

USDA
NATURAL RESOURCES
CONSERVATION SERVICE

MARYLAND CONSERVATION
PRACTICE STANDARD

LINED WATERWAY OR
OUTLET

CODE 468
(Reported by Ft.)

DEFINITION

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

PURPOSES

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

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

**CONDITIONS WHERE PRACTICE
APPLIES**

The practice applies where one or more of the following exists:

1. Concentrated runoff is such that a lining is needed to control erosion;
2. Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion;
3. People or animals preclude use of vegetated waterways or outlets;

4. High-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space that produces higher velocities;
5. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

CONSIDERATIONS

Consider the effects upon components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and ground water recharge.

Consider the filtering effects of vegetation on the movement of sediment and dissolved sediment attached substances

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 establishing filter strips on each side of the waterway to improve water quality and adding a vegetative buffer 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.

When designing riprap linings and specifying rock gradations, consider that rock delivered to

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the [Natural Resources Conservation Service - Maryland](#) or visit the [electronic Field Office Technical Guide \(eFOTG\)](#).

the site is often segregated by size or does not conform exactly to the specified gradation. Adequate safety factor should be incorporated.

CRITERIA

General Criteria

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

Lining	"n" Value
Concrete	
Trowel finish	0.013
Float finish	0.015
Gunite	0.019
Flagstone	0.022
Gabion	0.030
Riprap	Determine from Fig. 1 or $0.047 (D_{50} S)^{0.147}$ *
Grid Pavers	Manufacturer's Recommendations
Turf Reinforcement Fabrics	Chapter 7, Engineering Field Handbook

* If using **Design of Rock Chutes** methodology, use the above equation. Otherwise, use Figure 1.

Velocity – Maximum design velocity and rock gradation limits for rock riprap-lined channel sections shall be determined using Appendix 16A, Engineering Field Handbook unless a detailed design analysis appropriate to the specific slope, flow depth and hydraulic conditions indicate that a higher velocity is acceptable. When using Appendix 16A, D₅₀ rock size shall be used in place of D₁₀₀ for Figure 16A-1.

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%:

$$D_{50} = [q (S)^{1.5} / 4.75(10)^{-3}]^{1/1.89}$$

For channel slopes between 10% and 40%:

$$D_{50} = [q (S)^{0.58} / 3.93(10)^{-2}]^{1/1.89}$$

$$z = [n(q) / 1.486(S)^{0.50}]^{3/5}$$

D₅₀ = Particle size for which 50% of the sample is finer, in.

S = Bed slope, ft./ft.

z = Flow depth, ft.

q = Unit discharge, ft³/s/ft

(Total discharge ÷ Bottom width)

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

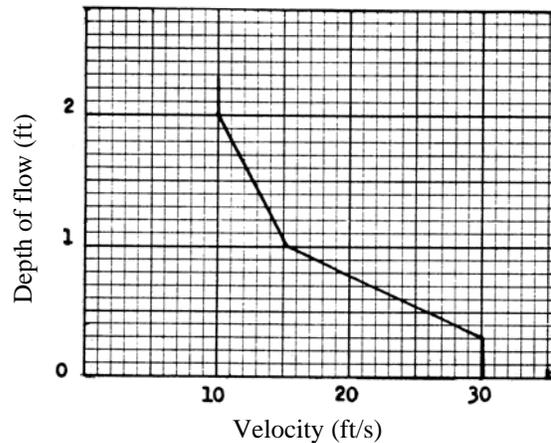


Figure 2. Maximum velocity versus depth of flow for concrete-lined channels

Maximum design velocity for synthetic turf reinforcement fabric lined channels shall be 10 ft/s.

Maximum design velocity for grid pavers shall not exceed manufacturer's recommendations.

Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding critical shall be restricted to straight reaches.

Waterways or outlets with velocities exceeding critical shall discharge into an energy dissipater to reduce velocity to less than critical, or to a ve-

locity the downstream soil and vegetative conditions will allow.

Cross Section – The cross section shall be triangular, parabolic, or trapezoidal. Cross sections 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 and maintained. No freeboard is required if vegetation can be grown and maintained.

Side Slope – The steepest permissible side slopes, horizontal to vertical shall be:

- Non-reinforced concrete:
- Hand-placed, formed concrete
 - Height of lining, 1.5 ft or less..... Vertical
 - Hand-placed screened concrete or mortared in place flagstone
 - Height of lining, less than 2 ft..... 1 to 1
 - Height of lining, more than 2 ft..... 2 to 1
 - Slip form concrete:
 - Height of lining, less than 3 ft..... 1 to 1
 - Rock riprap..... 2 to 1
 - Synthetic Turf Reinforcement Fabric.... 2 to 1
 - Grid Pavers..... 1 to 1

Lining Thickness – Minimum lining thickness shall be:

- Concrete.....4 in. (In most problem areas, minimum thickness shall be 5 in. with welded wire fabric reinforcing.)
- 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 – Installation 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 dissipaters shall meet the hydraulic and structural requirements of the applicable Maryland NRCS Conservation Practice Standard.

Outlet– 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.

Filters or Bedding – Filter or bedding shall be used 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.

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 at least 3,000 pounds per square inch. Cement used shall be Portland cement. Types I, II, or if required, Types IV or V. Aggregate used shall have a maximum size of 1½ inch.

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.

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 ft. Provide welded wire fabric or other uniform support to the joint to prevent unequal settlement.

Rock Riprap or Flagstone – 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.

Cutoff – Concrete walls shall be used at the beginning and ending of concrete lining and rock riprap lining shall be keyed into the channel bottom at both ends of the lining. Depth of cutoff shall be determined by site needs.

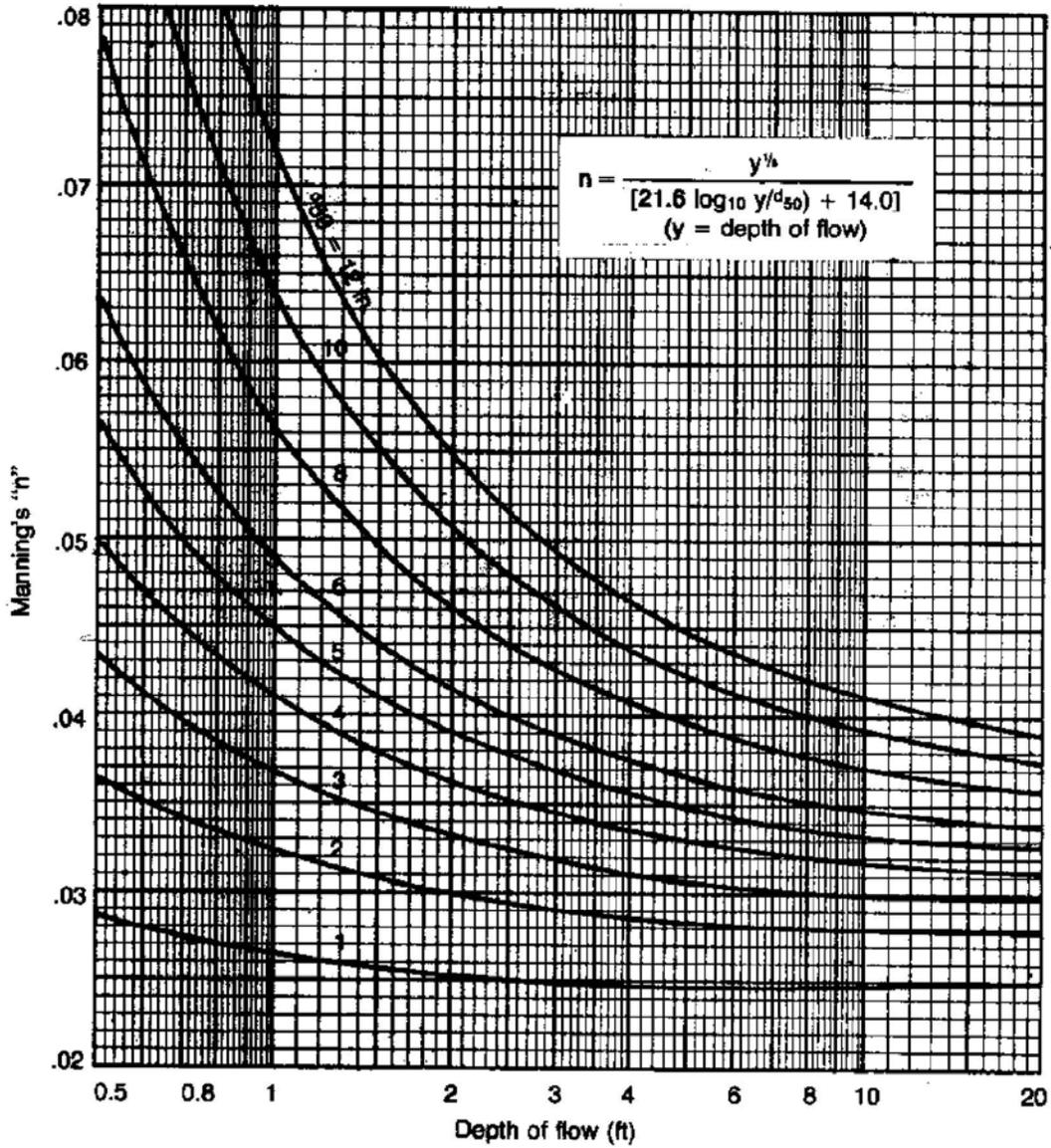


Figure 1.—Values of n for riprap-lined channels, d_{50} size vs depth of flow.

PLANS AND SPECIFICATIONS

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

The foundation shall be cleared of trees, stumps, roots, sod, loose rock, or other objectionable material.

The cross section shall be excavated to the neat lines and grades as shown on the plans. Over excavated areas shall be backfilled with moist soil compacted to the density of the surrounding material.

No abrupt deviations from design grade or horizontal alignment shall be permitted.

Concrete linings shall be placed to the thickness shown on the plans and shall be finished in an appropriate manner. Provisions shall be made to protect freshly placed concrete and to insure proper curing.

Surfacing materials shall not be placed on a wet subgrade.

Filter, bedding, and rock riprap shall be placed to line and grade and in the manner specified. Riprap shall be placed so that it does not reduce the design section more than 10 percent.

Construction operations shall be done in such a manner that erosion and air pollution are minimized and held within reasonable and legal limits. The completed job shall present a good appearance.

All disturbed areas shall be vegetated or otherwise provided with a cover to protect the areas against soil erosion. Seedbed preparation; time of seeding; seeding mixture and rate; stabilizing crop, mulching, or mechanical means of stabilizing; and fertilizer and lime requirements shall be specified for each applicable area. Stabilization shall be in accordance with conservation practice standard Critical Area Planting (342).

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.

1. Pavement or lining should be maintained as built to prevent undermining and deterioration. Trees should be removed next to pavements, as roots can cause uplift damage. Lining damaged by machinery or erosion must be repaired promptly;
2. Inspect lined waterways regularly, especially following heavy rains. Damaged areas shall be repaired immediately. Remove sediment deposits to maintain capacity of lined waterways;
3. Vegetation next to the lining should be maintained in good condition to prevent scouring if the lining is overtopped. See Standards and Specifications for Critical Area Planting for vegetative details;
4. Landowners should be advised to avoid areas where forbs have been established when applying herbicides;
5. Avoid using waterways as turn-rows during tillage and cultivation operations;
6. Prescribed burning and mowing may be appropriate to enhance wildlife values, but must be conducted to avoid peak nesting seasons and reduced winter cover.
7. Control noxious weeds;
8. Do not use as a field road;
9. Avoid crossing with heavy equipment.

SUPPORTING DATA AND DOCUMENTATION

Field and Design Data

Record on appropriate engineering paper. The following is a list of the minimum required design data:

1. Plan view of lined waterway or outlet;
2. Soils investigation that includes rock content and depth to seasonal high water table;
3. Profile of the lined waterway showing channel grade, lining thickness, and ground lines;
4. Cross section showing cross section shape, width and design depth;
5. Lining requirements (size, thickness, geotextile, etc.) and installation details;
6. Seeding, fertilizing and mulching requirements if required;
7. Quantities;
8. Manufacturer design data specifications for synthetic turf reinforcement fabrics and grid pavers.

Construction Check Data/As-Built

1. Installation and construction check notes are to be recorded in sufficient detail to show that the practice meets this standard and applicable specification. Minimum requirements are:
 - a) Measurements to show length, and width; and grade of completed lined waterway or outlet marked in red on the "as-built" plans;
 - b) A statement as to the lining size and thickness is to be placed on the "as-built" plans;
 - c) The certification statement and signature on the "as-built" plans;
 - d) Measurements and computations for quantities will be recorded and filed to

the extent that they are required to determine the number of practice units performed, or as requested by the landuser;

- e) Copy of the manufacturer's installation instructions for synthetic turf reinforcement fabrics and grid pavers.
2. Provide a statement on seeding;
3. Sign and date notes including statement that the practice meets or exceeds plans or specifications.

REFERENCES

1. Maryland Department of Transportation, State Highway Administration, October 1993. *Standard Specifications for Construction Materials*. Baltimore, Maryland;
2. Robinson, K.M., C.E. Rice, and K.C. Kadavy, 1998. *Design of Rock Chutes*. Transactions of ASAE, Vol. 41(3): 621-626;
3. USDA, Natural Resources Conservation Service, *Maryland Field Office Technical Guide, Section IV, Standards and Specifications*;
4. USDA, Natural Resources Conservation Service, *National Handbook of Conservation Practices*;
5. USDA, Natural Resources Conservation Service, *Engineering Field Handbook*, Part 650.