Module 26:
Advanced Flowmeters
Answer Key

Exercise/Activity

1. What is the normal flow for midday, which is about half way between each date stamp?

Ans: About 1600 to 1200 gpm.

2. There were 2 rain events when the intensity went above 0.06 inch. What was the affect to the flows?

Ans: Very little impact. Flowmetering indicates that I/I is not much of a problem.

Exercise/Activity

1. What is the normal flow for midday (look at the first two days)?

Ans: About 200 to 500 gpm.

2. What happens during rain events?

Ans: For the time period between the first Tuesday and Wednesday, the two events caused the peak flow to go up almost twice the normal range. Additionally, the flow took a long time to decrease which illustrates that the water continued to get into the system. A second rainfall event caused the flow to quadruple. In our previous discussion about how one municipality may use EDUs to report possible flows, the above data showing impact from a rainstorm would be missed.

I/I is a very bad problem in this system and must be corrected.

Calculation

1. If you have an 8 inch diameter pipe and the velocity is 2.5 fps, what is the flow rate? (Hint: $A = \pi r^2$)

Ans: 8 inch diameter pipe equals a radius of 0.33 feet.

Therefore, area = $\pi(0.33\ ft)^2$.

This calculates to 0.34 sq. ft.

If the velocity is 2.5 fps and the area is 0.34 sq. ft, the resultant flow is 0.85 cubic feet per second (cfs).

0.85 cfs X 7.48 gals/cu. ft X 60 seconds/minute = a flow of about 384 gpm.

Instructor Note: This illustrates how you can determine flow through a line without directly having a flowmeter.

Class Expansion of Problem (use if there is time available)

If the pipe is the force main from a pumping station and is 1,000 feet long, how long would it take 1 gallon of wastewater to travel through the force main if the flowrate is 384 gpm?

Ans: Since the flow rate has been determined based on an 8 inch diameter pipe and a velocity of 2.5 fps, divide the 1,000 feet by 2.5 fps and it would take 400 seconds. This could be confirmed by adding a dye directly to the pump suction, through a pressure gauge fitting, and timing it until it appears at the downstream manhole.

This might help you decide if an odor control chemical has sufficient time to react with the wastewater as it travels through the pipe at the calculated flow rate.

2. Given a flow rate of 0.87 cfs conveyed in a 12 inch diameter sewer line, what would be the velocity? (Hint: $A = \pi r^2$). If this is a sewer line, would settling of solids be a concern?

Ans: Remember to keep units the same, therefore, convert 12 inches to feet.
12 inches/12 inches = 1 ft

The radius is equal to half the diameter.
1 ft/2 = 0.5 ft

Determine the area.
Area = $(3.14)\ (0.5\ ft)^2 = 0.78$ sq ft

Now determine the velocity.
V = Q/A = 0.87 cfs/ 0.78 sq ft = 1.11 fps

Typically, a sewer line should not have a velocity of less than approximately 2 fps. Therefore, solids may settle out unless flows increase. Settling of solids would be a concern.

This illustrates how knowing a flow rate can help you determine if other operational problems could exist.

Calculation

1. Find the hydraulic radius of a 12 inch diameter pipe, if the depth is 9 inches. Use the "Wetted perimeter in a pipe" figure in this unit and Table 6.2 in Appendix C.

Because most tables reference diameters in feet, we will convert inches to feet in the following calculation.

Ans: All units MUST be the same.
Depth of flow is 9 inches. Convert 9 inches to feet.
9 inches/12 inches = 0.75 foot

Diameter of pipe is 12 inches. Convert 12 inches to feet.
12 inches/12 inches = 1 foot

d/D = 0.75 /1 = 0.75, refer to Table 6.2 which shows that the wetted perimeter factor is 0.3017 times the diameter of 1 foot.

2. What is the velocity if the wetted perimeter is 0.3017 ft, the slope is 0.007, and the pipe is a 12 inch diameter sanitary sewer line with a normal amount of internal slime, showing a Manning factor of 0.013?

Ans:

$$V = \frac{1.486\ R^{2/3}\ S^{1/2}}{n}$$

$$V = \frac{(1.486)\ (0.3017\text{ft}^{2/3})\ (0.007^{1/2})}{0.013}$$

$$V = \frac{(1.486)\ (0.44987\ \text{ft})\ (0.08367)}{0.013}$$

$$V = \frac{0.0559}{0.013}$$

Therefore the velocity is 4.3 feet per second (fps).

3. Determine the volume conveyed by the typical sewer line depicted in Problem 2 by using Q=AV and ISCO Table 6.2 in Appendix C.

Ans: Since we know the velocity is 4.3 fps and we can find the area by using Table 6.2, we can use the Q = AV formula to determine the volume conveyed by this typical sewer line.

Table 6.2 shows the area factor for a 0.75 depth of flow pipe is 0.6318. Multiply the area factor by the diameter $^{\text{(squared)}}$.
$A = (0.6318)\ (1\ \text{ft})^2 = 0.6318$ square feet.

Multiplying the area of 0.6318 sq ft by the velocity of 4.3 fps yields a volume of 2.12 cubic feet per second.

Exercise/Activity

Compare the maximum flow capacity of a 10 inch Kennison versus a 10 inch Parabolic Nozzle. Look at Appendix C - ISCO Tables 3-8 and 3-9.

Ans A Kennison nozzle has a maximum capacity of 0.80 mgd and a parabolic nozzle has a 1.2 mgd capacity.

Exercise/Activity

A well-operated WWTP has an effluent flow that ranges from 10 gpm to 1,500 gpm. We do not anticipate an unacceptable amount of solids because the weir will be installed as a WWTP effluent flowmeter. What are the possible weir options? Use Appendix C - ISCO Table 5-3A.

Ans

1. If you look at the table you will notice that only V-notch weirs are within this range. (This illustrates how concentrating the flow through a narrow opening, such as a V-notch, provides proper hydraulic conditions.)
2. Within the V-notch ranges, at the lower flow rate of 10 gpm, there are only three possibilities of either a 22 ½, 30, or 45 degree notch weir.
3. At the upper range of 1,500 gpm, the only one which fails to comply with a maximum of 1,500 gpm is the 22 ½ degree V-notch.
4. Therefore, using the V-notch with the widest opening, to reduce potential problems when algae builds up in the notch, our choice would be the 45 degree.

Exercise/Activity

If we have a 2 ft rectangular weir without end contractions and the depth is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 11-3. Using Table 5-3, what is the flow range for this PHCE?

Ans 566.6 gpm, 0.8159 mgd.
Approximately 400 gpm for a lower limit and approximately 4,000 gpm for an upper range.

☑ Exercise/Activity

If we have a 2 ft Cipolletti weir and the depth of flow is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 12-3.

Ans Based on ISCO Table 12-3, the flow is 573 gpm.

☑ Exercise/Activity

1. For a 12 inch Parshall Flume, where is the measuring point in relationship to the start of the throat? The throat is the size of the flume and is where the sides are parallel. Use Appendix C - ISCO Table 4.1A and the Parshall flume diagrams on the previous pages.

Ans From ISCO Table 4.1A, column 2/3A, the answer is 3 feet.

☑ Exercise/Activity

2. If we have a 6 inch flume and the depth of flow is measured to be 0.42 feet at the head, what is the flow rate in gallons per minute (gpm)? In million gallons per day (mgd)? Use Appendix C - ISCO Table 13-4.

Ans ISCO Table 13-4 shows the flows are 235 gpm or 0.3380 mgd.

☑ Exercise/Activity

Select a flume that could be used for flows ranging from about 1 gpm up to 900 gpm. The type of material in the flow is normal fecal matter and paper most commonly present in domestic wastewater. Use Appendix C - ISCO Table 5-4.

Ans Look at various flow rates shown on ISCO Table 5-4. There are several H-type flumes and an extra large 60 degree trapezoidal flume that will work. Because we are not sure of the amount of solids that could clog the flume or settle out, we may want to consider the trapezoidal flume.

Calculation

If we have a pipe of 5 inch diameter, using the separation distance guidelines, what is the absolute minimum distance of straight pipe that is needed (excluding the width of the meter)?

Ans 10 D = (10) (5 inches) = 50 inches upstream

5 D = (5) (5 inches) = 25 inches downstream

50 + 25 = 75 inches. We will need at least a 75 inch section of straight unobstructed pipe, excluding the width of the meter.

Exercise/Activity

Using Appendix C Table 4-1a, find the sensor location for the following Parshall Flumes:

1 foot wide = Ans: 2/3 Ha is 9 17/32 inches

2 foot wide = Ans: 2/3 Ha is 10 7/8 inches

Calculation

Determine if a flowmeter needs calibration based upon comparing the flowmeter totalizer reading with calculations from the elapsed time meters for a pump station and a calibrated flow curve.

- The pumping station has two pumps. Refer to the pump performance curve from Gorman-Rupp on model S8A in Appendix E. Each pump was tested to provide 1,800 gallons per minute at a total dynamic head of 116 feet.
- The elapsed time meter for pump No 1 is 135 minutes, pump No. 2 is 140 minutes, and the simultaneous elapsed time meter had no run time.
- The discharge pressure on the pumps is normally 50 psi.
- Compare this with the flowmeter reading of 49,500 gallons per day.
- The flowmeter was calibrated by a new company who was not sure if there is a multiplier factor for the meter.

Ans: Pump No. 1 running for 135 minutes at 1,800 gpm conveys 243,000 gallons for the day.

Pump No. 2 running for 140 minutes at 1,800 gpm conveys 252,000 gallons for the day.

Pumps Nos. 1 and 2 do not run at the same time, therefore, there are no flow components for simultaneous operation of the pumps.

The total volume conveyed is 243,000 gallons plus 252,000 gallons for a total of 495,000 gallons for the day.

The flowmeter reading shows 49,500 gallons per day but the calculated flow is 495,000 gallons per day. The flowmeter is 1/10 of the calculated flow. It appears that when the flowmeter was calibrated, a factor of 10 was inadvertently missed.

☑ Exercise/Activity

1. A 9 inch Parshall Flume on the raw wastewater line was checked by WWTP staff and the depths in inches are shown below, along with the depth converted to feet. Should an instrumentation person be contacted to inspect the flume? Refer to Appendix C - ISCO Table 13-5.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
1.2	0.10	10
3	0.25	165
4.5	0.38	310
6	0.50	477
7.5	0.62	663

Ans Although the meter shows a noticeable deviation from the table at the lowest flow, the other readings match the table. Since 4 of the 5 readings match the table, it is probable that the first reading was not done properly.

Note: ISCO Table 13-5 starts at 0.10 feet, so the first reading is at the lowest end of the table. This is not desirable and could have caused some of the meter inaccuracy.

2. A 2 foot Cippoletti Weir is used at the effluent end of a WWTP. What is your opinion of the meter readings? Use Appendix C - ISCO Table 12–3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	270
2.52	0.210	291
2.76	0.230	333
3.00	0.250	378
3.60	0.300	497
4.32	0.360	653
5.00	0.417	795

Ans The depth was measured very precisely based upon three significant figures. This allows for the correct calculation of three significant figures and the meter readings are acceptable.

3. There is a two foot wide board that an operator installed trying to fabricate a rectangular weir without end contractions. The operator measured directly above the weir with the following results. Was it measured properly and what are the flows? If measured properly, Appendix C - ISCO Table 11-3 can be used.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
0.5	0.04	
1.0	0.08	
1.5	0.12	
2.0	0.17	

Ans The readings are not valid because the flows were measured directly above the weir which is incorrect. Additionally, the board does not produce a sharp crested weir. Otherwise, you could use ISCO Table 11-3 if a sharp-crested weir was installed.

4. There is a sharp-crested 2 foot long rectangular weir without end contractions at a WWTP. Having taken this course, the operator measured at the proper location upstream of the weir. What are the flows? Use Appendix C - ISCO Table 11-3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	*267*
2.52	0.210	*288*
2.76	0.230	*330*
3.00	0.250	*374*
3.60	0.300	*491*
4.32	0.360	*646*
4.92	0.410	*785*

Ans The readings are valid because the flows were determined at the proper location. You could use ISCO Table 11-3. Correct readings are inserted in the table above.

5. Determine the amount of error an incorrect depth reading of ½ inch creates in a 120 degree V-notch weir if the perceived depth was 7 inches versus 7.5 inches. Determine its impact for a typical day at that rate. Use Appendix C, table 9-6.

Ans: At a depth of 7 inches (0.583 feet), the flow would be 498 gpm or a daily flow of 0.72 mgd but at 7.5 inches (0.625 feet), the closest value in the table is 0.62 feet and the flow at this depth is 588 gpm or a daily flow of 0.85 mgd.

The error of the average flow rate is 588 – 498 = 90 gpm.

If the flow rate stayed constant throughout the day, the error would be approximately 0.13 million gallons per day in error.

☑ Exercise/Activity

The average flow through a facility was estimated to be 200 gpm, based on water records. A 120 degree V-notch weir was installed. The staff reported a lack of flow detection sensitivity. The staff needed to interface a chemical feed disinfection system with the flowmeter and were able to determine that the minimum flow might be about 20 gpm and the maximum flow might be about 450 gpm. The metering point is the effluent from the WWTP, with suspended solids always below 30 mg/L, which allows the use of a V-notch weir. Use Appendix C - ISCO Tables 9-3, 9-5, and 9-6 to select a better V-notch weir.

Ans Either the 45 degree or 60 degree V-notch weir would work but the 45 degree V-notch is almost at its maximum range and would be operating at 1 foot of depth.

The 60 degree V-notch weir would only be operating at 0.87 feet (10 inches), which is better.

Select and use the 60 degree V-notch weir.

Emphasize that the 120 degree was too coarse of a measuring device.
