LINED WATERWAY OR OUTLET

(Feet)

Code 468

Natural Resources Conservation Service
Conservation Practice Standard

I. Definition

A waterway or outlet having an erosion-resistant lining of concrete, stone, synthetic turf reinforcement fabrics, or other permanent material. ~~The lined section extends up the side slopes to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected.~~

II. Purposes

~~To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.~~ 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 where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.
- Protect and improve water quality.

III. Conditions Where Practice Applies

This practice applies to waterways or outlets having linings of reinforced or non-reinforced, cast-in-place concrete; flagstone mortared in place; rock riprap; synthetic turf reinforcing fabric, or similar permanent linings if the following or similar conditions exist.

- Concentrated runoff is such that a lining is needed to control erosion.
- Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.
- The location is such that use by people or animals preclude use of vegetated waterways or outlets.
- High-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.
- Limited space is available for design width, which requires higher velocities and lining.
- Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

This practice does not apply to:

- Irrigation water conveyance, grassed waterways with stone centers or small lined sections to carry prolonged low flows.
- Waterways that exceed a capacity of 200 cubic feet per second when flowing at design depth.
- Rock chute grade stabilization structures.
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IV. Federal, Tribal, State, and Local Laws

Users of this standard should be aware of potentially applicable federal, tribal, state and local laws, rules, regulations or permit requirements governing lined waterways or outlets. This standard does not contain the text of federal, tribal, state, or local laws.

V. Criteria

The following criteria apply to all purposes.

A. Capacity

The minimum capacity shall be adequate to convey the peak discharge from a 10-year frequency, 24-hour duration storm, unless the lined waterway or outlet protects components of manure management systems. In that case, the minimum capacity shall convey the peak discharge from a storm frequency consistent with

the hazard involved but not less than a 25-year frequency, 24-hour duration storm.

–Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows(see Table 1).:

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

Table 1
Manning's "n" Values

Lining	"n" Value
Concrete	
Trowel finish	.012 – .014
Float finish	.013 – .017
Gunite	.016 – .022
Flagstone	.020 – .025
Rock Riprap	Determine from Table 2

Lining	"n" Value
Concrete – trowel finish	0.0110 – 00.015
Concrete – 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 percent with a rock mantle thickness of 2 x D_{50}.

Where:
D_{50} = median rock diameter (in.)
S = lined section slope (ft/ft) (.02 ≤ S ≤ 0.4)

The lined section shall extend up the side slopes to the design depth. The earth above the permanent lining may be vegetated or otherwise protected from erosion.

Table 2
Manning's "n" Values for Various Sizes of Rock Riprap

D_{50}*		n= $0.04D^{1/6}$**
(inches)	(feet)	
2	0.17	.030
4	0.33	.033
6	0.50	.036
8	0.67	.037
10	0.83	.039
12	1.00	.040

* Where 'D' is diameter of rock, the size of which is such that by weight, 50% is larger and 50% is smaller than this diameter.

**D in feet.

B. Velocity

The maximum design velocity for linings other than rock and synthetic turf reinforcement fabrics shall be as shown in Figure 1.

The maximum design velocity for rock lining shall be the product of the velocity shown in Table 3 times the appropriate slope adjustment factor from Table 4.

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 the critical velocity shall be restricted to straight reaches.

Waterways or outlets with velocities exceeding the critical velocity (super critical) shall discharge into an energy dissipater to reduce the outflow velocity to less than critical.

Table 3
Maximum Velocities for Various Rock Sizes and Shapes

D_{50} Cubical (inches)	D_{50} Spherical (inches)	Maximum Velocity (fps)
12	–	10.8
10	12	9.9
8	10	8.8
6	8	7.6
4	6	6.3
3	4	5.3
2	3	4.3

Table 4
Slope Adjustment Factors to Maximum Velocity for Rock Lining

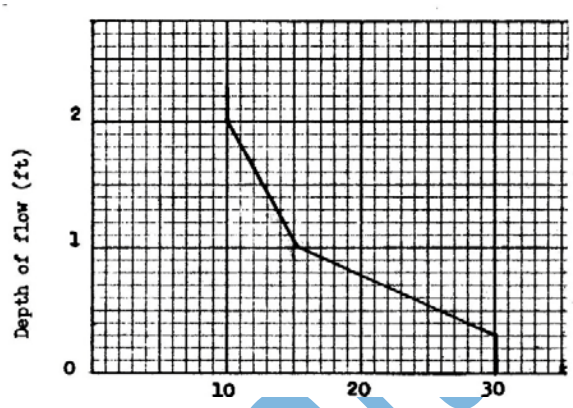
Slope (horizontal to vertical)	Slope (ft/ft)	Adjustment* Factor
3:1	0.33	0.80

~~4:1~~	~~0.25~~	~~0.85~~
~~5:1~~	~~0.20~~	~~0.89~~
~~6:1~~	~~0.17~~	~~0.91~~
~~7:1~~	~~0.14~~	~~0.92~~
~~8:1~~	~~0.13~~	~~0.93~~
~~9:1~~	~~0.11~~	~~0.94~~
~~≥10:1~~	~~0.10~~	~~1.00~~

θ = angle of bed slope

~~* Factor = $\sqrt{\text{Cos}\,\theta - \text{Sin}\,\theta}$~~

Figure 1
Maximum Velocity vs. Depth of Flow for Linings Other Than Rock and Synthetic Turf Reinforcement Fabrics



C. Alignments

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 the critical velocity shall be restricted to straight reaches. Design guidance on the use of this equation is available in NEH 654.14C.

Use transition sections of at least 50 feet long to change channel dimensions.

D. Rock Riprap Linings

The following criteria apply to all rock riprap linings:

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

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

  For channel slopes between 2% and 10%:
  $D_{50} = (FS)(SF)[q(S)^{1.5}/4.75(10)^{-3}]^{0.53}$

  For channel slopes between 10% and 40%:
  $D_{50} = (FS)(SF)[q(S)^{0.58}/3.93(10)^{-2}]^{0.53}$

  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, $ft^3/s/ft$

- Rock shall meet the material requirements of Wisconsin Construction Specification 9, Loose Rock Riprap.
- A minimum factor of safety (FS) of 1.2 shall be used to size the rock.
- A shape factor (SF) of 1.0 shall be used for cubical rock.
- An additional shape factor (SF) of 1.4 shall be used for spherical rock.
- The cross section of the completed lined waterway shall be trapezoidal. Side slopes shall be 2 horizontal to 1 vertical or flatter.
- The rock-lined slope shall be on slopes between 2 percent and 40 percent.
- The minimum depth for the rock riprap linings shall be the design flow depth needed to pass the design flow through a trapezoidal-shaped plus freeboard.
- The minimum rock thickness shall be 2 times the D_{50} rock size.
- A geotextile must be placed beneath the rock. If a sand-gravel bedding is used, the bedding thickness shall be a minimum of 2 inches and placed beneath the geotextile.
- The rock gradation shall be as shown in Table 2.

Table 2
Rock Gradation

Percent Passing	Size[1] (in.)
100	1.5 x D_{50} – 2.0 x D_{50}
85	1.3 x D_{50} – 1.8 x D_{50}
50	1.0 x D_{50} – 1.5 x D_{50}
10	0.8 x D_{50} – 1.3 x D_{50}

[1] Round up to nearest inch.

E. Synthetic Turf Reinforcement Fabrics

Maximum design velocity for synthetic turf reinforcement fabrics and grid pavers shall not exceed manufacturer's recommendations. (Not to exceed 10 feet/second for erosion-resistant soils and 8 feet/second for easily eroded soils as defined in NRCS NEH Part 650, EFH Chapter 7.)

Turf reinforcement fabrics which outlet into permanent tailwater or other conditions which will not support continuous vegetation shall be protected from erosion by drop structures, rock riprap, or other suitable methods.

~~C~~F. Cross Section

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

The steepest permissible side slopes, horizontal to vertical (h:v), shall be as listed in Table 5.~~:~~

Table 5
Steepest Permissible Side Slopes

Lining Material	Side Slope (h:v)
Hand-placed, formed concrete*	
Height of lining, 1.5 feet or less	Vertical
Hand-placed screeded concrete* or mortared-in-place flagstone	
Height of lining, less than 2 feet	1:1
Height of lining, more than 2 fe	2:1
Slip f	
Height of lining, less than 3 feet	1:1
Rock riprap	2:1
Synthetic Turf Reinforcement Fabrics	2:1
Grid Pavers	1:1

Velocity (feet/sec.)

*Non-reinforced concrete.

~~D~~G. Freeboard

~~The minimum freeboard for all rock lined waterways or outlets shall be 0.25 feet above the design water depth. If erosion resistant vegetation cannot be grown adjacent to the rock lined side slopes, an additional 0.25 feet of freeboard will be added (0.5 feet total).~~

No freeboard is required ~~for linings (other than riprap)~~ if vegetation can be grown adjacent to the lined side slope~~and maintained~~.

~~The minimum freeboard for all other lined waterway materials shall be 0.25 feet above the design water depth where erosion resistant vegetation cannot be grown adjacent to the lined side slope.~~The minimum freeboard shall be 0.25 feet above the design depth where erosion-resistant vegetation cannot be grown adjacent to the lined side slopes.~~No freeboard is required for linings (other than riprap) if vegetation can be grown and maintained.~~

~~E~~H. Lining Thickness

Minimum lining thickness shall be:

Table 6
Lining Thickness

Lining Material	Thickness
Concrete	4 inches (without reinforcement) 5 inches (steel bar 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

~~F~~I. Concrete

~~Concrete mixes 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.~~ Concrete shall meet or exceed the requirements of Wisconsin Construction Specification 4, Concrete.

~~Contraction~~ Control joints, 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. ~~Contraction~~ Control joint spacing may be increased based on design procedures used in industry guidelines such as the American Concrete Institute.

Uniform support to the joint to prevent unequal settlement shall be provided.

~~G~~J. ~~Rock Riprap or~~ Flagstone

~~Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing, and thawing. Rock shall meet the material requirements of Wisconsin Construction Specification 9, Loose Rock Riprap.~~

~~The rock gradation shall be:~~

~~**Table 7**~~
~~**Rock Riprap Gradation**~~

~~Percent passing by weight~~	~~Size (inches)*~~
~~100~~	~~2 x D_{50}~~
~~60-85~~	~~1.5 x D_{50}~~
~~25-50~~	~~D_{50}~~
~~5-20~~	~~0.5 x D_{50}~~
~~0-5~~	~~0.2 x D_{50}~~

~~*round to nearest inch~~

Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking. 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 (94 pounds).

~~H~~K. Filters or Bedding

Filters, bedding, or geotextiles shall be used to prevent piping of base materials through the lining. Drainage shall be used to reduce uplift pressure and to collect water, as required. Weep holes may be used with drains if needed.

~~I~~L. Related Structures

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

~~J~~M. Crossings

Crossings shall be in accordance with the criteria contained in Wisconsin NRCS Field Office Technical Guide, Section IV (WI FOTG) Conservation Practice Standard 578, Stream Crossing.

VI. Considerations

Additional recommendations relating to design which may enhance the use of, or avoid problems with, this practice, but are not required to ensure its basic conservation function are as follows.

A. Effects on components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and groundwater recharge.

B. Variability of the practice's effect caused by seasonal and climatic changes.

C. Filtering effects of adjacent vegetation on the movement of sediment and dissolved and sediment attached substances.

D. Effects on the visual quality of landscape or water resources.

E. Short-term and construction-related effects on the quality of water resources.

VII. 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 purpose(s). As a minimum the plans and specifications shall include the following.

- A plan view of the layout of the lined waterway or outlet.
- Typical cross section of the lined waterway or outlet.
- Profile of the lined waterway or outlet.
- 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.

VIII. Operation and Maintenance

An Operation and Maintenance Plan shall be developed that is consistent with the purpose of this practice, intended life of the components, and criteria for design.

The plan shall include but is not limited to the following.

- ~~A.~~ Inspection of channel linings and outlets periodically and after major runoff events.
- ~~B.~~ Replacement of lining materials damaged by runoff events.

- Maintenance of planned v~~C.~~egetation and control of trees and brush.

IX. References

USDA, NRCS, Wisconsin Field Office Technical Guide, Section IV, Conservation Practice Standards and Specifications.

USDA, NRCS National Engineering Handbook (NEH), Part 650, Engineering Field Handbook.

American Society of Agricultural and Biological Engineers (ASABE) Paper No. 002008, An Excel Program to Design Rock Chutes for Grade Stabilization.