COMPUTING FIELD LOSSES FOR FURROW IRRIGATION

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The goal of every irrigator should be to apply the right amount of water as uniformly as possible to meet the crop needs. To do the job right, irrigators need to take into account how much water is applied during irrigation and where the water goes (uniformity). Achieving a uniform water application is not easy when using furrow irrigation. However, with a better understanding of how irrigation system management affects water distribution and a willingness to make management changes, the uniformity and efficiency of most systems can be improved. This paper outlines the use of the "cutoff ratio" and how irrigators can use this management parameter to evaluate irrigation system performance.

CUTOFF RATIO

Soil texture, slope, and surface conditions (whether the furrow is smooth or rough, wet or dry) all influence how quickly water advances down the furrow. The speed of advance is directly related to how uniformly irrigation water is distributed within the soil profile. Prior to all irrigations soil surface conditions should be evaluated and the set size and corresponding stream size chosen accordingly. Having too many furrows running will slow the water's advance rate, resulting in excessive deep percolation at the head of the field, Figure 1a. Using a small set (relatively few gates open) results in a quicker, more suitable advance time and a more even, uniform, infiltration profile, Figure 1b.

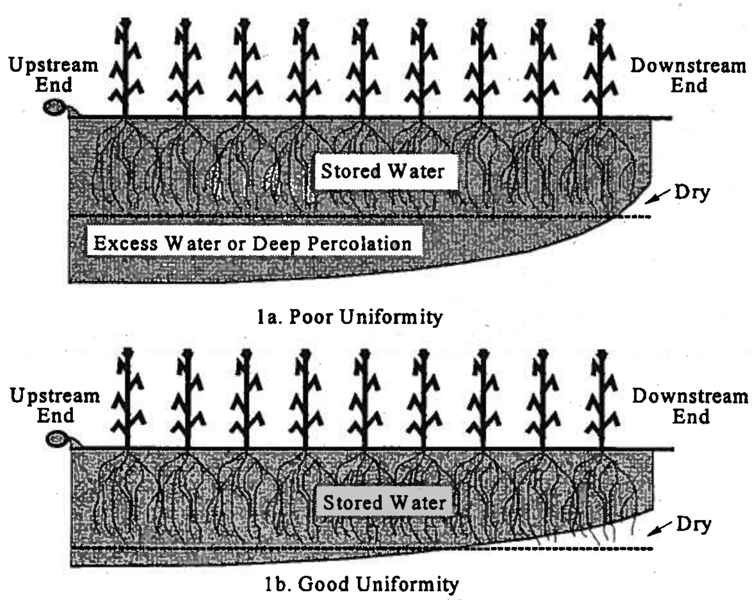

Figure 1. Infiltration profiles under conventional furrow irrigation.

However, small sets coupled with a long set time may cause excessive runoff. So what is the correct compromise between runoff and deep percolation that will result in the highest system efficiency? The *cutoff ratio* is a management parameter that helps surface irrigators determine the proper balance and evaluate system performance.

The *cutoff ratio* is defined as:

$$CR = \frac{t_L}{t_{co}}$$

where: CR = cutoff ratio,
t_L = advance time to the end of the field, and
t_{co} = set time.

In general, low *cutoff ratios* result in large amounts of runoff, but good uniformity. While high *cutoff ratios* result in small amounts of runoff, but poor distribution. The *cutoff ratio* that provides the maximum irrigation efficiency is dependent both on soil characteristics and irrigation system configuration. Table 1 shows recommended *cutoff ratios* for three broad soil textural classes and several different irrigation system configurations. In Table 1, *Open Reuse System* refers to a system where the runoff from one field is applied to an adjacent field; *Closed Reuse System* refers to a system where runoff water is reapplied to the same field.

Table 1. Recommended cutoff ratios to achieve maximum efficiency.

	Clayey	Silty or Loamy	Sandy
No Reuse	0.90	0.70	0.50
Open Reuse System	0.70	0.50	0.35
Closed Reuse System	0.50	0.40	0.20
Blocked ends (low slope, 0.1%	0.95	0.85	0.70
Blocked ends (moderate slope, 0.5%	0.95	0.80	0.65

Researchers in Nebraska have developed relationships between the *cutoff ratio* and a set of irrigation performance parameters that can be used to predict infiltration depth and evaluate irrigation field losses like runoff and deep percolation:

$$R_i = Infiltration\ Ratio = \frac{Infiltration\ depth\ exceeded\ in\ 90\%\ of\ field}{Gross\ depth\ applied}$$

$$R_p = Deep\ Percolation\ Ratio = \frac{Depth\ of\ percolation}{Gross\ depth\ applied}$$

$$R_r = Runoff\ Ratio = \frac{Depth\ of\ runoff}{Gross\ depth\ applied}$$

Table 2 contains values for these performance ratios for three broad soil textural classes and a range of cutoff ratios. The values presented assume a cutoff time (t_{co}) of 12 hours, a time of recession equal to 1 hour, and that the infiltrated depth occurs at $^9/_{10}$ of the furrow length.

Table 2. Furrow irrigation performance ratios*: R_i – ifiltration, R_p – deep percolation, and R_r. – runoff.

Cutoff	Clayey			Silty or Loamy			Sandy		
Ratio	R_i	R_p	R_r	R_i	R_p	R_r	R_i	R_p	R_r
0.1	0.188	0.001	0.811	0.315	0.002	0.683	0.495	0.005	0.500
0.2	0.316	0.006	0.679	0.454	0.015	0.532	0.613	0.030	0.358
0.3	0.421	0.015	0.565	0.549	0.035	0.417	0.677	0.063	0.263
0.4	0.511	0.028	0.462	0.617	0.061	0.323	0.709	0.102	0.192
0.5	0.586	0.046	0.369	0.664	0.094	0.245	0.720	0.147	0.137
0.6	0.648	0.069	0.284	0.691	0.134	0.178	0.714	0.198	0.094
0.7	0.696	0.099	0.207	0.700	0.182	0.122	0.692	0.255	0.060
0.8	0.727	0.138	0.138	0.691	0.239	0.075	0.67	0.318	0.034
0.9	0.737	0.190	0.077	0.662	0.308	0.038	0.608	0.388	0.016
1.0	0.720	0.260	0.027	0.608	0.392	0.011	0.545	0.260	0.001

*Preliminary Data

The following example demonstrates the application of these performance ratios.

Example:

Let's choose one of the recommended cutoff ratios given in Table 1, *CR = 0.4* (silty or loamy soil with a closed recovery system), and a gross irrigation application of 5 inches. Using the performance ratios find; the infiltrated depth at x_f = 0.9 (x_f is ratio of position along the furrow to total furrow length), depth lost to deep percolation, depth of runoff, and application efficiency.

From Table 2: $R_i = 0.617$
$R_p = 0.061$
$R_r = 0.323$

$$Infiltration\,depth\,exceeded\,in\,90\%\,of\,field = 5\,inches\,x\,0.617 = 3.1\,inches$$

$$Depth\,of\,percolation = 5\,inches\,x\,0.061 = 0.3\,inches$$

$$Depth\,of\,runoff = 5\,inches\,x\,0.323 = 1.6\,inches$$

For a closed runoff recovery system, application efficiency is calculated using:

$$AE = Application\,Efficiency = \left[\frac{1 - R_r - R_p}{1 - R_r R_T}\right] x\,100$$

where: R_T = return ratio (efficiency of the recovery system)
= volume applied from the recovery system divided by the volume of runoff
= 0.85 (assumed)

$$AE = \left[\frac{1 - 0.323 - 0.061}{1 - (0.323\,x\,0.85)}\right] x\,100 = 85\%$$

This example illustrates a system operating at maximum efficiency. For this efficiency to be attained the infiltration depth exceeded in 90% of the field (R_i) must be less than the available storage capacity in the soil profile. If R_i exceeds available storage capacity, the field has been uniformly over-irrigated and the calculated application efficiency is no longer valid. If the irrigator is not able to increase the available storage, perhaps the profile could be dried-down further before irrigation occurs, then other practices that reduce infiltration depths, such as every-other-furrow irrigation or shorter set times, must be considered.

RULES-OF-THUMB

The way that runoff is managed greatly affects the amount of water lost to deep percolation, and the uniformity of water distribution along the row. When *cutoff ratio* guidelines are properly used deep percolation decreases and uniformity improves. In an effort to encourage wider adoption of the *cutoff ratio* concept, practical "rules-of-thumb", that generally adhere to the recommended *ratios* shown in Table 1, were developed. The two rules-of-thumb are the less-than-half rule and the three-quarters-plus rule. These general guidelines are broadly applied to two categories of systems, those with runoff reuse and those without runoff reuse.

Systems with Runoff Reuse

When runoff is reused, apply the less-than-half rule to obtain uniform application: the average furrow advance time should be less than half of the total set time. The exception is the first irrigation of the year when advance should take closer to 60-65% of the total irrigation time. This rule will be easier to follow as the season progresses and advance times quicken, as furrows tend to smooth out. If the irrigator normally uses 12-hour sets, shorter set times should generally be used during the first irrigation, to avoid uniformly over-irrigating the whole field.

Systems without reuse of runoff

If there is no reuse system, apply the three-quarters-plus rule to estimate the advance time: water should get to the end of the field in about three fourths of the total irrigation set time. This rule applied throughout the growing season, both for early season and later irrigations. For example: if you run 12-hour irrigations, your set size should be adjusted so that water reaches the end of the field in an average of 9 hours. Although a 9-hour advance time follows the three-quarters plus rule, a 12-hour set time may still result in poor irrigation uniformity and efficiency. For the first irrigation of the season when the root zone is shallow, 12-hour sets are likely too long on 1/4 mile rows.

Blocking the lower end of the field is one method that is sometimes used to retain water that would otherwise be runoff. The practice of blocking furrow ends often results in excessive deep percolation, especially at the downstream end of the field. If blocked-end furrows are used, apply the three-quarters-plus advance time rule discussed earlier. By properly managing blocked-end furrow irrigation, deep percolation cannot be eliminated, but it can be minimized.

Summary

The goal of every irrigator should be to apply the right amount of water as uniformly as possible to meet the crop needs. With a better understanding of how irrigation system management affects water distribution and a willingness to make management changes, the uniformity and efficiency of most surface irrigation systems can be improved. This paper presented some generalized irrigation management rules-of-thumb that if properly applied will improve irrigation system performance. Application of the *cutoff ratio* concept to evaluate irrigation performance was also illustrated. More detailed *cutoff ratio* resources are available through Nebraska Cooperative Extension.

SELECTING SPRINKLER PACKAGES FOR LAND APPLICATION OF LIVESTOCK WASTEWATER

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INTRODUCTION

Livestock operations have changed dramatically in the last ten years. For example the number of hog farms has decreased from 600,000 to 157,000 in the last fifteen years. (Harkin 1998) During this same time the overall output of pork has increased. This increase of size also indicates an increased concentration of animals. Problems associated with any traditional livestock production unit are multiplied as the size increases. Management of the wastewater stream becomes a major component of the management strategy. Maintaining the environmental quality for the area of the livestock operation is critical to the overall success.

Livestock wastes may be applied by a number of methods. Tractor towed manure spreaders or slurry wagons are used to apply to the soil surface. Tractor towed slurry tanks with equipment to 'inject' the waste into the soil are used. Another choice is a plow down system where a tractor tows an injection unit attached to a long hose connected to a pump and the lagoon. On-land application units such as fixed head sprinklers, traveling guns or a center pivots are also commonly used.

Decisions on the type of waste application system are important to the economics of the livestock operation. Timing is one issue, which plays a key role in determining application methods (Hardeman 1997). Most of the methods listed above are only viable in the spring before the crop is planted or in the fall after it is harvested. Center pivots are not however limited by whether a crop is present or not as they may be used to apply over an active crop.

Center pivots, due to their characteristics, are considered to have advantages with regards to applying livestock wastes, particularly from a lagoon with large amounts of water to handle. Some of these characteristics include limited labor input required, application uniformity, ease in handling large quantities of effluent