Lined Waterway or Outlet

Definition: A waterway or outlet having an erosion-resistant lining of concrete, stone, 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.

Purpose: To provide for safe disposal of runoff from other erosion and sediment control 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.

Conditions where Practice Applies: This practice applies if the following or similar conditions exist:

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. The location is such that use by 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.

5. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

6. Installation of nonreinforced 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.

Planning Considerations

Water Quantity

1. Effects upon components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation transpiration, deep percolation, and ground water recharge should be considered.
2. Seasonal and climatic changes generally will have more effect than the presence or absence of the lined waterway.

Water Quality

1. Filtering effects of vegetation on the movement of sediment, and dissolved and sediment attached substances will be evaluated. Suspended pollutants may move more quickly to a receiving water body.

2. Effects on the visual quality of the water resources will be evaluated. Concentrated erosion may be controlled or eliminated by the practice installation.

3. Short-term and construction-related effects on the quality of water resources will be considered.

Design Criteria

This practice applies to waterways or outlets having linings of nonreinforced, cast in-place concrete; flagstone mortared

in place; rock riprap; or similar permanent linings. This standard may also be used for grassed waterways with stone centers or small lined sections to carry prolonged low flows. The maximum capacity of the waterway flowing at the design depth shall not exceed 200 cubic feet per second. A lined outlet shall be adequate to carry the flow of the pipes or structures discharging into it.

Capacity: The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year frequency storm. In cases where a lined outlet is designed to carry flows from a structure, diversion, or any other water conveyance, the lined outlet shall be designed to convey the same peak flow as that structure, diversion, or conveyance without causing damage by erosion or flooding. Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows:

Concrete	
Trowel Finish	.012 - .014
Float Finish	.013 - .017
Gunite	.016 - .022
Flagstone	.020 - .025
Masonry Units (block)	.030 - .050
Riprap	see Figure 8

Velocity: Maximum design velocity shall be as shown in Figure 11. 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.

Cross section: The cross section shall be triangular, parabolic, or trapezoidal. A cross section made of monolithic concrete may be rectangular.

Side slope: The steepest permissible side slopes, horizontal to vertical, shall be as follows:

Nonreinforced concrete:
- Hand-placed formed concrete
  - Height of lining, 1.5 ft or less.. Vertical
- Hand-placed 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

Suggested Design Procedure for Riprap Lined Waterways:

1. For a given discharge, slope, and estimated d_{50} size, select a trial bottom width and side slope.

2. Estimate the depth of flow.

3. Determine Manning's "n" from Figure 8.

4. Compute the discharge capacity of the waterway for the estimated depth of flow using Manning's formula. See Figure 9 for the elements of channel sections.

5. If the computed discharge is less than the discharge used for the design, increase the depth of flow and repeat the procedure from step 3.

   If the computed discharge is greater than the discharge used for the design,

decrease the depth of flow and repeat the procedure from step 3.

Repeat the procedure until the computed discharge equals the design discharge. The depth at which this occurs is the normal depth of flow for the waterway.

6. Compute the velocity of flow for the waterway using the design discharge and the cross-sectional area of flow at normal depth.
   (V = Q / A)

   Compare this velocity to the allowable velocity taken from Figure 10.

   If the computed velocity is less than the allowable velocity, the riprap is stable. If the computed velocity is also less than the maximum design velocity from Figure 11, the design is acceptable.

   If the computed velocity fails either of the above conditions, increase the channel width and/or the d50 size and repeat from step 2.

Lining Thickness: The minimum lining thickness shall be as follows:

Concrete	4 in. (If welded wire fabric reinforcing is used the minimum thickness shall be 5 in.
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 in., including mortar bed

Extent of lining: The lining shall be used to protect the waterway or outlet to the point where the velocity is reduced below the maximum allowable for the soil type shown in table 3.

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 adjacent to the paved side slopes. No freeboard is required if vegetation can be grown and maintained.

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

Filters or bedding: Filters 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 SCS 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 lb/in^2. Cement used shall be Portland cement, Types I, II, or if required, Types IV or V. Aggregate used shall have a maximum size of 1-1/2 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 for 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. Riprap shall be reasonably well-graded between the specified minimum and maximum sizes. Maximum size shall be 1.5 times the d50 size. Minimum size shall be no less than 3 inches. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking.

Operation and Maintenance

Provisions must be made for timely maintenance to insure lined waterways function properly. Items that should be considered are suggested below. These are not the only items that may need to be considered. Each plan must be site specific.

1. Inspect periodically, at least after every design frequency storm.
2. Repair blowouts, slumps, and eroded areas.
3. Regrade and reseed bare areas above the lining.
4. Replace riprap to design grade if settling or washing has occurred.
5. Inspect concrete for cracks, spalls, or damage needing repair.
6. Remove debris from channel.
7. Repair flagstones or hand-laid rock.

Plans and Specifications

Plans and specifications for constructing lined waterways or outlets shall describe the requirements for applying the practice to achieve its intended purposes.

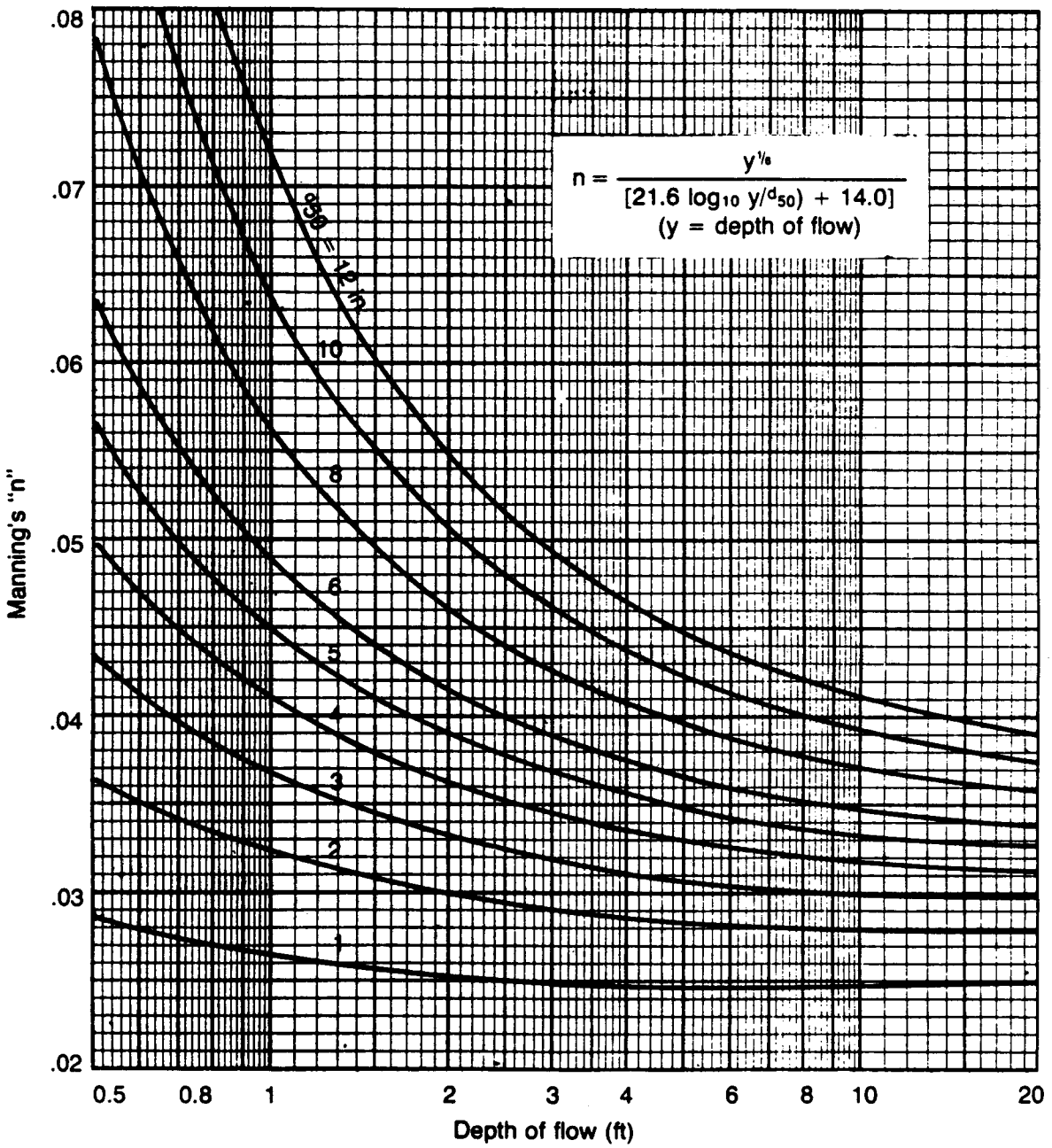
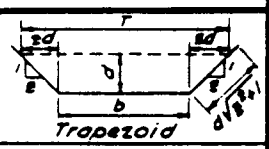
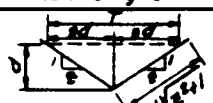
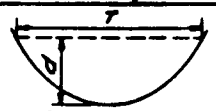


Figure 8 — Values of n for Riprap-Lined Channels, d_{50} Size vs Depth of Flow.

Section	Area a	Wetted Perimeter p	Hydraulic Radius r	Top Width T
 Trapezoid	$bd+zd^2$	$b+2d\sqrt{z^2+1}$	$\frac{bd+zd^2}{b+2d\sqrt{z^2+1}}$	$b+2zd$
 Rectangle	bd	$b+2d$	$\frac{bd}{b+2d}$	b
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$
 Parabola	$\frac{2}{3}dT$	$T+\frac{8d^2}{3T}$ [1]	$\frac{2dT^2}{3T^2+8d^2}$ [1]	$\frac{3a}{2d}$

[1] Satisfactory approximation for the interval $0 < \frac{d}{T} \leq 0.25$
When $d/T > 0.25$, use $p = \frac{1}{2}\sqrt{16d^2+T^2} + \frac{T^2}{8d}\sinh^{-1}\frac{4d}{T}$

Figure 9 — Elements of Channel Sections

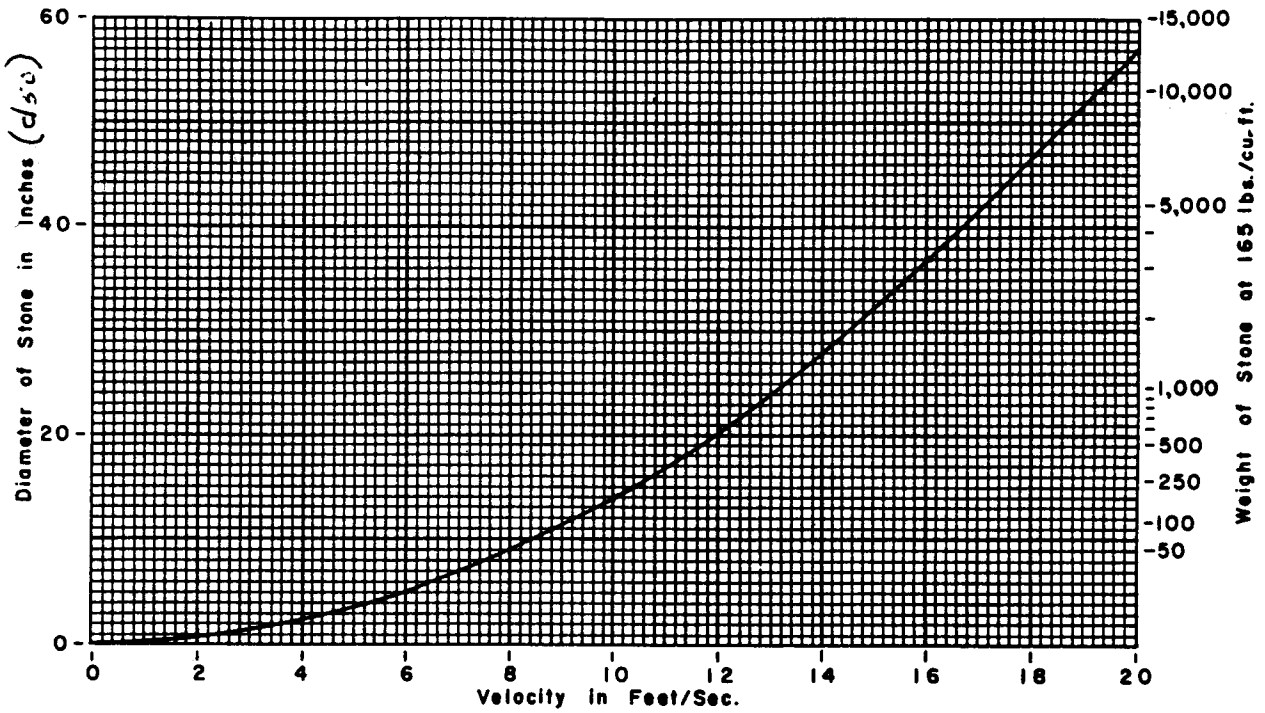


Figure 10 — Allowable Velocity for d_{50} Size

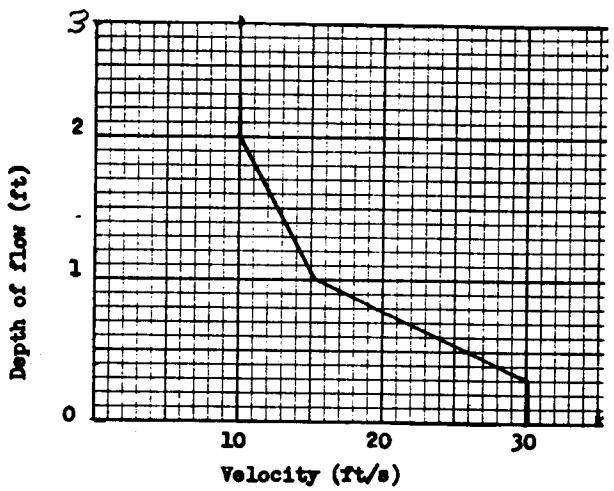


Figure 11 — Maximum Design Velocity vs Depth

Table 3 — Allowable Velocity for Soil.

Soil Material	Velocity ft/sec
Fine Clean Sands (SW, SP)	1.5
Silty Sand (SM)	2.0
Coarse Clean Sand (SW, SP)	2.5
Alluvial Silt, Noncolloidal (ML)	2.5
Alluvial Silt, Colloidal (MH)	3.0
Clayey Sand (SC)	3.0
Lean to Moderately Cohesive Clay (CL)	3.0
Silty Gravel (GM)	3.5
Fine Clean Gravel (GW, GP)	4.0
Clayey Gravel (GC)	4.5
Stiff Clay (CH)	4.5
Coarse Clean Gravel (GW, GP)	5.0
Cobbles and Boulders	6.0
Weathered Shale and Hardpan	6.0

Specifications

Detailed specifications shall be prepared for each installation. These specifications need to consider, as a minimum, the following items.

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 shall be permitted from design grade or horizontal alignment.

Concrete linings shall be placed to the thickness shown on the plans and finished in a workmanlike manner. Adequate precautions shall be taken to protect freshly placed concrete from freezing or extremely hot temperatures, and to insure proper curing.

Filter, bedding, and rock riprap shall be placed to line and grade and in the manner specified.

A protective cover of vegetation shall be established on all exposed surfaces where soil and climatic conditions permit. Lime and fertilizer shall be spread at the specified rate and shall be disked into the soil to a depth of 4 inches to prepare a seedbed. Seed and mulch shall be applied at the specified rate. In some cases, temporary vegetation may be used for protection until conditions are suitable for establishment of permanent vegetation.

Where soil or climatic conditions do not permit the establishment of vegetation, and protection is needed, nonvegetative means such as mulches or gravel may be used.

Construction operations shall be done in a manner that will minimize sediment, air, and water pollution and keep such pollution within legal limits. The completed job shall present a good workmanlike appearance.