

DETERMINING RUNOFF POTENTIAL

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INTRODUCTION

Sprinkler irrigation systems and specifically center pivots have been adapted to operate on many different soils, to traverse extremely variable terrain, and to provide water to meet a number of different management objectives. **The main goal for water application systems** is to apply water uniformly in sufficient quantities to meet crop water needs without generating runoff. As a buyer, you will be furnished with an array of different sprinkler types, many that are capable of performing adequately. However, you should make a selection based upon accurate field based information, system installation and operating costs, and careful consideration of the interaction between the water application system and field conditions. Only then will the system meet your expectations.

Water runoff is a problem often associated with sprinkler irrigation systems operated on sloping terrain. Fields with steep slopes typically have little soil surface storage to keep water where it is applied. A number of water quality and crop production problems are the direct result of surface runoff. Surface runoff can dislodge and transport soil particles, fertilizers and pesticides from their field positions causing degradation of surface and/or ground waters. Other potential problems associated with runoff include a lack of soil moisture in localized areas of the field, crop nutrient deficiencies, washed-out seeds or plants, and increased pumping costs.

Water Application Uniformity

We begin with the assumption that water is uniformly applied by the irrigation system. Nonuniform water distribution may contribute to runoff problems. Uniform water application requires that the correct sprinklers be at each position along the pivot lateral, that the pumping plant deliver water at the appropriate pressure and flow rate, and that the system is not operated under adverse atmospheric conditions. Another aspect of water application uniformity is the uniformity of infiltration. Even if water could be applied to the soil at 100% uniformity, runoff causes poor infiltration uniformity. Thus, the goal must be to consider how well the sprinkler package will match up with the field conditions.

It is safe to say that the uniformity of water application generally increases with a decrease in sprinkler spacing. This statement assumes that the operating characteristics of the sprinkler do not change. Narrowing the spacing results in more overlap among the water application patterns of individual sprinklers. A narrow spacing also makes it more difficult for wind to alter the overall system water application pattern.

Uniformity can also be influenced by field topography. In the absence of some sort of flow control, the topographic features of the field change the water pressure delivered to each sprinkler/nozzle location. Since each sprinkler has an orifice through which water is metered, altering the pressure supplied to that orifice changes the sprinkler output. If the field is sloped uphill from the pivot point, sprinklers located at the highest elevation will be distributing less water than those close to the pivot point. For this reason, it is recommended that flow control devices be installed if the elevation difference results in a change of flow greater than about 10%. NebGuide G88-888, *Flow Control Devices for Center Pivot Irrigation Systems*, presents some considerations for different types of flow control devices.

Zero Runoff Goal

The zero runoff goal requires that the sprinkler package selected for the system be carefully matched to the field conditions and to the operators management scheme. Too often the desire to reduce pumping costs clouds over the issue of overall water application efficiency. Some systems like LEPA (Low Energy Precision Application) are designed so water does not immediately soak into the soil. However, proper LEPA designs also call for tillage practices that hold the water on the soil surface where it lands until it has time to infiltrate into the soil.

Water droplet impact should be considered with all sprinkler package selections. Each sprinkler will deliver water to the soil with a particular range of water droplet sizes and distribution of water droplets. In general, larger water droplets are concentrated toward the outside edge of the water application pattern and smaller droplets fall closer to the sprinkler/nozzle. It is the large water droplets that tend to be a concern. Large water droplets carry a substantial amount of energy that is transferred to the soil upon impact. The impact will tend to break down the soil clods causing the soil to consolidate. Eventually a thin crust will be formed on the surface that can reduce soil infiltration by up to 80% compared to soils protected by crop residues.

A computer program "CPNOZZLE", based on research conducted at Mead, NE, provides an opportunity to establish how well suited a sprinkler package is to a field's soils and slopes. The program is also useful in predicting how much the design or operation should be changed to eliminate a runoff problem. For example, if the normal operation is to apply 1.25 inches of water per revolution, the program can be used to see if runoff might occur and, if so, what application depth would be acceptable. If you are in the process of altering the sprinkler package, the program can be used to select an appropriate system flow rate and sprinkler wetted diameter.

The program works by overlaying a soil infiltration rate curve with a water application pattern. Figure 1 shows an infiltration rate curve for a NRCS Intake Family of 0.5 and the water application pattern of a low pressure spray nozzle mounted at truss rod height. Beginning from the right hand side of the graph, the program mathematically compares the water application rate to the soil infiltration rate for each minute that water is applied to the field. For example, at 9 minutes after water application started, the water

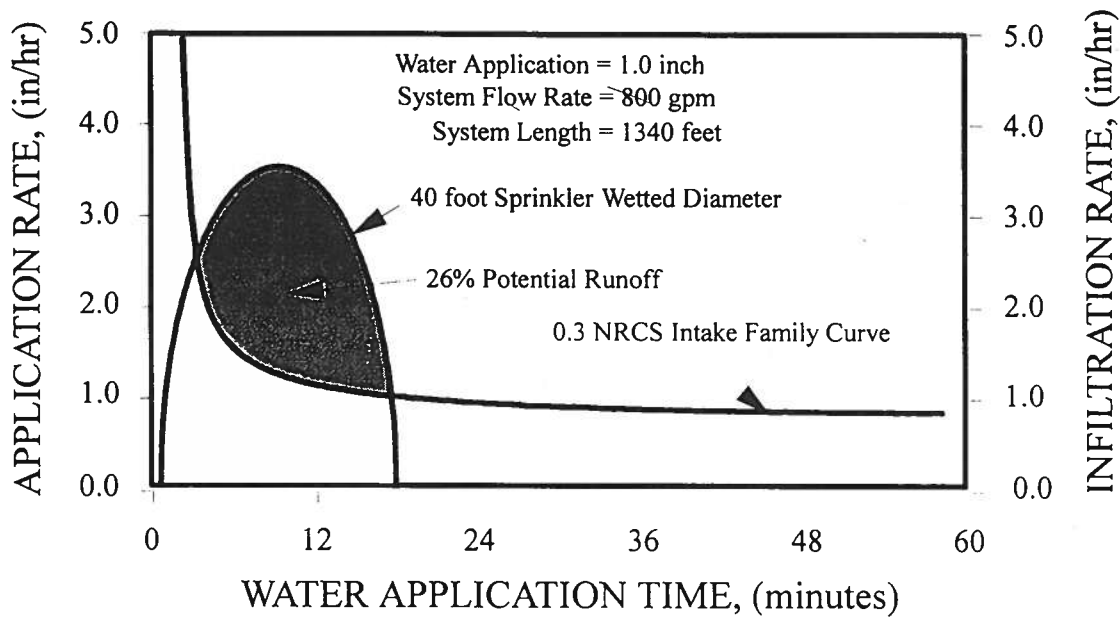


Figure 1. Estimated runoff for a 1340 foot center pivot supplied with 800 gpm and applying 1.0 inch of water using a nozzle package with a 40 foot wetted diameter.

application rate was 3.6 inches per hour and the soil infiltration rate was 1.2 inches per hour. Since the water application rate is greater than the infiltration rate, water will begin ponding on the soil surface. The program mathematically totals the amount of water that is applied in excess of the soil infiltration rate. When the program has compared the two curves for an entire water application pattern, the sum of the water applied in excess of the soil infiltration rate is the potential runoff signified by the shaded area in Figure 1.

Case Study

One way to demonstrate how the program might be used is to run through a series of examples changing only one of the data inputs. Let's assume that our base system has the characteristics given in Table Ia. Data entered in each column could influence runoff potential. Soil texture and intake family, defined by the Natural Resource Conservation Service (NRCS), determine how fast water will infiltrate into the soil. In this example, the field has a *silt loam* soil with an NRCS Intake Family designation of 0.3. *Slope*, or the change in elevation within the field, influences how much water will naturally puddle or be stored on the soil surface to infiltrate later, and how easily the water will flow to a lower part of the field. In this example, the field has a moderate *slope of 3-5 percent*.

The characteristics of center pivot influence how intensely water is applied to the soil. Lets use a system capacity of 800 gallons per minute, system length equal to 1340 feet, application depth of 1.0 inch per revolution, and a sprinkler head wetted diameter of 40 feet. The estimated runoff resulting from this field-system combination is 26 percent, which means 26 percent of the water pumped through the system may not infiltrate where it landed. The runoff moved to another part of the field or it left the field altogether. As a result, water application efficiency was reduced by 26 percent.

Each of the land surface factors and center pivot characteristics are varied individually in Tables Ib - Ig. These examples indicate how each factor influences overall runoff. All runoff data are reported as the percentage of applied water that did not infiltrate where landed.

Soil texture cannot be changed in a given field. It has a tremendous impact on runoff as given in Table Ib. A soil in intake family 0.1 (clay, silty clay or silty clay loam) has very slow infiltration and produces 44 percent runoff. However, a silt loam, very fine sandy loam, fine sandy loam or loamy fine sand in the 1.0 intake family can infiltrate all of the applied water from this system with no runoff.

Slope (or changes in field elevation) is usually an unchanged factor. Table Ic shows a field with a slope of 1-3 percent has 8 percent runoff while a slope greater than 5 percent has 35 percent runoff. The influence of land surface factors on runoff shows sprinkler packages must be designed for each field. Pressure on flow regulators can compensate for slope changes within the field and keep application uniform. However, steeper slopes will still produce more runoff than flatter slopes, even if water application is the same.

Irrigation system capacity influences application rate or intensity if other system characteristics are the same. Table Id shows the influence of changing system capacity on runoff. When system capacity drops to 700 gallons per minute, runoff is 22 percent. When system capacity increases to 900 gpm, runoff is 29 percent. Although not shown in Table I, runoff is greater near the outer end of the system than near the center. Outer spans have more area to water in the same amount of time, allowing less time for the water to infiltrate and increasing the potential for runoff.

Application amount of each irrigation also influences runoff. Table Ie shows that if the operator speeds up the pivot and puts on 0.75 inch instead of 1.0 inch, runoff is 16 percent. If the pivot is slowed to put on 1.25 inches, runoff is 33 percent. The practical limits for irrigation applications are normally 0.75-1.25 inches. Smaller applications are less efficient in delivering water to the crop; larger applications have the potential for more runoff.

Wetted diameter of the sprinkler pattern has a large influence on runoff, as shown in Table 1f. The wetted diameter is determined by the type of sprinkler device and operating pressure of the irrigation system. A maximum wetted diameter should be selected to produce little or no runoff. Eliminating runoff through sprinkler selection is usually more important than moving the sprinkler heads nearer or into the canopy to gain application efficiency.

Table Ig shows how changing more than one system characteristic affects runoff potential. Here the application depth ranged from 0.50 inch to 1.25 inches for a wetted diameter of 60 feet or 80 feet. Compared to the base system, increasing the wetted

Table I. Examples of estimated potential runoff from center pivot irrigation systems with differing operating characteristics. Results from CPNOZZLE program.

| Soil Intake Family | Field Slope (%) | System Capacity (gpm) | System Length (feet) | Application Depth (inches) | Wetted Diameter (feet) | Estimated Runoff (%) |
|--|-----------------|-----------------------|----------------------|----------------------------|------------------------|----------------------|
| Table Ia. Base system characteristics. | | | | | | |
| 0.3 | 3-5 | 800 | 1340 | 1.0 | 40 | 26 |
| Table Ib. Influence of soil intake family (soil texture) on runoff. | | | | | | |
| 0.1 | 3-5 | 800 | 1340 | 1.0 | 40 | 44 |
| 0.3 | 3-5 | 800 | 1340 | 1.0 | 40 | 11 |
| 0.5 | 3-5 | 800 | 1340 | 1.0 | 40 | 0 |
| Table Ic. Influence of field slope. | | | | | | |
| 0.3 | 0-1 | 800 | 1340 | 1.0 | 40 | 0 |
| 0.3 | 1-3 | 800 | 1340 | 1.0 | 40 | 8 |
| 0.3 | >5 | 800 | 1340 | 1.0 | 40 | 35 |
| Table Id. Influence of system capacity. | | | | | | |
| 0.3 | 3-5 | 500 | 1340 | 1.0 | 40 | 14 |
| 0.3 | 3-5 | 700 | 1340 | 1.0 | 40 | 22 |
| 0.3 | 3-5 | 900 | 1340 | 1.0 | 40 | 29 |
| Table Ie. Influence of application depth. | | | | | | |
| 0.3 | 3-5 | 800 | 1340 | 0.50 | 40 | 3 |
| 0.3 | 3-5 | 800 | 1340 | 0.75 | 40 | 16 |
| 0.3 | 3-5 | 800 | 1340 | 1.25 | 40 | 33 |
| Table If. Influence of wetted diameter. | | | | | | |
| 0.3 | 3-5 | 800 | 1340 | 1.0 | 30 | 48 |
| 0.3 | 3-5 | 800 | 1340 | 1.0 | 60 | 15 |
| 0.3 | 3-5 | 800 | 1340 | 1.0 | 80 | 8 |
| Table Ig. Influence of application depth and wetted diameter on runoff. | | | | | | |
| <i>60 Foot Wetted Diameter</i> | | | | | | |
| 0.3 | 3-5 | 800 | 1340 | 0.50 | 60 | 0 |
| 0.3 | 3-5 | 800 | 1340 | 0.75 | 60 | 7 |
| 0.3 | 3-5 | 800 | 1340 | 1.25 | 60 | 22 |
| <i>80 Foot Wetted Diameter</i> | | | | | | |
| 0.3 | 3-5 | 800 | 1340 | 0.50 | 80 | 0 |
| 0.3 | 3-5 | 800 | 1340 | 0.75 | 80 | 2 |
| 0.3 | 3-5 | 800 | 1340 | 1.25 | 80 | 15 |
| Table Ih. Influence of distance from the pivot point. | | | | | | |
| 0.3 | 3-5 | 800 | 268 | 1.0 | 40 | 0 |
| 0.3 | 3-5 | 800 | 620 | 1.0 | 40 | 20 |
| 0.3 | 3-5 | 800 | 1072 | 1.0 | 40 | 33 |

diameter to 60 feet reduced runoff by about 11 percent. An increase in wetted diameter to 80 feet reduced overall runoff by about 17 percent of the applied water.

Tables Ia-Ig report weighted potential runoff or the amount of runoff based on how much of the irrigated area contributes to runoff. The CPNOZZLE program divides the system into 10 equal increments of the total system length and then calculates the weighted potential runoff. Table Ih shows how the potential for runoff changes based on position along the center pivot. Table Ia reports the weighted potential runoff of 26 percent for the entire system. Note the influence of the inside portion of the system on the overall value.

Water Application Efficiency

The LEPA system has been advertised as one method that can both uniformly apply water within the crop canopy and maintain a high application efficiency. Based on the success of the LEPA system, variations of in-canopy application have been tried in hopes of similar results. When only a part of the LEPA system is used, however, the potential for saving water may not be the same. The application efficiency could be lower than above canopy packages and application uniformity may decrease resulting in increased water loss.

In a Nebraska study, runoff was measured from three different systems; a LEPA system with bubblers located at 18 inches, Spinners located 42 inches above the ground and Spinners located above the corn canopy. A comparison also was made between normal cultivation and furrow diking. Field slope varied between 1 - 3 percent. The results of these studies are shown in Figures 2 and 3. The LEPA system resulted in 15 - 25 percent runoff from both irrigation events. The Spinners located at 42 inch height had runoff of between 10 - 15 percent. Spinners above the canopy with furrow diking had the lowest runoff at approximately 8 percent.

The amount of runoff when 0.7 inch of water was applied and the Dammer-Diker¹ was used (Figure 3) decreased from 15 percent at 42 in height to 8 percent at truss rod height. A 1 - 2 percent savings in evaporation losses can be expected when sprinkler devices are moved from above to within the crop canopy.

Comparing the LEPA system with the above-canopy devices resulted in runoff being reduced from 20 percent to 8 percent. Based on Texas data, a 10 percent savings can be achieved when using a LEPA system, compared to using above-canopy devices. In this instance, trying to save 10 percent using LEPA reduced application efficiency by 12 percent due to runoff. In either case, the water runoff loss is unacceptable.

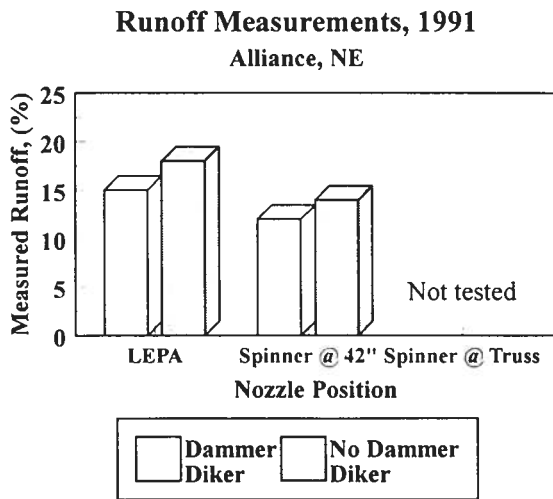


Figure 2. Percent runoff for LEPA system and Spinners at 42 inch height for a 1.0 inch application.

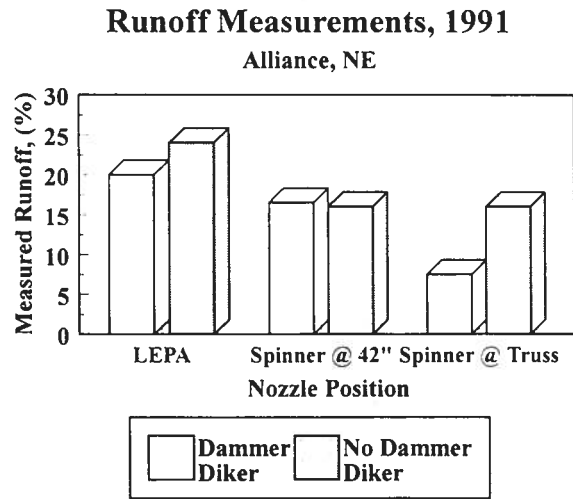


Figure 3. Percent runoff for LEPA system, Spinners at 42 inch height, and Spinners at truss rod height for a 0.7 inch application.