FURROW IRRIGATION MANAGEMENT

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Furrow irrigation management encompasses decisions of when and how much to irrigate (irrigation scheduling) and decisions regarding the set size and furrow stream size. These decisions are made on a daily basis during the irrigation season and affect the effectiveness of each irrigation event.

This workshop is designed to help irrigators using graded furrow irrigation systems to make better management decisions regarding furrow irrigations. The first part of the workshop deals with some basics of furrow irrigation management such as determination of the application depth and selection of stream sizes. The second part is an introduction to surge irrigation, a method which we believe can improve irrigation efficiency in many furrow irrigated fields.

HOW SOIL CHARACTERISTICS AFFECT SURFACE IRRIGATION

Harry L. Manges

In surface irrigation, water is conveyed over the land surface to the point of infiltration. Irrigation is accomplished as water flowing over or ponded on the land surface infiltrates into the soil profile. The driving force for infiltration into the wetted area is gravity. After the water has entered the soil, it may be redistributed by forces other than gravity such as capillary forces in furrow irrigation and corrugation irrigation.

SOIL CHARACTERISTICS

Soil characteristics of special importance in surface irrigation are total available water, infiltration and lateral movement.

Total Available Water

Total available water is the soil water available to growing plants. It is defined as the difference in the moisture content of the soil between field capacity and permanent wilting point. It is determined to a large degree by soil texture and to a lesser degree by soil structure.

Field Capacity - The soil moisture content when the excess water has drained from the soil profile, usually measured two days after an irrigation.

Permanent Wilting Point - The soil moisture content when a plant wilts and will not revive when placed in a saturated atmosphere with little or no consumptive use.

Soil Texture - The sizes of the particles making up a soil determine its texture. There is no practical way to alter soil particle size and thereby soil texture.

Soil Structure - The grouping together of individual soil particles into a stable aggregate. The existence of aggregates assures a desirable soil structure.

Total available water is commonly expressed in inches of water per foot of soil (in/ft) or as depth of water in inches in the root zone of the crop grown (in). Table 1 gives the total available water for soils in selected SCS Intake Families. The table values are for deep soils suitable for irrigation. The SCS has assigned soil series to intake families based on surface texture. Intake family and total available water can be obtained from SCS for the major irrigated soil series.

TABLE 1. Total available water.

SCS intake family	Total available water in/ft
0.1	2.0
0.3	2.1
0.5	2.4
1.0	2.0
1.5	1.9
2.0	1.1
3.0	0.8

Adapted from Kansas Irrigation Guide, SCS, USDA.

Infiltration

Infiltration is the rate at which water enters the soil surface expressed in inches per hour (in/hr). It controls the amount of water entering the soil during an irrigation and affects the rate overland flow advances across a field. For a given inflow rate, advance rate is lowered on soils with a high infiltration rate because depth of water causing flow is less. Conversely, advance rate is increased when infiltration rate is decreased.

Infiltration rate is high when irrigation is initiated and decreases with time, approaching a constant rate referred to as the basic infiltration rate. The numerical value of the intake family given in Table 1 is this basic infiltration rate in in/hr.

Infiltration is a complex process dependent not only on soil characteristics and properties but also on other factors including initial soil moisture content, previous wetting history, cultivation practices, freezing and thawing during winter, and irrigation practices such as surge irrigation.

Infiltration of water into a dry soil is very rapid, especially in those soils with a high enough clay content to crack on drying. Wet soils have a low initial infiltration rate and the basic infiltration rate is reached soon after irrigation begins.

Rainfall or an irrigation smooths and compacts the soil surface. Infiltration rate is reduced for irrigations subsequent to either of these events.

Tilling tends to reduce the density of the soil leading to an increase in infiltration rate. Smoothing and compacting the soil surface will reduce infiltration. Minimum tillage practices which leave considerable quantities of crop residues on the soil surface will lead to increased infiltration rates. Freezing and thawing during winter will help build favorable soil structure with the same effects on infiltration rate as tillage and minimum tillage practices.

Surge irrigation is a practice which often increases the advance of overland flow across the field and decreases infiltration rate.

Lateral Movement

Lateral movement of water is important for furrow irrigation. The wetted pattern below a watered furrow is bulb shaped. Width of the bulb depends on the soil texture and structure and whether or not the soil is layered. Watered furrows should be close enough together to provide a wetted zone beneath each crop row.

CALCULATING HOW MUCH WATER WAS APPLIED

Israel Broner

Knowledge of water application rates and amounts during and after an irrigation event are an essential part of irrigation management. This knowledge is needed to prevent over-irrigation during the irrigation event and to calculate the soil water balance after the irrigation event. The soil water balance determines the timing of the next irrigation. The first step in calculating how much water was applied is water measurement. Usually when speaking of water measurement, we refer to measuring flow. Flow measurements in furrow irrigation are more complicated, difficult to obtain and less accurate than in sprinkler irrigation. However, even crude measurements and a rough knowledge of the amount of water applied is better than nothing.

Definitions and Conversions

Terms related to water measurement and the conversion between flows and volumes (amount) are as follows:

Amount of Water Applied--can be expressed as volume (gallons, cubic feet, acre-feet) or as depth (inches, feet) when considered as a volume spread over a given area. One acre-inch of water spread over 1 acre has a depth of 1 inch. When saying that 1 inch of water is applied to a 96 acre field, it translates to a volume of 96 acre-inch or 96/12 = 8 acre-feet.

1 cubic foot = 7.48 gallons
1 acre foot = 43,560 cubic feet = 325,829 gallons
1 acre inch = 27,154 gallons

Flow--is the rate at which a volume of water is moved or passes a given point. Flow is measured with units of volume per time (cubic feet per second [cfs], gallons per minute [gpm]). Water flowing at the rate of 1 cfs occurs when a cubic foot of water passes a given point every second.

1 cfs = 448.8 gpm

Flow to Volume (amount) Conversions--total amount or volume of water applied is the rate of flow multiplied by the time of application. If a flow of 1 cfs is applied for 1 hour, the total volume applied is 3600 cubic feet because there are 3600 seconds in 1 hour. This volume spread over 1 acre is a depth of 1 inch (3600/43560 square feet in acre = 0.083 feet = 1 inch).

1 cfs = 1 acre inch per hour = 2 acre feet (24 acre inch) per day

FURROW IRRIGATION EVENTS

Water distribution under furrow irrigation can be described in a depth-length diagram shown in Figure 1. Part of the total water (gross application) which is applied at the upper end of the furrow is infiltrated through the soil (infiltrated water) and part is lost as runoff. Runoff water (tail water) is the water that exits the furrow at the down stream end. Part of the infiltrated water is retained in the effective root zone (net application) and part of it is lost as deep percolation. Deep percolation is the water infiltrated that is in excess of the soil moisture deficit. For irrigation management purposes, knowledge of the net application is important because this is the amount or depth of water which is available for crop use. For a full application (soil moisture deficit replenished throughout the field), the net application should equal the soil moisture deficit.

Three typical results of furrow irrigation are illustrated in Figure 1. Under-irrigation is when the water is cutoff too soon, and the net application, at some point along the furrow, is inadequate to meet the soil moisture deficit. The complete-irrigation is the one desired, where the soil moisture deficit is satisfied without deep

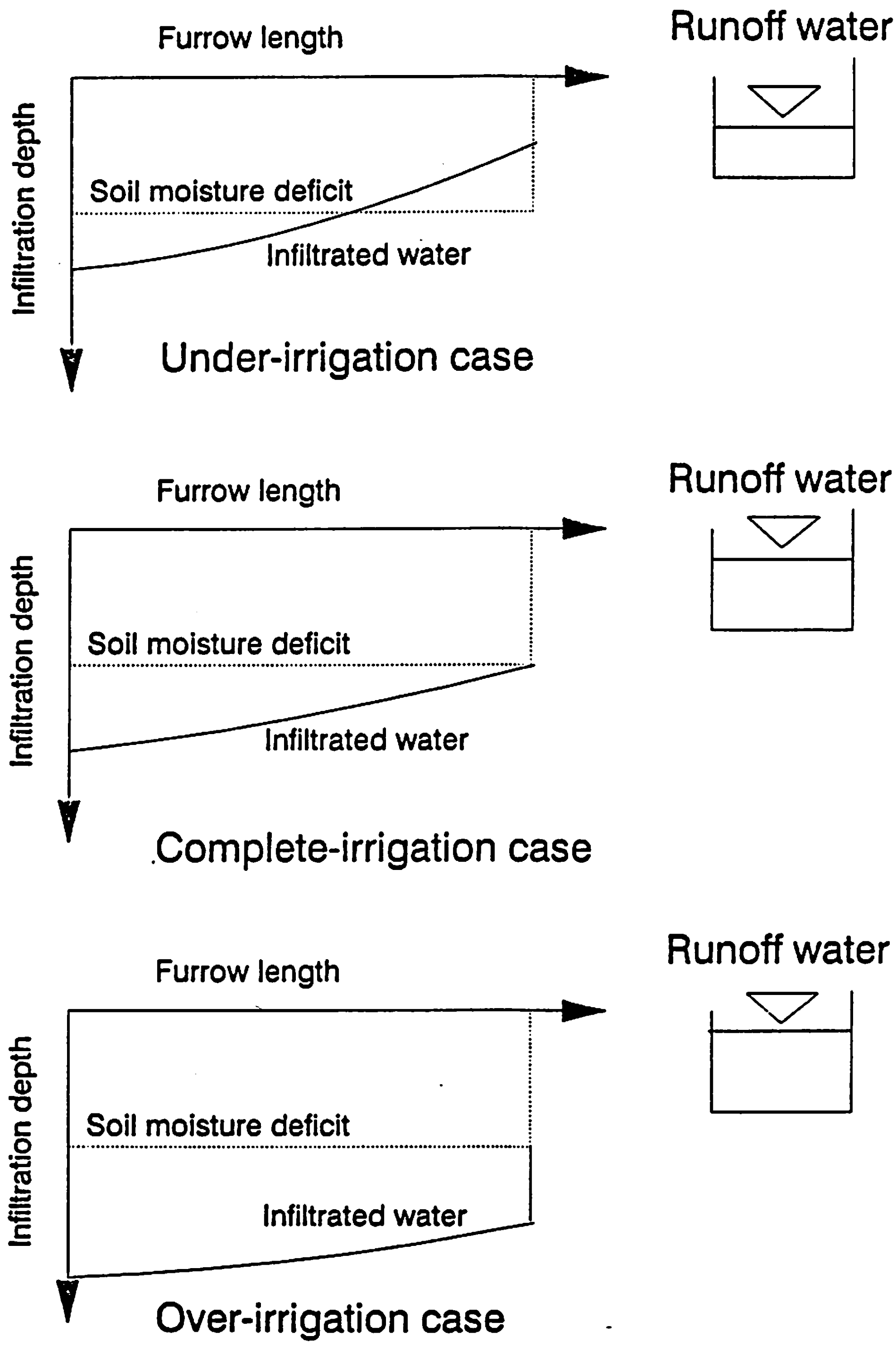


Figure 1. Typical results of furrow irrigation.

percolation at the downstream end. Over-irrigation is when the applied depth exceeds the soil moisture deficit at all locations. This description of the irrigation event is obtained by measurement of advance and recession and calculating the infiltration at each point along the furrow. This is not practical for field application; however, the irrigator can roughly figure the average net application using simple measurements and calculations.

WATER MEASUREMENTS AND CALCULATIONS

Gross Application--if not measured by a flowmeter or a flume, the gross application can be calculated by multiplying the flow rate by the application time. Flow rate of a siphon tube or a gate can be measured with a bucket and a stop watch. The flow rate of a siphon tube can also be estimated by measuring the head (H) over the siphon outlet as described in Appendix A.

Runoff--Runoff water can be measured by flumes or weirs placed in the tail water ditch. The only other alternative to directly measuring runoff is a rough estimation of the flow rate in the tail water ditch and multiplying it by the duration of runoff. Flow rate can be estimated using the following relation:

$$Q = V*A$$

Where Q is the flow rate in cfs, V is the velocity of flow in feet per second (use a stop watch and a piece of wood to measure), and A is the cross section area of the tail water ditch in square feet. The runoff amount or volume is the flow (Q) multiplied by the duration it occurred. The rest of the components of the applied water cannot be measured directly and must be calculated.

Infiltrated Water--is calculated by subtracting the runoff water from the gross application.

Net Application--the net application is the infiltrated water less the deep percolation.

Deep Percolation--amount or depth of deep percolation is calculated by subtracting the replenished soil moisture deficit from the infiltrated water. In the cases of complete irrigation and over-irrigation, the soil moisture deficit is replenished throughout the root zone; therefore, the replenished soil moisture deficit equals the soil moisture deficit (also the irrigation requirement). However, in the case of under-irrigation, the soil moisture deficit is not replenished throughout the root zone, and the calculation of deep percolation water requires the calculation of the water distribution along the furrow to determine the point where under-irrigation begins.

Water Distribution--water distribution along the furrow, which is the depth water penetrated at different points, can be estimated from the average infiltration rate of the soil and the opportunity time. A more practical method for field applications is to use a soil probe. Depth of water penetration can be sampled along the furrow to determine the water distribution.

EXAMPLE

A corn field having a 3.5 inch soil moisture deficit is irrigated with sets consisting of 50 1½-inch siphon tubes. The length of run is 1300 feet and row spacing is 2.5 feet. During the irrigation event, the head above the siphon outlet is measured as 6 inches. Water is applied for 12 hours, and the advance is completed in 6 hours. The tail water ditch flows constantly for 5 hours. Velocity of flow is 0.5 ft/sec, and the cross section area of the ditch is 1.5 square feet. To calculate the gross application, infiltrated water and average application efficiency:

Total irrigated area = 2.5 (feet) * 50 (rows) * 1300 (feet) =
= 162,500 square feet = 3.73 acre

From Appendix A, we find that the flow rate of each siphon tube is 20.2 gpm.

Gross application = 50 (siphons) * 20.2 (gpm) * 12 (hours) * 60 (min/hour) =
= 727,200 gallon = 97,219 cubic feet
= 97,219/162,500 = 0.59 feet = 7.18 inches

Runoff = 1.0 (ft/sec) * 1.5 (square feet) * 5 (hours) * 3600 (seconds) =
= 27000 cubic feet

Infiltrated water = 97219-27000 = 70219 cubic feet =
= 70219/162500 = .43 feet = 5.18 inches

Using a soil probe to probe the down stream end of the field, it is determined that the soil moisture deficit was replenished throughout the field (complete or over-irrigation). Therefore the deep percolation is: 5.18-3.5 = 1.68 inches.

Deep percolation amount = 1.68/12(feet) * 162,500 (square feet) =
= 22,750 cubic feet = 170,170 gallons

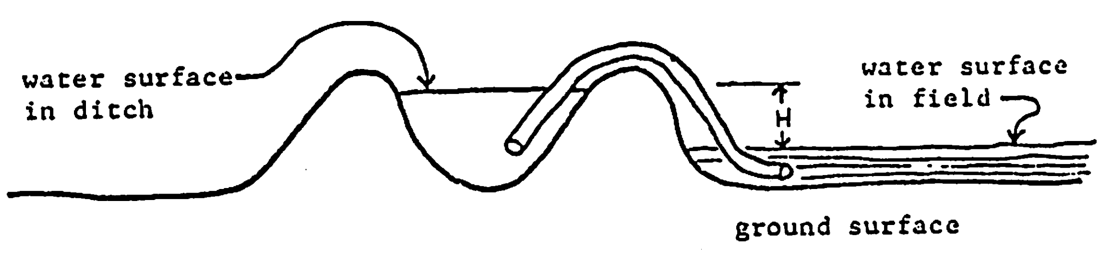
Average application efficiency = 3.5/7.18 * 100 = 49%

APPENDIX A

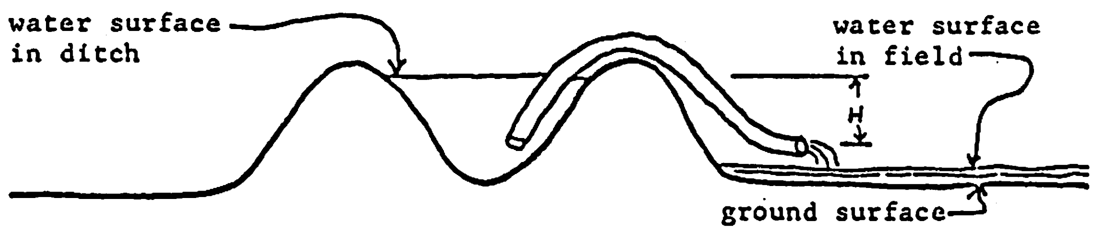
APPROXIMATE SIPHON TUBE FLOWS

Tube diameter (inches)	Flow per tube in gallons per minute at given head (H in inches)			
	2"	4"	6"	8"
1/2	1.3	1.8	2.2	2.5
3/4	2.9	4.1	5.0	5.8
1	5.1	7.3	9.0	10.5
1 1/4	8.1	11.5	13.7	16.3
1 1/2	11.7	16.5	20.2	23.0
2	20	29	35	41
3		66	81	92
4		117	142	166
5		176	220	255
6		260	320	370

SIPHON TUBE WITH SUBMERGED OUTLET



SIPHON TUBE WITH FREE OUTLET



ADJUSTING FURROW IRRIGATION STREAM SIZE AND SET TIME

Joel Cahoon

Many variables play a role in determining the uniformity and efficiency of furrow irrigation systems. The irrigator has no control over some of these irrigation management variables, for example, soil characteristics. Other variables may be controlled by the irrigator but often with some headaches or expense involved. Examples of these are field slope, furrow length and the shape of the furrow cross section. Fortunately, there are two irrigation management variables that the irrigator has direct control over and are not accompanied by capital purchases or difficult changes in the irrigation system. These variables are the furrow stream size and the set time.

Effect of Changing Set Time and Stream Size

The stream size is controlled by the number of gates opened or number of tubes set. The stream size of each furrow is determined by dividing the total flow rate at the source (pump or canal turnout) by the number of furrows running at any given time.

The stream size controls the rate at which water advances down the furrow. The larger the stream size, the faster water will reach the end of the furrow. As the advance rate increases, the uniformity of water infiltrated increases also (less difference between the amount of water soaked in at the top of the furrow and the amount soaked in at the bottom of the furrow). Unfortunately, as stream sizes are increased, runoff also increases. Excessive runoff may be acceptable when using a re-use system, but otherwise it may result in an inefficient system. So the answer is not always an increase in stream size, but finding the best stream size given the set time you choose.

Figure 1 shows the infiltration profiles that result from several different stream sizes if only one set time is used. Infiltration profiles show the amount of infiltration (water soaked in) from the top of the furrow to the bottom. The profiles shown in Figure 1 are not for any particular case (soil, slope, etc.), but simply show the effect of changing stream sizes in general terms.

Figure 1 shows that changes in stream size do not affect infiltration at the top of the furrow. All the curves start at the same point because the infiltration at the top of the furrow is controlled only by the set time. The characteristic that changes most dramatically when stream size is changed is the shape of the infiltration curve. As the stream size is increased, the curve flattens out becoming more uniform. For a given set time, more runoff is produced as the stream size is increased.

Changing the set time has a different affect on the infiltration curves. Instead of changing the shape of the infiltration curve, the position is altered. As the set time increases, the infiltration curve is shifted downward. As the curve moves downward, it also becomes longer (extends farther to the right). This effect is shown in Figure 2 for a given stream size and a generic situation. The curves presented are for set times that are too short, about right and too long, considering that only one stream size is presented.

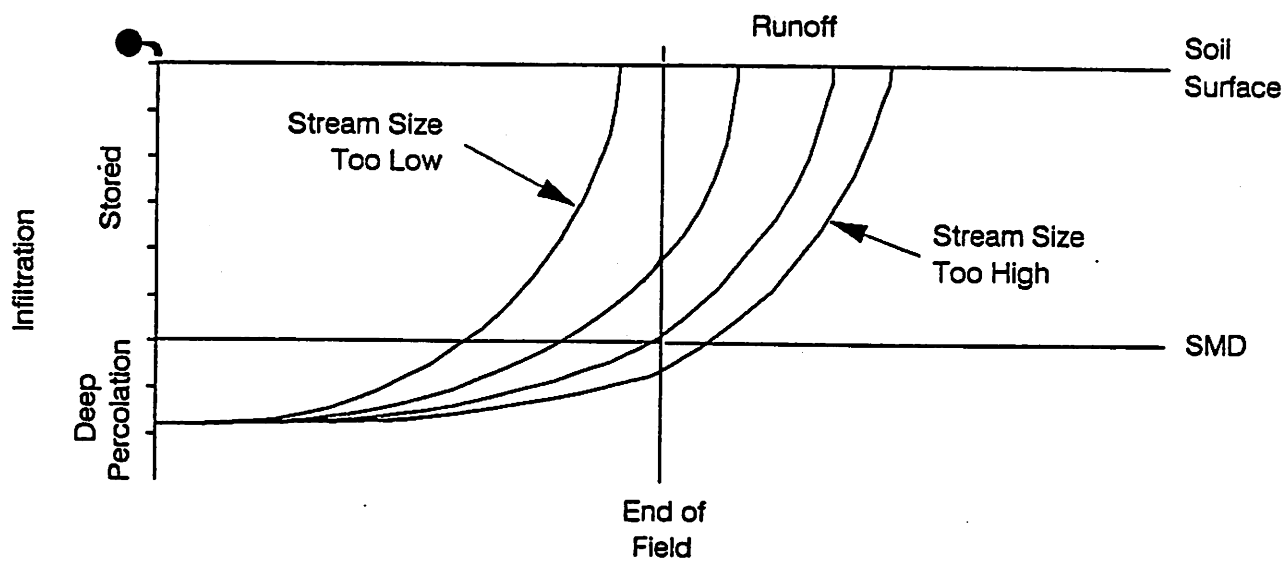


Figure 1. Effect of changing stream sizes for one set time.

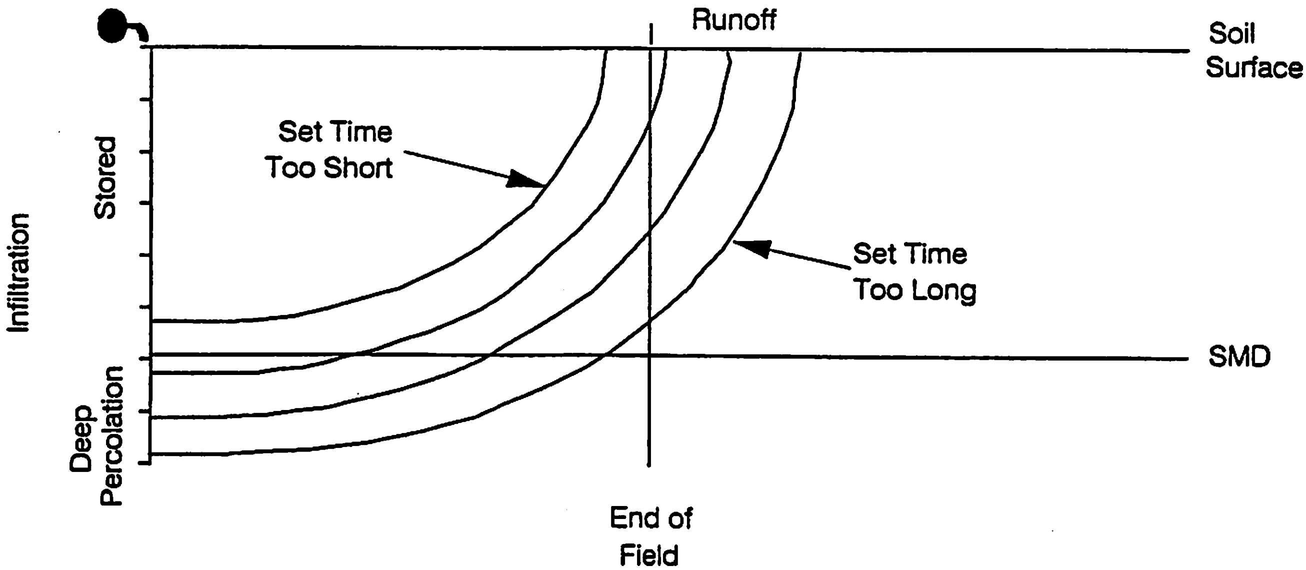


Figure 2. Effect of changing set times for one stream size.

Practical Considerations and Limitations

By now it is probably obvious that both the set time and stream size should be adjusted to achieve the best furrow irrigation settings. Discussing the effects of changing stream sizes and set times in general terms is a lot easier than actually deciding what settings to use. There are, however, some things that can be done in the field to determine the direction and relative magnitude of any changes.

The proper set time may be determined by using a soil probe at the top of the field. At the end of an irrigation, probe several locations across the width of a furrow and note the depth of saturation. The average depth of saturation should be greater than the root depth but not by more than about 30 percent. This will vary with conditions, but in general, the goal is to refill the root zone at the top of the field with some, but not excessive, deep percolation.

Once the set time is determined, the same probing technique should be used at the bottom of the field to help find the right stream size. The bottom of the field should be close to fully irrigated, with a little deficit (not quite fully filling the root zone) allowed. The stream size would be selected that yields this condition, without producing an intolerable amount of runoff (unless runoff is desired for re-use).

There are some practical limitations. Many irrigators cannot change their set time because of labor demands. This often limits set time to 24, 12 and sometimes 8 or 6 hours. If an electric well is used, a timer may be installed which will overcome this problem. In many cases the water savings that result from using non-traditional set times will convince an irrigator to alter labor schedules. Changing the stream size is usually no problem unless the source (canal or well) flow rate is high, and there are not many furrows being irrigated. Small fields will usually have only two or three different stream sizes that can be used because of the limitation on the number of sets. Large fields can use any desired stream size by adjusting the number of gates by plus-or-minus one while moving across the field (see Appendix 1).

APPENDIX 1

UNIFORM FURROW IRRIGATION SET SIZES

If you have problems making the number of sets you use with gated pipe furrow irrigation come out even, the following procedure should help. For example, an irrigator has a 55-acre block with 1/4 mile runs and 30" rows. This means he has 726 furrows to irrigate. He wants to use 31 gates per set. If he opens 31 gates on every set, he will have 23 sets plus 1 set left over that only has 13 gates open. To make it come out even, he can run different combinations of sets with 30, 31 or 32 gates per set. Here's how to determine the proper number:

Instruction	Our Example	Your Calculation
1. Write down total number of furrows	a. 726	a. ______
2. Write down the desired number of gates per set	b. 31	b. ______
3. (a.)÷(b.)	c. 23.42	c. ______
4. Round off (c.) to nearest whole number	d. 23	d. ______
5. (a.)÷(d.), using long division, the whole number remainder are important		
31 23)726 690 36 23	e. 31	e. ______
13	f. 13	f. ______
6. (d.)-(f.)	g. 10	g. ______
7. (b.) + 1	h. 32	h. ______

Results

Our Example:

Run (g.) 10 sets with (e.) 31 gates open
and
run (f.) 13 sets with (h.) 32 gates open.

Your Calculations

Run (g.) __ sets with (e.) __ gates open
and
run (f.) __ sets with (h.) __ gates open.

(Note: This may not be helpful on fields with only a few of sets.)

FUNDAMENTALS OF SURGE IRRIGATION

Israel Broner

Furrow irrigation is a widely used irrigation method. When irrigating a long field with furrows, the objective is to advance the water rapidly to the lower end of the field, and once the advance is completed, the objective is to reduce runoff at the lower end of the field. One way to accomplish these objectives is to use a "cut back" practice, that is, reducing the furrow stream size after the advance is completed.

Since the soil is the distribution system in furrow irrigation, different soils pose different challenges to the irrigator. Light soils have a high rate of water intake; therefore a large stream is needed to speed the advance. In heavier soils that have a low rate of water intake, a small stream size is needed during the soaking phase to reduce tail water.

Consequently, many attempts were made over the years to automate the "cut back" practice. During these trials, it was realized that turning water valves on and off was easier than partially turning off a water valve. This was the beginning of surge irrigation. Additional trials of surge irrigation showed the surge phenomenon had more advantages than just automation of the cut back practice.

What is Surge Irrigation?

Surge irrigation is the intermittent application of water to furrows in a series of surges of constant or variable time spans. Usually the water is alternated between two sets of furrows until the irrigation is completed. Surge irrigation, in its modern form, is a relatively new irrigation technique and was first introduced by Utah State University (Stringham and Keller, 1979). However, the phenomenon of alternating water has been known to irrigators for more than three decades. Many irrigators found it impossible to complete the advance phase of furrow irrigation following a major cultivation because of the high water intake rate. They discovered that the advance phase could be completed by interrupting the stream furrow flow and then reapplying it hours or days later--a practice sometimes called "bumping."

Surge can be applied manually by alternating water between two sets of furrows. However, labor is prohibitive in most cases because usually more than a few surges are needed. In today's typical installation, surge irrigation is applied through the use of an automatic "surge valve" located between two sets of gated pipes (Figure 1). Water is alternated between the right and left sides of the surge valve. Therefore, for each set of furrows, a series of on and off time periods is created as depicted in Figure 1. For example, a furrow on one side of the surge valve receives water for 40 minutes, and then water is shut off for 40 minutes. This furrow will receive the second surge of water after 1 hour and 20 minutes (80 minutes). The second surge duration can again be 40 minutes or longer according to the particular program used. This process continues until the advance is completed.

Cut back for the soaking phase in surge irrigation can be done in two ways. The first way is to divide the flow between the two sets which reduces the stream size by 50 percent. The second way is to continue to alternate the water between the two sets of furrows on short time intervals which cuts back time and the average stream size.

Advantages

1. Faster water advance to the end of the field reduces deep percolation at the upper end of the field.

2. Automatic cut back reduces tail water.

3. Allows lighter applications of water.

4. More uniform water distribution along the furrow.

5. More opportunities to save water and energy.

Disadvantages

1. Requires a higher level of management (may be a problem when using unskilled labor).

2. Surge equipment must be maintained properly just as any piece of machinery.

3. Additional cost of surge valve and gated pipe if not already used.

To properly apply furrow irrigation, some cut back method is needed. Surge irrigation automates of the "cut back." Instead of cutting back or reducing the continuous stream size, surging reduces the average stream size that the furrow receives.

Furthermore, early trials of surge irrigation showed the surge phenomenon (alternating water between two sets of furrows) has more advantages than just automation of the "cut back" practice. Reduced infiltration rate is a major phenomenon often associated with surge irrigation. Several explanations have been suggested for the reduced infiltration rate, however, few have been scientifically verified. As a consequence of the reduced infiltration rate, advance is completed even faster, and deep percolation at the upper end of the furrow is reduced even more than by just cutting back. Runoff is reduced mainly because of the "cut back."

In some soils having a high initial but very low basic intake rate, the reduced infiltration rate may be a problem. In these soils, surge irrigation will require a longer time to soak in, thereby requiring a longer irrigation time.

Converting from gated pipe irrigation to surge irrigation is straightforward and will be explained in the sections that follow.

Implementation

Automatic surge valves are commercially available. A typical valve has a controller powered by a battery charged with a solar panel. Consequently no power source is required in the field. The valve usually is located in the middle of two sets of gated pipes as shown in Figure 1.

In a typical installation, the result is that the gated pipe on one side of the valve is on a down-slope while the gated pipe on the opposite side is on an up-slope. This situation does not pose a problem where the water source has enough pressure or there is a sufficient elevation difference to maintain uniform stream sizes on both sides of the gated pipe. Sediment accumulation in the gated pipe on the up-slope side might cause a problem because water velocity is slower. If collapsible tubes are used as the gated pipe then both sides need to be on a down slope. It is not necessary to locate the surge valve in the middle of the two sets. The valve can be located at the upper end of the field and a delivery pipe can be used to supply the lower set of gated pipes as shown in Figure 2. This configuration will allow both sets of gated pipes to be on a down slope.

A new type of valve was developed recently which is termed "in-line" surge valve. This valve is also designed for gated pipe implementations, however, it is installed in line with the gated pipe and does not require any additional pipe. This valve operates like a drop gate in an irrigation canal and requires an elevation drop to operate properly.

Most of the surge controllers are capable of automatically performing several programs. Two basic options are available in most of the automatic controllers. The first option is a manual control, and the user can enter a sequence of surge cycles to be performed by the valve. The second option is referred to as the auto mode, and it requires only one input, such as out-time of continuous flow irrigation or the length and slope of the field. The sequence of surges, on-time and cut-back time are determined by the controller. The auto mode makes the controller very easy to operate, but reduces the fitness of the surge sequence to the particular field conditions. By observing irrigations, one can find an optimal surge sequence that completes the advance fast and minimizes tail water, and programs it in the controller using the manual mode. Programming these controllers is very simple and can be learned in a short time.

Ditch Implementation

Surge irrigation can be implemented in concrete ditches. Figure 3 shows the required layout of the concrete ditch. A surge gate that replaces the drop gate is needed for this type of installation. To control the gate, the same controller that is used for the automatic surge valves can be used. Implementation of surge in concrete ditches is not very common yet, but it is possible and has been done at several locations on the western slope of Colorado.

References

Stringham, G. E. and J. Keller. 1979. Surge flow for automatic irrigation. Proc. 1977 Irrigation and Drainage Specialty Conference, ASCE, Albuquerque, New Mexico. 10 pp.

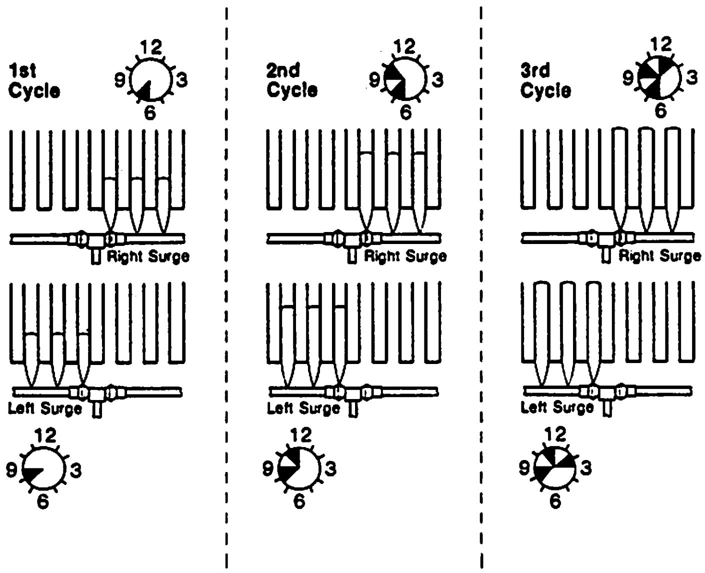


FIGURE 1. Surge cycles and water advance.

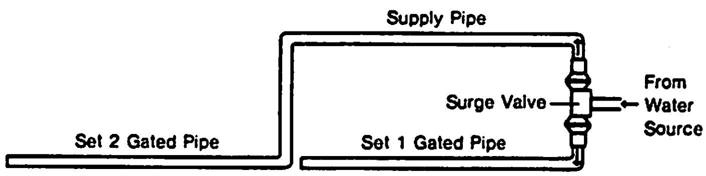


FIGURE 2. Locating the surge valve at the upper end of the field.

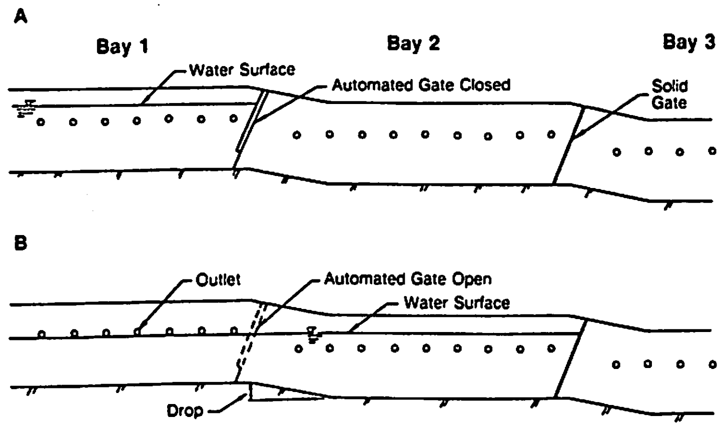


FIGURE 3. Schematic diagram of applying surge in ported ditches.

SURGE IRRIGATION: RESULTS AND OBSERVATIONS

Joel Cahoon

The results of surge irrigation trials can be discussed in two terms: replicated research farm results and observations made of farmers using surge irrigation.

Research Results

Surge irrigation trials have been conducted by the University of Nebraska for several years (1983 through 1989) at a variety of sites. The technique used to evaluate surge irrigation was to determine if surged furrows showed a reduction in advance time when compared to continuous flow furrows using the same stream size. This test indicates the effect of surge flow on the soil infiltration characteristics. If water advances faster under surge flow, it is due to an alteration in the ability of the soil to absorb water. If no reduction in advance time occurs, the surge phenomena had no affect on the soil's water intake capability. The results of the University of Nebraska field trials are given in Table 1.

TABLE 1. Surge irrigation test results (NebGuide G91-1018).

Year	*Row Identity Soft/Hard*	*Soil Type*	*Irrigation Number*	*Advance Time Reduction (%)*
1983	soft	Hastings Silt Loam	1st	0
1985	soft	Hord silt loam	1st	0
1985	soft	"	2nd	0
1986	hard	"	1st	0
1986	soft	"	1st	52
1986	hard	Keith silt loam	1st	0
1986	soft	"	1st	29
1987	hard	Hord silt loam	1st	0
1987	soft	"	1st	0
1987	hard	Keith silt loam	1st	20
1987	soft	"	1st	36
1988	soft	Hastings silt loam	1st	23
1988	soft	Tripp very fine sandy loam	1st	0
1988	soft	"	1st	40
1988	soft	"	2nd	20
1989	soft	"	1st	25
1989	soft	"	2nd - reditched	0
1989	soft	"	3rd	0
1989	soft	"	1st	50
1989	soft	"	1st	35
1989	soft	"	2nd - reditched	38
1989	soft	"	3rd	14
1989	soft	Hastings silt loam	1st	0
1989	soft	"	2nd	0
1989	soft	Holdredge silt loam and Butler silty clay loam	1st	21
1989	soft	"	2nd	19

From Table 1, it is shown that surge irrigation changed the soil intake characteristics in about half (14 out of 26) of the cases examined. When advance time was reduced due to surge flow, the average reduction in advance time was 30 percent. So if we were to generalize, we could state that: surge irrigation is effective in about half the cases studied, and when it was effective, it caused about a 30 percent reduction in advance time.

On-Farm Observations

Another way to evaluate the effect of including a surge valve as part of a furrow irrigation system is to look at the way the valve influences management practices. For example, the presence of a surge valve may cause the irrigator to alter his set time and/or stream size regardless of the affect of surge flow on infiltration. The number of people using surge valves in furrow irrigation systems has increased to the point that most people know what they are and what they can be used for, but many people are still not sure how to use them. Basically, a surge valve will have little or no affect on an irrigation system if a person installs one and continues to operate the system as he did before installing the valve without a change in irrigation scheduling.

Here is an example of a conventional to surge conversion where adequate changes were **not** made (assume a 40-acre field with 36-inch by 1/4-mile rows, thus having 440 rows):

Year 1 - Conventional	Year 2 - Surge
Set time: 12 hrs	Set time: 24 hrs (12 hrs per side)
Gates open: 50	Gates open: 100 (50 per side)
Time to get across field: 4.5 days	Time to get across field: 4.5 days

The only thing that changed in the above example is the amount of time between trips to the field to change sets. Water is running down each row for 12 hours during each irrigation. At any given time, 50 gates are open with the conventional or the surge system. Nothing changed, so we would not expect the surge valve to be a valuable addition to the irrigation system in terms of applied water when used in this manner. It may be argued that the surge system provided a more uniform irrigation than did the conventional. This does not always happen, and when it does, it is very difficult to respond to that change with a meaningful change in irrigation schedule.

Now let's look at an example of a conversion where an effective change in the system operation **was** made (same 40-acre field):

Year 1 - Conventional	Year 2 - Surge
Set time: 12 hrs	Set time: 12 hrs (6 hrs per side)
Gates open: 50	Gates open: 72 (36 per side)
Time to get across field: 4.5 days	Time to get across field: 3 days

By decreasing the number of gates running water at any time by 28 percent and decreasing the amount of time that water is running into a given row by 50 percent, this irrigator is covering the field in one-third less time--using 33 percent less water per irrigation. Now he may have to irrigate more often, but hopefully he is putting more of the water applied into the root zone; so even if he does irrigate a little more often, he'll still save water over the season. If this irrigator tried the above surge settings and decided the bottom end of the field was not getting enough water, he could go to 8 hours on each side of the valve. The point is--he would not know until he tried!

Keep in mind that this is just an example not a recommendation. Irrigators may find that it takes trial-and-error use of the surge valve to figure out what should be changed and by how much. In general, changing the number of gates per set, which is really just an easy way to change the stream size in each furrow, will be the easiest change to make. In any case, changes should be in the right direction. If getting water through the field is a problem with the conventional system, try increasing the furrow stream size (less gates running at a time) and reducing the total amount of time that water runs into each row. If excessive runoff is a problem with the conventional system, try adjusting the "cutback" or "soak cycles" that the surge valve uses. The canned "advance" cycles that the surge valve uses can be adjusted to get the water to the end of the field prior to the first soak cycle. If you are using an electric well, a shutoff timer allows you to use any set time you want. This will provide the opportunity to really fine-tune your surge settings. Remember--try changing one set at a time; the worst that can happen is that you try something else on the next set!