to pipe



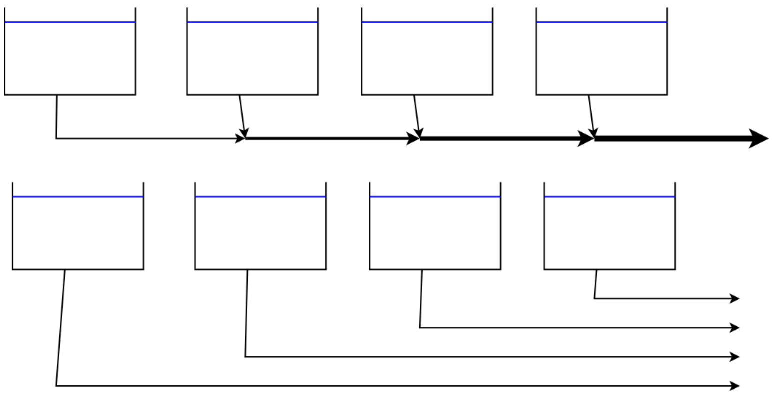
Friction losses

LANDING AQUACULTURE

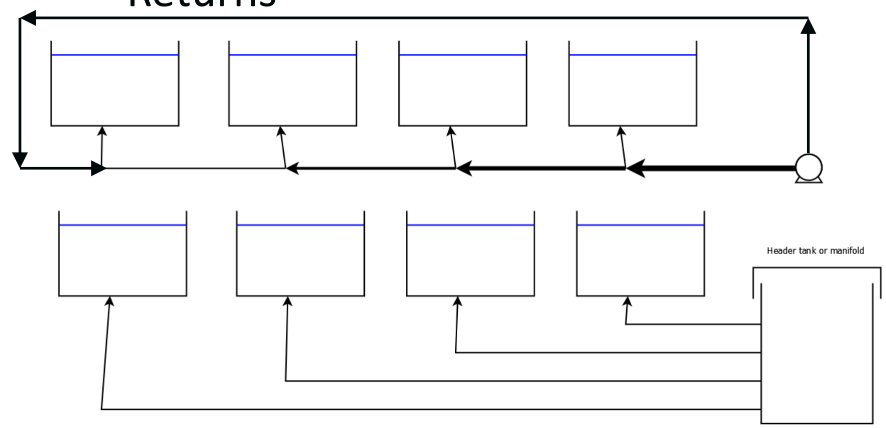
DESIGN ADVICE FOR SMALL SYSTEMS

Interconnected tanks – solutions

Drains



Returns



DESIGN ADVICE FOR SMALL SYSTEMS

Final comments:

Pipe velocities are your most important design factor

In small systems, low velocities and short length of pipes = very small friction losses

Avoid complex pipe networks

The equations work mostly on single pipe lines. If you have many pipes connected and interacting, you will need special software

Bigger, simpler pipe is more expensive upfront, but more energy efficient and simpler to control

LANDING AQUACULTURE