Trapezoidal Grassed Swale Sample Design - Solution

Step 1: Determine the bottom width (w_b) for the trapezoid swale using equation (2).

$$w_b = \frac{(0.014)\,(0.2)}{0.076^{1.67} - 0.02^{0.5}} - (3)\,(0.076) = 1.24\ \text{m}\ (4\ \text{ft})$$

Step 2: Determine the top width (w_t) for the swale and cross-sectional area, using equations (3), and (4).

w_t = 1.22 + 2 (0.076)(3) = 1.68 m (5.5 ft) A_x = (1.24)(0.076) + 3 $(0.076)^2$ = 0.11 m^2 (1.19 ft^2)

Step 3: Determine the flow velocity in the channel using equation (5).

$$U = \frac{0.014}{0.11} = 0.13\ \text{m}^2/\text{s}\ (\text{ft}^2/\text{s})$$

Computed U is less than the required 0.27 m/s (0.9 ft/s), OK to proceed.

Step 4: Compute the required length of the swale using equation (6).

$$L = (0.13)(60)(9) = 70\ \text{m}\ (227\ \text{ft}).$$

Since w_b is less than the maximum value, it may be possible to reduce the length (L) by increasing w_b. Set L = 55 m (180 ft) and solve for w_b by substituting variables in equations (2), (3), (4), and (5).

$$U = \frac{55}{60(9)} = 0.10\ \text{m/s}\ (0.33\ \text{ft/s})$$

$$w_b = \frac{0.014 - (0.01)\,(3)\,(0.076)^2}{(0.01)\,(0.76)} = 1.61\ \text{m}\ (5.28\ \text{ft})$$

Step 5: Check for stability at the computed dimensions

Calculate Q for the 100-yr, 24-h storm. Assume that Q was established at 0.045 m^3/s (1.6 ft^3/s). Base the check on a grass height of 76 mm (3 in) with “fair” coverage. From table 3, the degree of retardance is category D. Assume soil analysis has established soils as erosion resistant, and the maximum velocity (U_{max}) is 1.5 m/s (5 ft/s). Select a trial Manning's n value of 0.04, and obtain the UR_h value (velocity x hydraulic radius) using figure 90. Convert the UR_h value from English to metric units:

$$UR_{h\ (\text{metric})} = UR_{h\ (\text{engish})} \times 0.0929 = 3\ \text{ft}^2/\text{s} \times 0.0929 = 0.28\ \text{m}^2/\text{s}.$$

Calculate the hydraulic radius (R_h) using the following equation using equation (7).

$$R_h = \frac{0.28}{1.5} = 0.19\ \text{m}\ (0.6\ \text{ft})$$

Using the computed hydraulic radius, obtain the actual UR_h by using equation (8).

$$UR_h = \frac{1}{0.04} 0.19^{1.67} 0.02^{0.5} = 0.22 \text{ m}^2/\text{s} \ (2.37 \text{ ft}^2/\text{s})$$

In this example, the estimated UR_h value is not within five percent of the computed UR_h value above. If a new trial Manning's n value of 0.038 is used, the new estimated UR_h = 0.37 m^2/s (4 ft^2/s), the recomputed R_h is 0.25 m (0.8 ft), and the recomputed UR_h = 0.35 m^2/s (3.81 ft^2/s). The new value is within five percent of the estimated value, and the stability check can proceed.

The actual velocity for the new design is recomputed using equation (9).

$$U = \frac{0.35}{0.25} = 1.40 \text{ m/s} \ (4.59 \text{ ft/s})$$

The actual velocity is less than the estimated U_{max} of 1.5 m/s (5 ft/s), and the stability check can proceed.

Calculate the cross-sectional area for the stability design using equation (10).

$$A_x = \frac{0.045}{1.40} = 0.032 \text{ m}^2 \ (0.34 \text{ ft}^2)$$

The stability area of 0.032 m^2 (0.34 ft^2) is less than the capacity area of 0.11 m^2 (1.19 ft^2) and the stability check can proceed. If the stability area was larger, it would be necessary to select a new trial size for width and flow depth (based on space and other considerations) and recalculate the cross-sectional area until this condition is met.

The depth of flow at the stability check design flow rate then needs to be computed for the final dimensions of the swale by solving for H in equations (2) and (3).

$$H = \frac{-1.62 \pm \sqrt{1.62^2 + (4)(3)(0.11)}}{2(3)} = 0.061 \text{ m} \ (0.06 \text{ ft}), \text{ when } w_b = 1.62 \text{ m} \ (5.33 \text{ ft})$$

The greater of the two flow depths from capacity or stability should be used. The greater depth in this case is the capacity flow of 0.076 m (0.25 ft). Add 0.3 m (1 ft) of freeboard to this depth and compute the top width for the swale.

$$w_t = 1.61 + (2)(0.38)(3) = 3.9 \text{ m} \ (12.76 \text{ ft}), \text{ where } H = 0.38 \text{ m} \ (1.25 \text{ ft})$$

Using Manning's equation, the Manning's n value selected in the capacity design, and the calculated channel dimensions, recompute the flow capacity for the channel.

Using equations (4) and (12),

$$A_x = 1.62\,(0.38) + (3)\,(0.38)^2 = 1.05 \text{ m}^2 \ (11.35 \text{ ft}^2)$$

$$R_h = \frac{1.05}{(1.61)(0.38) + 2\,(0.38)\,(3^2+1)^{0.5}} = 0.35 \text{ m} \ (1.15 \text{ ft})$$

Using equation (1),

$$Q = \frac{(1.05)\,(0.35)^{0.667}\,(0.02)^{0.5}}{0.2} = 0.37 \text{ m}^3/\text{s} \ (13.0 \text{ ft}^3/\text{s})$$

The flow capacity of 0.37 m^3/s, is greater than the stability check design storm rate of

0.045 m^3/s (1.6 ft^3/s). If this was not the case, the cross-sectional area should be increased as needed for this conveyance, and new channel dimensions specified.