

**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 and are suitable for the type of lining planned.

**CRITERIA**

**General Criteria Applicable To All Purposes**

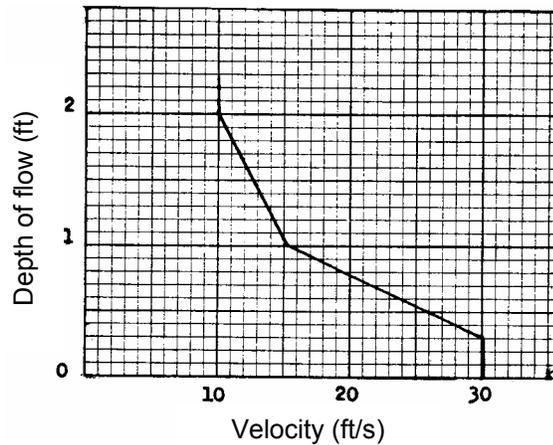
**Capacity.** The maximum capacity of the waterway flowing at designed depth shall not exceed 200 ft<sup>3</sup>/s. The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm. Velocity shall be computed by using Manning's Formula with a coefficient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

Lining	"n" Value
Concrete	
Trowel finish.....	0.012 – 0.014
Float finish.....	0.013 – 0.017
Shotcrete.....	0.016 – 0.022
Gabion Mattress	0.025 – 0.030
Flagstone.....	0.020 – 0.025
<sup>1/</sup> Riprap - (Angular Rock)	n = 0.047(D <sub>50</sub> xS) <sup>0.147</sup>
Synthetic Turf Reinforcement Fabrics and Grid Pavers	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)

**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.



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

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

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%:

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

For channel slopes between 10% and 40%:

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

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

$D_{50}$  = 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)

n = Manning's roughness coefficient

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 velocity shall be restricted 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.

Flagstone lined waterways or outlets shall be limited to a maximum velocity of 10 ft./sec.

**Limitations.** Non-reinforced concrete or mortared flagstone linings are only recommended for low shrink-swell soils that are well drained or where subgrade drainage facilities are installed. Table 1 describes which soils could be considered low shrink-swell and which soils may require treatment. For soils requiring treatment, a blanket material or other soil amendments shall be installed under the concrete structure. Blanket materials shall consist of soils with a Liquid Limit of 30 or less and a Plastic Index of 6 or less.

Concrete lined outlets shall be limited to the following entrance head (D) and fall (F), where D is equal to the depth of flow (He) plus 0.25 feet of freeboard:

<u>Maximum D (ft.)</u>	<u>F (ft.)</u>
2.75	10
2.25	16
1.75	22
1.25	24

Concrete lined outlets with a slope of 10 horizontal to 1 vertical or flatter, have no limit on the total amount of fall. The steepest permissible exit slope for a concrete lined outlet is 2 horizontal to 1 vertical.

Gabion mattress lined outlets shall be limited to the following, where D and F are as described above:

<u>Maximum D (ft.)</u>	<u>F (ft.)</u>
2.5	8
2.3	10
2.1	12
1.9	14
1.5	18

The steepest permissible exit slope for a gabion mattress is 3 horizontal to 1 vertical.

**Table 1  
General Guidance Concerning Base Grade Soils for Concrete and Flagstone Lined Outlets**

Soil Group <sup>1</sup>	Soil Classification		Atterberg Limits	
	USDA Texture	Unified	Liquid Limit (LL)	Plasticity Index (PI)
1	vfsl	ML-CL, ML	< 28	NP-7
	fsl	ML-CL, ML SM-SC, SM	< 26	NP-7
	sl	ML, SM	< 25	NP-4
	lvfs	SM	--	NP
	lfs	SM	--	NP
	ls	SM	--	NP
	vfs	SM	--	NP
	fs	SM, SP-SM	--	NP
	s	SM, SP-SM	--	NP
2	scl	CL, SC	25-37	8-16
	sil	CL,ML-CL, ML	22-37	8-13
	l	CL,ML-CL, ML	20-37	2-14
3	sicl	CL	33-50	12-25
	sc	CL, SC	35-50	14-22
	cl	CL	31-50	10-26
4	c	CH, MH, CL	≥ 45	≥ 20
	sic	CH, CL	41-70	18-38

Soil Group 1 – Very low to low shrink-swell potential. Blanket material or soil amendments are not needed.

Soil Group 2 – Moderately low (PI < 13) to moderate shrink-swell potential. Will normally not require blanket material or soil amendments. However, soils in the upper range of LL or PI for this group may require treatment.

Soil Group 3 – Moderately low (PI < 13) to high shrink-swell potential. Will normally require blanket material or soil amendments. However, soils in the lower range of LL or PI for this group may not require treatment.

Soil Group 4 – High to very high shrink-swell potential. Always use blanket material or soil amendments.

<sup>1</sup> - Regardless of Soil Group, if dispersive clays are present, either blanket material or soil amendments are required.

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

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 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

Gabion Mattress ..... 2.5 to 1  
 Synthetic Turf Reinforcement Fabrics ..2 to 1  
 Grid Pavers.....1 to 1

**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 feet above design high water in areas where erosion-resistant vegetation cannot be grown adjacent

to the paved or reinforced side slopes. Freeboard above the lining is not required if vegetation can be grown and maintained.

Adjacent earthen structures shall be constructed and vegetated a minimum of 0.5 feet above the design high water line to prevent overtopping.

**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
- Gabion Mattress 9 in.
- Flagstone.....4 in., including mortar bed
- Synthetic Turf
- Reinforcement Fabrics
- and Grid Pavers.....Manufacturer's Recommendations

**Erosion control blankets.** Biodegradable erosion control blankets may be used under the following conditions:

1. Design velocities for vegetative lined channels that are within the allowable limits.
2. Temporary erosion control measures are needed to control erosion on the channel banks and/or the channel bottom until adequate vegetative cover can be established.
3. Erosion control blankets are considered as temporary cover and, therefore, may not be substituted for needed permanent linings.
4. Erosion control blankets are applied in accordance with the manufacturer's recommendations.

**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.** Nonwoven 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. The geotextile shall be Class I and have a minimum weight of 8 ounces per square yard. Placement shall be with the length perpendicular to the direction of flow. All overlaps shall be a minimum of 18 inches.

**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.

Bedding for gabion mattresses and where required for concrete lined outlets shall consist of a 3 inch layer of concrete sand and a nonwoven geotextile.

**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 3,000 pounds per square inch. Cement used shall be Portland cement. Types I or II, or if required, Types IV or V. Aggregate used shall have a maximum size of 1-1/2 in.

**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.

**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 94 pound bag of cement.

**Vegetation.** Where vegetation is planned as an integral part of the system for controlling erosion, plantings shall be in keeping with the criteria found in Conservation Practice Standard 342-Critical Area Planting.

## CONSIDERATIONS

Consider the use of fiber reinforcement additives to concrete structures for added durability.

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. Plantings should be in keeping with Conservation Practice Standard 645-Wildlife Upland Habitat Management. 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 in accordance with Conservation Practice Standard 393-Filter Strip.

When designing riprap linings and specifying rock gradations, consider that rock delivered to the site is often segregated by size and/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

A written 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. Replace soil adjacent to and under the lined waterway that has been disturbed by burrowing animals.

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 or as field roads. Avoid crossing the waterway with heavy equipment.

Prescribed burning and mowing may be appropriate to enhance wildlife values, but must be conducted in accordance with Conservation Practice Standard 338 and timed to avoid peak nesting seasons and reduced winter cover. Control of noxious weeds, when necessary, should be in keeping with Conservation Practice Standard 595-Pest Management.

## 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.



**NATURAL RESOURCES CONSERVATION SERVICE  
CONSERVATION PRACTICE GENERAL SPECIFICATIONS**

**LINED WATERWAY OR OUTLET**

(No.)

**CODE 468**

**CONSTRUCTION SPECIFICATIONS**

The foundation area 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.

Linings shall be placed to the thickness shown on the plans and shall be finished in a workmanlike manner. Riprap shall be placed so that it does not reduce the design section more than 10 percent.

Concrete. Concrete shall be placed to the lines and grades as shown on the plans or as staked in the field. The concrete shall be delivered to the site and discharged into the forms within 1-1/2 hours after the introduction of the cement to the aggregates unless a mix design with a set retarder is approved for use by the technician. Concrete shall not be placed when the outside temperature is below 40 degrees or above 90 degrees Fahrenheit. Concrete placed during cold weather shall be protected from freezing during the curing period. The concrete shall be cured by covering with burlap, canvas, or other suitable material and kept from drying out for at least 7 days. The concrete may be cured by coating the surface with an approved white-pigmented curing compound.

Concrete lined outlet tolerances shall be as follows:

1. Lining thickness shall not be more than 1/2 inch less than the designed thickness

measured perpendicular to the concrete surface.

2. Inlet crest shall be within  $\pm$  0.1 foot of the design elevation.
3. Outlet floor shall not be more than 0.1 foot above the design elevation.
4. All other elevations and dimensions shall equal or exceed design requirements.

Rock. Rock use for rip rap shall be durable and meet the specified gradation requirements. Only angular to subrounded rock shall be used. Rock may be placed by equipment or by hand. Placement must ensure that rocks are reasonably homogeneous with larger rocks uniformly distributed and in firm contact with one another and smaller rocks filling in the voids.

Except as provided below, the rock for loose rock and gabion lined outlets shall have the following properties determined by ASTM method C127.

- a. Bulk specific gravity > 2.5 determined by ASTM C127
- b. Absorption < 2% determined by ASTM C127
- c. Soundness: Weight loss in 5 cycles < 10% in sodium sulfate. Weight loss in 5 cycles < 15% in magnesium sulfate.

As determined by ASTM C88 coarse aggregate and modified by Material Specification 523.

Rock that fails to meet the above criteria may be accepted if similar rock from the same source has been demonstrated to be sound

after 5 years or more of serviced under conditions erosive forces similar to those anticipated for the rock to be installed.

Rock gradation shall be as specified on the drawings for the particular site. Rock for gabion mattresses shall meet the following gradation requirements:

Size of Rock	% Smaller By Weight
8 inches	100
6 inches	60-80
5 inches	25-50
4 inches	5-20
# 4	0-5

Gabion Mattresses. Gabion mattress units shall consist of compartmented rectangular basket containers 6 feet wide, 9 inches thick and divided into 3 feet compartments lengthwise. Specifications for materials and installation can be found in NEHB, Chapter 642, Construction Specification 64 – Wire Mesh Gabions and Mattresses, Twisted (Woven) or Welded Mesh.

Rock filling operations shall proceed with placement by hand or machine so as not to damage the wire coating, to assure a minimum of voids between rocks, and to maintain alignment throughout the filling process. The maximum height from which rock may be dropped into the basket units is 36 inches.

of weather, wetting and drying, and Geotextile. Geotextile fabrics shall be of the type specified in the design for the intended purpose. Geotextiles shall meet the requirements of Class I as defined in Material Specification 592 – Geotextile (Part 642 National Engineering Handbook). Installation shall be in accordance with the manufacturers' recommendations. In no case shall material be dropped onto an uncovered geotextile from a height greater than 3 feet.

Prior to placement of the geotextile, the soil surface shall be prepared reasonably smooth and free of loose rocks, holes, projections, mud or standing water. The geotextile shall not be placed until it can be properly anchored and covered within 48 hours.

Sand Bedding. Sand bedding shall consist of a maximum 3 inch layer of concrete sand meeting ASTM C-33.

Synthetic Turf Reinforcement Fabrics and Grid Pavers. Reinforcement fabrics and grid pavers must be approved for the intended use. All manufacturers' recommendations must be followed for the installation of the product.

For reinforcement fabrics placed over seeded areas, the fabric shall be installed within 48 hours of seeding.