Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SPRINKLER SYSTEM

CODE 442

(ac)

DEFINITION

A distribution system that applies water by means of nozzles operated under pressure.

PURPOSE

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

- Apply water on irrigated lands, efficiently and uniformly.
- Improve plant condition, productivity, health, and vigor.
- Prevent the entry of excessive nutrients, organics, and other chemicals in surface and groundwater.
- Improve condition of soil contaminated with salts and other chemicals.
- Reduce particulate matter emissions to improve air quality.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to the planning and functional design of all sprinkler system components such as laterals, risers, nozzles, heads, and pressure regulators.

This standard applies to planning and design of sprinkler application systems for—

- Meeting crop water demands.
- Crop cooling, frost protection, or bloom delay.
- Leaching or reclamation of saline or sodic soils, or soils contaminated by other chemicals that can be controlled by leaching.
- Application of chemicals, nutrients, and wastewater.
- Dust and particulate control from—
  - Confined animal pen areas.
  - Unpaved roads.
  - Staging areas.
  - Equipment storage yards.

This standard applies to renozzling existing sprinkler systems to reduce pressure, reduce flow rate, or increase distribution uniformity.

This standard does not include criteria for mini- or micro-sprinkler systems, which are covered by NRCS Conservation Practice Standard (CPS) Irrigation System, Microirrigation (Code 441).

CRITERIA

General Criteria Applicable to All Purposes

The sprinkler system must be an integral part of a conservation plan addressing intended purposes and operator needs. Base system selection on site evaluation, operating conditions, soils, and topography. Design sprinkler positions, flow rates, and operating pressures within manufacturers' recommended ranges. Apply irrigation water using criteria established in NRCS Conservation Practice Standard (CPS) Irrigation Water Management (Code 449).

Plan, design, and construct the practice to comply with all Federal, State, Tribal, and local laws and 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 the project installation prior to construction.

System capacity

Sprinkler capacity must be adequate to accomplish the primary purposes of the system. Determine capacity based on appropriate design application efficiency. Select design application efficiency based on system type and purpose. General values for application efficiencies can be found in NRCS National Engineering Handbook (NEH) (Title 210), Chapter 2, "Irrigation Water Requirements," or use industry standards.

In computing capacity requirements, provide an allowance for reasonable application water losses, system maintenance downtime, and auxiliary water requirements such as leaching.

Additional Criteria for Efficient and Uniform Application of Water on Irrigated Lands

Design application rate and depth

Select application rates and depths that minimize runoff, translocation of water or soil, and deep percolation unless planned for leaching requirement.

Design maximum application rates to be consistent with soil intake rate, slope, and conservation practices used on the land. If sprinkler design application rate exceeds soil infiltration rates, use boom backs or additional storage features such as furrow dikes and enhanced residue management to minimize runoff. In lieu of approved runoff model simulation results such as CPNozzle, use field observations to assess the need for runoff prevention measures.

Distribution patterns, nozzle spacing, and height

Select a combination of sprinkler spacing, nozzle sizes, and operating pressures that provide the design application rate and a uniform distribution.

Use coefficient of uniformity (CU) or distribution uniformity (DU) as defined in NRCS 210-NEH, Part 623, Chapter 11, "Sprinkler Irrigation," when selecting sprinkler spacing, nozzle size, and operating pressure.

Center pivot and linear move systems

For center pivot and linear move systems, select sprinkler spacing, nozzle height, and operating pressure to provide required CU. For center pivots, compute CU using the Heermann-Hein weighted area method. For linear systems, compute CU using equivalent unit areas (Christensen method). The minimum CU value for a pivot or linear move system is 85 percent or a DU value of 76 percent. Use Center Pivot Evaluation and Design (CPED) software, or other NRCS approved modeling software to estimate CU values when manufacturer-provided CU information is not available. Limit nozzle spacing and pressures to within manufacturer's recommended ranges.

For center pivot and linear move systems with nozzles that operate in canopy for 50 percent or more of the growing season, nozzle spacing must not exceed every other crop row or 80 inches maximum. Avoid placing nozzles at heights of high leaf concentration such as placing sprinkler in corn field near the ear height (4 feet). Use nozzle heights higher or lower than high leaf concentration areas. Do not use in-canopy operation on narrow and ultra-narrow row plantings.

Low energy precision application (LEPA)
Do not exceed a nozzle spacing of 80 inches. Discharge water through a sock or hose dragged on the ground, or through a nozzle with a bubble shield or pad set at a uniform height of 18 inches or less.

LEPA systems are only applicable on crops planted with furrows or beds with row patterns that match the lateral line movement. For example, lateral line movement is circular for center pivots and straight for linear move. Do not irrigate tower wheel tracks. Eliminate runoff and water translocation under LEPA systems by appropriate methods such as furrow dikes, implanted reservoirs, or residue management.

Mobile drip irrigation (MDI)
Do not exceed drop spacings of every other row or a maximum of 80 inches. MDI systems require filtration and flushing that meet criteria established in NRCS CPS Irrigation System, Micro-Irrigation (Code 441). Limit field slope as specified by the manufacturer's recommendations for an MDI system. This ensures structural stability of the pivot tower by reducing the potential for tipping or overturning due to field slope and dragline pull.

Fixed solid-set, big gun, periodic move, and traveling sprinkler systems
For fixed solid-set, big gun, and periodic move sprinkler systems, select sprinkler spacing, nozzle size, and operating pressure to provide the required CU or DU. For field or forage crops having a rooting depth of 4 feet or more and where fertilizers and pesticides are not applied through the system, the CU must not be less than 75 percent or the DU not less than 60 percent. For high-value crops, crops where fertilizers and pesticides are applied through the system, and crops having a rooting depth less 4 feet, the CU must not be less than 85 percent and the DU not less than 76 percent. Comply with tables 1a and 1b if CU/DU data are not provided.

Table 1a: Maximum Spacing for Fixed Solid-set, Big Gun, and Periodic Move Sprinklers with Rectangular Pattern

Sprinkler Classification & (Operating Pressure)	Average Wind Velocity (mph)	Lateral Spacing (percent)*	Sprinkler Spacing (percent)*
Low (2–35 psi), Moderate (35–50 psi), Medium (50–75 psi)	0 to 1	65	50
	1 to 5	60	50
	5 to 10	50	50
	> 10	45	50
	Average Wind Velocity (mph)	Maximum diagonal distance between sprinkler locations on adjacent laterals (percent)*	
High (> 75 psi)	0 to 4	65	
	4 to 10	50	
	> 10	30	
*Percent of wetted diameter when operating at design pressure based on manufacturer's performance tables.			

Table 1b: Maximum Spacing for Fixed Solid-set, Big Gun, and Periodic Move Sprinklers with Triangular Pattern

Sprinkler Classification & (Operating Pressure)	Average Wind Velocity (mph)	Lateral Spacing (percent)*	Sprinkler Spacing (percent)*
Low (2–35 psi), Moderate (35–50 psi), Medium (50–75 psi)	0 to 1	70	65
	1 to 5	65	65
	5 to 10	54	65
	> 10	48	65
*Percent of wetted diameter when operating at design pressure based on manufacturer's performance tables in a triangular pattern.			

For traveling sprinkler irrigation systems use table 2 for towpath spacing.

Table 2: Towpath Spacing for Traveling Sprinkler Systems

Average Wind Velocity (mph)	Ring Nozzle(percent)*	Taper Nozzle (percent)*
0 to 1	80	80
1 to 6	70	75
6 to 10	60	65
> 10 **	50	55
*Percent of wetted diameter when operating at design pressure based on manufacturer's performance tables in a rectangular pattern. ** Because the distribution pattern of traveling systems is seriously affected by wind, operation in winds greater than 10 mph is not recommended.		

Land slope
Unless additional analysis is completed, limit field slope for the following conditions: (1) Limit field slope for a LEPA system to a maximum of 1 percent on more than 50 percent of the field with the remaining portion of the field having a maximum slope of 3 percent; (2) Field slopes for other center pivots or linear move systems with sprinklers on drops must not exceed 3 percent on more than 50 percent of the field for fine and moderately fine textured soils; and (3) On coarse soils, limit slopes to 5 percent.

Conditions that exceed the above criteria must show how runoff is controlled on a center pivot or linear move system by analyzing runoff based on a runoff mode such as CPNozzle.

On other center pivot or linear move systems where sprinklers are not located on drops, limit application rates based on soil texture and slopes described in National Engineering Handbook, Part 623, Sprinkler Irrigation, Chapter 11, Table 11-5. Conditions that exceed these criteria must also document how runoff is controlled by analyzing runoff based on a runoff model such as CPNozzle.

Soil textures are described in the National Engineering Handbook, Part 652, Irrigation Guide, Chapter 2, Soils, Table 2–5.

Maximum field slopes for center pivot or linear move systems must not exceed manufacturer's slope limitations based on pivot profile, span length, pipe diameter, and tire size.

Pressure regulators
In the absence of manufacturer's recommendations, ensure line pressure upstream of all regulators is at least 5 pounds per square inch (psi) above rated regulator pressure.

Linear move/periodic move lateral lines
Design lateral lines so that pressure variation along the line does not exceed 20 percent of the average operating pressure or 10 percent of the flow unless pressure or flow control devices are installed at each outlet. Acceptable devices include: pressure reducers, pressure regulators, or other pressure compensating or flow control.

Risers
Except for under-tree operation, place the riser pipes used on lateral lines high enough to prevent interference with the distribution pattern when irrigating the tallest crop. Riser heights must not be less than shown in Table 3.

Table 3: Riser heights

Sprinkler discharge (gpm)	Riser height* (in)
Less than 10	6
10–25	9

Sprinkler discharge (gpm)	Riser height* (in)
25–50	12
50–120	18
More than 120	36
* Risers over 36 inches in height must be anchored and stabilized.	

Additional Criteria for Improved Plant Condition, Productivity, Health, and Vigor

Design capacity

As a minimum, use peak daily evapotranspiration for design capacity on sprinkler systems used for soil cooling.

For sprinkler systems used for foliar cooling, provide adequate capacity to satisfy the crop's evaporative demand on a minute-by-minute basis throughout peak use hours during peak use days.

For systems used in cooling or frost protection, design the capacity to allow water application to the entire area simultaneously.

Design application rate

For frost protection, base application rate on minimum air temperature, maximum anticipated wind speed, and relative humidity. Design sprinkler system uniformity coefficient of not less than 85 percent. For under-tree sprinkling, use design application rates of 0.08 to 0.12 in/hr and for over-tree sprinkling, use design application rates of 0.15 in/hr or greater.

Additional Criteria for Preventing the Entry of Excessive Nutrients, Organics, and Other Chemicals in Surface and Ground Water

Comply with all Federal, State, and local laws, rules, and regulations regarding backflow and antisiphon prevention measures on the installation and operation of a sprinkler system designed for the purpose of chemical, nutrient, or wastewater application. Protect surface waters from direct chemical, nutrient, or wastewater applications.

Locate injectors (for chemical, fertilizer, or pesticide) and other automatically operating equipment adjacent to the pump and power unit. Install injectors in accordance with State regulations or in compliance with manufacturer's recommendation. The chemical injection device must be accurate to within one percent of maximum injection rates and easily calibrated and adjustable for all chemicals and all injection rates.

Design sprinkler irrigation systems used to apply wastewater with inlet filtration or with sprinkler nozzles of sufficient size to prevent clogging.

Design application rate and timing

Follow label instructions for chemical application rates. Duration of chemical applications must be the minimum length of time required to apply the chemicals and flush the pipelines.

For chemical application, comply with runoff criteria set forth in the section "Additional Criteria for Efficient and Uniform Application of Water on Irrigated Lands."

Coefficient of uniformity

Use distribution and uniformity requirements stated in the section "Additional Criteria for Efficient and Uniform Application of Water on Irrigated Lands."

In sustained wind conditions exceeding 10 miles per hour, or in wind conditions exceeding product label directions, do not use sprinklers to apply chemicals, nutrients, or wastewater.

Additional Criteria Applicable to Improving Condition of Soil Contaminated with Salts and Other Chemicals

Design application depth
Base design application depth on crop rooting and salinity tolerance thresholds as provided in the National Engineering Handbook, Part 623, Chapter 2, Irrigation Water Requirements.

Design application rate
Use application rates less than soil intake rates to prevent ponding and runoff. Use distribution and uniformity requirements stated in the section “Additional Criteria for Efficient and Uniform Application of Water on Irrigated Lands.”

Additional Criteria for Reducing Particulate Matter Emissions to Improve Air Quality

Install and operate sprinkler systems for confined animal pen dust control to cover the majority of each pen area occupied by livestock except for concrete feed bunk aprons and similar areas. The quality of applied water must be fit for animal consumption.

Capacity and application depth
Size sprinkler system with capacity and flexibility to apply the design application rate in a cycle of 3 days or less. Determine application rate requirements with an allowance for reasonable application losses.

The minimum design application amount must equal the maximum total daily wet-soil evaporation, with allowances for moisture input to pen areas from animal manure and urine.

When used to suppress dust in confined animal pen areas, avoid overapplication and excessive sprinkler overlap to minimize runoff and reduce odor, fly problems, and chronically wet areas.

Verify water supplies are adequate to meet other operating needs during sprinkler system operation.

Water amendments
Sprinklers may apply chemical injectants labeled for dust suppression when the system has backflow prevention and antisiphon devices.

When chemicals are applied through the sprinkler system, protect surface waters and livestock watering facilities from direct application unless chemical labels indicate that direct application will not negatively impact human, animal health, or water quality.

Distribution patterns and spacing
Space sprinklers along laterals between 50 and 75 percent of the wetted diameter listed in manufacturer’s performance tables.

Spacing between laterals must comply with the following criteria:

- For medium pressure sprinkler nozzles (50–75 psi), the spacing of laterals along the main line must be between 70 and 90 percent of the wetted diameter.
- For high pressure sprinklers (>75 psi), the maximum distance between two sprinklers on adjacent lateral lines must not exceed 100 percent of wetted diameter.

Risers
Construct risers in a manner that provides protection from corrosive soils, equipment damage, and livestock damage. Place the discharge sprinkler not less than 6 feet above ground surface. Anchor and stabilize risers.

System valves and controllers
Due to high application rates, variable operating conditions, and needed system flexibility and control, utilize an automated control system to ensure maximum operating efficiency of the sprinkler system. Equip

systems with a rain sensor connected to the control system to prohibit system operation during rainfall events.

Because wind may affect water distribution patterns, equip the automated system controller with timer overrides that allow the system to be operated manually during periods of calmer winds, such as evening, nighttime, and early morning. The operating system must provide the flexibility to change sprinkling duration in 1-minute increments and have a minimum of 6 start times per day to provide for adjustments for climate conditions.

Utilize automatic valves for the automated control system to facilitate operation of individual sprinkler nozzles. The valves must be of a size and quality consistent with standard engineering practice. Incorporate zone isolation valves on laterals to allow partial system operation during periods of maintenance and repair. Install pressure regulators, pressure compensating valves, or flow-control devices at each sprinkler outlet.

Minimize line drainage to the lowest sprinkler in areas of uneven or sloping terrain by incorporating a control valve or low-head drainage device at each sprinkler.

Additional Criteria for Reducing Energy Use

Provide an analysis that demonstrates reduction of energy use from practice implementation by documenting reduction in one or more of the following:

- pressure
- flow rate
- seasonal hours of operation
- application depth

Sprinkler operating pressure or flow rate reduction must correspond to pumping plant reduction in discharge pressure or flow.

Calculate energy reduction as the difference between average annual or seasonal energy uses compared to previous operating conditions.

CONSIDERATIONS

General Considerations

For guidance on selecting design application efficiency, use local irrigation guides, NEH Part 652, Irrigation Guide, or NEH, Part 623, Chapter 11, Sprinkler Irrigation.

Refer to NRCS NEH, Part 623, Chapter 2, Irrigation Water Requirements for additional guidance on using sprinkler irrigation systems for temperature control and chemigation.

Use of pressure regulators on a sprinkler system increases pumping cost because increased operating pressures are required upstream of each regulator/nozzle to overcome losses through the regulator, typically assumed to be 5 psi.

Beneficial effects of conservation practices applied to limit translocation and runoff may diminish over the irrigation season.

Systems designed to operate with multiday irrigation sets should consider varied time increments or set times to balance effects of day and night temperature and wind patterns.

Filter or screen irrigation water before it enters the system if it contains particulate matter, algae, or other material that could plug sprinkler nozzles.

Consider the impacts to fish, wildlife, and wetland habitat when converting from surface irrigation to sprinkler. Consider the impacts to water quality by reducing return flows and the potential to carry nutrients and pesticides.

Additional Considerations for Wastewater Application

To avoid sprinkler plugging and reduce system operating pressure when applying wastewater, solids should be removed by use of solid separators, screens, filters, two-stage lagoons, waste-holding ponds, or similar methods.

The use of wastewater may reduce system life due to corrosion or abrasion. If fresh water is available, the system should be flushed after use.

Additional Considerations for Pivot/Linear-Move

Computation of the effective irrigated area of the system should be based on a system radius from pad to the last sprinkler plus 75 to 80 percent of wetted radius of last sprinkler or end gun.

Elevation changes in the field have more impact on systems with lower system design pressures.

Consider using pressure regulators even on relatively level ground if the system flow rate fluctuates significantly due to variable inlet water surface elevation or other reasons such as corner systems or end guns.

Light, frequent applications can reduce runoff problems but may increase soil-surface evaporation.

Use nozzle offsets or booms to reduce peak application rates and tower wheel track rutting.

Keller and Bliesner (2000) recommended end-gun wetted sector angle settings of 135 degrees (L90, R45) for guns operated only in corners, and 150 degrees (L105, R45) for smaller end guns continuously operated.

To conserve energy on pivot/lateral move systems, consider using an end gun booster pump in lieu of providing increased pressure to the entire system.

Cyclic on/off operation of center pivot corner arm units and end guns impact system performance and application uniformity. A large end gun may reduce the average CU by 1 percent for each 1 percent of area covered past the main system hardware. Transition speed and dual operating characteristics will impact pumping plant performance and can impact water supply and delivery system performance.

Flexible drop tubes should be installed alternately on both sides of pivot/linear-move span pipe when used in-crop. Flexible drops should be weighted or secured in windy areas.

Center pivots and linear-move systems that are full of water will cause deflection in the span pipes and towers. Consider deflection amount when determining drop lengths and nozzle heights. Any wheel track rutting depth will also affect nozzle height. When the system is full of water, all nozzles installed on drops should be at the same relative height along the lateral.

Nozzle discharges on center pivot or linear move systems can be diverted away from wheel tracks to reduce rutting.

Additional Considerations for Traveler Systems

Reduce reel hose length to only what is needed for the longest field. Standard supplied hose lengths are often longer than needed. The additional length reduces pressure for every application and increases energy use. Also consider increasing hose diameter.

Additional Considerations for Solid Set and Periodic Hand Move

Consider limiting pressure loss in laterals to a maximum of 10 percent of the operating pressure to improve water distribution uniformity.

Additional Considerations for Particulate Matter Emission Reduction

Scraping and removing manure between operations may reduce the amount of dust control needed. As a stand-alone practice, this may be sufficient to eliminate the need for sprinklers. For more information, see NRCS CPS Dust Control from Animal Activity on Open Lot Surfaces (Code 375).

Open-lot management practices that can be applied include: scraping and removing manure in pens between occupations, shaping of the holding areas to prevent ponding water, and managing chronically wet areas.

Riser pipes used in lateral lines must be high enough to minimize interference from surrounding structures.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for constructing sprinkler systems which describe the requirements for properly installing the practice to achieve its intended purpose. As a minimum, include—

- Plan map showing location of system, application area, elevations, north arrow, and scale.
- System design pressure and flow rate.
- Sprinkler location, type, nozzle size, operating pressure, and flow rate.
- Appurtenance location, type, size, and installation requirements.

OPERATION AND MAINTENANCE

Provide an operation and maintenance (O&M) plan to the landowner and review with them. The plan should include specific instructions to ensure that the system functions properly throughout the expected lifespan. It should also provide information regarding periodic inspections and prompt repair or replacement of damaged components. Disconnect electrical service and check for stray voltage before servicing or retrofitting any electrical equipment.

The plan should include—

- Periodic check and removal of debris and sediment as necessary from nozzles to assure proper operation.
- Inspection or testing of pipeline and pumping plant components and appurtenances, as applicable.
- Regular testing of pressures and flow rates to assure proper operation.
- Periodic checks of nozzles and spray heads for proper operation and wear.
- Routine maintenance of mechanical components in accordance with the manufacturer’s recommendations.
- Reference inspection and testing of backflow prevention devices regularly and per state/municipal law as applicable.

Any additional information regarding operation of the system will be included in the irrigation water management plan, waste recycling plan, nutrient management plan, pest management plan, or salinity management/reclamation plan, as applicable for the practice purpose.

REFERENCES

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