



**Natural Resources Conservation Service**  
**CONSERVATION PRACTICE STANDARD**  
**IRRIGATION SYSTEM, SURFACE AND SUBSURFACE**

**CODE 443**

**(ac)**

**DEFINITION**

A system that delivers irrigation water by surface means, such as furrows, borders, and contour levees, or by subsurface means through water table control.

**PURPOSE**

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

- Efficiently convey and distribute irrigation water to the soil surface point of application without causing excessive water loss, erosion, or water quality impairment
- Efficiently convey and distribute irrigation water to the subsurface point of application without causing excessive water loss or water quality impairment
- Apply chemicals and/or nutrients as part of a surface irrigation system in a manner that protects water quality including downstream drinking water sources.
- Reduce energy use

**CONDITIONS WHERE PRACTICE APPLIES**

This practice applies to areas suitable for irrigation with an adequate water supply of sufficient quantity and quality to make irrigation practical for the planned crops to be grown and application methods to be used.

For surface irrigation, site conditions must be suitable to enable target application efficiency and distribution uniformity to be achieved.

For subsurface irrigation, site conditions and water supply must be suitable to raise and maintain the water table in the crop root zone during the growing season using water control structures and buried perforated pipe or shallow ditch structures.

This standard does not apply to irrigation systems employing subsurface line-source emitters on buried drip tapes or tubing that are addressed by NRCS Conservation Practice Standard (CPS) Irrigation System, Microirrigation (Code 441).

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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## CRITERIA

### **General Criteria Applicable to All Purposes**

Plan, design, and construct the irrigation system to meet all Federal, Tribal, State, and local regulations. Notify landowner and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

This standard does not apply to the detailed design criteria and construction specifications for individual water control, conveyance structures, or appurtenances. Refer to the appropriate NRCS CPSs for requirements for these components.

### **Conservation irrigation methods**

Design the irrigation system as an integral part of an overall plan of conservation land use and treatment for the farm that is based on capabilities of the land and needs of the irrigated area.

Base the system design on sound irrigation water application methods that are suited to the soils, topography and crops to be grown. Choose methods that provide efficient use of water without causing irrigation-induced soil erosion or downstream water quality degradation.

### **Capacity**

The irrigation system must have adequate capacity to meet the intended purposes. If more than one irrigation method will be used on the same field, the system capacity must be adequate for the method requiring the highest water delivery rate.

Design all structures and water delivery components to include adequate capacity and freeboard for the expected maximum flow conditions.

### **Water control**

The farm irrigation systems must include the necessary structures required for water regulation and control, such as measuring devices, division boxes, checks, turnouts, pipelines, lined ditches, valves, pumps, and gates.

### **Irrigation water management plan**

Prepare an irrigation water management plan that addresses the volume, frequency, and application rate of irrigation water using the criteria in NRCS CPS Irrigation Water Management (Code 449).

### **Additional Criteria Applicable to Surface Irrigation Systems**

Design the components necessary to implement this practice using criteria in the appropriate NRCS CPSs:

- Irrigation Pipeline (Code 430)
- Irrigation Canal or Lateral (Code 320)
- Irrigation Field Ditch (Code 388)
- Structure for Water Control (Code 587)
- Pumping Plant (Code 533)
- Irrigation Land Leveling (Code 464)
- Irrigation and Drainage Tailwater Recovery (Code 447)
- Other pertinent standards

**Application efficiency and distribution uniformity**

Use local irrigation guides or NRCS National Engineering Handbook (NEH) (Title 210), Part 623, Chapter 4, "Surface Irrigation" to select the appropriate surface irrigation method and combination of field slope, length, configuration, flow rate, and tailwater management to achieve target or design application efficiencies and distribution uniformity values.

Application efficiency should be no greater than 90 percent for properly designed, level surface irrigation systems and a maximum of 80 percent for graded systems. Guidance for selecting design application efficiencies is provided in 210-NEH, Part 623, "Irrigation" and Part 652, "Irrigation Guide."

**Capacity**

In computing capacity requirements, make allowances for reasonable water losses during application and any leaching requirements.

**Design application rate**

Design the rate of application within the range established by the minimum practical application rate for climatic conditions and the maximum rate consistent with the soil water intake rate and conservation practices used on the land.

**Water surface elevation**

Design the water surface elevation at field takeout points with at least 4 inches of head to provide the required flow onto the field surface.

**Location of delivery ditches or aboveground, multioutlet distribution pipelines**

Locate delivery ditches or pipelines so irrigation water can be applied uniformly over the entire field without causing erosion. Space the ditches or pipelines so irrigation run lengths are not longer than the maximums specified in the local irrigation guide or those determined acceptable based on field slopes. If more than one crop is to be grown or more than one method of irrigation used, the ditch or distribution pipeline spacing must not exceed the allowable run length determined for the limiting crop or method.

**Aboveground, multioutlet distribution pipeline**

The maximum working pressure for all aboveground, multioutlet distribution pipes except for polyethylene irrigation tubing is 10 pounds per square inch or 23 feet of head. Install appropriate head control appurtenances to reduce the maximum working pressure to acceptable levels.

For polyethylene irrigation tubing, follow the manufacturer's recommendations for maximum allowable working pressure. If the manufacturer's recommendations are not available, use the hoop stress formula in 210-NEH-636, Chapter 52, "Structural Design of Flexible Conduits" to determine maximum working pressure, with a 1.5 safety factor.

Design the capacity of the pipeline to deliver an adequate irrigation stream to the design area for the planned irrigation method. For design purposes, friction head losses must be no less than those computed by the Hazen-Williams equation, using roughness coefficients of  $C=130$  for aluminum pipe and  $C=150$  for plastic or polyethylene irrigation tubing. At full capacity, the velocity in the pipeline must not exceed 7 feet per second unless appropriate surge protection is provided.

Individual outlet gates must have the capacity at the design working pressure to deliver the required flow to a point at least 4 inches above the field surface. The working head must be least 0.5 feet above outlet gates, unless a detailed design or manufacturer's literature

indicates a lower head is adequate to deliver the required water to the field. If either the design working head exceeds 5 feet or stream flows are erosive, install an effective method of energy dissipation at each gate, or establish and maintain permanent vegetation along the pipeline to provide erosion control.

Include a suitable outlet at the end of the pipeline for flushing the line free of sediment or other debris.

Use aluminum or plastic pipe material certified for aboveground use. All fittings and couplers must have a pressure rating that exceeds or is equal to the pressure rating of the pipe. They must be made of material recommended by the manufacturer as compatible for use with the pipe.

Select rubber gaskets according to the manufacturer's standard design dimensions and tolerances for the pipe material selected. Each gasket must be the size and shape that, after assembly, adequate compressive force is provided against the spigot and socket to provide a positive seal. The gasket must be a continuous elastomeric ring and the sole element depended upon to make the joint flexible and watertight.

The minimum allowable wall thickness for aluminum gated pipe is:

- 6 inches to 10 inches in diameter — 0.05 inches
- 12 inches in diameter — 0.058 inches

Provide corrosion protection for aluminum pipe when—

- Conveying water with a copper content exceeding 0.02 parts per million.
- In contact with soil having a resistivity of less than 500 ohm-centimeters.
- In contact with soil having a pH less than 4 or greater than 9.

The minimum allowable wall thickness for PVC gated pipe including consideration of any standard manufacturing tolerances is 0.09 inches with a pressure rating of 22 pounds per square inch or greater, prior to gate installation.

The minimum allowable wall thickness of polyethylene irrigation tubing is 6 mil (0.006 inches).

### **Related structures**

When an open ditch is used to supply water to a multioutlet pipe, include a permanent water control structure as the inlet to multioutlet pipe.

When the water supply for polyethylene irrigation tubing is greater than 0.5 feet above the ground, use a PVC or aluminum fitting to convey water between the supply outlet and the polyethylene irrigation tubing at ground level.

### **Erosion control**

Design irrigation systems to convey and distribute irrigation water without causing damaging soil erosion. Provide nonerosive gradients on all unlined ditches. If water is conveyed on slopes steep enough to cause erosive flow velocities, install structural erosion control measures such as pipe drops, chutes, buried pipelines, or erosion-resistant ditch linings. Polyacrylamide may be used for erosion control according to NRCS CPS Anionic Polyacrylamide (PAM) Application (Code 450) in lieu of, or in combination with, structural measures.

**Seepage control**

If site conditions require conveyance of water across excessively permeable soils, design the irrigation system to provide for pipelines, flumes, or lined ditches to prevent excessive seepage losses.

**Tailwater and excess runoff removal**

Include facilities of adequate capacity for the saferemoval of irrigation tailwater and storm water runoff. If erosion is a hazard, collection facilities (ditches) constructed for this purpose must be on nonerosive gradients or stabilized by lining or structural measures. If field elevations do not permit nonerosive disposal of tailwater or excess water by gravity flow, provide for installation of pumping plants and other needed appurtenant structures.

If excess water will be reused for irrigation, include a tailwater reuse system that conforms to NRCS CPS Irrigation and Drainage Tailwater Recovery (Code 447).

**Additional Criteria Applicable to Subsurface Irrigation Systems**

Design subsurface irrigation systems to maintain the water table at predetermined design elevations below the ground surface at all points in the application area during the growing season. Procedures and guidance for subsurface irrigation system planning and design are provided in 210-NEH, Part 624, Chapter 10, "Water Table Control."

Space feeder ditches or conduits for subsurface irrigation so the variation in depth from the land surface to the water table provides adequate irrigation of the most limiting crop to be grown.

Subirrigation systems in enclosed greenhouses shall include the necessary components to provide sufficient quality and quantity of water and nutrients to the plants, and ensure complete capture of all water for treatment and reuse (zero-runoff systems). Examples of zero-runoff subirrigation systems include:

- Systems that provide a periodic introduction of a water table, such as troughs, ebb-and-flow benches, and flood floors.
- Systems that provide a constant water table, such as capillary mats, buoyant trays, and V-bottom beds.

Design components used for subsurface irrigation using the criteria in NRCS CPSs:

- Subsurface Drain (Code 606)
- Structure for Water Control (Code 587)
- Pumping Plant (Code 533)
- Other pertinent standards

**Soils and topography**

Soils and topography must be such that water can move laterally from open ditches or subsurface pipes to form and maintain a water table at the design depth as specified in the irrigation water management plan. Do not use subsurface irrigation unless the irrigated area has a slowly permeable water restrictive layer below the subsurface pipes.

Soil survey information for the irrigated area can be used in preliminary planning. Base the final design on onsite lateral hydraulic conductivity measurements or average lateral hydraulic

conductivity determined from laboratory tests of each soil layer.

### **Lateral spacing**

Space laterals equally in each subunit. Maximum spacing of subsurface pipes or open ditches must be no more than one-half the lateral or ditch spacing specified in local drainage guides, or no more than one-half the lateral or ditch spacing computed using procedures found in 210-NEH, Part 650, Chapter 14, "Water Management (Drainage)" or 210-NEH-624-10.

### **Water control**

Within each managed subunit, provide a water level control structure of sufficient size to allow adequate flow to meet water requirements of that subunit. The control structures should be set at elevation intervals not exceeding 1 foot.

Water level control structures must be covered or otherwise protected to prevent accidental entry by animals, livestock, machinery, or humans.

### **Application efficiency**

Base system capacity on the appropriate design application efficiency. Design application efficiency should be no greater than 90 percent for soils with minimal lateral losses and a maximum of 75 percent for all other soils.

### **Additional Criteria Applicable for Application of Chemicals and/or Nutrients with a Surface Irrigation System**

The installation and operation of an irrigation system for the purpose of chemical and/or nutrient application must comply with all applicable Federal, State, and local laws, rules, and regulations. This includes backflow and antisiphon prevention measures to protect surface water and ground water sources. Additionally, protect surface waters from direct application and runoff.

Design of physical components shall be in accordance with NRCS CPSs:

- Irrigation Pipeline (Code 430)
- Waste Transfer (Code 634)
- Structure for Water Control (Code 587)
- Pumping Plant (Code 533)
  
- Other pertinent standards

### **Capacity**

Ensure the design capacity is adequate to supply the specified amount of chemical and/or nutrients to the design area in the specified operating period.

### **Nutrient and Pest Management**

Apply chemicals, fertilizers, waste water, and liquid manure in accordance with NRCS CPSs Nutrient Management (Code 590), Pest Management Conservation System (Code 595), or Waste Recycling (Code 633).

### **Additional Criteria Applicable to Reduce Energy Use**

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

Calculate the reduction of energy use as an average annual or seasonal energy reduction

compared to previous operating conditions.

## CONSIDERATIONS

When planning this practice consider how irrigation practices might affect the following items:

- Effects of soluble salts, nutrients, and pesticides on surface and ground water quality.
- Effects of saturated water levels on soil nutrient processes such as plant nitrogen use or denitrification, and root development.
- Effects on the soil biota that will alter nutrient cycling and carbon utilization. Waterlogged and tillage-dominated soils become bacteria-driven systems that denitrify and ineffectively utilize carbon.
- Effects on aquatic and wildlife communities, wetlands, or water-related wildlife habitats, including effects on pollinator foraging and nesting habitats.
- When planning and designing surface and subsurface irrigation systems, soil texture, compaction, corrosivity, seepage, intake rate, slope, and soil depth are important soil properties that influence installation and performance. Designers should refer to soil survey information for the irrigated area during preliminary planning and conduct onsite soil investigations prior to final design.

When designing a surface irrigation system the following should be considered:

- To improve surface irrigation efficiency, surface tillage should be reduced when possible. The destruction of soil structure caused by physical and chemical disturbance can severely impede the ability of some soils to take in water.
- Impact of salt leaching requirements on system management, capacity, and drainage requirements.
- Effects of erosion and movement of sediment and sediment-attached substances carried by runoff, such as salinity, nutrients, pesticides, seeds, and vegetative portions of invasive plants on downstream receiving waters.
- Effect of elevated irrigation tailwater temperatures on downstream receiving waters.
- Design, evaluation, and simulation models such as WinSRFR can be very useful tools in finalizing surface system designs.

When designing a subsurface irrigation system the following should be considered:

- Potential benefits of water level control on downstream water quality.
- Potential effects of practice management on lateral seepage.
- Orienting lateral lines along the contour maximizes the area influenced by each water level control structure.
- Soil layers in the water transmission zone (root zone) should have a higher lateral saturated

hydraulic conductivity than the vertical saturated hydraulic conductivity of the water restrictive layer. However, if lateral hydraulic conductivity of any single soil layer in the root zone exceeds 10 times that of other layers, lateral seepage may make it difficult to raise the water table to the design depth.

- During periods of drought, additional pumping capacity may be needed to raise the water table to provide the needed level of irrigation.



When planning a surface irrigation system employing an above ground, multioutlet, distribution pipeline the following should be considered:

- Provisions should be made for thrust control at locations subject to pipe movement.
- Good grade control along the pipeline and along the rows is needed to assure uniform water distribution.
- Consider the water source and potential trash types and amounts when designing or selecting inlet screen types and sizes.
- Plan for disposal of used polyethylene irrigation tubing and encourage recycling.
- Polyethylene irrigation pipe may need to be anchored if exposed to windy conditions
- PVC gated pipe with wall thickness less than 0.12 inches will be more flexible making soil support and uniform pipe grade more important if an irrigation stream contains sand. Sand will tend to settle and accumulate in any gated pipe low points.

### **PLANS AND SPECIFICATIONS**

Prepare plans and specifications for surface and subsurface irrigation systems to comply with this standard and that describe the requirements for applying this practice to achieve its intended purpose. As a minimum include—

- Plan view of site showing layout, field slopes, and topography, as needed, existing and planned features, and other appurtenances.
- Profiles and cross-sections of pipes, ditches, and fields, as needed.
- Materials and quantities needed.
- Construction specifications describing in writing the installation of the practice.

### **OPERATION AND MAINTENANCE**

Prepare an operation and maintenance plan specific to the facilities installed for use by the landowner or operator responsible for operation and maintenance. The plan should provide specific instructions for operating and maintaining facilities to ensure they function properly. At a minimum, address—

- Periodic cleaning and regrading of tailwater collection facilities to maintain proper drainage, capacity, and functionality.
- Periodic checks and removal of debris as necessary from trash racks and structures to ensure proper operation.
- Periodic removal and proper disposal of sediment from traps and/or storage facilities to maintain design capacity and efficiency.
- Periodic inspection and testing of all pipeline and pumping plant components and appurtenances.
- Routine maintenance of all mechanical components in accordance with the manufacturer's recommendations.
- Periodic land smoothing or grading of surface irrigated fields required to maintain the design grade in the direction of flow.

For subsurface irrigation, the plan will also include—

- Water control structure elevation settings by date required to maintain water table at



design depth.

- Inclusion of specification and locations of all required ground water observation wells.

## REFERENCES

USDA NRCS. 2012. National Engineering Handbook (Title 210), Part 623, Chapter 4, Surface Irrigation. Washington, D.C. <https://directives.sc.egov.usda.gov/>

USDA NRCS. 2001. National Engineering Handbook (Title 210), Part 624, Chapter 10, Water Table Control. Washington, D.C.

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