

## Lined Waterway or Outlet (Ft.) 468

### DEFINITION

A waterway or outlet having an erosion-resistant lining of concrete, stone, synthetic turf reinforcement fabrics, or other permanent material.

### PURPOSE

This practice may be applied as part of a resource management system to support one or more of the following purposes:

- Provide for safe conveyance of runoff from conservation structures or other water concentrations without causing erosion or flooding
- Stabilize existing and prevent future gully erosion
- Protect and improve water quality

### CONDITIONS WHERE PRACTICE APPLIES

This practice applies if the following or similar conditions exist:

1. Concentrated runoff, steep grades, wetness, prolonged base flow, seepage, or piping is such that a lining is needed to control erosion
2. Use by people or animals precludes vegetation as suitable cover.
3. Limited space is available for design width, which requires higher velocities and lining.
4. Soils are highly erosive or other soil or climatic conditions preclude using vegetation only.

### CRITERIA

#### General Criteria Applicable to All Purposes:

Lined waterways shall be planned, designed, and installed to meet all federal, state, local, and tribal laws and regulations.

**Capacity.** The maximum capacity of the waterway flowing at designed depth shall not exceed 200 ft<sup>3</sup>/s. The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm. Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows:

Lining	"n" Value
Concrete	
Trowel finish	0.011– 0.015
Float finish	0.013 - 0.016
Shotcrete	0.016 – 0.025
Flagstone	0.020 – 0.025
<sup>1/</sup> Riprap - (Angular Rock)	$n = 0.047(D_{50} S)^{0.147}$
Synthetic Turf Reinforcement Fabrics and Grid Pavers	Manufacturer's recommendations

<sup>1/</sup> Applies on slopes between 2 and 40% with a rock mantle thickness of 2 x D<sub>50</sub> where:

D<sub>50</sub> = median rock diameter (in.),

S = lined section slope (ft./ft.) (.02 ≤ S ≤ 0.4)

**Velocity.** Maximum design velocity and rock gradation limits for rock riprap-lined channel sections shall be determined using National Engineering Handbook (NEH), Part 650, Engineering Field Handbook, Chapter 16, Appendix 16A, or NEH 654.14C, unless a detailed design analysis appropriate to the specific slope, flow depth and hydraulic conditions indicate that a higher velocity is acceptable.

Maximum design velocity for concrete-lined sections should not exceed those using Figure 2.

Maximum design velocity for synthetic turf reinforcement fabrics and grid pavers shall not exceed manufacturer's recommendations.

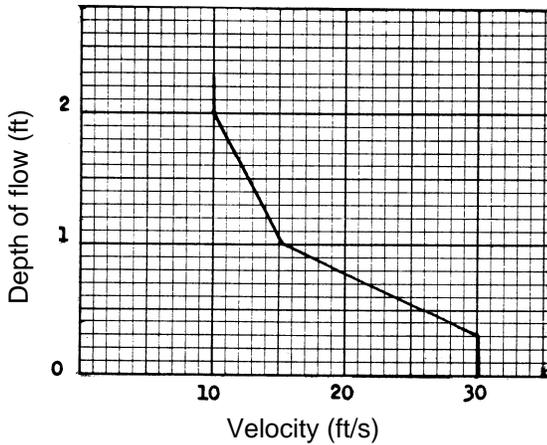


Figure 2. Maximum velocity versus depth of flow for concrete-lined channels

Stable rock sizes and flow depths for rock-lined channels having gradients between 2 percent and 40 percent may be determined using the following detailed design process. This design process is from **Design of Rock Chutes** by Robinson, Rice, and Kadavy.

For channel slopes between 2% and 10%:

$$D_{50} = [q(S)^{1.5}/4.75(10)^{-3}]^{0.53}$$

For channel slopes between 10% and 40%:

$$D_{50} = [q(S)^{0.58}/3.93(10)^{-2}]^{0.53}$$

$$z = [n(q)/1.486(S)^{0.50}]^{0.6}$$

where:

$D_{50}$  = Particle size for which 50% (by weight) of the sample is finer, in.

S = Bed slope, ft./ft.

z = Flow depth, ft.

n = Manning's roughness coefficient

q = Unit discharge, ft<sup>3</sup>/s/ft

(Total discharge ÷ Bottom width)

Avoid channel slopes between 0.7 and 1.3 of the critical slope except for short transition sections. Supercritical flow shall be restricted to straight reaches. *Design guidance on the use of this equation is available in NEH 654.14C.*

Waterways or outlets with supercritical flow shall discharge into an energy dissipator to reduce discharge velocity to less than critical.

**Side slope.** The steepest permissible side slopes, horizontal to vertical, shall be:

Nonreinforced concrete:

Hand-placed, formed concrete

Height of lining, 1.5 ft or less .....Vertical

Hand-placed screeded concrete or mortared in place flagstone

Height of lining, less than 2 ft .....1H to 1V

Height of lining, more than 2 ft .....2H to 1V

Slip form concrete:

Height of lining, less than 3 ft .....1H to 1V

Rock riprap .....2H to 1V

Synthetic Turf Reinforcement Fabrics...2H to 1V

Grid Pavers.....1H to 1V

**Cross section.** The cross section shall be triangular, parabolic, or trapezoidal. Cross section made of monolithic concrete may be rectangular.

**Freeboard.** The minimum freeboard for lined waterways or outlets shall be 0.25 ft above design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the paved or reinforced side slopes. No freeboard is required if vegetation can be grown and maintained.

**Lining thickness.** Minimum lining thickness shall be:

Concrete.....4 in. (minimum thickness shall be 5 in. if the liner is reinforced).

Rock riprap.....Maximum stone size plus thickness of filter or bedding

Flagstone.....4 in., including mortar bed

Synthetic Turf

Reinforcement Fabrics

and Grid Pavers.....Manufacturer's Recommendations

**Lining Durability.** Use of non-reinforced concrete or mortared flagstone linings shall be made only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

**Related structures.** Side inlets, drop structures, and energy dissipators shall meet the hydraulic and structural requirements for the site.

**Outlets.** All lined waterways and outlets shall have a stable outlet with adequate capacity to prevent erosion and flooding damages.

**Geotextiles.** Geotextiles shall be used where appropriate as a separator between rock, flagstone, or concrete linings and soil to prevent migration of soil particles from the subgrade, through the lining material. Geotextiles shall be designed according to AASHTO M288, Section 7.3, *NEH 654.14D*, or *NRCS Design Note 24, Guide for the Use of Geotextiles*.

**Filters or bedding.** Filters or bedding shall be used where appropriate to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to *NEH Part 633, Chapter 26*. Weep holes may be used with drains if needed.

**Concrete.** Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product shall be required. Specify a mix that can be certified as suitable to produce a minimum strength of 3,000 pounds per square inch.

**Contraction joints.** Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 8 to 15 feet. Provide *steel reinforcement* or other uniform support to the joint to prevent unequal settlement.

**Site and Subgrade Preparation.** *Proper site preparation is necessary to provide a stable, uniform foundation for the waterway lining. The site should be graded to remove any rutting or uneven surfaces and to provide good surface drainage throughout the construction period and the design life of the waterway or outlet. Proof rolling can be used to identify soft pockets of soil, additional rutting, or other soil conditions that require removal, and replacement by compacted soil to provide a uniform surface for base, subbase, or concrete liner.*

**Vegetation.** *Plant all areas to be vegetated as soon as practical after construction. If completion does not coincide with appropriate planting dates for permanent cover, use a cover of temporary vegetation to protect the site until permanent cover*

*can be established. Native or functioning-as-native plant species are preferred. Use NRCS Conservation Practice Standard, Critical Area Planting, Code 342, where vegetation is unlikely to become established by natural regeneration, or where acceleration of the recovery of vegetation is desired.*

## CONSIDERATIONS

Consider the potential effects of installation and operation of lined waterways on the cultural, archeological, historic, and economic resources.

**Streambank Soil Bioengineering.** *Trees, shrubs, forbs and grasses can be incorporated into or adjacent to the lined portions of the channel. This may improve aesthetics and habitat benefits as well as reduce erosion potential. Plantings are especially beneficial where the channel transitions to natural ground. However, such plantings are not appropriate in all circumstances. Guidance on the use of plantings is available in NEH 654.14I and NEH 654.14K.*

**Fish and Wildlife Resources.** *This practice may impact important fish and wildlife habitats such as streams, creeks, riparian areas, floodplains, and wetlands.*

*Aquatic organism passage concerns (e.g., velocity, depth, slope, air entrainment, screening, etc.) should be evaluated to minimize negative impacts. Swimming and leaping performance for target species should be considered.*

Important fish and wildlife habitat, such as woody cover or wetlands, should be avoided or protected if possible when siting the lined waterway. If trees and shrubs are incorporated, they should be retained or planted in the periphery of the grassed portion of the lined waterways so they do not interfere with hydraulic functions and roots do not damage the lined portion of the waterway. Mid- or tall bunch grasses and perennial forbs may also be planted along waterway margins to improve wildlife habitat.

*Plant selections that benefit pollinators should be incorporated into the design. Waterways with these wildlife features are more beneficial when connecting other habitat types: e.g., riparian areas, wooded tracts, and wetlands.*

### **Other Considerations.**

- 1) Filter strips established on each side of the waterway may improve water quality.
- 2) Consideration should be given to livestock and vehicular crossings as necessary to prevent damage to the waterway. Crossing design shall not interfere with design flow capacity.
- 3) *Reinforcement of concrete liners should be considered where high pore water pressures exist in the subgrade, movement of the subgrade may occur, or in reaches where failure would endanger public safety or property.*

### **PLANS AND SPECIFICATIONS**

Plans and specifications shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use.

Support data documentation requirements are as follows:

- Inventory and evaluation records
  - Assistance notes or special report
- Survey notes, where applicable
  - Design survey
  - Construction layout survey
  - Construction check survey
- Design records
  - Physical data, functional requirements, and site constraints, where applicable
  - Soils/subsurface investigation report, where applicable
- Design and quantity calculations
- Construction drawings/specifications with:
  - Location map
  - “Designed by” and “Checked by” names or initials
  - Approval signature
  - Job class designation
  - Initials from preconstruction conference
  - As-built notes
- Construction inspection records
  - Assistance notes or separate inspection records
  - Construction approval signature
- Record of any variances approved, where applicable

- Record of approvals of in-field changes affecting function and/or job class, where applicable.

### **OPERATION AND MAINTENANCE**

An Operation and Maintenance (O&M) plan shall be developed for this practice. The O&M plan shall be consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for the design.

### **REFERENCES**

*AASHTO M288. Standard Specification for Geotextile Specification for Highway Applications.*

*National Engineering Handbook, Part 654, Stream Restoration Design, August 2007.*

National Engineering Handbook, Part 650, Engineering Field Handbook: Chapter 16, Streambank and Shoreline Protection.

*National Engineering Handbook, Part 633, Soil Engineering: Chapter 26 – Gradation Design of Sand and Gravel Filters.*

Robinson, K.M., C.E. Rice, and K.C. Kadavy. 1998. Design of Rock Chutes. Transactions of ASAE, Vol. 41(3): 621-626.

*USDA, NRCS Guide for the Use of Geotextiles. Design Note 24 (210-VI-DN-24, 1991).*