Water Resources Design Task

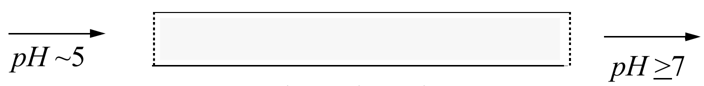
1.101 Fall 2006

Design strategies.

$1 \text{ psi} = 6.895 \times 10^3 \text{ Pa}$

$$Q = KA \cdot \frac{\Delta h}{\Delta x}$$

$ma = F$



$$Q = \frac{nV}{T_r} = \frac{nAL}{T_r}$$

$$h = z + \frac{p}{(\rho g)}$$

1” white PVC pipe	\$0.49
1” clear PVC pipe	\$2.66
2” clear PVC pipe	\$5.56
3” clear PVC pipe	\$11.99
4” clear PVC pipe	\$18.06

$$A = \pi \cdot D^2 / 4$$

1 psi = 70 cm water

1 gal = 3.8 liters

1 Kg weighs 2.2 lb. (on earth)

Where to start?....

What’s given?.... What info. do I need?

What’s do I want to get out, to “size”?

Start: read the “requirements”

- *pH* of the water delivered at the tap is to be 7 or higher.
- Decrease in flow rate at the tap (or shower head) is to be tolerable, if not go unnoticed.
- Pressure drop is not to exceed 15% of the supply pressure.
- System should not leak
- Space needs should not be excessive

Deduce, construct a list of "specifications"

- *pH* of the water delivered at the tap is to be 7 or higher.

What is the *pH* of the water at the source? Test protocol says *pH* = 5. (See Prof. Gschwend's lecture also).

- Decrease in flow rate at the tap (or shower head) is to be tolerable, if not go unnoticed.

What does this mean? What is a household flow rate? Estimate (guess), measure, look up.

- Pressure drop is not to exceed 15% of the supply pressure.

What is an ordinary supply pressure? How high is Payson Park holding resevoir relative to Cambridge? Look up. Note that test protocol specifies 40-60 psi.

Design parameters:

Q: the flow rate $<L^3/T>$ Specified - a user requirement, a "given"

$\boldsymbol{T_r}$**:** residence time $<T>$ Crudely Specified - a system requirement

n*:* material porosity Specified - a material(s) property.

K: conductivity $<L/T>$ Specified - a material(s) property.

A: pipe xsect. area $<L^2>$ To be determined, chosen.

L: pipe length $<L>$ To be determined, chosen.

D: pipe diam $<L>$ To be determined, Note: Choose from 4 options

h: total "head" $<L>$ Δh is specified to be less than some number.
a user requirement.

z: height of in, out. $<L>$ To be determined, chosen.

ρ***g***: weight density of water $<M/(L^2T^2)>$ A given value.

p: water pressure $<M/(LT^2)$ Given at inlet.

“Sizing” the system.

A popular method:

Choose a material, e.g., C33. This sets the porosity, n, and residence time (roughly) $\boldsymbol{T_r}$

With a flow rate, $\boldsymbol{Q}$, specified, from $\boldsymbol{Q = \frac{nAL}{T_R}}$ find the volume of pipe required = $\boldsymbol{AL}$

Choose a diameter, $\boldsymbol{D}$, one of 4 discrete options.

Determine $\boldsymbol{A}$, then form above, the required length $\boldsymbol{L}$.

If L> 1000 meters, check for errors (units?, calculations?).

If L> what you think is reasonable but not outlandish, try another material, or try a smaller residence time. (Remember, only crudely specified). Or try a bigger pipe area (if available).

Not finished; need to make sure pressure drop is below 15% of source pressure.

From $\boldsymbol{Q = KA \cdot \frac{\Delta h}{L}}$ determine $\Delta \boldsymbol{h}$ the system will experience.

If too big, check for errors, etc.

If ok, check cost. Any other options?

A more “complete” method.

From $\boldsymbol{Q = KA \cdot \frac{\Delta h}{L}}$ “solve” for L. $\boldsymbol{L = KA \cdot \frac{\Delta h}{Q}}$

Now specifiy our user friendly flow rate as some minimum value, $\boldsymbol{Q_{min}}$

So we want $\boldsymbol{Q > Q_{min}}$ **and** at the extreme situation when $\Delta \boldsymbol{h}$ is at maximum tolerable value (15% of supply pressure) $\Delta \boldsymbol{h}_{\text{max}}$

This two settings and Darcy’s equation give an upper bound on the length L

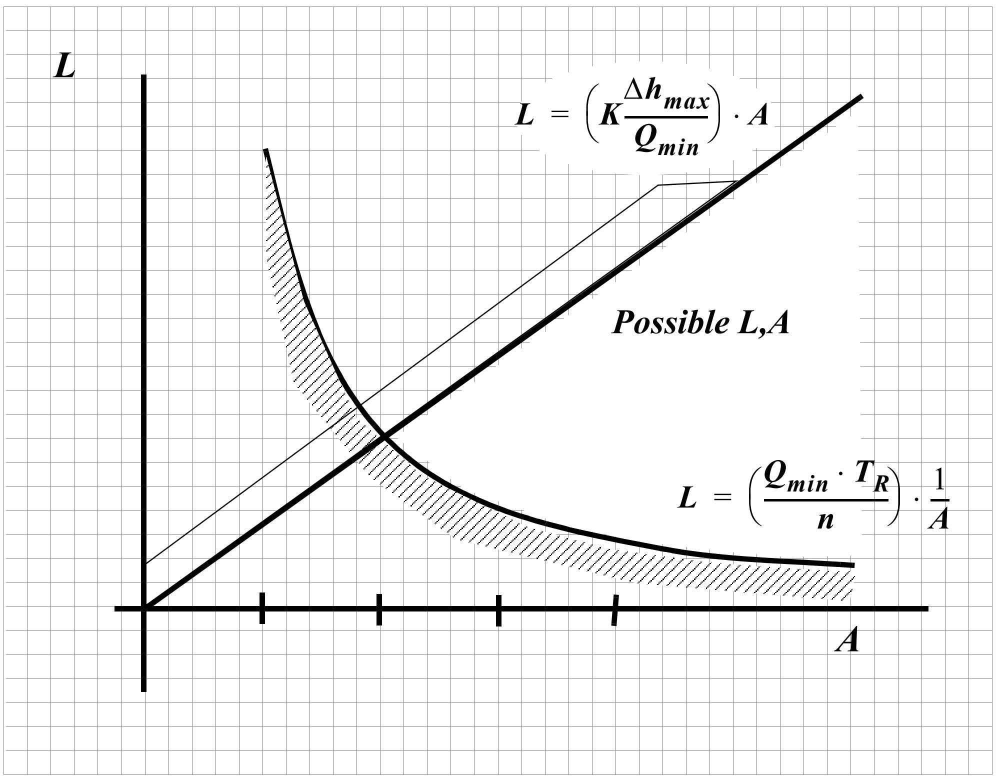
$$\boldsymbol{L \le KA \cdot \frac{\Delta h_{max}}{Q_{min}}} \quad \text{or} \quad \boldsymbol{L \le \left(K \frac{\Delta h_{max}}{Q_{min}}\right) \cdot A} \qquad \text{eqn. (1)}$$

where the bracketed term is some number, once we have chosen a material.

A lower bound from the other principle relationship $Q = \frac{nAL}{T_R}$ namely

$$L \geq \frac{Q_{min} \cdot T_R}{nA} \qquad \text{or} \qquad L \geq \left(\frac{Q_{min} \cdot T_R}{n}\right) \cdot \frac{1}{A} \qquad \text{eqn. (2)}$$

Now we plot *L* versus *A* at the limiting conditions (when the equality holds in the two equations.



For a given material, residence time, minimum Q, maximu Δh