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

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

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 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

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Engineering Handbook (NEH), Part 650, Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection, 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.

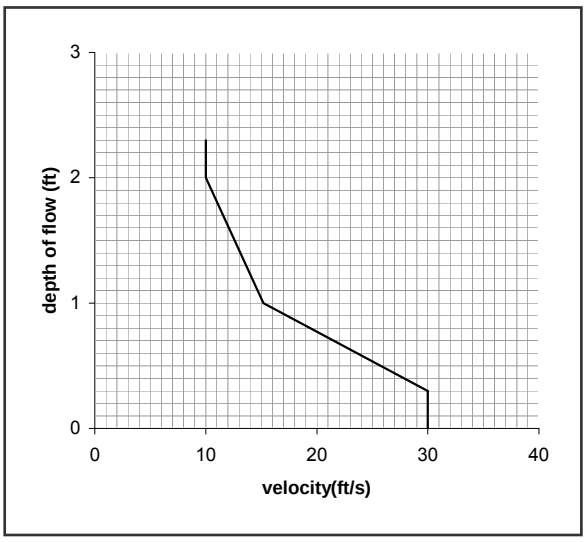
Maximum design velocity for concrete-lined sections should not exceed those using Figure 1.

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

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
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%:

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

For channel slopes between 10% and 40%:

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

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

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)

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 the above equation is available in NEH 654.14C.

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 (minimum thickness shall be 5 inches if the liner is reinforced).
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

Toe-walls. Use toe-walls at the beginning and end of the lining. For concrete or rock riprap, toe-walls shall be of sufficient depth below the bottom of the lining (minimum 24 inches or 1.5 times the thickness whichever is greater) and thickness (minimum of 6 inches) to prevent undermining and extended the full width of the lining.

Toe walls for synthetic turf reinforcement fabric shall be as recommended by the manufacturer.

Cutoff walls. Use cutoff walls on all concrete lined waterways and outlets. The cutoff walls shall be placed at intervals along the length of the concrete to intercept any seepage and prevent piping under the concrete. The cutoff walls shall extend a minimum of 24 inches below the lining bottom and shall be a minimum of 6 inches thick. Extend the cutoff walls the full width of the lining.

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. Provide for energy dissipation as needed.

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, NEH 654.14D, or NRCS Design Note 24, Guide for the Use of Geotextiles.

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 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 lining.

CONSIDERATIONS

Streambank Soil Bioengineering. Trees, shrubs, forbs and grasses may be incorporated into or adjacent to the lined portions of the channel to improve aesthetics and habitat benefits as well as reduce erosion potential. For liners with geotextiles, caution shall be taken to only incorporate vegetation that will not penetrate the geotextile or reduce channel capacity.

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.

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).

Plant selections that benefit pollinators should be incorporated into the design.

Other Considerations.

Filter strips established on each side of the waterway may improve water quality.

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.

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.

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, but not limited to, the following:

- Location of lined waterway or outlet
- Profile and typical cross-section(s) of the lined waterway or outlet.
- Details and location of toe walls, cutoff walls, etc.
- Type and quality of materials used to line the waterway or outlet.
- Thickness of liner.
- Subgrade preparation.
- Seepage control details.

- Disposal requirements for excess soil material.
- Site specific construction specifications that describe the installation of the lined waterway or outlet. Include specification for control of concentrated flow during construction.

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan shall be provided to and reviewed with the landowner. The O&M plan shall establish a maintenance plan to maintain waterway capacity and outlet stability.

The O&M plan shall include, but not limited to, the following items 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

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

NEH 654, Stream Restoration Design

NRCS, Design Note 24, Guide for the Use of Geotextiles

Robinson, K.M.; Rice, C.E. and Kadavay, K.C., Design of Rock Chutes, Transactions of ASAE, Vol. 41(3): 621-626. 1997