NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

LINED WATERWAY OR OUTLET

(Feet)
Code 468

DEFINITION

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

PURPOSE

- To provide for safe conveyance of runoff from conservation structures or other water concentrations without causing erosion or flooding.
- To stabilize existing and/or prevent future gully erosion.
- To 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

Plan, design and construct the lined waterway or outlet to meet all Federal, state, and local laws and regulations.

Impact to cultural resources, wetlands and Federal and state protected species shall be evaluated and avoided or minimized to the extent practicable during planning, design and implementation of this conservation practice in accordance with established National and Florida policy, General Manual (GM) Title 420-Part 401; Title 450-Part 401, Title 190-Parts 410.22 and 410.26, National Planning Procedures Handbook (NPPH) Florida Supplements to Parts 600.1 and 600.6, National Cultural Resources Procedures Handbook (NCRPH), National Food Security Act Manual (NFSAM), and the National Environmental Compliance Handbook (NECH).

Capacity. The maximum capacity of the waterway flowing at design depth shall not exceed 200 cfs. The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm. Compute the

velocity by using Manning's Formula with a coefficient of roughness "n" as shown in Table 1.

Velocity. Determine the maximum design velocity and rock gradation limits for rock riprap-lined channel sections using National Engineering Handbook (NEH), Part 650, Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection, Appendix 16A, 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 1.

Table 1 - Manning's Coefficient of Roughness "n" for Various Linings.

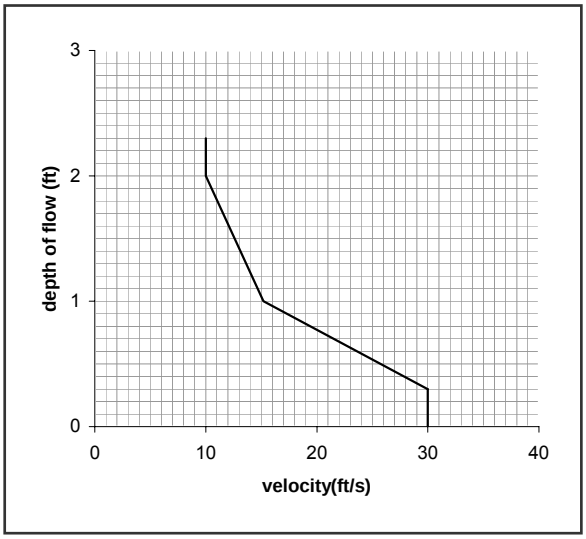
Lining	"n" Value
Concrete	
Trowel finish	0.012 – 0.014
Float finish	0.013 – 0.017
Shotcrete	0.016 – 0.022
Flagstone	0.020 – 0.025
Riprap [1/] - (angular rock)	$n = 0.047(D_{50}S)^{0.147}$
Synthetic Turf Reinforcement Fabrics and Grid Pavers	Manufacturer's Recommendations

[1/] Applies on slopes between 2 and 40% with a rock mantle thickness of 2 x D_{50} where:

D_{50} = median rock diameter (inches),

S = lined section slope (ft./ft.) ($0.02 \leq S \leq 0.40$)

Figure 1 - Maximum Velocity vs. Depth of Flow for Concrete-lined Channels



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

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%:

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

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

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

S = Bed slope, ft./ft.

z = Flow depth, ft.

q = Unit discharge, $ft^3/s/ft$
(Total discharge ÷ Bottom width)

Except for short transition sections, avoid flow in the range of 0.7 to 1.3 of the critical slope unless the channel is straight. Restrict velocities exceeding critical velocity to straight reaches.

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

Side slope. The steepest permissible side slopes shall be as shown in Table 2.

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 foot 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 as shown in Table 3.

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.

Table 2 – Steepest Permissible Side Slopes for Various Linings.

Lining	Side Slopes, Horizontal to 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 that 2 feet	1:1
Height of lining, more than 2 feet	2:1
Slip form concrete:	
Height of lining, less than 3 feet	1:1
Rock riprap	2:1
Synthetic Turf Reinforcement Fabrics	2:1
Grid Pavers	1:1

Table 3 – Minimum Lining Thickness.

Type of Lining	Thickness
Concrete	4 inches (In most problem areas, minimum thickness shall be 5 inches with appropriate reinforcement.)
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 inches including mortar bed
Synthetic Turf Reinforcement Fabrics and Grid Pavers	Manufacturer's Recommendations

Related structures. Side inlets, drop structures, and energy dissipaters 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. Use geotextiles 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. Design geotextiles according to AASHTO M288, Section 7.3.

Filters or bedding. Use filters or bedding where appropriate to prevent piping. Use drains to reduce uplift pressure and to collect water, as required. Design filters, bedding, and drains in accordance with NEH, Part 633 Chapter 26, Gradation Design of Sand and Gravel Filters and NEH, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage). Use weep holes with drains if needed.

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

Contraction joints. Form contraction joints in concrete linings, if required, 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.

Foundation. Design the foundation to support the type of lining used. The foundation design shall include the type of material and compaction requirements.

CONSIDERATIONS

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

Avoid or protect important wildlife habitat, such as woody cover or wetlands, 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.

Lined waterways may increase flow velocities and peak discharge rates to downstream properties and systems. Flow dissipaters and/or structures may be necessary to mimic historical conditions.

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).

As a minimum, the plans and specifications shall include:

- Location of lined waterway or outlet
- Profile and typical cross-section(s) of the lined waterway or outlet.
- Type and quality of materials used to line the waterway or outlet.
- Thickness of liner.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be provided to and reviewed with the landowner.

A maintenance program shall be established to maintain waterway capacity and outlet stability.

The plan shall include the following items and others as appropriate.

- 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.
- 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

AASHTO M288, Section 7.3.
General Manual
Title 420-Part 401
Title 450-Part 401
Title 190-Parts 410.22 and 410.26
K.M. Robinson K.M., C.E. Rice,and K.C. Kadavay, Design of Rock Chutes, Transactions of ASAE, Vol. 41(3): 621-626. 1997
National Cultural Resources Handbook
National Environmental Compliance Handbook
National Food Security Act Manual
National Planning Procedures Handbook
Florida Supplements to Parts 600.1 and 600.6
NEH, Part 633 Chapter 26, Gradation Design of Sand and Gravel Filters
NEH, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage).
NEH, Part 650, Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection