Chapter 1
Basic Hydraulic Principles

Problem 1-1

The cross-section of a rough, rectangular, concrete channel ($k = 0.2 \times 10^{-2}$ ft) is 6×6 ft. The channel slope is 0.02 ft/ft. Using the Darcy-Weisbach friction method, determine the maximum allowable flow rate through the channel to maintain one foot of freeboard (freeboard is the vertical distance from the water surface to the overtopping level of the channel).

Maximum allowable flow rate: **754.13 ft^3/s**

For these conditions, find the following characteristics (note that FlowMaster may not directly report all of these):

a) Flow area = **30.00 ft^2**

b) Wetted perimeter = **16.00 ft**

c) Hydraulic radius = **1.88 ft (not directly reported by FlowMaster)**

d) Velocity = **25.14 ft/s**

e) Froude number = **1.98**

Problem 1-2

A 450-mm circular concrete ($n = 0.013$) pipe constructed on a 0.6-percent slope carries 0.1 m^3/s.

a) Using Manning's equation and normal depth assumptions, what are the depth and velocity of flow? **Depth = 0.21 m; Velocity = 1.35 m/s**

b) What would the velocity and depth be if the pipe were constructed of corrugated metal ($n = 0.024$) instead of concrete? **Depth = 0.31 m; Velocity = 0.84 m/s**

Problem 1-3

A trapezoidal channel carries 2.55 m^3/s at a depth of 0.52 m. The channel has a bottom width of 5 m, a slope of 1.00 percent, and 2H:1V side slopes.

a) What is the appropriate Manning's roughness coefficient? ***n* = 0.07**

b) How deep would the water be if the channel carried 5 m^3/s? **Depth = 0.76 m**

Problem 1-4

Use Manning's equation to analyze an existing brick-in-mortar ($n = 0.015$) triangular channel with 3H:1V side slopes and a 0.05 longitudinal slope. The channel is intended to carry 7 cfs during a storm event.

a) If the maximum depth in the channel is 6 in., is the existing design acceptable?

No (calculated depth is 6.2 in).

b) What would happen if the channel were replaced by a concrete ($n = 0.013$) channel with the same geometry? **The calculated depth would be 5.9 in.**

Problem 1-5

A pipe manufacturer reports that it can achieve Manning's roughness values of 0.011 for its concrete pipes, which is lower than the 0.013 reported by its competitors. Using Kutter's equation, determine the difference in flow for a 310-mm circular pipe with a slope of 2.5% flowing at one-half of the full depth.

Manning's $n = 0.013$ results in a flow of 0.080 m^3/s. For an n-value of 0.011, the result is 0.099 m^3/s – a flow increase of 0.019 m^3/s, or almost 24%.

Problem 1-6

A grass drainage swale is trapezoidal, with a bottom width of 6 ft and 2H:1V side slopes. Using whatever friction method you feel is appropriate, answer the following questions:

a) What is the discharge in the swale if the depth of flow is 1 ft and the channel slope is 0.005 ft/ft?

Manning's: $n = 0.030$; $Q = 23.42$ ft^3/s
Kutter's: $n = 0.030$; $Q = 20.71$ ft^3/s

b) What would the discharge be with a slope of 0.010 ft/ft?

Manning's: $n = 0.030$; $Q = 33.11$ ft^3/s
Kutter's: $n = 0.030$; $Q = 29.33$ ft^3/s

Problem 1-7

A paved highway drainage channel has the geometry shown in the following figure. The maximum allowable flow depth is 0.75 ft (to prevent the flow from encroaching on traffic), and the Manning's n-value is 0.018 for the type of pavement used.

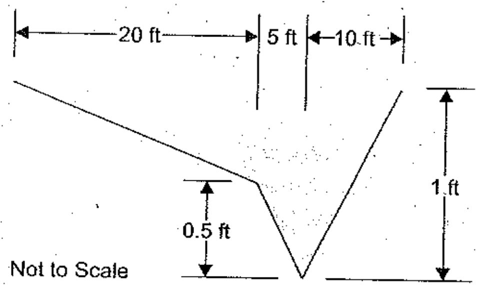
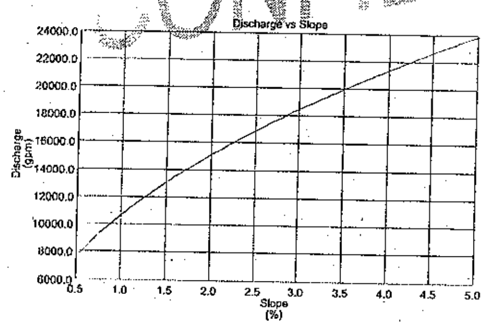


Figure for Problem 1-7

a) What is the capacity of the channel given a 2% longitudinal slope? **33.63 ft^3/s**

b) Create a rating curve to demonstrate how the capacity varies as the channel slope varies from 0.5% to 5%. Choose an increment that will generate a reasonably smooth curve.



Problem 1-8

Using the Hazen-Williams equation, determine the minimum diameter of a new cast iron (C = 130) pipe for the following conditions: the upstream end is 51.8 m higher than the downstream end, which is 2.25 km away. The upstream pressure is 500 kPa, and the desired downstream pressure and flow rate are 420 kPa and 11,000 l/min, respectively. What is the minimum diameter needed? Assume pipes are available in 50-mm increments.

Diameter = 300 mm (282 mm, rounded up to the nearest 50-mm increment)

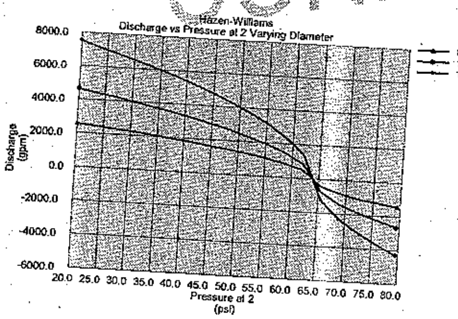
Problem 1-9

2,000 gallons of water per minute flow through a level, 320-yard-long, 8-in-diameter cast iron pipe (C =130, k = 2.5908e^{-4} m) to a large industrial site. If the pressure at the upstream end of the pipe is 64 psi, what will the pressure be at the industry? Is there a significant difference between the solutions produced by the Hazen-Williams method and the Darcy-Weisbach method?

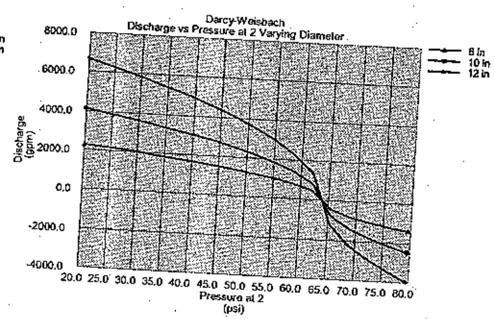
The Hazen-Williams equation results in a pressure of 36.6 psi, and the Darcy-Weisbach equation results in a pressure of 30.5 psi. The significance of the difference between these two answers depends on the project criteria. If the industry requires a minimum pressure of 35 psi at the connection, the difference is significant. If the industry requires 30 psi at the connection, the difference is not significant.

Problem 1-10

Develop a performance curve for the pipe in Problem 1-9 that shows the available flow to the industry with residual pressures ranging from 20 psi to 80 psi (assume the source can maintain 64 psi regardless of flow rate). Create similar curves for 10-in and 12-in diameter pipes and compare the differences in flow.



Hazen-Williams



Darcy-Weisbach

Note that the flow rate is negative when the pressure at the industry is above 64 psi. In order for the industry to have pressures as high as 80 psi, it would need to pump water back into the system! This is an excellent time to discuss the concept of "negative" flows (inflows) with the students. This may also be a good time to discuss water/sewer cross-connections and the possible effects of water distribution system pressures dropping too low.