CE 3372 – Water Systems Design
Exercise Set 4

Purpose: Review of closed conduit hydraulics and use of energy equation for water distribution systems analysis

Exercises

1. Equation 1 is the Hazen-Williams head loss model.

$$Q = 1.318 C_h A R^{0.63} S^{0.54} \tag{1}$$

where;

Q is the discharge in ft^3/sec;
A is the cross section area of pipe in ft^2 ($A = \frac{\pi D^2}{4}$; D is the pipe diameter.);
C_h is the Hazen-Williams friction coefficient (depends on pipe roughness);
R is the hydraulic radius in ft; and
S is the slope of the energy grade line ($\frac{h_f}{L}$); L is the length of pipe.

(a) Rearrange the equation in terms of head loss ($h_f = \dots$).

(b) Look up the Hazen-Williams loss coefficient (C_h) for enamel coated, steel pipe.

2. Estimate the head loss in a 10,000 foot length of 5-foot diameter, enamel coated steel pipe that carries carries 60^{o}F water at a discharge of 295 cubic-feet per second (cfs), using the Hazen-Williams head loss model.

3. Equation 2 is an explicit formula (based on the Darcy-Weisbach head loss model and the Colebrook-White frictional loss equation)for estimating discharge from head loss and material properties (Swamee and Jain, 1976).

$$Q = -2.22 D^{5/2} \times \sqrt{g h_f / L} \times [log_{10}(\frac{k_s}{3.7D} + \frac{1.78\nu}{D^{3/2}\sqrt{g h_f/L}})] \tag{2}$$

where;

Q is the discharge in L^3/T;
D is the pipe diameter;
h_f is the head loss in the pipe;
g is the gravitational acceleration constant;
L is the length of pipe;
k_s is the pipe roughness height;
ν is the viscosity of liquid in the pipe;

(a) Find the viscosity for water at 50^{o}F. Cite the source of your value.

(b) Find the sand roughness height of ductile iron pipe. Cite the source of your value.

(c) How deep is a column of water if the pressure at the bottom of the column is 20 psi?

(d) Estimate the discharge in the 3 mile long, 24-inch diameter, ductile iron pipeline connecting points A and B depicted in Figure 1. Point A is 30 feet higher in elevation than point B. The pressure at point B is 20 pounds per square-inch (psi) greater than the pressure at point A.

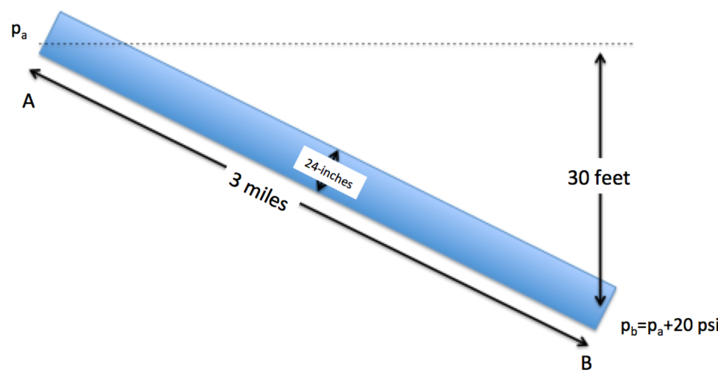

Figure 1: Pipeline Schematic

4. Equation 3 is a formula to estimate the required pipe diameter for a particular discharge, head loss, and roughness (Swamee and Jain, 1976).

$$D = 0.66[k_s^{1.25} \times (\frac{LQ^2}{gh_f})^{4.75} + \nu Q^{9.4} \times (\frac{L}{gh_f})^{5.2}]^{0.04} \tag{3}$$

where;

D is the pipe diameter;
k_s is the pipe roughness height;
L is the length of pipe;
g is the gravitational acceleration constant;
Q is the discharge in L^3/T;
h_f is the head loss in the pipe;
ν is the viscosity of liquid in the pipe;

(a) Find the viscosity for water at 60^oF. Cite the source of your value.

(b) Find the sand roughness height of cast-iron pipe. Cite the source of your value.

(c) Estimate the diameter of a cast-iron pipe needed to carry 60^oF water at a discharge of 10 cubic-feet per second (CFS) between two reservoirs 2 miles apart with an elevation difference between the water surfaces in the two reservoirs of 20 feet as depicted in Figure 2.

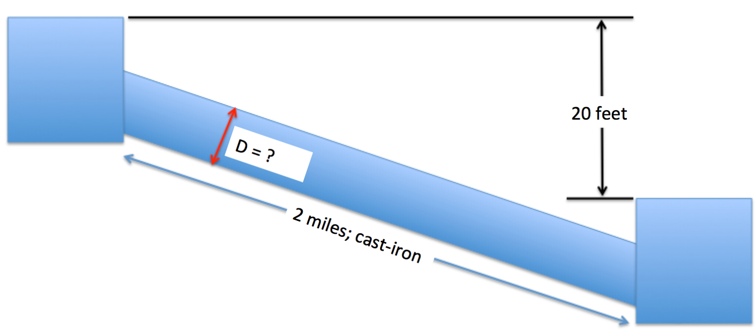

Figure 2: Pipeline connecting two reservoirs

5. A water supply system draws from a river at an elevation of 800-feet and delivers the water to a storage reservoir at elevation 820-feet. The supply pipeline is a 1000-foot long, 10-inch diameter, cast iron pipe. A single pump with the pump characteristic curve in Figure 3 is used to fill the reservoir.

   Determine:

   a) Sketch the system described in the problem statement.
   b) Inlet and outlet minor loss coefficients, cite your source of minor loss coefficients.
   c) The roughness ratio for use in the Moody chart, cite your source of roughness height.
   d) The energy equation for the system.
   e) The system loss for a discharge of 1200, 1600, 2000, 2400, and 2800 gallons-per-minute. Show the calculation of Reynolds number for the different flow rates. Show the the friction factors on the attached Moody chart (Figure 4).
   f) The operating discharge for the system using the supplied pump curve.
   g) The electric power supplied to the pump to lift the water at the operating point.[1]

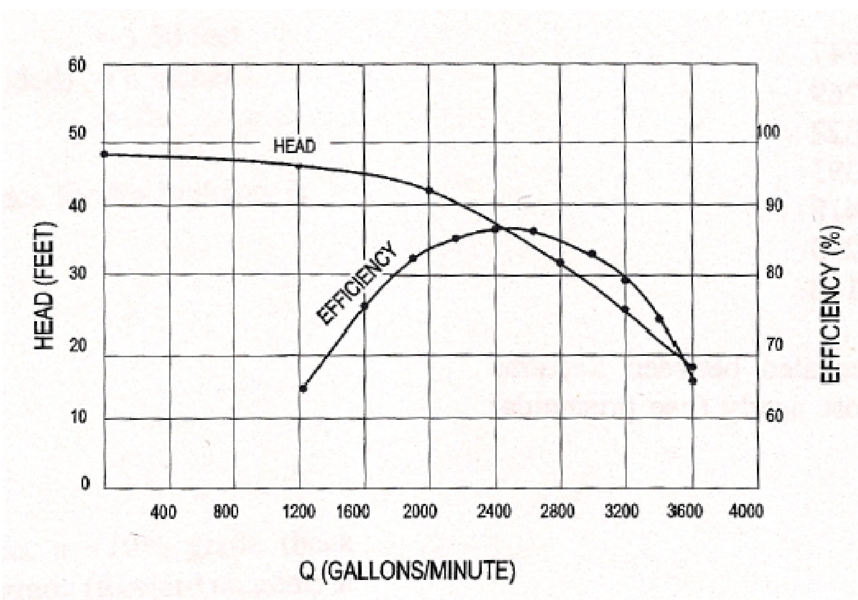

Figure 3: Pump characteristic curve

[1] Assume the efficiency on the pump curve is representative of the wire-to-water efficiency.

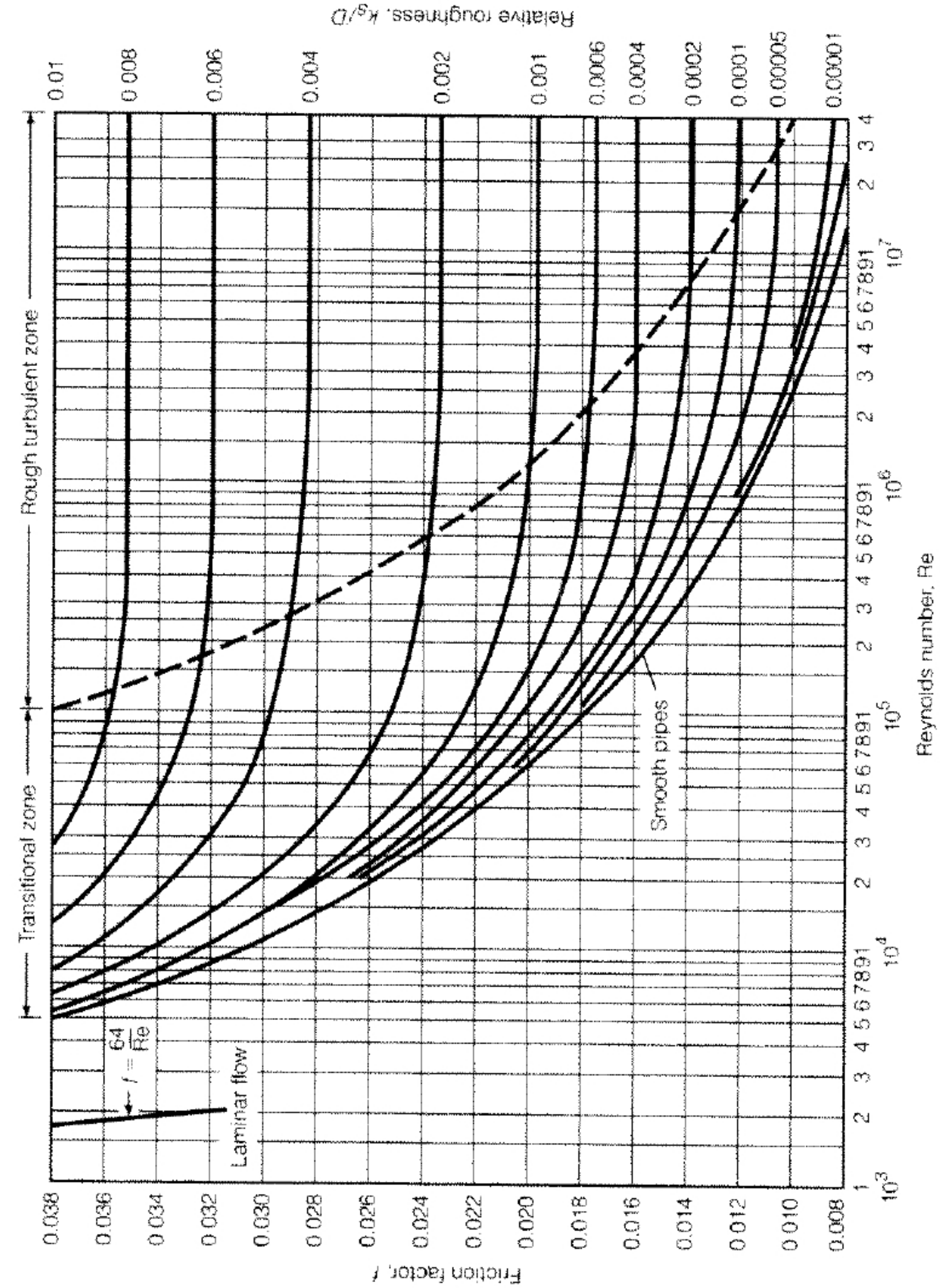

Figure 4: Moody-Stanton Chart

6. Figure 5 is a layout of a water distribution system for the subdivision. The blue line segments are pipes and are labeled (P1, P2, . . .). The blue circles are nodes and are labeled (N1, N2, . . .). The yellow polygons represent the demand lots assigned to each node. For example, node N2 supplies the six (6) individual lots located near the node.

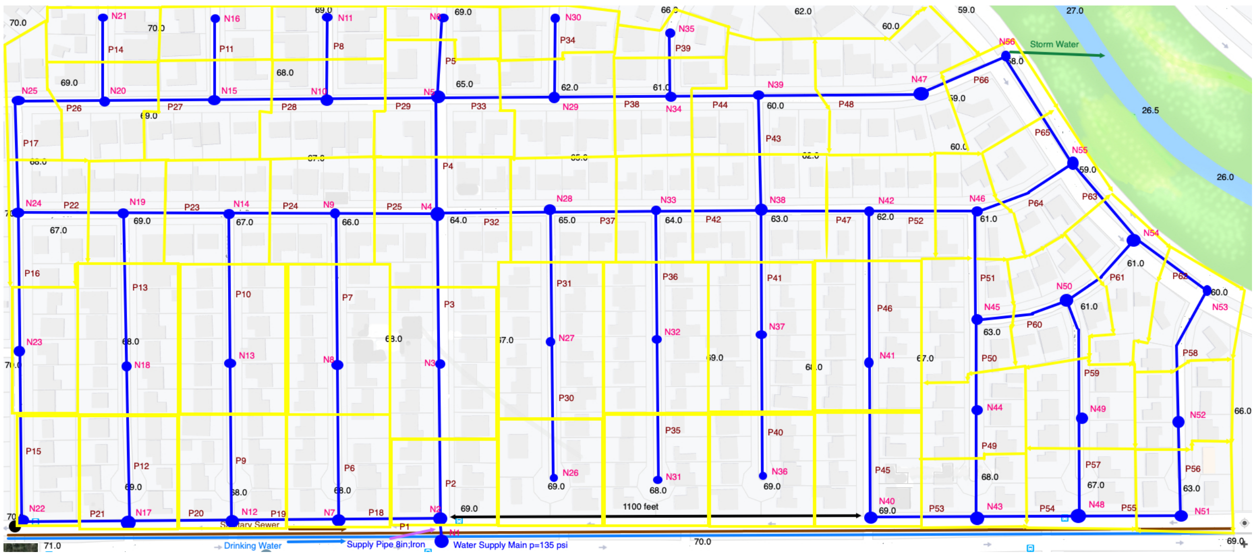

Figure 5: Water Distribution (Skeleton) System.

a) Determine the length of each pipe in the sketch.

b) Select an appropriate material for each pipe using San Marcos, Texas water system design guidelines and determine an appropriate Hazen-William's loss coefficient for each pipe.

Use your values to produce a completed version of Table 1. Save the table (in Excel or something similar) – you will need it later in the design project RP-1.

Table 1: Pipe Properties for Somewhere USA Distribution System

Pipe ID	L (feet)	D (inches)	Material	C_H	k_s (inches)
P1	44	8	Ductile Iron	130	0.0024
P2	440	2	Ductile Iron	130	0.0024
P3	385	2	Ductile Iron	130	0.0024
P4	...	2	Ductile Iron	130	0.0024
P5	...	2	Ductile Iron	130	0.0024
P6	...	2	Ductile Iron	130	0.0024
P7	...	2	Ductile Iron	130	0.0024
P8	...	2	Ductile Iron	130	0.0024
P9	...	2	Ductile Iron	130	0.0024
P10	...	2	Ductile Iron	130	0.0024
P11	...	2	Ductile Iron	130	0.0024
P12	...	2	Ductile Iron	130	0.0024
P13	...	2	Ductile Iron	130	0.0024
P14	...	2	Ductile Iron	130	0.0024
P15	...	2	Ductile Iron	130	0.0024
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
P57	...	2	Ductile Iron	130	0.0024
P58	...	2	Ductile Iron	130	0.0024
P59	...	2	Ductile Iron	130	0.0024
P60	...	2	Ductile Iron	130	0.0024
P61	...	2	Ductile Iron	130	0.0024
P62	...	2	Ductile Iron	130	0.0024
P63	...	2	Ductile Iron	130	0.0024
P64	...	2	Ductile Iron	130	0.0024
P65	...	2	Ductile Iron	130	0.0024
P66	...	2	Ductile Iron	130	0.0024

References

Swamee and Jain, A. K., 1976. Explicit equations for pipe-flow problems. ASCE J. of Hyd. Div., 102(HY5) pp. 657-664