4.2.6.1 Channel and Swale Stabilization

Source: TNWRRC

Definition and Purpose

Channel and swale stabilization can refer to vegetative, bioengineered, conventional riprap, soil riprap, void-filled riprap, paved, or other linings. The purpose of this practice is to establish a non-erosive channel and reduce the velocity of concentrated flow (KTEC, 2015). This section will focus on vegetative stabilize within channels while hard armoring (Section 4.2.6.4) will focus on structural linings.

Appropriate Applications

This practice applies to construction sites that contain concentrated runoff in an open ditch, channel or swale. Typical locations include roadside ditches, channels at property boundaries, channels created by diversion structures, or channels and swales designed as part of a permanent storm water conveyance system for the site. All conveyances of concentrated runoff require stabilization.

Limitations and Maintenance

This measure only includes stabilizing a channel or swale. During inspections, check the channel for debris, scour, or erosion. For vegetated linings, check to see if vegetation is pushed over or lopsided. These are signs the measures do not provide sufficient stabilization. Repair any bare areas and report insufficient stability immediately. For stabilization guidance of such streams, refer to Section 3.3.2.1.

Planning and Design Considerations

Channel cross sections are most commonly trapezoidal, but can also be rectangular, V-shaped, or parabolic. Channels and swales are to be designed to convey the peak flow rate of the specified design storm in accordance with Section 4.3.2. Because these flows are concentrated, peak velocities and shear stresses may yield erosion within the channel and the outfall. Thus, stabilization is necessary within the channel and an energy dissipator (Section 4.3.4) may be needed at the discharge location.

There are a variety of types of stabilization measures that can be used to line channels and swales:

- Hard armoring (Section 4.2.6.4);
- Rolled erosion control products (Section 4.2.6.6);
- Grasses and vegetation (Sections 4.2.6.11, 4.2.6.12 and Appendix D).

Within each type, there are a variety of choices. For example, within hard armoring, linings may include conventional riprap, gabions, fabric formed revetments, and pavement. As specified in Section 3.3.2.1, Bank Protection, channel and swale stabilization measures must meet permissible velocity and sheer stress specifications. Refer to the previously mentioned sections for construction specifications, permissible velocities, and permissible shear stresses for individual liners. In general, grass lined channels, or vegetated channels are preferred as they more closely resemble natural conditions (KTEC, 2016). In cases where channel velocities, shear stresses, or slopes exceed the capacities of all ideal liners, consider placing check dams (Section 4.3.3) or other measures in the channel to dissipate energy. However, when added measures cannot sufficiently reduce flow velocity and shear within the channel, more extensive linings, such as turf reinforced mats or hard armoring, may be necessary. Impervious linings are generally considered as a last resort.

Ensuring permissible velocities and shear stress are less than peak velocities and maximum shear stresses in the channel is an iterative process (Figure 4.2.6.1-A). First, document the design flow rate, q_p, channel shape, and channel dimensions. Next considering site specific conditions, the surrounding ecosystem, longevity, and budget, determine which lining would be ideal for the given channel. This may involve discussions with an interdisciplinary team, including (but not limited to) engineers, hydrologists, and wildlife biologists. Using Tables in Sections 3.3.2.1, 4.2.6.4, and/or manufacturer specifications, note the Manning's n coefficient, permissible velocity, and permissible shear for the selected liner. Using professional judgment or guidance from the engineer, estimate the depth of flow in the channel during the design flow rate. With this depth, use Manning's equation (Eqn 8) from Section 2.1.2 to estimate an implied peak flow rate, q_i. If q_i is less than five percent different than q_p, the estimated flow depth was acceptable. If not, re-estimate the flow depth with knowledge gained from the preceding steps. Once an acceptable flow depth has been determined, calculate the maximum sheer stress, τ_{max} (Eqns 12-14) from Section 3.3.2.1. If τ_{max} multiplied by a predetermined factor of safety is less than the permissible shear stress of the selected liner, the linear is appropriate. If the permissible shear stress is greater than τ_{max} multiplied by a predetermined factor of safety, re-select an ideal linear that provides more stability. The process then must be repeated since the Manning's n value will be different.

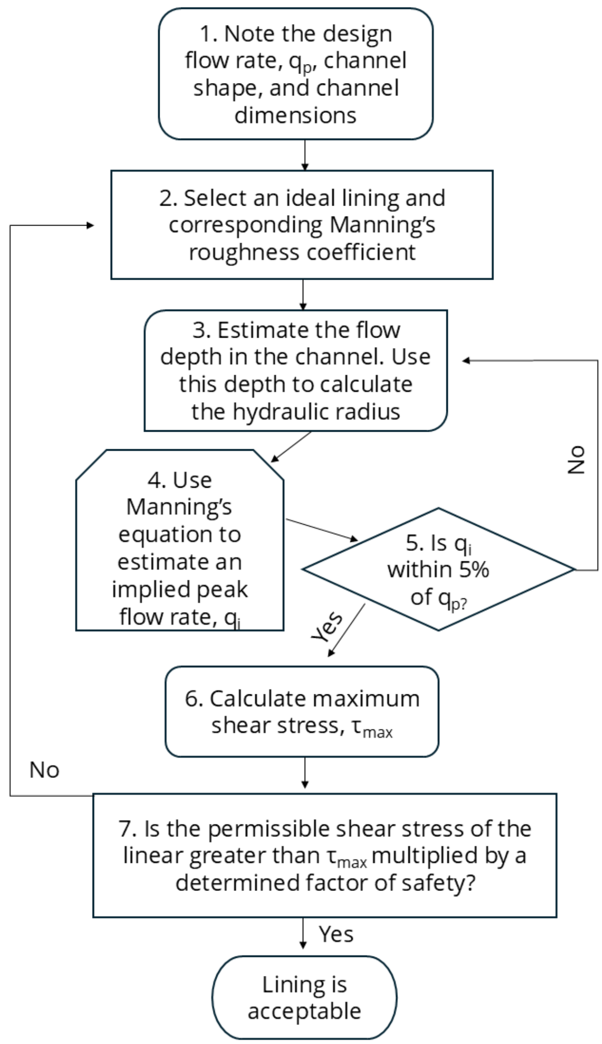

Figure 4.2.6.1-A: Procedure flow chart for determining an acceptable channel or swale lining. Adapted from FWHA (2005).

Remember to follow all construction specifications per individual channel lining. A successfully stabilized channel will not:

- Aggrade or degrade beyond tolerable limits;
- Exhibit signs of erosion;
- Develop sediment bars;
- Form gullies due to the entry of uncontrolled surface flow to the channel;

- Alter the flow capacity of the channel;
- Alter hydrologic properties of the channel;
- Alter the shape of dimensions of the preexisting channel beyond reason; or
- Negatively impact or degrade the surrounding ecosystem beyond reason.

Example Application

Example 1:

Given:

A proposed roadside ditch will extend a distance of 500 feet at a slope of 3.0%. The channel bottom of the ditch is 2 feet and the heigh must be kept below 4 feet. The ditch cross section has 3H:1V side slopes. The engineer has determined that the peak flow rate in the ditch will be 40 cubic feet per second. For aesthetic reasons, a vegetated liner is required for this location.

Determine:

a.) Depth of flow
b.) Velocity of flow
c.) Appropriate channel lining material

Solution:

a.) The depth of flow in the channel may be checked using Manning's equation (Eqn 8, Section 2.1.2) to equal q_p. However, the flow rate will vary based on the roughness, coefficient, so an ideal linear must be selected and tried. Because q_p is moderate, grass likely will not provide sufficient stability. All TRMs provide meet slope requirements, therefore, the least substantial (Type 5a) is tried. Per manufacturer specifications, the Manning's roughness coefficient of a Type 5a TRM is 0.05. Begin with a trial flow depth of 1.5 feet. For a trapezoidal cross section, the flow area, A, wetted perimeter, P, and hydraulic radius, R, are computed (Table 2-A):

$$A = b \times d + z \times d^2 = 2 \times 1.5 + 3 \times 1.5^2 = 9.75\ ft^2.$$

$$P = b + 2 \times d \times (1 + z^2)^{0.5} = 2 + 2 \times 1.5 \times (1 + 3^2)^{0.5} = 11.5\ ft.$$

$$R = A / P = 9.75 / 11.5 = 0.85\ ft.$$

Insert all variables into Manning's equation (Eqn 8, Section 2.1.2) to compute the flow rate corresponding to a depth of 1.5 feet yields:

$$q_i = (1.486 / n) \times A \times R^{0.667} \times S^{0.5}$$

$$q_i = (1.486 / 0.05) \times 9.75 \times 0.85^{0.667} \times 0.03^{0.5}$$

$$q_i = 45.03\ ft^3/s.$$

Since the computed flow rate is more than 5% than the design flow rate of 40 ft^3/s, the assumed trial depth is too low. The trial flow depth is varied as shown below:

Trial Depth (ft)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	q_i (ft^3/s)	Difference (%)
1.5	9.75	11.5	0.85	27.83	30.4
1.7	12.07	12.75	0.95	37.05	7.4
1.76	12.81	13.13	0.98	40.135	0.3

A flow depth of 1.76 feet yields an acceptable q_i.

b.) The flow area, A, for a discharge of 40 ft^3/s would be 12.81 ft^2. Using the Continuity equation (Eqn 7), the flow velocity, V, is computed as:

$$V = Q / A = 40 / 12.81 = 3.12 \text{ ft/s}$$

Since the flow velocity is greater than 2 feet per second, grass is not a suitable linear.

c.) Using Eqn 12 (Section 3.3.2.1), the maximum shear stress, τ_{max}, is computed as:

$$\tau_{max} = \gamma \times d \times S = 62.4 \times 1.76 \times 0.03 = 3.29 \text{ lb/ft}^2$$

Since the ditch is on a tangent section of roadway, it will not be necessary to adjust the computed maximum shear stress for curvature (Eqns 13 and 14 from Section 3.3.2.1). According to Table 4.2.6.10-A, a Type 5a linear has a permissible shear stress of 6 pounds per square foot which exceeds the design sheer stress. This linear provides adequate resistance such that a factor of safety is not required.

Example 2:
Given:

A straightened trapezoidal channel will be seeded and has the following characteristics:

q_p = 20 ft^3 /s
Channel side slopes = 3H:1V
Channel bottom width = 2 ft
Channel height = 3ft
Slope = 0.005 ft/ft

Determine:

d.) Depth of flow
e.) Velocity of flow
f.) Appropriate channel lining material

Solution:

a.) The depth of flow in the channel may be checked using Manning's equation (Eqn 8, Section 2.1.2) to equal q_p. However, the flow rate will vary based on the roughness, coefficient, so an ideal linear must be selected and tried. Because q_p is moderate, grass likely will not provide sufficient stability. Class A1 riprap (n =

0.033) with a trial flow depth, d, of 1 foot is tried. For a trapezoidal cross section, the flow area, A, wetted perimeter, P, and hydraulic radius, r, are computed (Table 2-A):

$$A = b \times d + z \times d^2 = 2 \times 1 + 3 \times 1^2 = 5 \text{ ft}^2.$$
$$P = b + 2 \times d \times (1 + z^2)^{0.5} = 2 + 2 \times 1 \times (1 + 3^2)^{0.5} = 8.32 \text{ ft}.$$
$$R = A / P = 5 / 8.32 = 0.6 \text{ ft}.$$

Insert all variables into Manning's equation (Eqn 8, Section 2.1.2) to compute the flow rate corresponding to a depth of 1 foot yields:

$$q_i = (1.486 / n) \times A \times R^{0.667} \times S^{0.5}$$
$$q_i = (1.486 / 0.033) \times 8 \times 0.56^{0.667} \times 0.005^{0.5}$$
$$q_i = 11.33 \text{ ft}^3/\text{s}.$$

Since the computed flow rate is more 5% less than the design flow rate of 20 ft^3/s, the assumed trial depth is too low. The trial flow depth is varied as shown below:

Trial Depth (ft)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	q_i (ft^3/s)	Difference (%)
1	5	8.32	0.6	1.56	43.3
1.2	6.72	9.66	0.7	16.79	15.6
1.3	7.67	10.22	0.75	20.16	0.8

A flow depth of 1.3 feet yields an acceptable q_i.

b.) The flow area, A, for a discharge of 20ft^3/s would be 7.67 ft^2. Using the Continuity equation (Eqn 7), the flow velocity, V, is computed as:

$$V = Q / A = 20 / 7.67 = 2.61 \text{ ft/s}$$

Since the flow velocity is greater than 2 feet per second, grass is not a suitable linear.

c.) Using Eqn 12 (Section 3.3.2.1), the maximum shear stress, τ_{max}, is computed as:

$$\tau_{max} = \gamma \times d \times S = 62.4 \times 1.3 \times 0.005 = 0.41 \text{ lb/ft}^2$$

Since the ditch is on a tangent section of roadway, it will not be necessary to adjust the computed maximum shear stress for curvature (Eqns 13 and 14 from Section 3.3.2.1). Tables 3.3.2.1-A and 3.3.2.1-C provides maximum allowable flow velocities and shear stresses for riprap; however, it is more ideal to check calculations against manufacturer specifications. Assuming a factor of safety is not needed a maximum velocity of 2.61 feet per second and shear stress of 0.41 are both less than the permissible values for riprap class A1 (permissible velocity of five feet per second and permissible shear stress of 3 pounds per square foot). It appears riprap may be an overdesign for this channel. Therefore, a rolled erosion control product is checked to see if it may be more ideal than riprap (see example in Section 4.2.6.6).

References

FHWA. (2005). *HEC 15: Design of Roadside Channels with Flexible Linings.*

KTC. (2015). *Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites*.

NCDEQ. (2013). *Erosion and Sediment Control Planning and Design Manual.*

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