NRCS reviews and periodically updates conservation practice standards. To obtain the current version of this standard, contact your Natural Resources Conservation Service State office or visit the Field Office Technical Guide online by going to the NRCS website at https://www.nrcs.usda.gov/ and type FOTG in the search field.

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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 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

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

\(^1\) 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 3⅛ 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

<table>
<thead>
<tr>
<th>Design velocity(^1) (ft/s)</th>
<th>Minimum thickness by climatic area(^2) (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warm</td>
</tr>
</tbody>
</table>

NRCS, NHCP
October 2020R
Velocities in short chute sections will not be considered design velocity.

Climatic area designation:

- **Warm** – January average temperature is above 40 °F
- **Cold** – January 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.

Ensure galvanized lining material meets the requirements 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 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.

Ensure the material in the bottom 3 inches of cover is 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>
<thead>
<tr>
<th>Design velocity(^1) (ft/s)</th>
<th>Minimum thickness by climatic area(^2) (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 9.0</td>
<td>1.5</td>
</tr>
<tr>
<td>9.0–12.0</td>
<td>2.5</td>
</tr>
<tr>
<td>12.0–15.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

\(^1\) Velocities in short chute sections will not be considered design velocity

\(^2\) Climatic area designation:

- **Warm** – January average temperature is above 40 °F
- **Cold** – January average temperature is below 40 °F
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

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum application rate/compacted thickness (lb/ft²)/(in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSPP</td>
<td>0.0125</td>
</tr>
<tr>
<td>STPP</td>
<td>0.0125</td>
</tr>
<tr>
<td>Soda Ash</td>
<td>0.025</td>
</tr>
<tr>
<td>Bentonite</td>
<td>See soil type</td>
</tr>
<tr>
<td>Silts</td>
<td>0.375</td>
</tr>
<tr>
<td>Silty sands</td>
<td>0.5</td>
</tr>
<tr>
<td>Clean sands</td>
<td>0.625</td>
</tr>
<tr>
<td>Soil cement</td>
<td>1.25</td>
</tr>
</tbody>
</table>
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
Ensure lined ditches 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, ensure the lined freeboard is 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

<table>
<thead>
<tr>
<th>Method</th>
<th>Height of Lining Less than 1½ ft</th>
<th>Height of Lining More than 2½ ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand-placed, formed concrete</td>
<td>Vertical</td>
<td>1H to 1V</td>
</tr>
<tr>
<td>Hand-placed, screeded concrete</td>
<td>¾H to 1V</td>
<td></td>
</tr>
<tr>
<td>Slip-form concrete</td>
<td></td>
<td>1¼H to 1V</td>
</tr>
<tr>
<td>Chemical treatment</td>
<td>1H to 1V</td>
<td></td>
</tr>
<tr>
<td>Covered lining</td>
<td>Not less than</td>
<td>3H to 1V</td>
</tr>
</tbody>
</table>

1H – 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.

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

**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.

**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**


