

SALINITY AND DRAINAGE

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INTRODUCTION

Without sufficient [drainage](http://www.fao.org/docrep/R4082E/TopOfPage) (<http://www.fao.org/docrep/R4082E/TopOfPage>), a salt balance cannot be maintained. Yields will decline, you will have to grow less salt-sensitive (usually less profitable crops), and in the long run, land will go out of production.

The basic problem is that all irrigation waters contain salts. Applying water to the soil adds both salts and water. But the crops will extract mostly pure water, leaving the salts behind.

Salts in agriculture can be both good and bad. Many fertilizers are salts. However, [excessive salts in the soil](http://www.fao.org/docrep/R4082E/chapter%207%20%20%20salty%20) (<http://www.fao.org/docrep/R4082E/chapter%207%20%20%20salty%20>

soils) is one of the most serious problems facing irrigated agriculture in the San Joaquin Valley.

There are many different types of salts such as sulfates, chlorides, and bicarbonates of sodium, calcium, magnesium, and potassium. Sometimes the problem is just the high level of salts in the soil and/or water (although in some areas a common problem is too little salts in the water), sometimes it is a problem of imbalance between the types of salts.

Excessive or imbalanced salts in soil and water cause four types of problems for agriculture . . .

1. General yield decline - This is the result of excessive total salts in the soil. The yield decline varies with the crop and management. Some crops are more salt-tolerant than others. And, there are certain techniques that can be used to minimize salt damage.
2. Poor soil structure and reduced water infiltration - This is a result of an imbalance of salt types. The extent of the problem depends on the imbalance, the amount of salts in the water, and also the clay content and type of clay in the soil.
3. Specific crop toxicities (direct action to stunt or kill the plant) - Boron is the most recognized toxic salt by Growers, especially in almonds.
4. Miscellaneous problems with quality (taste or appearance).

With some very poor quality water, damage to components (corrosion, encrustation) of the irrigation system becomes important. The problem of salts can be very obvious or very subtle. Most Growers will recognize a salt problem if they see white crusts in a field or have problems with getting water into the soil. However there could be significant crop

yield reductions for years without realizing the problem.

SOURCES AND MEASUREMENT OF SALINITY

There are three main sources of salts in agricultural soils, irrigation water, fertilizer, and naturally occurring salts in the soil that may be dissolved under irrigation. (Most of the time, the amount of salts dissolving from the soil is balanced by those salts precipitating out of solution.)

The water supply for Westlands includes both Grower-owned deep wells and Project contract water from the San Luis Aqueduct. Most of the deep well water in the District is of very poor quality. And, although the Project water is relatively good, it still adds about 500 pounds of salt to the soil for every acre-foot (AF) applied.

One measure of the level of salts in soil or water is in terms of a concentration, typically parts of salt per million parts of water. You may see salt levels described as "200 parts per million total dissolved solids" or, "200 ppm TDS" (about the level of salts in Aqueduct water). An AF of water weighs about 2,700,000 pounds. And at 200 ppm TDS, there are 200 pounds of salt per million pounds of water. Thus, every AF of this water contains about 540 pounds of salt. And if you apply three foot of water per acre per year, then you are putting 1620 pounds of salt on that acre.

A more common measure of salts in the soil and water for agriculture scientists is electrical conductivity. This is a measure of how much electric current will flow through water at a specific voltage. The more salts in water, the more current will flow through that water. You will see water described as having an "electrical conductivity of 1.5 dS/m", or

simply $EC_w = 1.5 \text{ dS/m}$ (dS/m stands for deci-Siemens of electrical conductivity per meter of water).

An approximate conversion between concentration and electrical conductivity is that 640 ppm TDS (parts per million total dissolved solids) = 1 dS/m. A comparison of some water qualities is seen below . . .

- Aqueduct-200-320 ppm TDS or .3 to .5 dS/m
- Friant-Kern Canal - 50 ppm TDS
- Rainwater - Near Zero
- Average deep well in the District, Sub-Corcoran:
 - East of Aqueduct - <1,300 ppm TDS
 - Westplains-Varies < 2,600 ppm TDS
- Sea-water - 35,000 ppm TDS
- Colorado River - 1000+ ppm TDS at the Mexican border

You may see the symbol "EC" followed by one of several letters. If you see "EC_w" then it is usually describing the electrical conductivity of the irrigation water. If "EC_e" it is usually the electrical conductivity of the saturated soil moisture extract. (Here, the laboratory has made a paste by saturating a soil sample with pure water, then drawn off the excess water and measured the electrical conductivity.) "EC_d" is usually used when measuring drainage water.

SUITABILITY STANDARDS FOR WATER USE

The [suitability of water](http://www.fao.org/docrep/T0667E/chapter%204%20%20water%20quality%20assessment) (<http://www.fao.org/docrep/T0667E/chapter%204%20%20water%20quality%20assessment>) for irrigation is judged on measurement standards that indicate the potential for causing one or more of the four classes of problems. For general yield declines and the necessity for leaching, the standard would be total dissolved solids or

the electrical conductivity. For soil structure problems scientists are interested in the sodium absorption ratio (SAR) in conjunction with the total dissolved solids. For specific toxicities, they look at the relative levels of specific salts.

Table-1 is the well-accepted Guidelines for Use of Irrigation Water (from FAO 29A, by Ayers/Westcott). Note that the suitability for use is reported in terms of None, Increasing, and Severe problems to be expected with continual use of the water. For example, a TDS reading of 450-2000 ppm is going to indicate an increasing potential problem while with water over 2000 ppm TDS the problem is likely to be severe.

Also, be aware of some of the assumptions that were made in developing the Guidelines. For example, looking at the notes under Site Conditions . . . "Drainage is assumed to be good, with no uncontrolled shallow water table present within 2 meters of the surface." Obviously in some areas of the District this is not true.

Remember, water quality is only one factor in judging the extent of, or potential for, a problem. Depending on the situation, crop selection, soil type, and soil/water management all affect crop yields and quality.

TABLE-1: Guidelines For Salinity, ppm TDS

	No Problem	Increasing Problems	Severe Problems
Salinity	< 450	450 - 2000	> 2000

SALINE SOILS AND GENERAL YIELD DECLINES

As was seen above, there are two ways in which to measure the level of salts. There are also several ways to describe the type of problem, "saline soils", "sodic (or alkali) soils", and "saline-sodic soils".

Saline soils have an excessive level of salts and are associated with poor yields. However they usually have sufficient permeability (water moves freely through the soil). Saline soils can be improved and/or yields maintained if a fairly good quality water supply and sufficient internal drainage are available.

To explain how salts can cause yield declines, remember that previous sections of the Handbook described that soil can hold water. The lower the soil water content, the harder soil holds the remaining water and the harder it is for the plant to extract this water. Thus, lower water levels in the soil put stress on the plant, reducing yields and if allowed to continue, killing the plant.

The water-holding forces of the soil are called "matric forces". But there is another force at work to reduce the amount of water that can be extracted by the plant, "osmotic forces". These osmotic forces increase with an increase in salts. Osmotic forces also act to restrict water extraction by crop roots.

The salts may also interfere with the plant's ability to take up nutrients from the soil. They can do this by affecting some of the chemical reactions inside/outside the plant.

The two forces, osmotic from excess salts and matric from the soil structure, are additive. Thus, in a saline soil, even if it appears wet,

the plant can have trouble extracting the amount of water it needs.

For example, use a scale of 1 - 10, with 10 being the highest force for the plant to overcome, to describe the level of osmotic and matric forces. Assume that you are using a furrow irrigation system on a normal soil. The total force working against the plant may peak at . . .

SODIC SOILS AND SOIL STRUCTURE PROBLEMS

Sodic or alkali soils have a salt imbalance. Typically the ratio of sodium to calcium and magnesium is too high. A measure of this potential imbalance is the "sodium absorption ratio". The potential for a problem is also dependent on the amount and type of clay in the soil.

It is a highly technical process to explain but in the wrong situation, excess sodium "attaches" itself to clay particles and weakens the soil structure. This leads to "dispersion" (commonly called puddling) of the soil, which can clog soil pores. The permeability is lowered and it becomes harder to get water into the soil.

Some clays/clay-loams are more susceptible than others. Many people will use the term "a shrinking/swelling" type of clay or clay-loam soil. These types of clay soils have the most potential for structural problems (montmorillite, 2:1).

Sodic soils are improved by changing the chemistry of the soil. Commonly a chemical amendment, such as gypsum, is applied. The gypsum may be broadcast or mixed with irrigation water. The calcium that is in the gypsum will replace the sodium that has attached to the soil. Improving sodic soils can

take some time as the infiltration rate has been reduced. This makes it harder to get the improving amendment into the soil. (It seems strange to say but when fixing a permeability problem, some Growers will purposely add salts to the water as saltier water will penetrate faster.)

Sulfuric acid can be used if there is already sufficient calcium in the soil. Acids work quicker than gypsum but must be carefully handled.

Always consult a qualified soil scientist when working with sodic soils. Take several samples of the field at different depths and have them analyzed to determine the proper amending chemical and required application rates.

SALINE-SODIC SOILS

Saline-sodic soils have both excess salts and the imbalance problem. They are improved by first treating the structural problem (the "sodic" problem) with chemical amendments. With the soil structure, and thus, infiltration rates, improved, the soil then can be reclaimed with leaching to remove the excess salts. Leaching Requirements When treating salt-affected soils or maintaining a salt balance, two things are required, a fairly good quality and sufficient water supply, and sufficient internal drainage. The only way to maintain yields with a salty water supply is to continually leach the excess salts applied with the irrigation water through the root zone. That is, a certain amount of applied water is meant to drain through the root zone. This internal drainage will carry excess salts out of the root zone.

There are two equations used to determine how much leaching water is required. The derivation of the first is somewhat technical and depends on some assumptions about

water extraction patterns by plants from different depths in the root zone. The one presented here is in widespread use. It says that . . .

$$(1) \quad LR = EC_w / 5 * EC_e - EC_w$$

where: LR is the decimal fraction of irrigation water that must be leaching water in order to maintain the root zone salinity at the desired level EC_e .

EC_w is the electrical conductivity of the irrigation water.

EC_e is the average electrical conductivity in the root zone that will result in a satisfactory yield.

EC_e , a measure of the average root zone salinity, is a management-chosen salinity level that will result in a satisfactory yield. You choose the EC_e you want to maintain. In most normal situations this would be an EC_e that allows 100% yields **with the most salt-sensitive crop in the rotation**.

This is an important point. Cotton is more salt-tolerant than fresh vegetables. The EC_e could be higher when growing cotton than green peppers. However, if you operated the irrigation system on a field to maintain an EC_e for cotton, and then decided to grow peppers in that field, the EC_e would be too high for maximum tomato yields. **Soil salinities must be managed for the most salt-sensitive crop in the rotation, "manage the soil, not the crop"**.

With the leaching requirement determined, the depth of water to apply can be calculated by . . .

$$(2) \quad AW = ET_c / (1 - LR)$$

where: AW = total net irrigation requirements (you will need to factor in your application efficiency to calculate the gross amount of water to apply)

ET_c = net crop evapotranspiration

LR = the leaching requirement as determined above.

Recommendations for annual leaching requirements are contained in the Management Techniques section below (Table 6-2). Always check with qualified agronomists when designing salt management programs.

DRAINAGE

There are two things needed to maintain a salt balance. One is a sufficient, good-quality water supply. But there must also be sufficient internal drainage. There has to be some place for the necessary deep percolation to go.

Problems occur, and are occurring in large portions of the District, when there is no place for this leaching water to go. Unfortunately, much of the District is underlain by what is known as the "Corcoran" clay. This is a geologic formation consisting of a relatively impermeable layer of clay that lies from 50 to 200 feet below ground. What has happened over a number of years is that excess water applications, including the deep percolation required for maintaining a salt balance in the soil (and thus, maintaining production), has "perched" on this clay layer until the saturated zone has moved back up into the root zone. Thus, a high water table is formed.

This causes several problems. The perched water table is usually of poor quality and salts are drawn up into the root zone from this table, thus, increasing the salinity of the soil.

Root pruning occurs as the water table reduces the effective root zone. And obviously, there is no place for the required deep percolation to maintain the salt balance.

Normally, in these situations, artificial drainage (tile drains) are installed. The excess deep percolation is drawn off the field by the drains and pumped out of the ground. The resulting water table would be drawn down near the drains and thus would cause the water table to be drawn down between the drains. The drains are laid at such a depth and spacing to produce the minimum required root zone at the mid-point between the drains while providing enough drainage to carry off the deep percolation.

The problem then becomes of disposing of the pumped tile drainage. Unfortunately, this tile drainage is of very poor quality and requires the presence of a "salt sink" somewhere to put the salty drain water without harming anyone. In the Imperial Valley, which has many of the same problems as the District (additionally having to use Colorado River Water at some 1000 ppm+ TDS), that salt sink is the Salton Sea. To the north of Westlands many Districts drain to the San Joaquin River and thus, eventually to the Ocean. The Westlands Water District has no such outlet. However, with very careful irrigation management, it has been seen that enough water will percolate through the restraining clay layer to allow continued successful production. [say something else about the District programs?] This careful management consists of restricting deep percolation to the absolute minimum needed to maintain a salt balance and choosing a crop rotation and cultural management regime that minimizes the required percolation.

MANAGEMENT TECHNIQUES

Salinity problems can frequently be managed to minimize reductions in crop yield with proper crop selection and irrigation management. The following management techniques deal with existing salinity problems and conditions. Always consult a qualified agricultural scientist when analyzing and treating salinity problems.

Salinity Testing - The extent and severity of a salinity problem must be determined before proper farm management decisions can be made. The salinity problem can be identified by testing soil samples for various salinity related factors. General guidelines for collecting soil samples can be given but conditions vary and individual situations must be considered when interpreting test results.

Possible salt affected areas are generally identified by plants that appear stressed or have low production. Several sampling sites should be selected for each problem area. Soil samples should be taken from the entire effective root zone. Sampling intervals may range from one- to two-foot increments in depth and extend down six or more feet. The salinity level in the top three inches of the seed bed is critical for germination and seedling development. Sampling the field outside the problem area need not be extensive, but is necessary for comparison purposes and to see if the problem is spreading.

General salinity estimates of the field can be made by sampling 20-acre blocks, if conditions are similar over the entire area. Additional sampling sites may be necessary in fields with several different soil types or layers.

When designing a testing program be aware of the effects of irrigation distribution uniformity on salt distribution in fields. If the lower end of a field is continually under-watered, there will not be as much leaching water applied in that area and salts may build up.

Westlands Water Conservation and Management Personnel will determine the EC of the saturated extract of soil samples brought to the District's Five Points Shop and Field Office by Westlands' water users. The EC of water samples taken from perched water tables or drains will also be determined. The sample must be identified as follows: (1) water user, (2) sampler, (3) date, and (4) location.

Other measurements that would be needed to identify salt-based problems would be . . .

- Measurements of the individual salts present (how much calcium, how much magnesium, etc.).
- Measurements of the different forms of fertilizer salts present (nitrate and ammonium nitrogen, phosphate phosphorous, and potassium).
- Boron.
- pH.
- SAR, sodium absorption ratio, (calculated from the individual measurements of sodium, calcium, and magnesium salts).

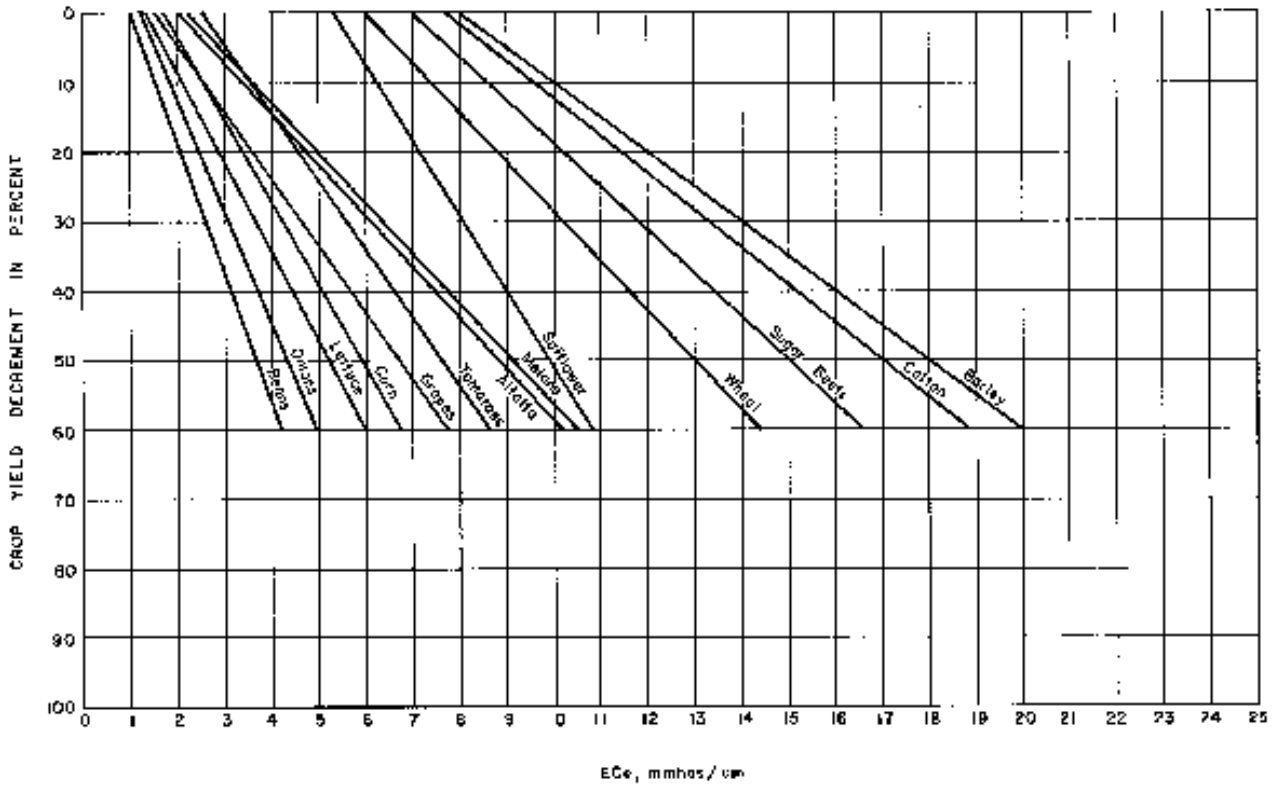
Crop Selection - Crop selection is a major management decision. Some crops, such as barley and cotton, can be grown on salty soil without large yield reductions. Other crops, such as almonds and onions, will have significant yield reductions when grown on soils with fairly low salt concentrations. Figure-1 indicates the average ECe of the root zone that will cause yield reductions due to soil salinity for selected crops. If your soil

tests indicate ECe's over those indicating substantial yield declines in Figure-1 for the crop you would like to grow, consider some other until you can reduce the salt concentrations in that field.

Salts can be managed by crop rotation so that they do not concentrate in the upper portion of the root zone. It can be difficult to apply additional water for leaching during the growing season for crops which have high ET requirements, such as cotton or alfalfa. Thus, some salts may start to accumulate in the root zone when growing these crops. However, additional water for leaching can be applied when winter crops with a low ET are grown in the rotation. The excess deep percolation will drive the salts below the effective root zone.

Crops can be used to manage salinity. Some crops, such as cotton, can use upwards flow of water from a shallow water table, even very poor quality water. This will lower the perched water table and make room for water used to leach salts from the upper portion of the soil profile allowing a more salt-sensitive crop such as tomatoes to be planted. .

Figure-1: Crop Sensitivity



Seed Germination - Average salinity through the root zone is not a useful measure when trying to anticipate germination problems. Salts may be excessive in the surface soil area surrounding the germinating seed.

Rainfall and preplant irrigations will move salts away from the seed zone if the rains are adequate or preplant irrigations are carefully managed. Sufficient rain, sprinkling, or other preplant irrigations applied to flat fields should easily control salts in the seed zone. However, listed fields, when irrigated through furrows, often have excessive salt buildup in the top or high point of the bed which may reduce or stop germination.

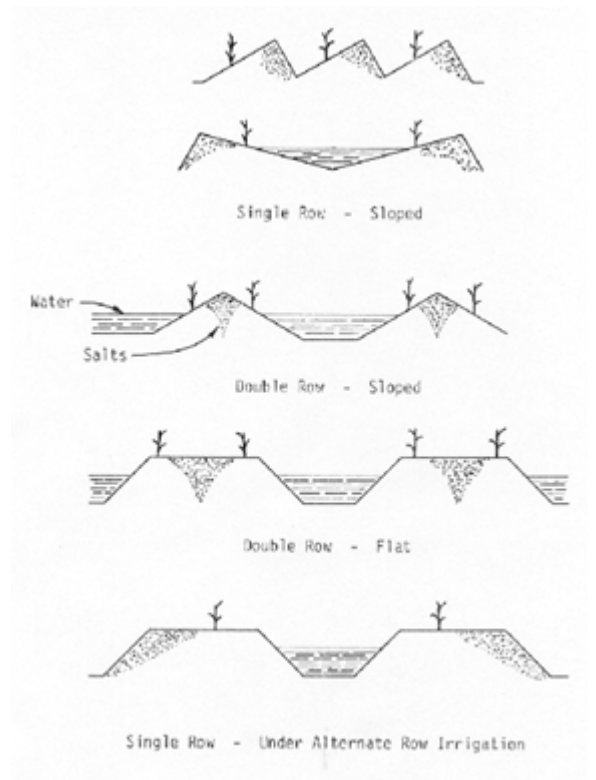
The salinity of the seed zone during germination must be minimized. If there is any question about the salinity, have representative seed zone soil samples tested. An EC_e of 3 or 4 mmhos/cm is about maximum for seed germination of sensitive crops. Once the developing roots reach a low salt area, the effects of salts near the seed become less of a factor in the health of the plants.

Seed placement can be adjusted to reduce the effects of salt on seed germination and plant development. Figure-2 shows the shapes of seed beds that will reduce salt in the seed area when irrigating by the furrow method.

Salts tend to concentrate at the center of a flat bed which has irrigation furrows on either side. Sloping the bed will allow salts to accumulate at the highest point (see Figure-2, top). Seed planted on the slope far below the top of the bed will be less likely to suffer salt damage. Single and double rows of seed can be planted on sloping beds. Double rows of seeds can be planted on a wide flat bed since the salts tend to concentrate at the center of

the bed away from the seed (see Figure-2, second).

FIGURE-2, Seed Beds/Seed Placement



Irrigating alternate furrows can flush salts away from properly placed seed. Salts will move away from the irrigated furrow to the opposite side of the bed or into the dry furrow (see Figure-2, fifth). However, alternate furrow irrigation should not be used with double-seeded rows. If the salt isn't driven far enough, it may end up in one of the seed rows.

Salt-sensitive crops have a greater chance of germinating if planted after preirrigation. Preirrigation will decrease the concentration of salts in the bed by leaching salts from the top of the root zone giving the seedlings a better chance to survive. Increased seeding

rates may improve the plant population in salt-affected areas.

Infiltration - Infiltration problems are related to an imbalance in the ratio of sodium to calcium and magnesium in the soil. Soil can seal up, either from swelling or dispersion (puddling), reducing the water infiltration rate. Soil crusting, compaction, water-logging, poor aeration, poor germination, excessive weeds, and diseases are problems that may be related to excessive sodium.

Chemical soil amendments, such as gypsum can be used to manage infiltration problems when the soil profile has good drainage. Gypsum is mixed into the soil or irrigation water. The sodium attached to the soil is replaced by the calcium from the gypsum. The sodium is then removed from the soil profile by leaching. This practice may require annual or semi-annual applications of gypsum over a number of years to effectively increase the infiltration rate to an acceptable level.

Sulfuric acid can also be used on alkali soil where there is already sufficient calcium present in the soil. Acid can improve soil properties quickly but requires extremely careful handling.

Agricultural laboratories can advise you on the proper soil amendment, application rate, and application method.

Organic residues incorporated into the soil surface also will increase water infiltration. Stubble mulches, such as cotton stalks or cover crops, can be disced into the soil. Animal manure can also be used, but it contains salts which could create additional problems when applied in large quantities.

Cultivation and deep tillage, such as plowing or chiseling, are often used to temporarily correct infiltration problems. These practices

create rough, cloddy furrows which also cause water to infiltrate more readily. However, the benefit is greatly reduced after one or two irrigations. (Also, rough cloddy furrows can result in extreme over-irrigation.) Although deep tillage can improve penetration in compacted soil, it may bring salts from the lower portion of the soil profile to the surface, which also reduces the benefits of tillage.

The amount of water infiltrated into the soil may be increased by lengthening the duration of irrigations. Reducing the flow into a furrow slows the rate of advance down the furrow to provide a longer infiltration period. This method works best for preirrigations, when standing water will not affect seeds or plants. Collecting and recalculating water with a tailwater return system also will allow water to be on the field for longer durations.

The slope of the field can be decreased to reduce the rate of advance of the water which provides more time for penetration into the soil. This may require land grading or a change in the direction of the furrows to reduce the slope. However, changing the direction of slope may be difficult when fields are uneven or irrigation systems are inflexible.

Irrigation systems that can apply water at the same rate as it enters the soil help solve infiltration problems. The application rate of sprinkler systems can be changed by altering operating pressures or nozzle sizes. However, the change in distribution uniformity must be considered as well. The application rate of a linear move sprinkler system can be adjusted by altering the systems' speed across the field. Sprinkler systems, as well as drip systems, can be turned off when ponding or runoff occurs and the irrigation interval adjusted accordingly.

Irrigation - Crop yields may be maintained by reducing the allowable depletion, since normal depletions can cause crop stress under saline conditions.

To further explain this technique, remember that there are both matric forces (the soil's water-holding force) and osmotic forces (from salts) at work. With a furrow irrigation system, where water is applied infrequently, the matric forces will increase substantially between irrigations. Thus, as an example . . .

$$\begin{aligned}\text{Force}_{\text{total}} &= \text{Force}_{\text{matric}} + \text{Force}_{\text{salt}} \\ &= 10 + 4 \\ &= 14\end{aligned}$$

Now, using a system that can apply water frequently (such as trickle), the matrix forces can be held very low, since with high frequency irrigations the soil moisture is consistently high. And . . .

$$\begin{aligned}\text{Force}_{\text{total}} &= \text{Force}_{\text{matric}} + \text{Force}_{\text{salt}} \\ &= 3 + 4 \\ &= 7\end{aligned}$$

The osmotic forces have not been affected. You've done nothing to reduce the amount of salts in the soil moisture. But since the soil moisture is kept at a high level, the crop can do better.

Frequent irrigations can decrease salt concentration in the root zone between applications. However, frequent irrigations from inefficient systems will waste water, can cause a rise in the water table, and may result in killing some plants.

Flood or furrow irrigation methods are not suitable for frequent irrigations. These methods can usually apply a large quantity of water efficiently, but irrigation timing and

amounts are often difficult to alter, making frequent irrigation inefficient and impractical.

Within limits, sprinkler systems can apply small amounts of water frequently and efficiently. Frequent irrigations reduced salt concentrations in the upper portion of the root zone by moving salts downward. Sprinklers also reduce soil crusting problems and improve germination by keeping the soil surface wet. But unless it is a solid-set system, labor costs will go up because of the more frequent moves.

Drip irrigation systems apply small amounts of water frequently. The entire soil profile is not wetted, but water is applied to a small area which moves the salts away from the roots. Frequent irrigations are necessary when drip systems are used in a saline environment because salts quickly concentrate in the restricted root zone. Daily application probably will be required during periods of high crop water use. A sprinkler irrigation or heavy rainfall on a drip irrigated crop might move salts into the root zone, causing damage to the crop. A leaching irrigation may be required prior to planting a crop to be grown under drip to reduce salinity in the root zone or to allow germination.

Toxicity - Excessive amounts of boron or chloride are toxic to plants. Crops vary in their tolerance to these elements and toxicities may occur when total salinity is low.

Certain symptoms may indicate toxicity to these elements. However, each may cause specific/general symptoms. Plant nutritional problems and chemical damage may cause symptoms similar to those caused by boron and chloride toxicity. Soil or foliar samples should be tested by an agricultural laboratory to determine the cause of the problem.

The first symptoms of boron toxicity include yellowing, spotting and/or drying of tissue at the tips and edges of older leaves. The yellowed or spotted areas may dry up and spread from the tip along the edges of the leaf, eventually going all the way to the mid-rib of the leaf. Seriously affected trees, such as almond, may discharge gummy substance.

Chlorides are most toxic to trees and vines. The first symptom is the drying of tissue at the tip of the older leaves, spreading along the leaf edge. Extreme toxicity may lead to leaf drop.

Sodium can also cause toxic symptoms.

Toxic salts can be leached out of the root zone as with the total salt load. Boron is more difficult to leach than chloride.

The choice of fertilizer and application methods can affect salt concentrations in the soil. Fertilizers high in salts, such as ammonium nitrate should be applied in split applications to reduce the salt concentration around the seed or plant.

Water Table - A perched water table containing a high concentration of salt aggravates the salinity problem when it rises into the crop root zone. Perched water containing low concentrations of salt and toxic elements can be used by the crops. However, [salt concentration in the perched water table](#) will increase over a period of time. A program of monitoring the EC of the perched water table and the soil profile can warn of developing problems.

Crop root extension will be restricted when they are not able to penetrate into poor quality perched water. This restricted root zone must be considered in irrigation management. Over-irrigation can cause the salty perched water table to rise into the active root zone. Small

frequent irrigations leach salts downward into the lower portion of the root zone and tend to keep the water table lower.

Water should not be over-applied where drainage is restricted. Excessive irrigation can only be removed by natural or artificial drainage, or crop water use of the high water table. The application efficiency needs to be very high on land which has a perched water table.

Maintaining Salinity Levels - Normal irrigation practices usually include adequate water to satisfy the maintenance leaching requirement. However, care should be taken in planning for soil salinity maintenance as irrigation systems and management practices become more efficient. Leaching that moves salts below the root zone usually occurs during pre-irrigation or early season irrigations. Irrigations during the growing season move salts from the upper portion to the lower portion of the root zone, since the entire root zone usually cannot be refilled with water at that time.

The EC_w of Project water is about .3 to .4 mmhos/cm. One AF of Project water contains about 500 pounds of salts. This salt will build up to concentrations which can reduce yields if it is not leached. As discussed previously a maintenance leaching program removes salts from the root zone which are supplied in irrigation water and maintains a long-term salt balance in the soil profile.

Table-2 shows the minimum leaching requirement selected crops to maintain a salt balance in the root zone and an acceptable production level. The calculated leaching requirement of the seasonal ET for crops irrigated with Project water.

Table-2 Maintenance Leaching Requirements

CROP	FT	CROP	FT
Alfalfa	.2	Lettuce	.05
Almonds	.2	Melons	.05
Beans	.2	Onions	.1
Corn	.1	Safflower	.05
Cotton	.05	Sugarbeet	.05
Grape	.1	Tomatoes	.05

The leaching requirement must be increased to maintain production if salt concentrations increase in the root zone. When using only a maintenance leaching requirement, irrigation intervals should be short or salt will concentrate to harmful levels in the upper portion of the root zone.

Groundwater may contain boron or other toxic salts and should be tested prior to use.

Recirculating Drainage Water – Recirculating tile drainage water is a short term solution and does not solve a drainage problem. The leached salts are only returned to the soil profile with the irrigation water. Some drainage water contains a toxic level of boron and should be used cautiously even though recent research has indicated that foliar symptoms due to boron appear on cotton before yield is affected.

Soil with a relatively low ECe will maintain crop production longer than soil with a higher ECe when drainage water is recirculated. It would be expected that the increase in the ECe of a four-foot soil profile for a slightly saline soil (ECe = 2.65 mmhos/cm), and moderately saline soil (ECe = 6.0 mmhos/cm) would stay in production longer. If you assume that the increase in the ECe is based on the application of 2.5 AF of Project

water applied annually, the slightly saline soil is projected to have an ECe of 8 after water is recirculated for 12 years while the moderately saline soil is projected to have an ECe of 8 in only 5 years.

Blending water - In times of drought, District growers will use deep wells. Well water is usually of very poor quality and can quickly cause problems, especially if the SAR (sodium absorption ratio, a measure of potential infiltration/soil structure problems) is high.

Blending of deep well and Project water may or may not physically be feasible on an individual field. Blending can reduce the infiltration problem potential since it will change the ratio of sodium, calcium and magnesium salts in the water. It will not change the total salt loading of the water. If you have 1 foot of Project water available (500 pounds of salt) and 1 foot of well water with 1500 pounds of salt, you are going to apply 2000 pounds of salts. It would not matter if you applied the Project water first, then the well water, or mixed them together.

But usually you would alternate the use of the good quality Project water and wells. Use the good quality Project water early for germination and seedling growth, then switch to the well water.

Please follow this link for an additional source of [information on this topic](http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652-chapter13.html) (http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652-chapter13.html) in the NRCS National Engineering Handbook, part 652.