DETERMINING RUNOFF POTENTIAL

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INTRODUCTION

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.

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. However, new low pressure spray devices mounting close to the soil surface result in lower wetted diameters. If the wetted diameter is reduced too much, surface ponding and runoff can result even on relatively flat terrain. A number of water quality and crop production problems are the direct result of surface runoff. Runoff can dislodge and transport soil, 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, 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, and that the pumping plant delivers water at the appropriate pressure and flow rate. Another aspect is the uniformity of infiltration. Even if water could be applied to the soil at 100% uniformity, runoff can result in poor infiltration uniformity. Thus, the goal must be to consider how well the sprinkler package will match up with the field conditions.

In most cases, the uniformity of water application 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 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, alterring 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 pivot. 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 operator's management scheme. Too often the desire to reduce pumping costs cloud over issues that determine 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 alterring the sprinkler package, the program can be used to select a system flow rate and sprinkler wetted diameter that limits or eliminates the potential for runoff.

The program works by overlaying a soil infiltration rate curve with a water application pattern. Figure 1 shows an infiltration rate curve for a 0.5 NRCS Intake Family, 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 application rate was 3.6"/hr 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. To account for differences in water application rates along the system, the program divides the system length into 10 equal increments, calculates potential runoff for each section, and then calculates the weighted potential runoff for the system.

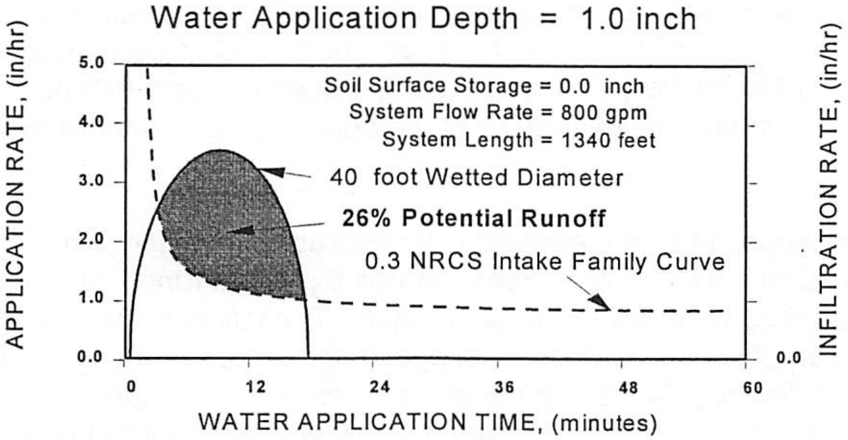


Figure 1. Estimated potential runoff for a 1340 ft. center pivot supplied with 800 gpm and applying 1.0 inches of water per revolution using a nozzle package with a 40 ft. wetted diameter.

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 at a time. 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*.

Some system characteristics influence how intensely water is applied to the soil. In this example, system capacity is *800* gallons per minute, system wetted length is *1340* feet, application depth is *1.0* inches per revolution and wetted diameter of the sprinkler is *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 which reduces the system water application efficiency.

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 potential runoff values are reported as the weighted average for the entire system.

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 may produce up to 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 is reduced to 700 gallons per minute, potential runoff is 22 percent. However, increasing system capacity 900 gpm could result in up to 29 percent runoff.

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	25	37
0.3	3-5	800	1340	1.0	55	18
0.3	3-5	800	1340	1.0	80	8
Table Ig.		**Influence of application depth and wetted diameter on runoff.**				
60 Foot Wetted Diameter						
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
80 Foot Wetted Diameter						
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

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 and position of the sprinkler relative to the soil surface. A maximum wetted diameter should be selected to produce little or no runoff. Eliminating the potential for runoff through sprinkler selection is more economical than performing corrective measures like specialized tillage.

The first two lines of Table If provide an indication of what can happen if sprinklers are positioned to operate within a corn canopy compared to above the canopy. Nebraska and Kansas research indicates that when positioned in the corn canopy, the water application pattern is intercepted by the plant leaves, stem and ear, effectively reducing the application pattern to approximately 55 feet down to 25 feet wide. The potential for runoff more than doubles while using the same sprinkler mounted from 3 to 7 feet closer to the soil surface.

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 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.

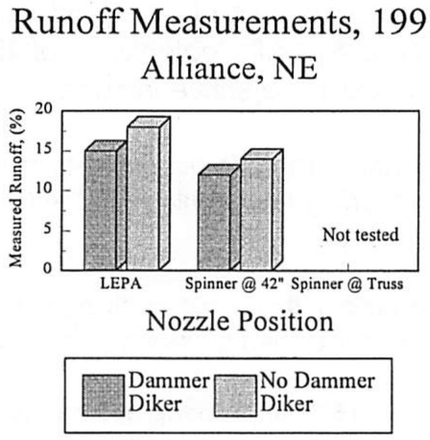
Tables Ia-Ig report weighted potential runoff or the amount of runoff based on how much of the irrigated area contributes to runoff. Table Ih shows how the potential for runoff changes based on position along the center pivot. Table Ia reports the weighted potential runoff of 26 percent for the entire system. Note the influence of the inside portion of the system on the overall value.

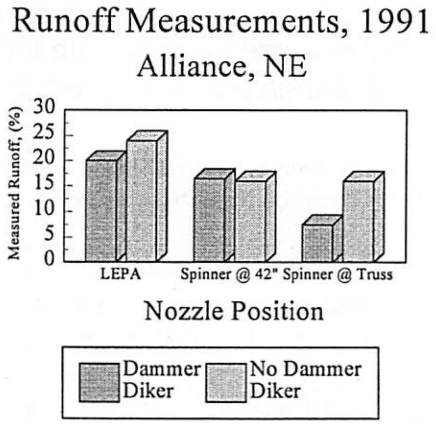
Water Application Efficiency

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 the same. For example, to achieve the 95+% application efficiencies, the crop canopy is not wetted, and less than half the soil surface receives water. An in-canopy application that wets part of the plant and nearly all of the soil surface will not result in those high efficiencies. In fact, the application efficiency could be lower than above canopy packages particularly if runoff is produced.

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-Diker[1] was used decreased from 15 percent at 42 inch height to 8 percent at truss rod height (Figure 3).

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.


Runoff Measurements, 1991
Alliance, NE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