United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

IRRIGATION DITCH LINING

CODE 428

(ft)

DEFINITION

An impervious material or chemical treatment lining an irrigation ditch, canal, or lateral.

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Improve the conveyance of irrigation water.
- Prevent waterlogging of land.
- Maintain water quality.
- Prevent erosion.
- Reduce water loss.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to constructed ditches that are part of an irrigation conveyance or distribution system and are subject to erosion or excessive seepage.

This practice applies to areas where irrigation systems are adequate and water supplies are sufficient to make deliveries practical for the types of crops grown and the methods of application used.

This practice does not apply to natural streams.

CRITERIA

General Criteria Applicable to All Purposes

Plan, design, and construct lined ditches, canals, and laterals to comply with all Federal, State, Tribal, and local laws and regulations.

Identify areas where ditches are susceptible to damage from side drainage flooding, and adequately protect these areas from such damage.

Make provisions to protect the lining from external water pressures, frost-heave, chemical reactions with the soil and water, animal damage, and fire.

Establish lining thickness based on engineering considerations for each site. Evaluate location, canal dimensions, velocity, subgrade conditions, the method of construction, operation, lining material, expected life, and climate in determining canal lining thickness.

Materials
On sites where sulfate, salts, or other strong chemical concentrations exist and may cause damage to the lining, ensure that the lining material is either compatible with, or protected from, the chemicals.

Concrete
For concrete liner design, follow criteria established in NRCS Conservation Practice Standard (CPS) Pond Sealing or Lining, Concrete (Code 522). In addition, limit concrete lining in ditches to—

- Bottom width not greater than 6 feet.
- Flow capacities equal to or less than 100 cubic feet per second.
- Design velocities equal to or less than 15 feet per second.

Fly ash may be used to replace up to 25 percent of the cement by weight when other pozzolans are not used. Meet the requirement of the most recent edition of ASTM C-618, “Standard Specification for Coal Fly Ash and Raw or Calcined Pozzolan for Use in Concrete.”

An air entrainment admixture can be used to improve workability and reduce damage caused by freeze-thaw cycles. The air content by volume should be between 4 and 6 percent for a concrete mixture containing a maximum aggregate size of less than 1 inch and 5 to 7 percent for a maximum aggregate size greater than 1 inch.

The water-cement ratio should be 0.50 plus or minus 0.05.

Install concrete linings in soils with high sulfate concentrations in accordance with those values shown below in table 1.

Table 1. Cement Requirements for Concrete Exposed to Sulfates[1]

Water-soluble sulfate (SO_4^{2-}) percent by weight	Dissolved sulfate (SO_4^{2-}) in water parts per million	Cement Type ASTM C150	Cement Type ASTM C595
$SO_4^{2-} < 0.10$	$SO_4^{2-} < 150$	Any	Any
$0.10 \leq SO_4^{2-} < 0.20$	$150 \leq SO_4^{2-} < 1,500$	II	Type IP, IS, or IT with (MS) designation
$0.20 \leq SO_4^{2-} \leq 2.00$	$1,500 \leq SO_4^{2-} \leq 10,000$	V	Type IP, IS, or IT with (HS) designation
$SO_4^{2-} > 2.00$	$SO_4^{2-} > 10,000$	V plus pozzolan or slag cement[2]	Type IP, IS, or IT with (HS) designation plus pozzolan or slag cement[2]

[1] Data taken from American Concrete Institute (ACI) 318, Tables 19.3.1.1 and 19.3.2.1.

[2] The amount of pozzolan or slag cement used should be at least the minimum amount determined by service record to improve sulfate resistance in Type V cement.

Ensure the minimum thickness for plain concrete linings in rectangular sections is 3½ inches. For trapezoidal or parabolic sections, ensure the minimum thickness is in accordance with table 2.

Table 2. Minimum Required Thickness for Trapezoidal or Parabolic Sections, Plain Concrete Ditch, and Canal Linings

Design velocity[1] (ft/s)	Minimum thickness by climatic area[2] (in)	
	Warm	Cold

Design velocity[1] (ft/s)	Minimum thickness by climatic area[2] (in)	
Less than 9.0	1.5	2.0
9.0–12.0	2.5	2.5
12.0–15.0	2.5	3.0

[1] Velocities in short chute sections will not be considered design velocity.

[2] Climatic area designation:

- Warm – Jan. average temperature is above 40 °F
- Cold – Jan. average temperature is below 40 °F

Steel and non-ferrous metal

Protect steel and nonferrous metals subject to damage from soils or corrosive water with coatings, cathodic protection, or other methods specifically designed to protect the liner.

Galvanized lining material must meet the requirements of the most current edition of ASTM A653/A653M, "Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process." Ensure the minimum thickness of the lining material is 24 gauge for individual sheets of 84 inches or less in width and 22 gauge for wider sheets. Ensure the minimum thickness of steel sheets used in bulkheads and related structures is 20 gauge.

Roll or press the edges of the lining sheet into a shape that will provide added strength at the corners and a firm anchorage into the ditch bank berm at the top of the lining.

Ensure that fasteners and anchors used in the assembly of liners are zinc plated, cadmium plated, stainless steel, or epoxy coated and that fasteners and linings are compatible according to the galvanic series. Ensure joints are flexible, watertight, and filled with sealant material capable of withstanding contraction and expansion of the lining material for the temperature variation expected at the site.

Geosynthetic and semi-rigid formed plastic

Protect geosynthetic and semi-rigid formed plastic linings from animal damage, excess heat, and fire. For geosynthetic liners protected by earth or earth and gravel covering, ensure the covering is not less than 6 inches thick and extends a minimum of 6 inches above the top edge of the lining unless recommended differently by the manufacturer. In areas subject to traffic by livestock, ensure the minimum thickness of the protective cover is 9 inches and free of particles larger than three-eighths of an inch, angular particles, and other sharp objects.

Material in the bottom 3 inches of cover must be free of particles larger than three-eighths of an inch, angular rock particles, and other sharp objects. Lining in the bottom of the ditch may require thicker material, as recommended by the manufacturer.

Covered linings require cutoffs and anchor trenches to secure the lining to the subgrade. Exposed linings require cutoffs and anchor trenches to secure the liner from uplift or tearing away from the bottom and sides if the seams release.

Ensure any exposed manufactured lining material has sufficient ultraviolet protection to prevent premature deterioration. Install polyurethane/geotextile composite linings so they are only exposed during installation, according to the manufacturer's recommendations.

The minimum required thickness for various lining materials should consider subgrade conditions, hydrostatic forces, and susceptibility of the lining to damage during or after installation.

Table 3. Minimum Required Thickness for Various Lining Materials

Material	Minimum thickness (mil unless noted)
PVC[1]	30
GCL[1]	0.75 lb/ft^2 sodium bentonite
EPDM	45
EPDM (reinforced)	45
Polyurethane/geotextile composite	45
HDPE	30
LLDPE	30
LLDPE (reinforced)	24
PE (reinforced)	36
FPP	30
FPP (reinforced)	36
Bituminous geomembrane	120
Chemical treatment	3 in
Compacted clay	3 in

[1] Cover required (will not be installed exposed).

Key: PVC – polyvinyl chloride.

GCL – geosynthetic clay liner.

EPDM – ethylene propylene diene monomer (synthetic rubber).

HDPE – high density polyethylene.

LLDPE – linear low-density polyethylene.

PE – polyethylene.

FPP – flexible polypropylene.

Chemical treatment

Chemical treatment includes the application of chemical compounds to the surfaces of earthen ditches. Bentonite or soil cement may be applied as treatment. Application requires the incorporation and compaction of the combined soil and treatment mixture as specified by field performance data or geotechnical laboratory reports. In the absence of these reports, apply treatment mixture at a rate equal to or greater than the amount specified in table 4. Install the liner in maximum lifts of 6 inches.

Table 4. Minimum Required Application Rate for Finished Compacted Lining for Chemical Treatment of Ditches

Material	Minimum application rate/compacted thickness (lb/ft^2)/(in)
TSPP[1]	0.0125
STPP[1]	0.0125
Soda Ash[1]	0.025
Bentonite[1]	See soil type
Silts	0.375
Silty sands	0.5
Clean sands	0.625
Soil cement	1.25

[1] Cover required (will not be installed exposed):

Key: TSPP – tetrasodium pyrophosphate.

STPP – sodium tripolyphosphate.

Soda Ash – sodium carbonate.

Bentonite – sodium bentonite (minimum free swell – 22 ml).

Soil Cement – a mixture of Portland cement, soil, and water.

Capacity
Lined ditches must have adequate capacity to meet the requirements of its intended purpose without damage or surpassing the design freeboard. For design purposes, compute capacity using Manning's formula based on maximum probable roughness condition with an "n" value not less than—

- Concrete – 0.015.
- Steel/nonferrous metal – 0.013.
- Geosynthetic/SRFP (covered) – 0.025.
- Geosynthetic/SRFP (exposed) – 0.011.
- Chemical treatment – 0.025.

Velocity
For channels with noncovered concrete or metal linings, avoid unstable surge flows by limiting velocities to 1.7 times the critical velocity in straight reaches that discharge into ditch sections or structures designed to reduce the velocity to less than critical velocity. Ensure maximum velocity in these straight reaches is less than 15 feet per second.

When using geosynthetic linings, follow the manufacturer's recommendations for velocity limitations.

For channels with covered linings, evaluate the stability of the cover material by computing the velocity using a Manning's roughness coefficient "n" no greater than 0.025.

When soil material is used as a protective cover over a liner, do not exceed the nonerosive velocity for the soil material or the material through which the canal or ditch passes, whichever is less. Local information on velocity limits for specific soils may be used if available. If such information is not available, base stability limits on the tractive stress design approach found in USDA Agricultural Research Service Agriculture Handbook Number 667, "Stability Design of Grassed-Lined Open Channels," or other comparable channel stability criteria.

Ensure the ditch velocity for water delivered onto the field through gates, turnouts, siphon tubes, or similar means is less than supercritical and sufficiently low to permit operation of the planned structure or device.

Freeboard
The required freeboard for a ditch can vary due to the ditch size and slope, materials used to construct the ditch, cross slope, intercepted drainage area, alignment, rate of water surface elevation changes, operation, and other site conditions. Ensure the minimum freeboard for any lined ditch or canal consists of 3 inches of lining above the design water surface. If the design velocity is within ±30 percent of critical velocity, the lined freeboard must be at least 6 inches above the design water surface.

The minimum freeboard requirement is based on the assumption that the finished channel bottom elevation will vary by no more than 0.1 feet from the design elevation. If a construction deviation greater than 0.1 feet is permitted, increase the minimum freeboard. Provide additional freeboard if required by velocity, flow depth, alignment, obstruction, curves, and other site conditions.

Water surface elevation
Design all lined ditches so the water surface elevations at field takeout points are high enough to provide the required flow onto the field surface. If ditch checks or other control structures are used to provide necessary head, include the backwater effect when computing freeboard requirements.

The required elevation of the water surface above the field surface varies with the type of takeout structure or device used and the amounts of water delivered. Provide a minimum head of 4 inches. Use energy dissipation devices where erosion is anticipated at outlets.

Ditch side slopes
For the construction methods and materials shown below, ensure side slopes are no steeper than indicated in table 5.

Table 5. Side Slope Steepness in Various Construction Methods and Materials

Hand-placed, formed concrete		
	Height of lining less than 1½ ft	Vertical
Hand-placed, screeded concrete		
	Height of lining less than 2½ ft	¾H to 1V[1]
	Height of lining more than 2½ ft	1H to 1V
Slip-form concrete		
	Height of lining less than 3 ft	1H to 1V
	Height of lining more than 3 ft	1¼H to 1V
Chemical treatment		
	Spray/stair-step applications	1H to 1V
	Incorporation on slope	3H to 1V
Covered lining		
	Not steeper than	3H to 1V

[1]H – Horizontal, V – Vertical

For materials not listed above, follow the manufacturer's recommendations.

Ditch banks
Shape ditch banks with earth to at least the top edge of the lining and provide necessary anchorage for the top edge of the lining. In cut sections, other than in rock, construct a berm no less than 2 inches above the top of the lining. Design banks and berms that are wide enough to ensure the stability of fills, the lining, and to prevent excessive deposition in cut sections.

When using siphon tubes, provide minimum berm or bank width of 12 inches at the top of the lining on both sides of the finished ditch. Ensure all other canals and laterals have a minimum berm or bank width of 18 inches at the top of the lining.

If the bank or berm is to be used as a roadway, ensure the top width is adequate for the purpose. The minimum recommended roadway width for straight sections is 12 feet.

Outside bank slopes and slopes above the berm elevation in cut sections are flat enough to ensure stability. A slope of 2H to 1V of flatter is recommended. Where vegetation will be maintained by mowing, ensure the slope is 3H to 1V or flatter.

Related structures
Provide adequate inlets, outlets, turnouts, checks, crossings, and any other related structures needed for the successful management of irrigation water. Install structures so the capacity or the freeboard of the ditch is not reduced, and the effectiveness of the lining is not impaired.

Install bulkheads for adequate anchorage that are formed to fit the lining, sufficient size to extend at least 12 inches into the earthen ditch pad for the entire width of the ditch lining, at the beginning and end of the lining section, and at intervening points.

Additional Criteria for Reducing Energy Use

Analyze the reduction of energy use from practice implementation by comparing the planned average annual or seasonal energy use to previous operation conditions. Use a documented methodology as approved by the NRCS.

CONSIDERATIONS

The addition of fiber reinforcement increases the durability and reduces the potential for minor cracking in concrete.

Wetlands or water-related habitats may be adversely affected by the reduction of canal seepage. Changes in vegetation growth along and near the conveyance system that are related to reduced seepage should be monitored, mitigated, and addressed as necessary.

Reduced canal seepage may have effects on the movement of dissolved substances into the ground water.

Changes in downstream flows may affect other water uses or users (e.g., drinking water supplies).

Mitigate short-term and construction-related effects on air quality.

PLANS AND SPECIFICATIONS

Describe the requirements for applying the practice to achieve its intended purposes, to include—

- A plan map showing the location of the lining for the different reaches.
- Typical cross-sections.
- Profiles.
- Site-specific construction details.
- Details for other structures installed with this practice.
- Specifications that describe the installation and materials to be used.

OPERATION AND MAINTENANCE

Determine operation and maintenance requirements based on the site-specific design. As a minimum include—

- A schedule for regular inspections of the lining installation.
- Removal of sediment and debris as required.
- Patching or replacement of damaged sections of lining.
- Other actions specific to the installation to ensure proper performance throughout the conservation practice lifespan.

REFERENCES

ASTM A653/A653M. 2023. Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process. ASTM International, West Conshohocken, PA. DOI: 10.1520/A0653_A0653M-23. http://www.astm.org

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