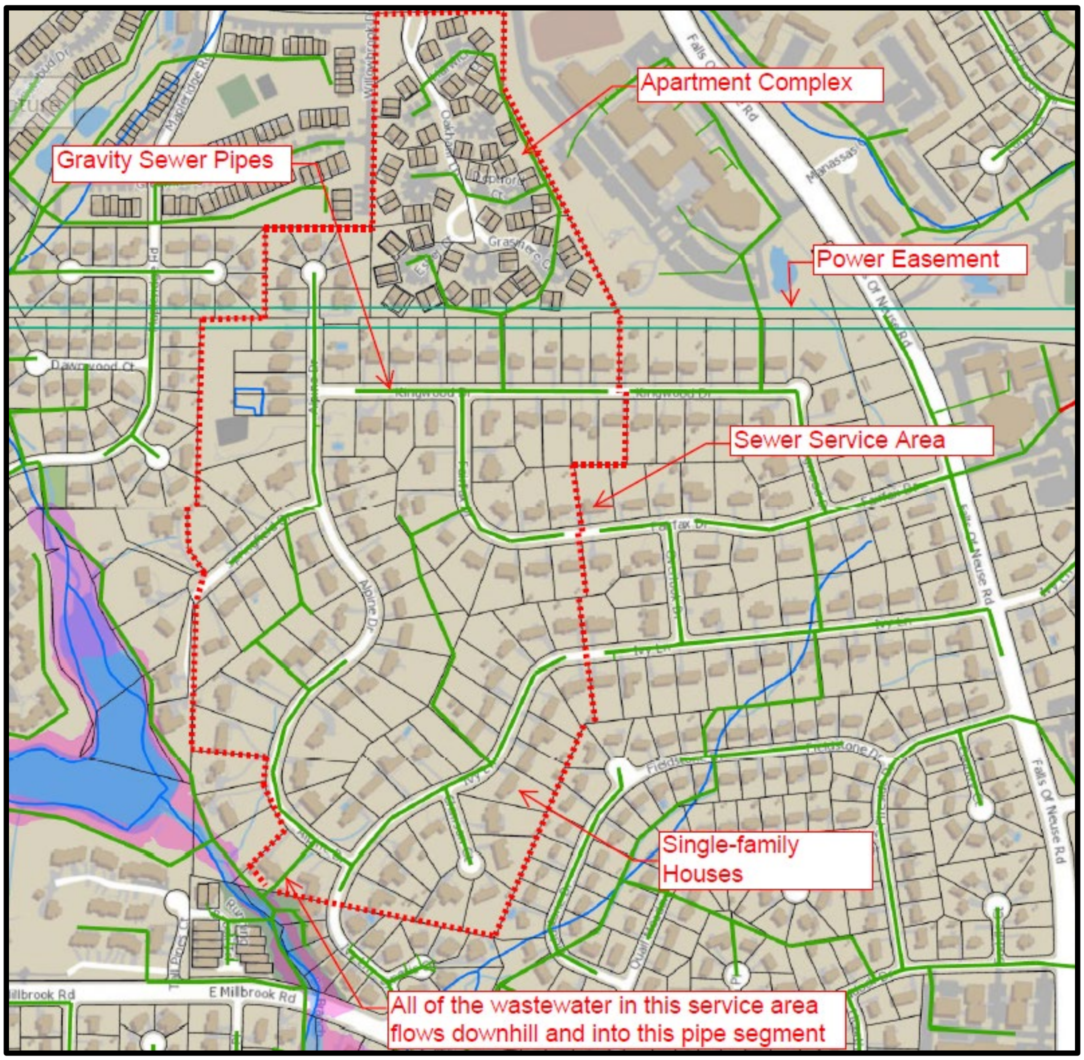
Connecting Industry to Mathematics Instruction

NSF ATE Award # 1954291

Solutions: Controlling the Flow: Wastewater Collection – Student Activity Sheet

Task 1: Sewers have to be sized to handle the area that they will serve. When the service area is new, engineers use unit flow rate factors to determine how much flow the sewer will need to handle.



In partnership with

Here are some typical average daily flow rates (in gallons per day; GPD) by type:

- Single family residential: 300 GPD per house
- Apartments: 290 GPD per apartment unit
- Office building: 25 GPD per employee
- Restaurant: 40 GPD per seat
- Hotel: 120 GPD per room
- Stadium/Auditorium: 5 GPD per seat

Based on these factors, along with the number and types of development in the service area, the average daily flowrate leaving the service area can be calculated. However, sewer pipes need to be sized for peak flowrates, not just average daily flowrates. We apply a peaking factor to account for this. When there is no site-specific data available, a typical peaking factor would range from 2.5 to 3.0 times the average daily flowrates. The peaking factor is multiplied by the average daily flow to estimate the peak flowrate to be used for sizing the pipe.

The capacity of a pipe can be determined by using the Manning Equation which is:

$$Q = \frac{1.49}{n} \, x \, A \, x \, (\frac{A}{P})^{\frac{2}{3}} \, x \, S^{\frac{1}{2}}$$

Where: Q = flowrate in CFS (pipe capacity when parameters below are for a full pipe. CFS is cubic ft per sec)
n = Mannings “n” (use 0.012 for most smooth pipes)
A = cross-sectional area of flow (pipe area when full) in square feet (SF)
P = wetted perimeter (pipe perimeter when full) in FT
S = pipe slope in FT per FT

The table below lists several pipe sizes available and their associated minimum required pipe slopes by size. Use the formula above to calculate the Flowrate (Q) for each given pipe diameter.

Pipe Diameter (in)	Slope (ft/ft)	Flowrate (Q-CFS)
8	0.0050	0.9277
12	0.0028	2.0468
16	0.0014	3.1170
24	0.0008	6.9469

One beneficial unit conversion is that 1 cubic foot = 7.5 gallons

Link to excel spreadsheet that we used to calculate Q above and answer Q1-Q3 below.

Question 1: Suppose a sewer service area contains 900 homes and 400 apartment units. What pipe size is required to convey the wastewater away from the area? Use a peaking factor of 3.

(900 homes x 250 GPD + 400 apt x 240 GPD) x 3(peaking factor) = 963,000 GPD. So, a 12 in pipe will work.

Question 2: Suppose a sewer service area was established with 12 in diameter pipes and contains 1100 houses and 400 apartments. A real estate developer wants to come in and build an apartment complex, on some open lots, that will contain 400 new apartment units. Can the existing pipe system convey the wastewater away from the area, after the new apartments are built?

(1100 homes x 250 GPD + 800 apt x 240 GPD) x 3(peaking factor) =1401000. So, no, the 12 in pipe can only handle a capacity of 1326341.5446.

Question 3: Suppose we need to convey 300,000 GPD of waste water, away from an area using a 12 in diameter pipe. What is the minimum slope requirement for the pipe? What does the minimum slope value represent in context? 0.00014. I found this answer using the “goal seek” feature in the spreadsheet. You could solve algebraically. The minimum slope represents for every horizontal change of 1 foot, there is a vertical change of 0.00014 feet.

Task 2: Pump Stations- In order to convey the water uphill, the pump must overcome the static and dynamic heads. Combined we call these heads “total dynamic head”. Static head is resulting from the slope uphill we are pumping the water and dynamic head is resulting from the friction resulting from the inside wall of the pipe.

Total dynamic head (TDH) = Static head (SH) + Dynamic head (DH)

In hydraulics, we express “heads” in feet of water column

For a force main piping system the static head is constant, but the dynamic head changes with flowrate. It is a power relationship described as: DH = k *x* $Q^{1.85}$

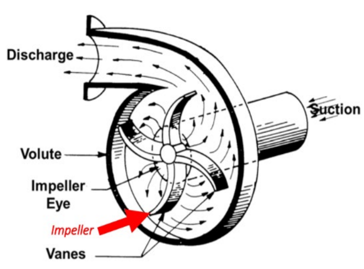
Therefore, TDH = SH + k *x* $Q^{1.85}$ where, SH is the static head in FT, Q is the pumping rate in GPM, and k is a constant that is a function of the piping system that takes into account the length, diameter, and pipe wall roughness.

Question 4: Find the equation for the head loss, TDH, for a force main system with a static head of 30 feet and a piping system k-factor of 0.0006. TDH = 30 + 0.0006$Q^{1.85}$

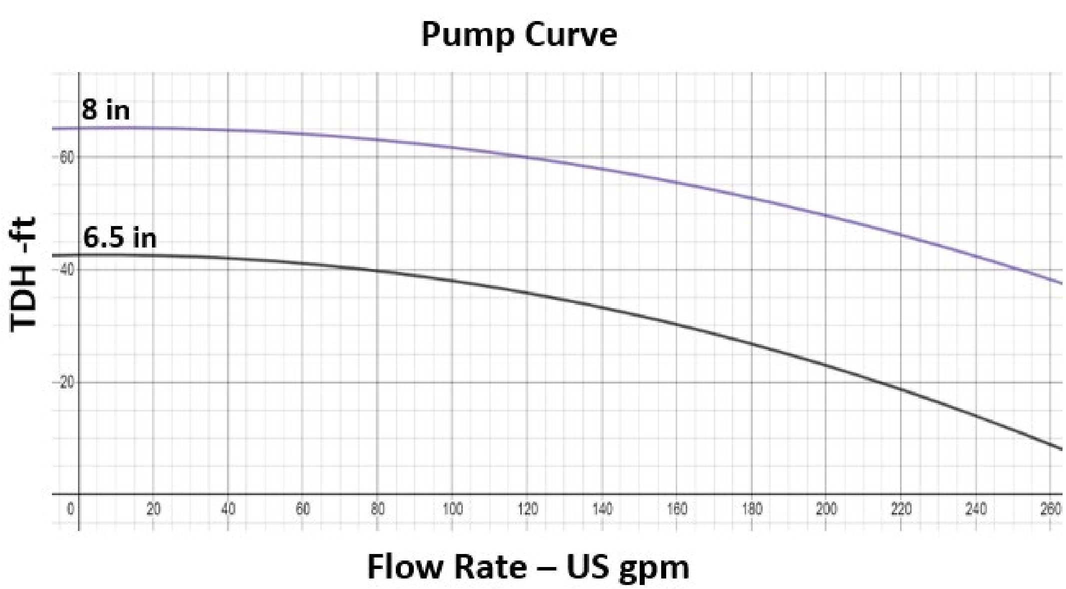
It may help to think of TDH as the pressure at the beginning of the pipeline, as you try to apply common sense to these hydraulic terms.

Question 5: What relationship exists between the pumping rate, Q and the head loss, TDH? Answers may vary. There is a positive relationship. As the pumping rate increases, the TDH increases. They may notice the equation and mention that it is a power function and/or graph it and mention it’s curved nature.

The most common pump used in wastewater conveyance is a centrifugal pump. For centrifugal pumps, the flowrate delivered by the pump is dependent on the TDH imparted by the piping system.



Pump Cut-away



On the pump curve diagram
above, two pump impeller sizes are shown: 6.5” diameter and 8” diameter. Where the pump curve and the system curve intersect is where the pump will operate.

Question 6: What is the expected pumping rate with each size impeller shown? Graphing the pump curves above along with the TDH equation from Q4, you can find the intersection where each pump will operate. We used desmos, and did Quadratic Regressions for the curves. The 6.5 in pump will operate at 128.6 gpm and the 8 in pump will operate at 231.0 gpm. These answers may vary slightly depending on which points students pull from the graph for their regression equation or if they choose to solve some other way.

Link to graph of solution: https://www.desmos.com/calculator/68ocjobrmy