

**NATURAL RESOURCES CONSERVATION SERVICE  
CONSERVATION PRACTICE STANDARD**

**LINED WATERWAY OR OUTLET**

(Ft.)

CODE 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**

All planned work shall comply with Federal, state, and local laws and regulations.

Lined outlets with slopes greater than 0.10 ft/ft shall meet or exceed the requirements specified for chute spillways contained in NRCS practice standard Grade Stabilization Structure (410).

**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
<b>Concrete</b>	
Trowel finish.....	0.012 – 0.014
Float finish.....	0.013 – 0.017
Shotcrete.....	0.016 – 0.022
Flagstone.....	0.020 – 0.025
<sup>1/</sup> Riprap - (Angular Rock)	n = 0.047(D <sub>50</sub> S) <sup>0.147</sup>
<b>Synthetic Turf Reinforcement Fabrics and Grid Pavers</b>	
	Manufacturer's recommendations

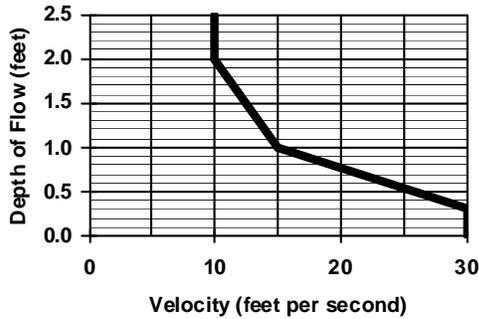
<sup>1/</sup> Applies on slopes between 2 and 40% with a rock mantle thickness of 2 x D<sub>50</sub> where:

D<sub>50</sub> = median rock diameter (in.),  
S = lined section slope (ft./ft.) (.02 ≤ S ≤ .4)

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resource Conservation Service or download the standard from the electronic Field Office Technical Guide for Missouri.

**Velocity.**

**Concrete.** Maximum design velocity for concrete-lined sections should not exceed those using Figure 1.



**Figure 1. Maximum velocity versus depth of flow for concrete-lined channels**

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

**Rock Riprap.** The design velocity for riprap shall be restricted to the safe velocity based on the D50 riprap size. Riprap gradations are shown on page MO-16-1, Engineering Field Handbook (NEH Part 650). [Riprap size is expressed with a subscript equal to percent smaller than. "D50" equals size for which 50 percent (by weight) is smaller. "D100" equals the maximum size.]

Stable rock sizes and flow depths for rock-lined channels having gradients between 2 percent and 10 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%:

$$D_{50} = [q(S)^{1.5}/4.75(10)^{-3}]^{0.529}$$

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

where:

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

S = Bed slope, ft./ft.

z = Flow depth, ft.

q = unit discharge, ft<sup>3</sup>/s/ft  
(Total discharge÷Bottom width)

For channel slopes greater than 10%, the outlet shall meet or exceed the requirements specified for chute spillways contained in NRCS practice standard Grade Stabilization Structure (410).

Except for short transition sections, flow in the range of 0.7 to 1.3 times the critical slope must be avoided unless the channel is straight. Velocities exceeding critical shall be restricted to straight reaches, except for discharges under 10 cubic feet per second or for velocities under 5 feet per second. When site conditions will not permit adjustment in alignment, the following criteria will apply:

1. Smooth simple curves should be used.
2. Curves will not be permitted with channel slopes in the range of 0.7 to 1.3 times critical slope ( $s_c$ ).
3. Curves with channel slopes greater than 1.3 times  $s_c$  will require the following:

Concrete lining - Rectangular cross section, steel reinforcement and superelevation.\*

Riprap lining - Superelevation.

\*Superelevation is defined as the elevation at outer edge of the curve.

Superelevation will be added to the channel depth and will be computed by the equation:

$$S = 0.037 (V^2T) \div R$$

where:

- S = Superelevation – feet
- R = radius of simple curve – feet
- V = design velocity - feet per second
- T = channel top width at design depth - feet

Waterways or outlets with velocities exceeding critical velocity shall discharge into an energy dissipater to reduce discharge velocity to less than critical.

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

Lining Material	Steepest Slope H:V
Reinforced concrete	Vertical
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	1:1
Height of lining, more than 2 ft	2:1
Slip form concrete: Height of lining, less than 3 ft	1:1
Rock riprap	2:1
Synthetic Turf Reinforcement Mat	2:1
Grid Pavers	1:1

**Cross section.** The cross section shall be triangular, parabolic, or trapezoidal. Cross section made of monolithic concrete may be rectangular. Minimum bottom width for riprap lined channel is 6 times D50 size riprap but not less than 2 feet.

**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:

Lining Material	Minimum Lining Thickness
Concrete	4 in. (In most problem areas, minimum thickness shall be 5 in. reinforced concrete.)
Rock riprap	D <sub>100</sub> stone size plus thickness of filter or bedding. (When a geotextile is used in lieu of a designed filter or bedding, the minimum thickness shall be 1.5 times D <sub>100</sub> stone size)
Flagstone	4 in., including mortar bed.
Synthetic Turf Reinforcement Mats 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.

Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing, and thawing. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking.

Use of synthetic turf reinforcement mats when design velocities exceed 8 feet per second, the soil subsurface is expected to be soft or irregular or the material requires protection from such potential hazards as mowing or fire the material matrix shall be soil filled as part of the installation.

**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. Geotextile shall be a non-woven needle punched fabric conforming to Missouri Construction Specification 753 Geotextile.

**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 NRCS standards. Weep holes may be used with drains if needed. Geotextile may be used in lieu of a filter or bedding.

**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. Concrete and reinforcing steel shall conform to Missouri Construction Specification 750, Reinforced Concrete.

**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 10 to 15 feet. Provide welded wire fabric or other uniform support to the joint to prevent unequal settlement. Dowel bars shall be unbounded to the concrete on at least one side of the joint.

**Uplift pressure.** Concrete and mortared flagstone linings shall be investigated for uplift pressure. When buoyancy exceeds lining weight, uplift pressure may be a problem. Weep holes shall be installed when buoyancy cross sectional area is 2.4 (or greater) times the lining cross sectional area and either:

1. Channel slope is 5 percent or flatter.
2. Lining depth is 2 feet or greater.

Minimum weep hole size is 3/4 inch. Weep holes over 1 inch in diameter will require a filter.

**Mortar.** Mortar used for mortared in-place flagstone shall consist of a workable mix of cement, sand, and water with a water-cement

ratio of not more than 6 gallons of water per bag of cement.

**Vegetation.** Disturbed areas that are not part of the lined surface shall be established to permanent vegetation as soon as practicable after construction. Refer to Conservation Practice Standard Critical Area Planting (342) if runoff, soil, climatic conditions preclude the use of vegetation and protection against erosion is needed, non vegetative means, such as mulch or gravel may be used.

## CONSIDERATIONS

Cultural resources need to be considered when planning this practice. Where appropriate, local cultural values need to be incorporated into practice design in a technically sound manner.

Consider adding widths of appropriate vegetation to the sides of the waterway for wildlife habitat.

Important 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. Waterways with these wildlife features are more beneficial when connecting other habitat types; e.g., riparian areas, wooded tracts and wetlands.

Provide livestock and vehicular crossings as necessary to prevent damage to the waterway. Crossing design shall not interfere with design flow capacity.

Establish filter strips on each side of the waterway to improve water quality.

When designing riprap linings and specifying rock gradations, consider that rock delivered to the site is often segregated by size or does not conform exactly to the specified gradation. Adequate safety factor should be incorporated.

## **PLANS AND SPECIFICATIONS**

Plans and specifications for lined waterways or outlets shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose(s).

## **OPERATION AND MAINTENANCE**

An operation and maintenance plan shall be provided to and reviewed with the landowner. The plan shall include the following items and others as appropriate.

A maintenance program shall be established to maintain waterway capacity and outlet stability. Lining damaged by machinery or erosion must be repaired promptly.

Inspect lined waterways regularly, especially following heavy rains. Damaged areas shall be repaired immediately. Remove sediment deposits to maintain capacity of lined waterways.

Landowners should be advised to avoid areas where forbs have been established when applying herbicides. Avoid using waterways as turn-rows during tillage and cultivation operations. Prescribed burning and mowing may be appropriate to enhance wildlife values, but must be conducted to avoid peak nesting seasons and reduced winter cover. Control noxious weeds. Do not use as a field road. Avoid crossing with heavy equipment.

## **REFERENCES**

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

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