Example Problem 4A-8_1, Evaluate an On-Grade SW-548 Barrier Grate Intake

Determine intercepted and bypass flows by calculating the efficiency of an on-grade SW-548 barrier grate intake located on an Interstate highway. Shoulder width is 12 ft.

Given:

Cross slope: $S_x = 0.03$ ft/ft.

Manning's coefficient for new pavement: n = 0.016.

Total flow rate: Q = 1.6 ft^3/s.

Longitudinal slope: $S_L = 0.02$ ft/ft.

Solution:

1. Use Equation 4A-6_4 from Section 4A-6 to find the gutter spread (T) directly upstream of the intake:

$$T = \left[\frac{nQ}{K_u S_x^{1.67}\sqrt{S_L}}\right]^{0.375} = \left[\frac{0.016 \times 1.6}{0.56 \times 0.03^{1.67} \times \sqrt{0.02}}\right]^{0.375} = 5.89 \text{ ft.}$$

   Allowable spread is the shoulder width of 12 ft. Gutter spread is less than allowable spread, so spread is acceptable.

2. Use Equation 4A-8_4 to calculate the grate frontal flow to total gutter flow (E_o):

$$E_o = \left[1-\left(1-\frac{W}{T}\right)^{2.67}\right] = \left[1-\left(1-\frac{(2.09)}{5.89}\right)^{2.67}\right] = 0.69 \text{ or } 69\%$$

3. Use Equation 4A-8_6 to calculate the average gutter velocity (V):

$$V = \frac{2Q}{T^2 S_x} = \frac{2 \times 1.6}{5.89^2 \times 0.03} = 3.08 \text{ ft/s}$$

4. Use Equation 4A-8_5 to calculate the frontal flow interception (R_f):

$$R_f = 1 - K_f(V - V_o) = 1 - 0.09(3.08 - 8.3) = 1.47 > 1.0$$

   Since the frontal flow interception (R_f) is greater than 1.0, use $R_f = 1.0$

5. Use Equation 4A-8_7 to calculate the side flow interception (R_s):

$$R_s = \frac{1}{\left[1+\frac{K_s V^{1.8}}{S_x L^{2.3}}\right]} = \frac{1}{\left[1+\frac{0.15 \times 3.08^{1.8}}{0.03 \times (3.33)^{2.3}}\right]} = 0.296 \text{ or } 30\%$$

6. Use Equation 4A-8_3 to calculate the efficiency (E):

$$E = R_f E_o + R_s(1 - E_o) = (1 \times 0.69) + 0.296(1 - 0.69) = 0.78 \text{ or } 78\%$$

   This exceeds 50%, so intake location is appropriate.

7. Use Equation 4A-8_1 to calculate the intercepted flow (Q_i):

$$Q_i = EQ = 0.78 \times 1.6 = 1.25 \text{ ft}^3/\text{s}$$

8. Use Equation 4A-8_2 to calculate the bypass flow (Q_b):

$$Q_b = Q - Q_i = 1.6 - 1.2 = 0.35 \text{ ft}^3/\text{s}$$

Discussion:

Efficiency exceeds 50%, so the designer could choose move the intake further downstream to increase distance between intakes and potentially reduce the number of intakes. However, intakes immediately upstream of a sag should be placed to achieve a higher efficiency to reduce bypass to the sag intake.

This example ignores the effect of clogging. Clogging is typically not an issue with barrier intakes located on rural facilities, which tend not to accumulate debris (e.g. leaves and branches). However, in an urban area, debris from landscaping, as well as trash (e.g. food wrappers and pop cans/bottles) can lead to clogging, and in these areas designers may want to consider a including a clogging factor as part of their intake calculations.