NATURAL RESOURCES CONSERVATION SERVICE
PACIFIC ISLANDS AREA

CONSERVATION PRACTICE STANDARD

IRRIGATION DITCH LINING

(Ft.)

CODE 428

DEFINITION

A lining of impervious material or chemical treatment, installed in an irrigation ditch, canal, or lateral.

PURPOSE

This practice may be applied as part of a resource management system to achieve one or more of the following purposes:

- Improve conveyance of irrigation water.
- Prevent water logging 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 subject to erosion or excessive seepage and are integral parts of an irrigation water distribution or conveyance system.

This practice applies where water supplies and irrigation deliveries for the area served are sufficient to make irrigation practical for the crops to be grown and the irrigation water application methods to be used.

This practice does not apply to natural streams.

CRITERIA

General Criteria Applicable to All Purposes

Lined ditches shall be located where they are not susceptible to damage from side drainage flooding, or they shall be protected from such damage.

Provision shall be made to protect the lining from external water pressures, frost heave, chemical reactions with the soil and water, animal damage and fire when the lining is subject to damage from excess heat or fire.

Thickness of canal linings must be established on the basis of engineering considerations for each site. Location, canal size, velocity, subgrade conditions, method of construction, operation, lining material, and climate shall be evaluated in establishing thickness to be used.

Materials. On sites where sulfate, salts or other strong chemical concentrations exist and may cause damage to the lining, the lining material must be resistant to or otherwise protected from the chemicals most likely to damage the lining.

Concrete. Concrete linings installed under this standard shall be limited to ditches with:

- bottom widths not greater than 6 feet,
- flow capacities equal to or less than 100 cubic feet per second, and
- design velocities equal to or less than 15 feet per second.

Fly ash can be used to replace up to 15 percent of the cement by weight, when other pozzolans are not used. Fly ash material shall meet the requirements of ASTM C-618 “Standard Specification for Coal Fly Ash and Raw or Calcined Pozzalon for Use in Concrete”.

If air-entrainment admixture is used to improve concrete workability and reduce damage due to freeze-thaw cycles, air content shall not exceed 7 percent of the volume of concrete.

Concrete linings in soils with high sulfate concentrations shall be installed in accordance with those values shown in Table 1.

Table 1. Cement Requirements for Concrete Exposed to Sulfates

Water-soluble sulfate (SO_4) percent by weight	Sulfate (as SO_4) in water parts per million	Cement type ASTM C150 or C595
$SO_4 \geq 0$	$SO_4 \geq 0$	Any
$SO_4 \geq 0.10$	$SO_4 \geq 150$	II, IP(MS), IS(MS), P(MS), I(PM)(MS), I(SM)(MS)
$SO_4 \geq 0.2$	$SO_4 \geq 1500$	V
$SO_4 > 2.00$	$SO_4 \geq 10000$	V plus pozzolan*

- Pozzolan known or shown to improve sulfate resistance in concrete with Type V cement

Minimum thickness for plain concrete linings in rectangular sections shall be 3½ inches. For trapezoidal or parabolic sections, minimum thickness shall be 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
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 shall not be considered design velocity.
[2]Climatic area:
Warm – Average January temperature is 40 °F and above
Cold – Average January temperature is less than 40 °F.

Steel and Non-Ferrous Metal. Steel and non-ferrous metals subject to damage from soils or water with high salt or other chemical concentrations shall be protected with coatings, cathodic protection, or other methods specifically designed to protect the liner from these chemicals.

Galvanized lining material shall equal or exceed the requirements of ASTM A-525 “General Requirements for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process.” The minimum thickness of the lining material shall be 24 gauge for individual sheets 84 inches or less in width, and 22 gauge for wider sheets. The minimum thickness of steel sheets used in bulkheads and related structures shall be 20 gauge.

The edges of the lining sheets shall be rolled or pressed 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.

Fasteners and anchors used in the assembly of liners shall be zinc plated, cadmium plated, stainless steel or epoxy coated. Joints shall be flexible, watertight, and filled with sealant material capable of withstanding contraction/expansion of the lining material for the temperature variations expected at the site.

Flexible Membrane and Semi-Rigid Formed Plastic. Flexible membrane and semi-rigid formed plastic linings shall be protected from animal damage and from excessive heat or fire.

For flexible membrane liners protected by an earth or earth and gravel covering, the covering shall not be less than 6 inches thick and must extend not less than 6 inches above the top edge of the lining, unless recommended by the manufacturer to leave uncovered.

In areas subject to traffic by livestock, the minimum thickness of the protective cover shall be 9 inches and be free of particles larger than 3/8 inch, angular particles, and other sharp objects.

The material in the bottom 3 inches of cover shall be soil free of particles larger than 3/8 inch, angular rock particles, and other sharp objects. Lining in the bottom of the ditch may need to be thicker, as recommended by 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.

Any exposed manufactured lining material shall have sufficient ultraviolet protection to prevent premature deterioration.

Polyurethane/Geotextile composite linings may be exposed when installed according to manufacturer’s recommendations.

The required thickness for flexible membrane, chemical treatment, compacted clay, and semi-rigid formed plastic shall be based on sub-grade conditions, the hydrostatic forces that will be acting on the lining and the susceptibility of the lining to damage during or after installation.

Table 3. — Minimum required thickness for flexible membrane, chemical treatment, compacted clay, and semi-rigid formed plastic linings

Material	Minimum thickness (mil unless noted)
PVC*	20
GCL*	0.75 lb/ft^2 sodium bentonite
EPDM	45
EPDM (reinforced)	45
Polyurethane/Geotextile composite	45
HDPE	30
LLDPE	20
PE (reinforced)	24
PP (reinforced)	24
Bituminous Geomembrane	120
Chemical Treatment	3 in
Compacted Clay	3 in

*Cover required (shall not be installed exposed)

Key: PVC – poly-vinyl chloride
GCL – geosynthetic clay liner
EPDM – ethelene propylene diene monomer (synthetic rubber)
HDPE – high-density polyethylene
LLDPE – linear low-density polyethylene
PE – polyethylene
PP – polypropylene

Chemical Treatment. Chemical treatment includes application of chemical compounds to the surfaces of earthen ditches and shall require incorporation and compaction of the combined soil/chemical mixture unless other wise noted.

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*	0.0125
STPP*	0.0125
Soda Ash*	0.025
Bentonite*	See Soil Type
Silts	0.375
Silty Sands	0.5
Clean Sands	0.625
Soil Cement	1.25

*Cover required (shall not be installed exposed)

Key: TSPP – tetrasodium pyrophosphate
STPP – sodium tripolyphosphate
Soda Ash – sodium carbonate
Bentonite – sodium bentonite (min. free swell – 22 ml)
Soil Cement – mixture of Portland cement, soil and water

Capacity. Lined ditches shall have adequate capacity to meet its requirement as part of the planned irrigation water distribution or conveyance system, without damage or overtopping.

For design purposes, capacity shall be computed using Manning's formula based on maximum probable roughness condition with an "n" value not less than:

- Concrete – 0.015
- Steel/Non-Ferrous Metal – 0.013
- Flexible Membrane/SRFP (covered) – 0.025
- Flexible Membrane/SRFP (exposed) – 0.011
- Chemical Treatment – 0.025

Velocity. In channels with non-covered 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.

Maximum velocity in these straight reaches shall be 15 feet per second.

When using flexible membrane linings, follow the manufactures recommendations for velocity limitations.

In channels with covered linings, the stability of the cover material shall be evaluated 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, the velocity in ditches shall 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, stability limits shall be based on the tractive stress design approach in USDA - ARS (Agricultural Research Service) Agriculture Handbook Number 667 - "Stability Design of Grassed-Lined Open Channels" or other comparable channel stability criteria.

The velocity in ditch reaches from which water is to be delivered onto the field through gates, turnouts, siphon tubes or by similar means, shall be less than supercritical and sufficiently low to permit operation of the planned structure or device.

Freeboard. The required freeboard varies according to the ditch, velocity of water, horizontal and vertical alignment, the amount of storm or wastewater that may be intercepted, and the change in water surface elevation that may occur when any control structure is operating. The minimum freeboard for any lined ditch or canal shall be 3 inches of lining above the design water surface. If the design velocity is within ± 30 percent of critical velocity, the freeboard shall be at least 6 inches.

Minimum freeboard requirement is based on assumption that the finished channel bottom elevation will vary no more than 0.1 feet from design elevations. If a construction deviation greater than 0.1 feet is permitted, the minimum freeboard shall be increased.

Additional freeboard shall be provided if required by velocity, depth of flow, alignment, obstruction, curves, and other site conditions.

Water surface elevations. All lined ditches shall be designed so that 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 to be used to provide necessary head, backwater effect must be considered in 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 to be delivered. A minimum head of 4 inches shall be provided. Where erosion is anticipated at outlets, energy dissipation devices shall be used.

Ditch side slopes. For the construction methods and materials shown below, side slopes shall not be steeper than:

Hand-placed, formed concrete:

Height of lining less than 1½ ft …....Vertical

Hand-placed, screeded concrete:

Height of lining less than 2½ ft ....3/4H to 1V*
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 less than ……..... 3H to 1V
*H – Horizontal, V – Vertical

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

Ditch banks. Ditch banks shall be shaped with earth to at least the top edge of the lining and to provide any necessary anchorage for the top edge of the lining. In cut sections, other than in rock, a berm shall be constructed not less than 2 inches above the top of the lining. Banks and berms shall be a wide enough to ensure stability of fills, the lining, and to prevent excessive deposition in cut sections.

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

If the bank or berm is to be used as a roadway, the minimum top width shall be adequate for the

purpose. Minimum recommended roadway width for straight sections is 12 feet.

Outside bank slopes and slopes above the berm elevation in cut sections must be flat enough to insure stability. A minimum slope is 2H to 1V is recommended. Where vegetation will be maintained by mowing, the minimum slope shall be 3H to 1V.

Subgrade. For flexible membranes, lining material shall be placed on a relatively smooth and firm surface. The top 6 inches of the subgrade shall be free of organic material, particles larger than 3/8-inch in size, angular rock particles, other sharp objects, or anything else that could damage the lining. If the subgrade does not meet these criteria, a 6-inch layer of sand or soil, free of particles larger than 3/8-inch diameter, angular rock particles, and other sharp objects, or an 8-ounce non-woven geotextile material, or a geomembrane composite, shall be used as padding beneath the lining.

Related structures. Plans for ditch lining installations shall provide for adequate inlets, outlets, turnouts, checks, crossings, and other related structures needed for the successful management of irrigation water.

Structures shall be constructed or installed such that the capacity or the freeboard of the ditch is not reduced and the effectiveness of the lining is not impaired.

Bulkheads, formed to fit the lining and of sufficient size to extend at least 12 inches into the earthen ditch pad for the entire width of the ditch lining, shall be installed at the beginning and end of the lining section and at intervening points, as needed, to provide adequate anchorage.

Additional Criteria Applicable to Reduce Energy Use

Provide analysis to demonstrate reduction of energy use from practice implementation.

Reduction of energy use is calculated as average annual or seasonal energy reduction compared to previous operating conditions.

CONSIDERATIONS

- The addition of fiber reinforcement to increase durability and reduce the potential for minor cracking in concrete
- Effects of downstream flows or aquifers that would affect other water uses or users
- Potential changes in growth and transpiration of vegetation located next to the conveyance because of elimination of leakage from the system
- Effects on the movement of dissolved substances into the groundwater
- Effects on wetlands or water-related wildlife habitats
- Effects on the visual quality of water resources
- Energy savings resulting from less water loss and improved irrigation water management
- Short-term and construction-related effects on air quality

PLANS AND SPECIFICATIONS

Plans and specifications for installing irrigation ditch and canal linings shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan shall be developed for irrigation ditch and canal linings. The plan should document needed actions to ensure that practices perform adequately throughout their expected life.

O&M requirements shall be determined as part of the design. Any requirements should be documented as brief statements in the plans, the specifications, or the conservation plan narrative, or as a separate O&M plan. Typical O&M may include sediment/debris removal, patching of cracked concrete, and replacement of deteriorated linings.