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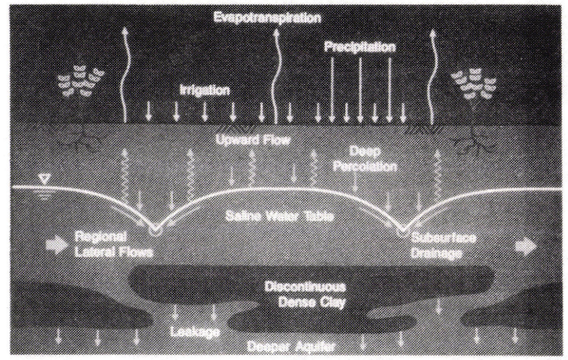
# SOIL and WATER

1989 - NO. 75

## FURROW IRRIGATION AND DRAINAGE REDUCTION

**Blaine R. Hanson**

What causes subsurface drainage?




Subsurface drainage water comes from nonuniform water applications and over-irrigation. Drainage from over-irrigation can be decreased by reducing the set time. Reducing drainage from nonuniform water applications, however, requires improving the uniformity of the applied water.

Uniformity refers to the evenness at which water is applied throughout the field. A

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## EMERGING TECHNOLOGIES: CAN THEY SOLVE THE DRAINAGE PROBLEM?

**Larry J. Schwankl**

Two recent irrigation system developments which may help deal with drainage problems are **linear move irrigation systems** and **buried drip irrigation systems.** Both of these irrigation systems have the potential to apply water with high uniformity. **Uniformity,** which is a measure of how nearly all portions of the field receive the same amount of water, is important because it constrains the irrigator as to the minimum amount of water which must be applied to adequately irrigate

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Fate of irrigation water in high water table areas.

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## USE OF SALINE DRAINAGE FOR IRRIGATING CROPS

**S. R. Grattan**

Irrigating crops with saline water may be a desirable practice where good quality water is either limited in supply or too costly to meet the crop water requirement during the entire season. In many of these situations, this practice has been successful and profitable. Others have considered using saline drainage water as a means of reducing drainage volume in areas where drainage water disposal is not possible due to physical, environmental, social, and

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Alternate furrow irrigation has been suggested as another means of reducing drainage volumes. Substantial drainage reduction can occur, however, only if converting to alternate furrow irrigation improves the uniformity of the applied water. This means that the normal field flow rate should be used on one-half of the number of furrows normally irrigated, which will increase the furrows inflow rate. If the same furrow flow rates are used, little drainage reduction may occur.

Difficulties

The need to reduce the set time creates some difficulties for growers. First, irregular set times (times other than 12 or 24 hours) create problems in labor management. Irrigators may have trouble keeping track of times required for set changes. Set changes at night further complicate matters. In some irrigation-water districts, inflexibility in the delivery system requires growers to accept water continually during an irrigation, which prevents stopping the irrigation during the night.

Salinity control

Salinity control will be a limiting factor in the amount of drainage reduction. Where no saline high water tables occur, and low-salinity irrigation water is used, leaching fractions of a few percent can be tolerated. However, where a saline high water exists, substantial salt accumulation will occur during an irrigation season due to upward flow of irrigation water into the root zone. One UC study showed that because of this upward flow and the subsequent salinization of the root zone, the allowable maximum application efficiency is about 75 to 89 percent under furrow irrigation. Higher efficiencies resulted in decreased profits, the result of yield reductions from soil salinity. The allowable maximum efficiencies were insensitive to drainage costs simply because the mechanisms of upward flow/salinization limited the options for controlling drainage.

Summary

The most effective measures for reducing drainage volumes under furrow irrigation are reduced run lengths and set times, followed by surge irrigation. Other measures can reduce drainage, but have limitations. The primary limiting factor, not only for furrow irrigation, but for all irrigation methods, is salinity control where saline high water tables continue to exist.

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EMERGING TECHNOLOGIES, con't.

all parts of the field. This may best be explained by an example. A field requires an irrigation application of 3 inches. In other words, in order to adequately irrigate the entire field, all portions of the field must receive at least 3 inches of water. Figure 1 shows a typical pattern by which a surface irrigation system applies water. In order to apply 3 inches of water to the tail of the field, the head of the field receives significantly greater amounts of water (5 inches in fig. 1). The important point is that an irrigator using the system in this example would be forced to over-irrigate portions of the field in order to adequately irrigate all of the field.



systems also have disadvantages, not least of which, is their cost. Growers will need to weigh the pros and cons of each system, taking into consideration their own unique conditions and requirements, before deciding on an irrigation system change.

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USE OF SALINE DRAINAGE WATER FOR IRRIGATING CROPS, cont.

and political factors. **However, using drainage water to reduce drainage volume should not be viewed as a substitute for good water management.** Drainage volume reduction can best be achieved by either improving existing surface irrigation practices or by switching to other, more water-controllable irrigation systems (e.g. sprinkler and drip). Nevertheless, saline water has been used as either an alternative or supplemental water supply for various reasons.

The concepts and principles of saline water use for successfully irrigating crops are described in this article. It is this information that must be digested before rational decisions regarding the feasibility of adopting or implementing such a practice, can be made.

Methods of applying saline drainage water to crops

Two strategies of irrigation with saline water have been proposed and tested. Both methods require that good quality water be available at least during part of the growing season.

1. Blending method--A method by which water of different qualities are blended together before or during an irrigation to achieve a suitable quality for each irrigation.

2. Cyclic method--A method by which good quality of water is used as pre-plant and early-season irrigations and undiluted drainage water is used at other times presumably when the crop is more tolerant to salinity.

In terms of plant performance, the cyclic method has more advantages than the blending method (table 1). Transient soil salinity conditions that are produced under the cyclic method allow for a more flexible cropping system in that more salt-sensitive crops can be included in the rotation. Second, a blending facility is not required. Third, intermittent leaching with good quality water is more effective than continuous leaching with poor quality water. Fourth, drainage water of higher salinity can be applied. This can be justified by the following. The salt tolerance of a crop (the extent to which economic yield can be sustained in the presence of root zone salinity) is dependent, in part, upon the length of time during the growing season the roots are exposed to salinity. With the cyclic method, saline water is applied later in the season therefore, yields are not as affected as they would be if it were applied from the beginning of the season (see figure 1). Furthermore, the salt tolerance of most crops increases as the crop matures. It is these reasons why there are so many field studies in arid regions of the world that have concluded that water conventionally classified as too saline for agricultural use have been used to irrigate certain crops without a

Table 1. Advantages and disadvantages of the "cyclic" and "blending" drainage water reuse methods.

| CYCLIC METHOD | BLENDING METHOD |
|---|---|
| Advantages: | Advantages: |
| - Drainage water of higher salinity can be applied | - Less demand on drainage supply |
| - No blending facility required | - Appropriate if drainage water itself is not too saline for crop |
| - Intermittent leaching with high quality water more effective than continuous leaching | - If cost of disposal exceeds the consequences of reduced yield and loss of usable water |
| - More salt-sensitive crops can be included in rotation | Disadvantages: |
| - Greater chance for crop to utilize drainage water | - May not require drainage volume |
| Disadvantages: | - Requires blending facility |
| - Drainage water available may not be synchronized with drainage water demand | - Upper part of soil profile is more saline --may effect salt sensitive or boron sensitive plants |
| - Possible drainage water management difficulties (storage facilities, distribution systems, etc.) | - Requires higher leaching fractions |

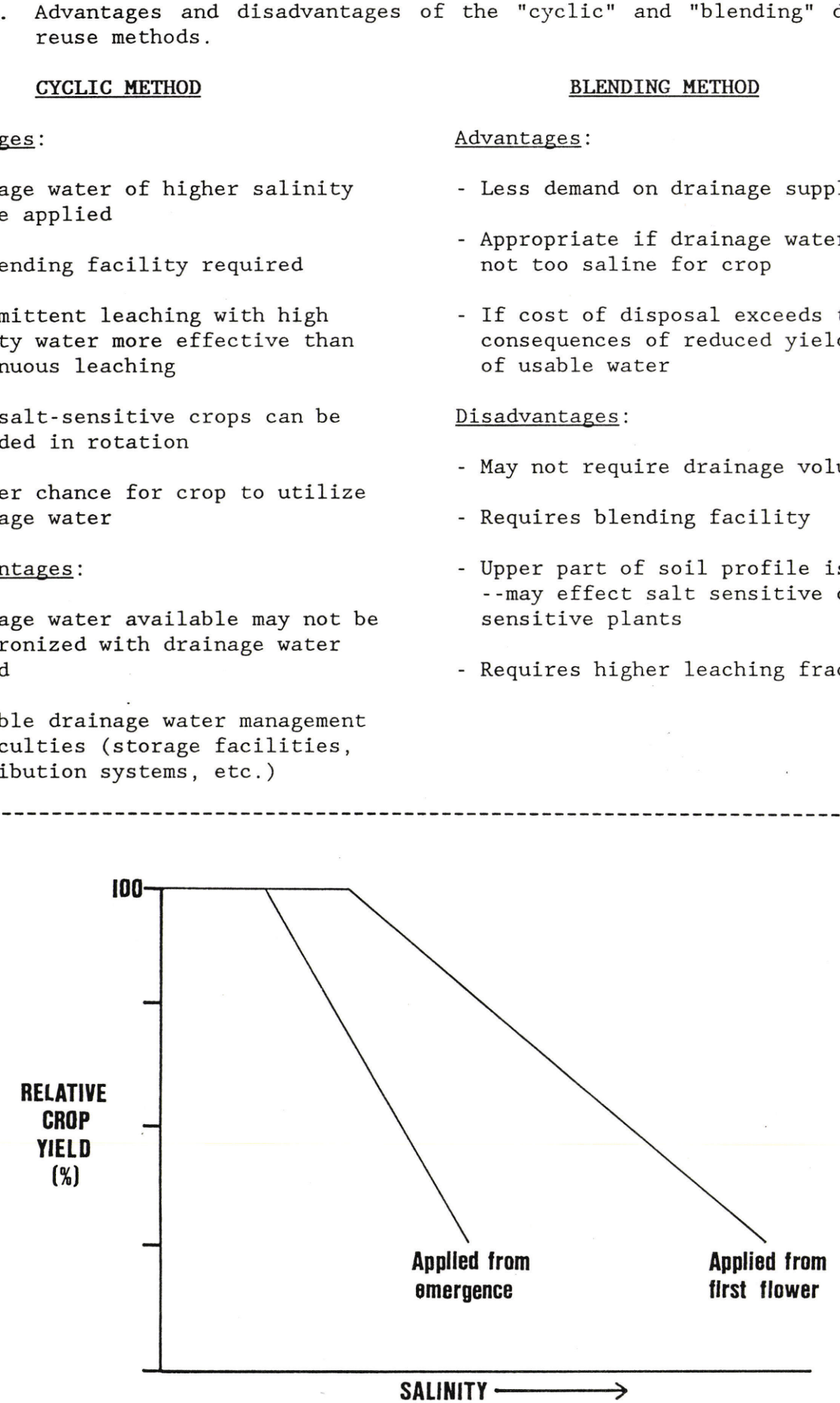



Figure 1. Influence of applying saline drainage water later in the season on the salt-tolerance of a typical crop.



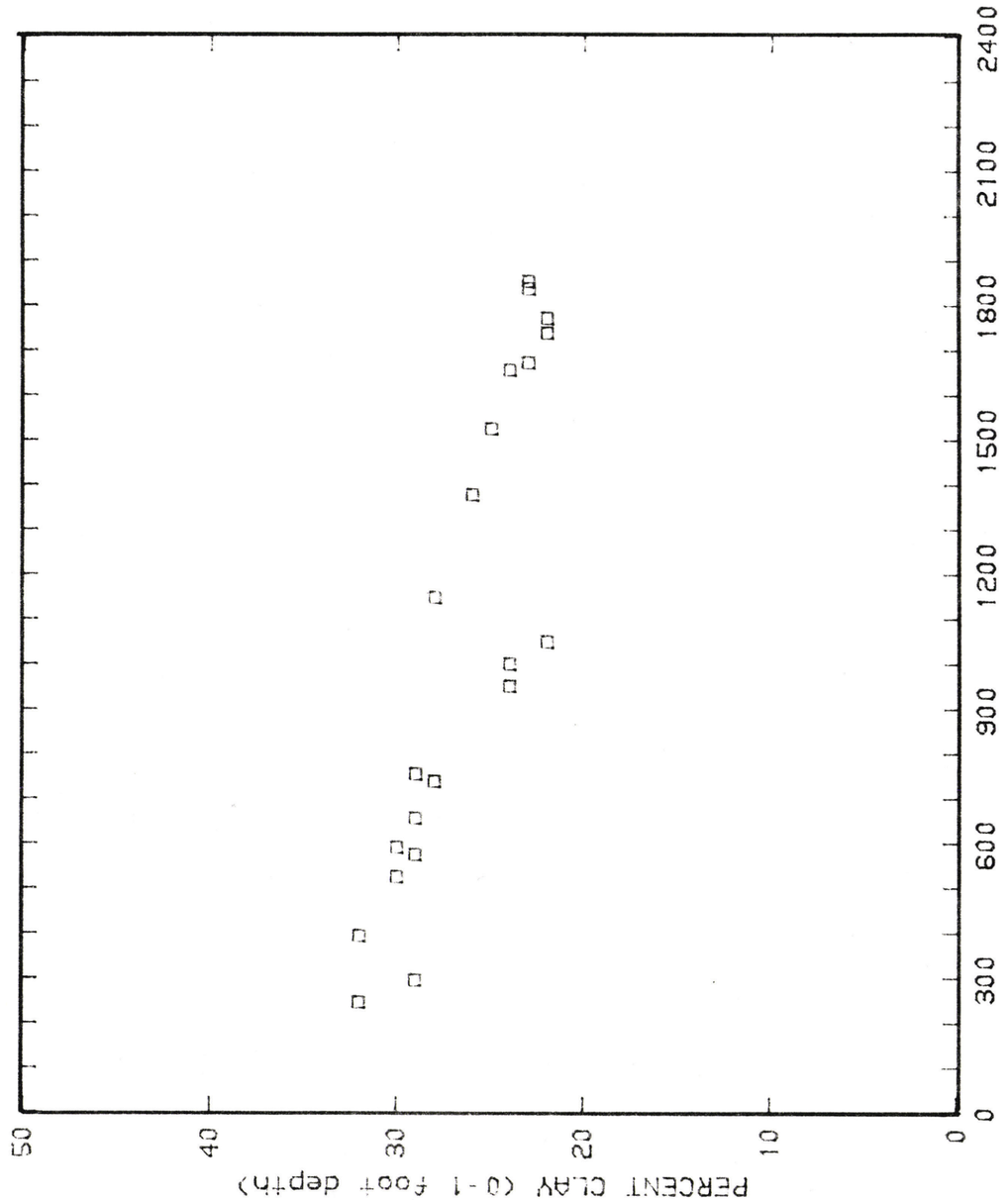



Figure 1. Percent clay fraction along the run length.

One advantage of this upgrade is a reduction in the variability in the soil infiltration rate. Figure 1 shows the percent clay along the field length to decrease with distance, which reflects an increase in infiltration with distance. The smaller run length reduced variability caused by a changing soil texture. Set times were reduced from 22 hours to about 9 hours.

Furrow inflow rates and set times

Table 2 shows the effect of increasing the furrow inflow rate and decreasing the set time for the first crop irrigation (June). Run lengths of ½ mile were used for both flow rates. Inflow rate was increased from 32 gpm to 44 gpm, and the set time was decreased from 22 hours to 12 hours. The end result was a reduction in infiltrated volumes from 6.9 inches to 5.1. Surface runoff was also reduced, mainly because the smaller set time for the higher inflow rate.

**Table 2.** Effect of increased furrow inflow rate and decreased set time on drainage for a first seasonal crop irrigation.

| | Furrow Inflow Rates | |
|---|---|---|
| | 32 gpm | 44 gpm |
| Applied water (inches) | 8.2 | 5.9 |
| Runoff (inches) | 1.3 | 0.8 |
| Infiltrated (inches) | 6.9 | 5.1 |
| Set time (hours) | 22 | 12 |

Surge irrigation

Surge irrigation can reduce subsurface drainage by 30 to 40 percent for some soil types, according to several studies. This decrease is due primarily from a reduced soil infiltration rate, caused by surging. However, on a clay loam soil, little difference occurred between an upgraded furrow system and surge irrigation. At this site, water flow into cracks was the main mechanism for infiltration, which was not affected by surging.

Other considerations

Night sets may be longer than day sets, which causes nonuniformity throughout a field. Uniformity can be improved by using the same set times during an irrigation.

Furrow compaction with torpedoes has been promoted as a method for reducing drainage. However, some preliminary observations indicated that the primary effect of the torpedoes may be to reduce furrow roughness, which in turn will decrease the time for water to reach the end of the field and improve uniformity. Compaction may be minimal.

Longer intervals between irrigations has been proposed as a drainage reduction measure. This approach increases the soil moisture depletion at the time of irrigation. If the normal volume of irrigation water is applied (that applied under the normal interval), the application efficiency will increase, and drainage volumes will decrease. This approach, however, will underirrigate parts of the field, thus, causing a yield reduction.



significant loss in yield or crop quality. The fifth advantage of the cyclic method is that there is a greater chance for the crop to utilize the drainage water, thereby reducing drainage volume than the blending method. The last advantage can be easily illustrated by the following example. Suppose a vegetable grower has access to two water supplies, one is of good quality, the other is drainage water that is as saline as sea water. If one gallon of good water is blended with one gallon of drainage water, the result is two gallons of water near half sea-water strength; or zero gallons of usable water by the crop. The original gallon of good quality water has now been lost or made unavailable to the crop by blending. This is an extremely important point since growers have been known to blend drainage water that is too saline for use. Consequently, there is no indication that the original drainage water was ever utilized by the crop or that drainage volume was in fact reduced.

In terms of management, the blending strategy may be more desirable than the cyclic strategy. Providing the drainage water is not too saline, blending demands less drainage water for a given irrigation. If the drainage water is not too saline, it may be easier or less expensive to mix the drainage water with the existing water supply rather than divert it to a holding facility.

**Management considerations and guidelines**

Certain management factors must be considered first before a drainage reuse practice can be implemented. Below is a list of important factors that should be considered.

Management considerations

1. Drainage water availability (collection, distribution, flows, etc.)
2. Drainage water quality (EC, boron, SAR, nitrate, etc.)
3. Crop selection criteria
   A. Economics/marketability
   B. Crop tolerance to salinity and boron
   C. Accumulation potential of selenium and other constituents
   D. Management practices/soil and climate conditions
   E. Crop quality enhancement (soluble solids)
4. Irrigation water management
   A. Stand establishment
   B. Irrigation method

In order for a reuse practice to be considered, drainage water must be available during mid- to late-season and its quality must be acceptable. Except for very salt tolerant plants, drainage water in excess of 6,000 mg/L TDS should not be used. Furthermore, water that contains elements that could be potentially toxic to the plant or the consumer should also be avoided. Various factors related to crop selection must also be considered. For example, the crop must be marketable and it must be able to withstand the levels of salinity and boron within the drainage water. Irrigation management can influence the potential success of a reuse practice. Precautions should be taken during pre-plant or early season irrigations to avoid

maintenance, Christiansen uniformities of 90 to 95 percent are possible.

2. **Reduced labor requirements**, as compared to conventional surface irrigation systems, are possible with buried drip irrigation. The systems are generally automated resulting in little labor to irrigate. Labor to perform maintenance is required so buried drip should by no means be considered maintenance-free.

3. Irrigation water and chemicals (fertilizer, nematicides, etc.) if chemigation is done are **delivered directly to the root zone**. This allows for efficient use of both water and chemicals.

4. A **dry field surface** exists where buried drip systems are used. This has the advantages of reducing weed growth as well as allowing access to the field wherever desired. Operation of buried drip systems installed at 6- to 10-inch depths result in a narrow, wetted band at the surface located above the drip tubing.

**Disadvantages** of buried drip irrigation include:

1. **Installation and removal** of buried drip systems can be both difficult and expensive. Installation costs may be as high as $400/ac. Placing the drip tubing at the desired depth, without damaging the drip lines, can be challenging. The deeper the depth of burial, the more difficult this may become.

2. **Maintenance requirements** of a buried drip system can be extensive. As with above-ground drip systems, buried drip systems may require sophisticated filtration, chlorine, and/or acid injection systems in order to prevent clogging of emitters. Other difficulties may arise depending on the irrigation water quality.

3. **Management requirements** of buried drip systems also may be extensive. A buried drip system is a sophisticated irrigation system and in order to take advantage of its capabilities, it should be managed in a sophisticated manner.

4. **Leaks and clogging** of buried drip systems are difficult to detect and may affect both crop performance and uniformity of application. Monitoring pressure and/or flow throughout the system can be used to spot leak or clogging problems.

5. **Root intrusion** into buried drip emitters can be a problem, particularly in permanent crops. Limited grower experience seems to indicate that frequent irrigation and chlorine injection may prevent or minimize the problem.

6. **Germination** of some crops, such as cotton or processing tomatoes may be difficult with a buried drip system, particularly with those systems buried deeply. In order to "sub" water to the seed and the soil surface, significant amounts of water may need to be applied. If much of this water is lost to deep percolation, the buried drip system is less efficient and may contribute to drainage problems.

7. The **high initial cost** of buried drip systems is also a disadvantage. These costs may be $1000/AC or more. These systems are among the most costly of all irrigation systems.

In summary, both linear move and buried drip irrigation systems have many advantages including the capability of applying water uniformly and thus minimizing drainage volumes. These



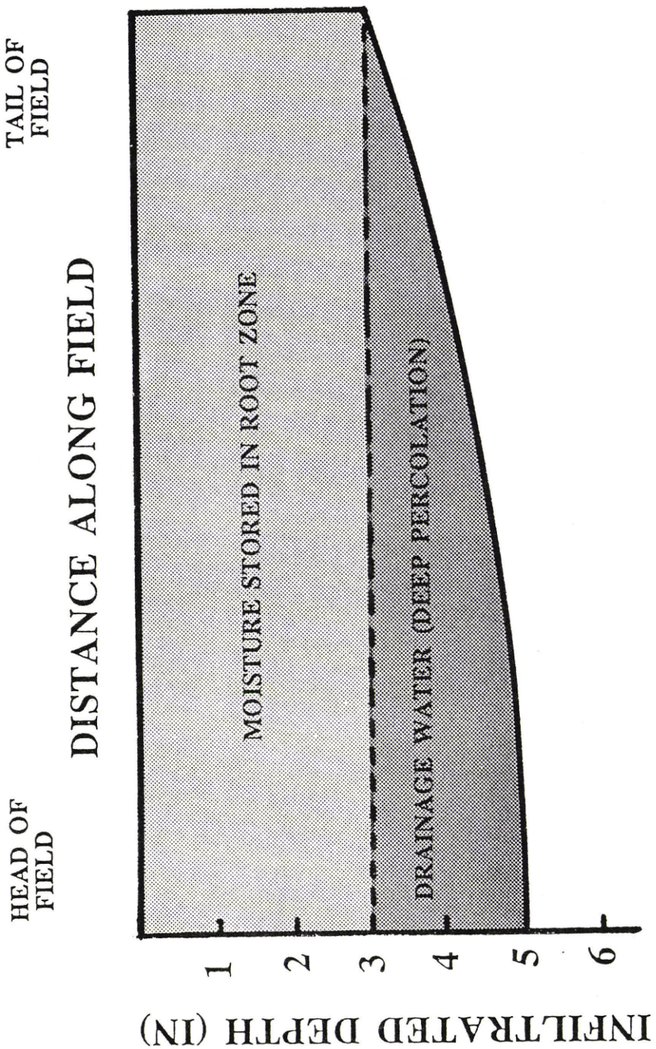



Figure 1. Distribution of infiltrated water along the length of the field.

There are two frequently-used measures of uniformity--**distribution uniformity** and **Christiansen's uniformity.** Distribution uniformity (defined below) is most frequently used to describe surface irrigation systems whereas Christiansen's uniformity (defined below) is most commonly used with sprinkler irrigation systems.

$$\text{Distribution Uniformity} = \frac{\text{average low quarter depth of water infiltrated}}{\text{average depth of water infiltrated}} \times 100$$

$$\text{Christiansen's Uniformity} = \frac{\text{average low half depth of water infiltrated}}{\text{average depth of water infiltrated}} \times 100$$

The average low quarter infiltrated depth is the average of the lowest ¼ of the infiltrated depth values, where each value represents the same area. Likewise, the low half infiltrated depth is the average of the lowest ½ of the infiltrated depth values.

It is important to know which measure of uniformity someone is referring to when they say, for example, "the uniformity was 85%." In almost all cases describing the same event, Christiansen's uniformity (CU) will result in a greater number than will distribution uniformity (DU).

Conversion between CU and DU can be approximated by:

$$CU = 100 - 0.63\ (100 - DU)$$

$$DU = 100 - 1.59\ (100 - CU)$$

In figure 1, the distribution uniformity equals 76 percent while Christiansen's uniformity equals 85 percent.

Irrigation systems which can apply water uniformly to the field, combined with good **irrigation scheduling** (knowing when and how much water to apply), provide the irrigation water manager with the tools to efficiently irrigate and minimize drainage volumes.

## Linear move irrigation

As with every irrigation system, both linear move sprinkler systems and buried drip systems have their advantages and disadvantages. Linear move irrigation systems have the following **advantages:**

1. **Reduced labor requirements** as compared to conventional surface irrigation systems. It should not be assumed that linear move systems are maintenance free. As with any high-tech irrigation system, there are opportunities for difficulties which require maintenance and attention.

2. **High application uniformity potential** exists with linear move machines. Linear move machines with closely spaced (approximately 1 meter) low-pressure spray nozzles can deliver water with a CU of 80 to 85 percent.

3. **Frequent, small application depths** can be applied with linear move machines. Machine speed can be adjusted to vary the application amount. This can be a particular advantage when the crop is young and frequent application amounts are desireable. Proper design of the linear move system is important to ensure that peak crop evapotranspiration demands can be met.



**Disadvantages** of the linear move machines are:

1. **Wind drift** can be a problem where sprinklers are used. Wind distorts the sprinkler application pattern and results in lower uniformity of application.

2. **Movement** of a linear move machine **is not continuous** but consists of a series of start/stop movements. One of the towers is a control tower (frequently the outside tower) and it moves regularly, but other towers move in a random start/stop manner in order to stay in alignment as the whole machine moves across the field. This random tower movement may reduce the application uniformity slightly.

3. Heavy soils may not lend themselves as well to linear move machines due to their lower intake rates resulting in **runoff**, and due to **traction difficulties** the machines may have in moving across the field.

4. System capital **cost** is quite high (approximately $600/acre) for linear move machines.

Low energy precise application (LEPA) is a special configuration of linear move irrigation system which has been used in Texas, but has seen limited use here in California. Instead of using sprinklers, water delivery is done via drop tubes with bubblers on the ends which place water directly into the furrow. In effect, LEPA is furrow irrigation with a traveling water source. Small "dikes" in the furrow are frequently used to ensure that water infiltrates where it is applied. This is particularly important where the field is not level. LEPA is not affected by wind and can be used on crops which the grower does not want to sprinkle. Tower movement and soil intake characteristics limit the uniformity which can be achieved. Additional system evaluation work needs to be done, but Christiansen's uniformities of 80 to 85 percent appear to be achievable with LEPA systems.

## Buried drip irrigation

Buried drip irrigation uses drip tapes or in-line emitter tubing specifically designed to be buried. The majority of drip emitters are not designed to be buried. Buried drip irrigation has been used primarily to irrigate high-value crops such as vegetables and strawberries, but recently it has been used with row crops such as cotton and tomatoes and even in permanent crops such as grapes and walnuts. Burial depths have varied from only a few inches to as deep as 18 inches. When used in row crops and permanent crops, the buried drip product is left in place for multiple years, and is frequently buried at greater depths (8 to 18 inches). A farming operation in Arizona has had drip tape in place in sandy soil for 5 to 10 years, but under much of California's heavier soil conditions, 3 to 5 years may be a more realistic expected life. This shorter life does not result so much from product failure as from the need to rip or deep-work the soil which cannot be done while the buried drip lines are in place.

**Advantages** of buried drip irrigation include:

1. The **potential for high application uniformity** exists with buried drip irrigation. With proper design and

crusting and poor stand establishment. Furthermore, certain irrigation methods that deliver saline water to the field might be more successful than others. For example, drip irrigation in saline environment allows for a higher soil water content on the average than furrow irrigation. Sprinkler irrigation on the other hand could be detrimental due to foliar burn.

Potential long-term effects

There are several potential long-term problems that can be created from reuse practices. These are listed below.

Potential long-term problems caused by reuse practices

1. Effects on soil physical condition

   A. Reduced water infiltration (especially during pre-plant irrigation)

   B. Reduced plant emergence due to crusting

2. Soil salinity and boron accumulation

3. Toxic constituent accumulation (e.g. selenium, molybdenum, heavy metals, etc.)

Effects on soil physical conditions can be reduced, in most cases, by incorporation of gypsum ($CaSO_4$) in the top part of the soil profile, providing the cause of poor soil conditions is related to the combined effects of low salinity irrigation water and a high exchangeable sodium percentage in the upper portion of the soil. This would improve water infiltration and reduce surface crusting. Irrigation practices must be managed properly to avoid salts and boron from accumulating in the root zone. It is recommended that soil salinity be closely monitored. The drainage water should also be analyzed for elements that are toxic to plants, animals or humans. Should concentrations exceed maximum permissable levels, it may be unwise to apply this to agricultural land.



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FURROW IRRIGATION AND DRAINAGE REDUCTION, con't.

uniformity of 100 percent means the same depth of water was applied throughout the field. No irrigation system has 100 percent uniformity, and thus, some areas of a field will receive more water. Thus, if the water applied to the least-watered part of the field equals the soil moisture depletion, other parts receive more than needed, and thus, subsurface drainage occurs. The more nonuniform the water application, the greater the differences between the least- and most-watered areas, and the greater the subsurface drainage.

Nonuniform water applications in furrow irrigation systems are caused by differences in infiltration times along the run, the result of the time required for water to flow across the field (advance time), and by variability in soil texture, random behavior within a soil texture and variability due to compaction (wheel vs. non-wheel furrows).

Nonuniformity from infiltration time differences can be reduced by decreasing the advance time through smaller run lengths and higher furrow inflow rates. Both measures require decreased set times. Nonuniformity from soil variability may be reduced by smaller run lengths where soil texture varies throughout a field, converting to surge irrigation, and compacting furrows to reduce wheel/non-wheel furrow differences.

Run lengths and set times

UC studies have shown that reducing the run length by one-half, and reducing the set time, can potentially decrease subsurface drainage by 50 to 70 percent. A disadvantage of this measure is that surface runoff will be much greater for the smaller run length compared to a longer run. Where appropriate, converting to level basins with furrows will eliminate the runoff problem.

Table 1 shows results from a study comparing an upgraded furrow system (run length reduced to about ¼ mile) with the normal system (run length of about ½ mile) during a preirrigation. A substantial reduction in the amount of infiltrated water occurred under the upgraded system, from 7.7 inches (½ mile run) to about 5.4 inches. However, a large increase in surface runoff occurred, from about 0.6 inches for the ½ mile run to about 2.3 inches for the upgraded system. Set times were reduced to about 9 hours for the upgraded system compared to a normal set time of about 22 hours.

**Table 1.** Effect of reduced run length and set time on drainage for a preirrigation.

| | Run Length ½ mile | ¼ mile |
|---|---|---|
| Applied water (in.) | 8.3 | 7.3 |
| Runoff water (in.) | 0.6 | 2.3 |
| Infiltrated water (in.) | 7.7 | 5.4 |
| Set time (hours) | 16 | 9 |