NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

IRRIGATION SYSTEM, SPRINKLER

(No. and Acre)

CODE 442

DEFINITION

An irrigation system in which all necessary equipment and facilities are installed for efficiently applying water by means of nozzles operated under pressure.

PURPOSE

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

- Efficiently and uniformly apply irrigation water to maintain adequate soil water for optimum plant growth without causing excessive water loss, erosion, or water quality impairment.
- For climate control and/or modification.
- Apply chemicals, nutrients, and/or wastewater.
- Reduction in particulate matter emissions to Improve Air Quality.

CONDITIONS WHERE PRACTICE APPLIES

The sprinkler method of water application is suited to most crops, irrigable lands, and climatic conditions where irrigated agriculture is feasible. Areas must be suitable for irrigation with water of suitable quality for the purpose intended.

This standard applies to the planning and design of sprinkler systems for irrigation water and/or wastewater application, chemical application, climate control and/or modification and particulate matter emission control.

This standard pertains to the planning and functional design of all sprinkler components except for special structures such as permanently installed main and lateral pipelines or pumping plants. Other components shall meet appropriate NRCS Conservation Practice Standards.

In addition to conventional impact and spray systems, this standard applies to newer types of systems such as Low Energy Precision Application (LEPA) *and Low Elevation Spray Application (LESA) Systems (1, 2, and 3).* This standard also *provides* criteria specific to Low Pressure In-Canopy (LPIC) systems, and low pressure above canopy systems such as Mid Elevation Spray Application Systems (MESA) (3). A crop change can sometimes change the system description and expected performance. Some lower elevation nozzle application systems could also be LPIC systems and would need to meet LPIC criteria. It does not include criteria for mini- or micro-sprinkler systems. These are covered by NRCS Conservation Practice Standard 441 – Irrigation System, Microirrigation.

LEPA sprinkler systems are only applicable on crops planted with furrows or beds.

CRITERIA

General Criteria Applicable to All Purposes Except Climate Control, Waste Water Application, and Particulate Matter Emission Reduction

The criteria for the design of components not addressed in NRCS practice standards shall be consistent with sound engineering principles.

Each irrigation system must be designed as an integral part of an overall plan of conservation land use and treatment for the irrigated area that is based on the capabilities of the land and the needs of the operator.

Sprinkler irrigation system selection shall be based on a site evaluation and expected operating conditions. The soils and topography shall be suitable for irrigation of proposed crops. An adequate supply of good quality water must be available for practical irrigation of crops to be grown.

Depth of application. Net depth of application shall be based on soil available water capacity in the crop root zone, or a lesser amount consistent with the land user's irrigation water management plan. The gross depth shall be determined by using field application efficiencies consistent with the conservation of water resources.

Capacity. The sprinkler irrigation system shall have adequate capacity to meet the intended purpose.

Pipelines. The design of main lines, sub-mains, and supply lines shall insure that required water quantities can be conveyed to all operating lateral lines at required pressures. For detailed criteria, see NRCS Conservation Practice Standard 430 – Irrigation Pipeline.

Pump and power unit. Where required, pump and power units shall be adequate to operate the sprinkler system efficiently at required capacity and total dynamic head. For detailed criteria, see NRCS Conservation Practice Standard 533 – Pumping Plant.

Slope. Sprinkler irrigation systems are generally adapted to a wide range of slope conditions. Specific slope criteria for various system types are included below.

Irrigation Water Management. An Irrigation Water Management plan, meeting NRCS Conservation Practice Standard 449 – Irrigation Water Management, shall be developed for this practice.

Specific Criteria Applicable to Applying Water Efficiently with Center Pivot or Linear-Move Sprinkler Systems

Capacity. Sprinkler irrigation systems shall have either (1) a design capacity adequate to meet water demands of all irrigated crops in the design area, or (2) adequate capacity to meet requirements of several selected irrigations during critical crop growth periods when less than full irrigation is planned. In computing capacity requirements, allowance must be made for reasonable water losses during application.

Design Application Rate. For center pivot sprinkler systems, application rate is dependent on sprinkler head type, nozzle wetted diameter and spray pattern, system capacity, distance from the pivot point, and speed of revolution. Application rates shall be set such that runoff, translocation, and deep percolation are eliminated, or additional measures, such as, furrow diking, dammer diking, in-furrow chiseling, conservation tillage and/or residue management shall be applied.

Distribution Patterns, Nozzle Spacing, and Height. A combination of sprinkler spacing, nozzle size, and operating pressure that most nearly provide the design application rate and distribution shall be selected.

Uniformity coefficient (Cu) data (or distribution uniformity (DU)) shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. Definitions of each of these uniformity values can be found in the National Engineering Handbook, Part 652, Irrigation Guide (1).

Minimum Cu for LEPA, LESA, LPIC, and MESA systems with nozzle heights less than 7 feet are noted in s**pecific criteria sections for those systems**. Cu for all other center pivot sprinkler shall not be less than 85% (76% DU).

In the absence of Cu data, sprinkler performance tables provided by manufacturers shall be used in selecting nozzle size, operating pressure, and wetted diameter for the required sprinkler discharge. Low pressure spray nozzle discharge systems shall be at uniform heights along the length of the lateral. Spray nozzle spacing along lateral lines shall not exceed 25% of the effective wetted diameter. Impact sprinkler spacing along lateral lines shall not exceed 50 percent of the wetted diameter given in manufacturer performance tables, when the sprinkler is operating at design pressure. The effective wetted diameter shall be determined from manufacturer's tables/information and nozzle height.

Low pressure, low and mid elevation nozzle application systems that discharge water in the crop canopy for a considerable length of time during the growing season shall meet LPIC system criteria (1).

Specific Criteria Applicable to Applying Water Efficiently with a Center Pivot or Linear-Move Sprinkler with Low Energy Precision Application (LEPA) or *Low Elevation Spray Application (LESA) Systems.*

Distribution Patterns, Nozzle Spacing, and Height. A combination of sprinkler spacing, nozzle size, and operating pressure that most nearly provide the design application rate and distribution shall be selected.

Nozzle discharge Cu data shall be used in selecting sprinkler spacing, nozzle size, and operating pressure.

Nozzle discharge Cu shall not be less than 94% for LEPA or LESA.

Nozzle spacing shall not be greater than two times the row spacing of the *crop with a maximum spacing of 80 inches*. For LEPA Systems water shall be discharged through a drag sock or hose on the ground surface, or through a bubble nozzle at uniform heights not to exceed 18 inches. For LESA Systems water shall be discharged through a spray nozzle at uniform heights not to exceed 18 inches.

Row Arrangement. LEPA systems are only applicable on crops planted with furrows or beds. LEPA systems shall have row patterns that match the lateral line movement (i.e., circular for center pivots). Water shall not be applied in the tower wheel track of a LEPA system. LEPA systems shall employ some method of providing surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs.

LESA Systems are applicable on crops flat planted, drilled, or planted with furrows or beds. LESA Systems should employ some method of providing surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs, or farming practices such as conservation tillage, in-furrow chiseling, and/or residue management to prevent runoff.

Slope. The slope for LEPA systems shall not exceed 1.0 percent on more than 50 percent of the field.

The slope for LESA systems shall not exceed 3.0 percent on more than 50 percent of the field.

Specific Criteria Applicable to Applying Water Efficiently with a Center Pivot or Linear-Move Sprinkler with Low Pressure In-Canopy (LPIC) *or Mid Elevation Spray Application Systems.*

Systems that utilize bubble nozzles or drag hoses for a portion of the crop year and spray nozzles for a portion of the crop year that do not meet all LEPA criteria could be considered LPIC systems if the system meets LIPC criteria.

Distribution Patterns, Nozzle Spacing, and Height. Water distribution is greatly affected by nozzle spacing and height for *LPIC and MESA* systems. In general, closer spaced nozzles will yield a higher uniformity. In-canopy heights should be set such that areas of high leaf concentration are avoided (i.e., corn near the ear height (approximately 4 feet)). Local experience with applicable crops should be used as a guide for establishing appropriate nozzle spacing, height, and row arrangement in keeping with this standard.

Cu shall not be less than 90% for all LPIC systems, and MESA Systems with nozzle heights less than 7 feet.

Cu shall not be less than 85% (76% DU) for MESA Systems with nozzle heights 7 feet or greater.

Slope. The slope for a LPIC and MESA systems shall not exceed 3.0 percent on more than 50 percent of the field.

Specific Criteria Applicable to Applying Water Efficiently with Fixed-Solid-set, Big Gun, and Periodic Move Sprinkler Systems

Capacity. Sprinkler irrigation systems shall have either (1) a design capacity adequate to meet water demands of all crops to be irrigated in the design area, or (2) adequate capacity to meet requirements of several selected water applications during critical crop growth periods when less than full irrigation is planned. In computing capacity requirements, allowance must be made for reasonable water losses during application.

Design application rate. The design application rate shall be within a range established by the minimum practical application rate under local climatic conditions, and the maximum application rate consistent with soil intake rate, slope, and conservation practices used on the land. If two or more sets of conditions exist in the design area, the lowest maximum application rate for areas of significant size shall apply.

Lateral lines. Unless pressure reducers/regulators are installed at each outlet or other pressure compensating or flow control devices are used, lateral lines shall be designed so that the total pressure variation, resulting from friction head and elevation differential, does not exceed 20 percent of the design operating pressure of the sprinklers.

Distribution patterns and spacing. A combination of sprinkler spacing, nozzle size, and operating pressure that most nearly provide the design application rate and distribution shall be selected.

If available, uniformity coefficient (Cu) data (or distribution uniformity (DU)) shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. Definitions of each of these uniformity values can be found in the National Engineering Handbook, Part 652, Irrigation Guide (1). Cu shall not be less than the following:

75 % (60% DU) for deep-rooted (4 feet or more) field and forage crops where fertilizers and pesticides are not applied through the system.

85 % (76% DU) for high-value or shallow-rooted crops and for any crop where fertilizer or pesticides are applied through the system.

In the absence of Cu data, maximum lateral and nozzle spacing shall comply with the following criteria:

1. For low (2-35 pounds/square inch (psi))-, moderate (36-50 psi)-, and medium (51-75 psi)-pressure sprinkler nozzles, the spacing along lateral lines shall not exceed 50 percent of the wetted diameter, as given in the manufacturer's performance tables, when the sprinkler is operating under design pressure. The spacing of laterals along the main line shall not exceed 65 percent of this wetted diameter. If winds that can affect the distribution pattern are likely during critical crop growth periods, spacing should be reduced to 60 percent for average velocities of 1 to 5 miles per hour (mph), to 50 percent for average velocities of 6 to 10 mph, and to 45 percent for average velocities greater than 10 mph.

2. For high-pressure and big gun type sprinklers (>75 psi), the maximum distance (diagonal) between two sprinklers on adjacent lateral lines shall not exceed two-thirds of the wetted diameter under favorable operating conditions. If winds that can affect the distribution pattern are likely during critical crop growth periods, the diagonal spacing should be reduced to 50 percent of the wetted diameter for average velocities of 1 to 10 mph and to 30 percent for average velocities greater than 10 mph.

Slope. Sprinkler irrigation systems are generally adapted to a wide range of slope conditions. Application rates on sloping land should be set so that surface water redistribution is minimized. If this is not practical, additional measures such as furrow dikes, dammer dikes, or implanted reservoirs or farming practices such as conservation tillage, in-furrow chiseling, and/or residue management shall be applied where needed.

Risers. Except for under-tree operation, riser pipes used in lateral lines shall be high enough to prevent interference with the distribution pattern when the tallest crop is irrigated. Riser heights shall not be less than shown below:

Sprinkler discharge *(gallons/minute)*	Riser length *(inches)*
Less than 10	6
10-25	9
25-50	12
50-120	18
More than 120	36

Specific Criteria Applicable to Climate Control and/or Modification

Sprinkler irrigation systems designed to provide temperature or frost control shall be in accordance with state and local guidelines and criteria.

Capacity. For temperature control, the sprinkler irrigation system shall have sufficient capacity to satisfy the evaporative demand on a minute-by-minute basis throughout the peak use period.

For frost protection, the system shall be capable of applying the necessary rate, based on the minimum temperature, maximum anticipated wind speed, and relative humidity, in a uniform manner. The capacity shall be sufficient to supply the demand for the entire crop being protected.

Specific Criteria Applicable to Chemical, Nutrient and/or Waste Water Application

The installation and operation of a sprinkler irrigation system for the purpose of chemical and/or nutrient application (chemigation) shall comply with all federal, state and local laws, rules and regulations. This includes backflow and anti-siphon prevention measures. Additionally, surface waters shall be protected from direct application.

Where implemented as a component of a Comprehensive Nutrient Management Plan (CNMP), a waste utilization plan and/or nutrient management plan shall be developed that meets the requirements of NRCS Conservation Practice Standard 633 – Waste Utilization and 590 - Nutrient Management, as appropriate.

Design Application Rate. For systems operated with application rates that exceed soil intake, measures shall be installed to prevent runoff. These may include but are not limited to nozzle offsets or booms, furrow dikes, dammer dikes, or implanted reservoirs or farming practices such as conservation tillage, in-furrow chiseling, and/or residue management.

Coefficient of Uniformity. If available, uniformity coefficient (Cu) data (or distribution uniformity (DU)) shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. Definitions of each of these uniformity values can be found in the National Engineering Handbook, Part 652, Irrigation Guide. Cu shall not be less than 85% (76% DU) for all systems through which fertilizer or pesticides are applied.

If Cu data is not available, distribution patterns and spacing requirements shall be in keeping with the appropriate specific criteria of this standard.

Nutrient and Pest Management. Chemicals, fertilizers and liquid manure shall be applied in accordance with appropriate NRCS Practice Standards: Nutrient Management (590), Pest Management (595), Waste Utilization (633) and/or Manure Transfer (634). Chemical and/or nutrient application amounts shall not exceed these standards.

Specific Criteria Applicable to Reduction in Particulate Matter Emissions to Improve Air Quality

Sprinkler systems used to improve air quality by controlling dust emissions from confined animal pen areas (4, and 5), and other critical areas such as unpaved roads, staging areas, and equipment storage yards.

This practice shall include installation of Fixed Solid Set Sprinklers, Big Guns, or Periodic Move Sprinkler Systems. The installation and operation of Sprinkler Systems for dust control on confined animal pen areas shall provide application coverage on the majority of pen areas occupied by livestock except for feed bunk aprons.

Capacity. For dust control, the sprinkler irrigation system shall have sufficient capacity to apply the design application depth every three days or less. The system frequency of operation and application shall be capable of replacing maximum daily, total soil evaporation (6). When determining capacity requirements, allowance shall be made for reasonable water losses during application.

Water Quality. Water applied with dust control sprinklers shall be of suitable quality for livestock consumption.

Water Amendments. Appropriately labeled chemicals for pest control or dust suppression may be applied through the sprinkler system. If chemicals are applied with the sprinkler system, s**urface waters and livestock watering facilities shall be protected from direct application, unless chemical labels**

indicate animal health and water quality will not be negatively impacted. The installation shall comply with all federal, state and local laws, rules and regulations. This includes back-flow and anti-siphon prevention measures.

Design application rate. The minimum design application rate shall be that required to meet the maximum total daily wet soil evaporation rate. When determining design application rate, moisture input to pen areas from animal manure and urine may be considered. System maximum application rate shall not produce excessive runoff for soil intake rate, slope, and lot condition.

Pipelines. The design of main lines, sub-mains, and supply lines shall insure that required water quantities can be conveyed to all operating lateral lines at required pressures. For detailed criteria, see NRCS Conservation Practice Standard 430 – Irrigation Pipeline.

Lateral lines. Unless pressure reducers/regulators are installed at each outlet or other pressure compensating or flow control devices are used, lateral lines shall be designed so that the total pressure variation, resulting from friction head and elevation differential, does not exceed 20 percent of the design operating pressure of the sprinklers.

Distribution Patterns and Spacing. A combination of sprinkler spacing, nozzle size, and operating pressure that most nearly provide the design application rate and distribution pattern shall be selected. Maximum spacing of sprinklers along laterals shall not be greater than 75 percent, and no closer than 50 percent of wetted diameter listed in manufacturer's performance tables.

Spacing between laterals shall comply with the following criteria:

1. For medium (51-75 psi)-pressure sprinkler nozzles, the spacing of laterals along the main line shall be no more than 90 percent, and no closer than 70 percent of wetted diameter.

2. For high-pressure sprinklers (>75 psi), the maximum distance between two sprinklers on adjacent lateral lines shall not exceed 100% of wetted diameter.

If winds impact distribution patterns during critical dust emission periods, the system shall be equipped with timer overrides and have the flexibility to be operated manually during periods of lesser wind, such as late evening and early morning.

Slope. Sprinkler irrigation systems are generally adapted to a wide range of slope conditions. Application rates on sloping land may exceed soil intake rates; the system shall have operational flexibility to allow duration and frequency adjustments to minimize surface water redistribution.

Risers. Riser pipes used in lateral lines shall be high enough to prevent interference with distribution pattern. The risers shall be constructed in a manner that provides protection from corrosive soils, equipment damage, and livestock damage. Riser lengths (heights) shall not be less than 6 ft.

System Valves and Controllers. Due to high application rates inherent with large sprinkler nozzle diameters (>0.5 inches), an automatic irrigation control system shall be utilized. The automated control system shall utilize electro-hydraulic valves facilitating automatic operation. The valves shall be of a size and quality consistent with standard engineering practice. If chemicals are injected through the system, the valves shall be rated for chemical application. The operating system should provide the flexibility to change sprinkling duration in one minute, increments and have a minimum of six, start times per day to provide for adjustment for climate conditions.

Manual zone isolation valves shall be incorporated to facilitate isolation of laterals allowing partial system operation to assist maintenance and allow continued partial system operation.

In areas of uneven slopes or sloping terrain a control valve or low-head drainage device shall be incorporated at each sprinkler to ensure that line drainage to the lowest sprinkler is minimized.

CONSIDERATIONS

Peak application rates near the end of the center pivot may exceed soil intake rate. Light, frequent applications can reduce runoff problems, but may increase losses from soil surface evaporation. Nozzle offsets or booms can be used to reduce peak application rates. If additional storage is required, surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs and/or farming practices such as conservation tillage, in-furrow chiseling, and/or residue management shall be utilized.For lower elevation application systems, row arrangement, nozzle spacing and height all impact Cu. System design and field management should complement each other to yield the highest Cu. In general, circular rows for center pivot systems and straight rows for linear move systems provide higher Cu's.

Some aspects of non-uniformity tend to average out throughout the irrigation season while others tend to concentrate. Factors that tend to average out during the irrigation season are climatic conditions and uneven travel speed for start/stop systems. Factors that tend to concentrate during the irrigation season are nozzle discharge variances due to pressure or elevation differences, surface movement of water, and poor water distribution around field boundaries.

Consider the effects of a center pivot's end gun operation on Cu. A large end gun may reduce the average Cu by 1.0 percent for each 1.0 percent of the area covered past the main system hardware.

Consider the on-off effects of corner arm units and end guns attached to a center pivot system on overall sprinkler performance.

Conservation tillage and/or residue management should be utilized as necessary to limit surface redistribution of water. Soil surface storage basins, furrow dikes, dammer dikes, or implanted reservoirs may also be necessary to reduce surface water movement. The effects of these practices may diminish over the irrigation season.

If surface water redistribution is a concern with center pivot or linear-move systems, the system speed should generally be increased. When the speed is increased, subsequent irrigation cycles will need to be more frequent to meet planned water application. However, the application depth should be large enough to prevent losing a large percentage of water to soil and canopy evaporation.

The velocity of prevailing winds and other physical conditions should be considered when planning a sprinkler system.

Where used, drop tubes should be installed alternately on both sides of the mainline and have a flexible joint between the gooseneck pipes and the application device. Drops should be weighted and/or secured in windy areas.

Consider different sprinkler application depths and application rates with hand move and center pivot systems. With hand move systems; the application rates more nearly match the soil infiltration rate so that large irrigations can be applied and number of hand moves reduced. With an automated system such as a center pivot, hand labor is not a major consideration and small applications at high rates are the norm.

Fertilizer and chemical application amounts may need adjustment from prior application methods and rates, due to precise applications possible with some sprinkler irrigation systems.

Management of sprinkler irrigation systems for reduced irrigation may include utilizing soil water stored in the root zone during critical crop growth stages.

Deflection of spans on center pivots and linear-move systems is common when the lateral is loaded (filled with water). This should be considered when determining nozzle heights. Wheel track depth will also affect nozzle height.

On center pivot or linear move systems, nozzles may need to be diverted away from wheel tracks to avoid rutting.

Low-pressure systems (35 psi or less) are sensitive to small changes in nozzle pressure. Consider using pressure regulators on all low-pressure systems where elevation differences, pumping depth variations, or end gun/corner arm operation can significantly change nozzle discharge and sprinkler uniformity. Also consider installing a pressure gauges at the end of the sprinkler system to ensure adequate pressure throughout.

Consider the systems effects on the water budget, especially the volume and rate of runoff, infiltration, evaporation, transpiration, deep percolation, and ground water recharge.

Consider the systems effects on erosion and movement of sediment, and soluble and sediment-attached substances carried by runoff.

Consider the systems effects of soil water in controlling the salinity of soils, soil water or downstream water quality including subsurface drains.

When utilized for particulate matter reduction a check should be made to insure available Animal Feeding Operation water supplies are adequate to meet other operating needs, while the sprinkler irrigation system is operating.

When utilized for particulate matter reduction, irregularly shaped pen areas that are impractical to treat with a sprinkler system should be treated for dust control with tanker water trucks equipped with hoses, and/or nozzles which should be designed to apply water at rates similar to an equivalent sprinkler system.

The installation and operation of a Sprinkler System for applying water uniformly for dust control on confined animal pen areas should provide application coverage on all practical occupied pen areas except feed bunk aprons.

When a Sprinkler System is utilized for particulate matter reduction, avoid over application, and excessive sprinkler overlap, which can contribute to odor and fly problems.

Open-feedlot management practices that minimize thickness of loose manure will reduce water demands for dust control, as well as, reduce wet areas and ponding.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing irrigation sprinkler systems shall be in keeping with this standard and shall describe the requirements for properly installing the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan must be prepared for use by the owner or others responsible for operating the system. The plan should provide specific instructions for operating and maintaining the system to insure that it functions properly. It should also provide for periodic inspections and prompt repair or replacement of damaged components. The plan, as a minimum, shall include provisions to address the following:

- Periodic checks and removal of debris and sediment as necessary from nozzles to assure proper operation.
- Inspection or testing of all pipelines and pumping plant components and appurtenances, as applicable.
- Regular testing of pressures and flowrates to assure proper operation.
- Periodic checks of all nozzles and spray heads for proper operation and wear.
- Routine maintenance of all mechanical components in accordance with the manufacturer's recommendations.
- Prior to retrofitting any electrically powered irrigation equipment, electrical service must be disconnected and the absence of stray electrical current verified.
- Application areas should be inspected periodically for signs of excessive irrigation induced erosion or excessive application.

REFERENCES

1. USDA, Natural Resources Conservation Service, National Engineering Handbook, Part 652 (NEH 652), National Irrigation Guide.
2. USDA, Natural Resources Conservation Service, National Engineering Handbook, Part 623 (NEH 623), Chapter 11, Sprinkle Irrigation.

3. Center Pivot Irrigation, Texas Agricultural Extension Service Publication, B6096, April 2002
4. Designing Better Feedlots, DPI Feedlot Services, Department of Primary Industries, Toowoomba, Queensland, AU, 1994
5. Feedlot Dust Control, Texas Agricultural Extension Service Publication, L1340, April 2002
6. USDA, Natural Resources Conservation Service, National Engineering Handbook, Part 623 (NEH 623), Chapter 2, Irrigation Water Requirements.

APPROVAL AND CERTIFICATION

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PRACTICE STANDARD APPROVED:

/s/ JOHN W. MUELLER	**10/23/03**
State Conservation Engineer	**Date**