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# **FROM THE GROUND UP**

## *Agronomy News*

### **Managing Soil Salinity**

**Investigation and explanations explain the strategies in place to sustain agriculture in the face of soil salinity problems in Colorado.**

About 30 percent of the irrigated land in the western United States has a moderate to severe potential for salinity problems. Where salinity problems occur, the productivity and sustainability of agricultural communities are diminished. Sustainable agriculture is defined as being productive and profitable while also conserving resources, protecting the environment and enhancing the health and safety of the public. Salinity has been addressed by the agricultural community for many years. Nonetheless, the inability to achieve sustainability in areas prone to salinity reflects the lack of an integrated, holistic approach to the problem.

“Salt problems are particularly insidious. They do not come charging at us with trumpets blowing and battle flags flying, a sight to set stirring the hearts of activists in any century. Rather, they slip in almost unnoticed. Time is of no concern, for they are supremely confident in their ultimate victory. History is on their side, as are the laws of physics



and chemistry and biology. They quietly destroy more civilizations than all of the mighty armies of the world.” (Warren A. Hall, July 1973, then acting director, Water Resources Institute, Dept. of Interior)

This newsletter focuses on Colorado's battle against salinity. There are two articles each on salinity research in the Arkansas River and South Platte basins. These are followed by articles on salinity measurement in the lab and in the field. The three final articles address management approaches to reducing the spread and impact of salinity. Let's work together to achieve sustainability for Colorado's irrigated agricultural communities!

# Field-Scale Salinity Mapping In Colorado's Arkansas River Basin

## Watershed study monitors water table depths and soil and water salinity.

Salinity levels of the canal systems along the Arkansas River increase from 300 ppm total dissolved solids (TDS) near Pueblo to over 4,000 ppm at the Colorado-Kansas border. Salts are significantly concentrated by consumptive use due to human activities. Consumptive use alone causes a seven-fold increase in the salt concentration in the Arkansas River. Evaporation from reservoirs, canals, high water table areas, and from cropland receiving excessive amounts of irrigation water or poorly timed applications are important consumptive uses. Evapotranspiration also occurs from crops and weeds.

In some areas, crop yields are being reduced and land is being lost from crop production because of high salinity levels. As a result, there is a need to blend improved yielding capabilities, crop types, economic returns, irrigation practices, and water quality concerns into a complete management package

that can be used by agricultural producers. The first step in this process is determining the status of salinity at the regional and field scale. Our research is designed to map salinity in the Arkansas River on a field scale.

Depth to the water table is being collected from observation wells that have been drilled in each of the fields. Between 7 and 11 observation wells are currently being monitored in each field. Using a differentially corrected GPS, the location and elevation of each well was obtained. The depth to water table has been collected every hour using a continuous water table recorder at some of the observation wells, in addition to weekly manual observations. The salinity of the water table is measured each week. Maps showing the weekly spatial variation in depth to water table and groundwater salinity have been generated. A map for one of the fields for which data is being collected is shown below.

A set of weekly figures showing the depth to water table for each field has been combined into animations which allow us to view not only the spatial variation, but also the temporal variation for each field. A second set of animations has been generated showing the temporal and spatial variation in the groundwater salinity for each field. Research is underway to determine the crop yield reduction due to salinity and water-logging in order to generate animations which show the temporal and spatial variation in crop yield reduction.

The soil salinity measurements were done using two different instruments that use the principle of electromagnetic-induction to determine the soil salinity. The first instrument is a hand-held unit called an EM-38 (described in more detail in the article beginning on page 9). Three soil salinity surveys (beginning, middle and end of the season) for each field were done in

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### FROM THE GROUND UP

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Web Site: <http://www.colostate.edu/Depts/SoilCrop/extension/Newsletters/news.html>

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## Field-Scale Salinity Mapping In Colorado's Arkansas River Basin (Continued)

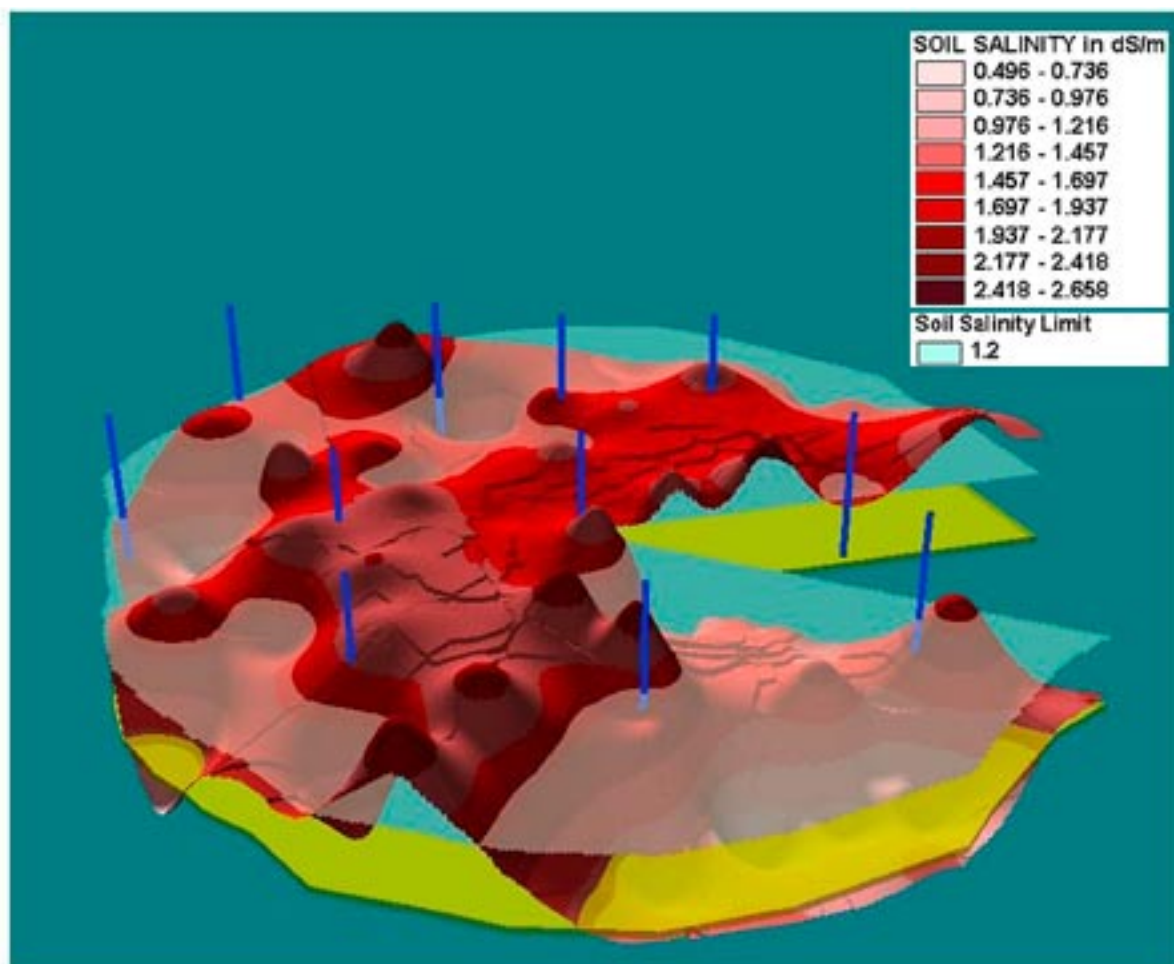
2000 using the EM-38. The second method that was used to obtain soil salinity data involves a trailer fitted with electromagnetic sensors (Veris system). The trailer is pulled with a truck that contains a differential GPS unit. The sensor sends readings every few seconds. These readings are combined with a differential GPS signal to generate the maps. At the present time research is being conducted by the Agricultural Research Service to obtain calibration curves that will allow for the development of soil salinity values from the electromagnetic readings of the Veris system.

The information collected for depth to water table, groundwater salinity and soil salinity is currently being analyzed. Geographic Information System (GIS) is being used to determine if there is spatial and/or temporal correlation between the soil salinity, depth to water table and/or groundwater salinity.

The detailed measurements of changes in soil salinity, groundwater salinity and water level create a clear picture of how soil salinity, groundwater depth and groundwater salinity change over the season. Using this information, we are trying

to determine crop yield reduction in different parts of the field and present this data to the farmers. The ability to use GIS to visualize the temporal and spatial variation has been a valuable tool in presenting these results to farmers. It allows farmers to quantify and visualize the impact that salinity is having on field productivity. Many of the data products from this project are available on the World Wide Web (<http://www.ids.colostate.edu/projects/arkansas>).

*by Luis Garcia  
Extension Agricultural Engineer*



**Figure 1. New technology allows mapping of spatial variations in soil salinity.**

# Water Relocation In The Arkansas Valley?

**CSU faculty proposes feasibility study of a possible solution to “Silent Killer”.**

A “silent killer” stalks the Arkansas River Valley in the form of salinity. Seventy percent of the irrigated fields in the Arkansas Valley are affected by increased salinity, resulting in an estimated 10-50% yield reduction for alfalfa and corn. Some 25,000 to 30,000 acres of the roughly 250,000 farmable acres in the Arkansas Valley have been lost to agricultural production because of this increased salinity. As a result, farmers in the Valley are seeking ways to maintain a viable agricultural economy, including the innovative alternative of moving water from highly saline soils to potentially high yielding soils within the basin that are not presently being irrigated.

Water relocation involves identifying those soils that are heavily damaged by salinity inside the present irrigation canal systems boundaries. Land outside the present canal systems boundaries that has not been irrigated and is not saline must also be identified. The soils damaged by salt will normally be located in the areas that have been irrigated for many years (since the late 1800’s) inside the area of the supply canals. Relocating the water above and below the present canal systems to land that has been determined to be good land for irrigation would offer multiple benefits.

The first potential benefit is significantly increased irrigation efficiency from the use of center pivot or drip irrigation systems on the “new” land. Additionally, production costs could be reduced because of



larger fields and fewer, if any, field ditches to maintain. Yields would be substantially increased on non-saline soils. Seepage could be reduced by using pipelines to carry the reduced amounts of water needed by the more efficient irrigation systems. These systems would also reduce runoff carrying salts back to the river. The present saline fields could be planted to salt-tolerant grasses to provide better wildlife habitat and/or grazing land, and eventually be reclaimed. Finally, since the water would still be used in an area close to the present communities, the economy of the area could be improved due to the higher yields and lower production costs.

Analysis of the relocation concept is needed to examine its feasibility. A proposed study could be conducted under the direction of several university faculty already doing research in the Valley. The tasks envisioned are to survey the native vegetation and soils using existing data in both the old irrigated lands and those that might become newly irrigated under a water relocation plan. The spatial variability of soil salinity, and water salinity, in both surface water and groundwater

needs to be understood and mapped. Some of this work has already been conducted. Where feasible, return flow patterns need to be examined under current and proposed irrigation patterns. The economics and legalities of moving the water also must be analyzed. Options for actually carrying out such a water relocation program need to be examined.

Reclaiming the saline soils in the Arkansas Valley will cost millions — to lower the river, install drainage systems, line the canals and leach the salts out of the soils. Instead of spending that money to reclaim saline soil, relocating the water to non-saline areas with good drainage may be a better and cheaper option. Jim Valliant (Regional Irrigation Specialist for southeast Colorado) and Tom Pointon (a director of the Southeast Colorado Water Conservancy District and a member of the Arkansas River Compact Commission) are optimistic about the possibilities of this potential solution. Hopefully, funding will become available to study this concept’s merits.

*by Jim Valliant  
Regional Irrigation Specialist  
Robert Ward  
Director, Colorado Water Center*

# Weld County Soil Conservation District Examines Salinity Problem

**More than 2000 acres of South Platte Basin are mapped.**



Beginning in the mid 1990's, Weld County producers noticed increasing salinity problems. The soil surface of some fields appeared white where it never had before, dry edible beans could no longer be grown in places where they had previously produced well, and vegetable growers saw yields start to decrease. The West Greeley Soil Conservation District (WGSCD), with assistance from the Natural Resources Conservation Service, decided to examine the increasing salinity problem. The District received a matching grant from the Colorado Natural Resources Matching Grant Program to buy equipment necessary to start a salinity testing program.

The first tool purchased was a Geonics EM-38, which is an electromagnetic instrument that measures the apparent conductivity (EM readings) of the soil. A GPS unit was purchased to record the location of each measurement taken. A laptop computer and GIS software were also

purchased to produce 2-D and 3-D maps of salinity levels. The District also hired a technician to do the testing, bought an all-terrain vehicle to quickly cover more acreage, and the program was underway.

A problem was found when using software to convert EM readings to the actual electrical conductivity of a saturated extract (ECe). There was a correlation between the methods, but after sending samples to a lab for salinity analysis, computer generated ECe values were lower or higher than the measured values. Laboratory analysis of several samples from each field was cost prohibitive. Therefore, WGSCD bought a Hach Salinity Appraisal Laboratory for in-house ECe testing. Concurrently, the US Salinity Laboratory in Riverside, California released their free ESAP software. The ESAP software uses geo-statistics to choose the best places in a field to correlate EM readings to ECe. After testing the

selected samples using the Hach Lab, the EM readings can be correlated to ECe automatically using ESAP. ESAP also predicts yield loss for most crops and has map-making capabilities.

So far WGSCD has tested over 2000 acres. The District has provided testing for a diverse group of producers including: corn, bean, alfalfa, and beet growers. Vegetable growers use the service most, because of both the low salinity threshold and high dollar value of vegetable crops. Most acres tested in Weld County have an ECe value between 1.0 dS/m and 3.0 dS/m. However, some areas with poor irrigation and/or a high water table have ECe values greater than 5.0 dS/m. On average, ditch irrigation water has an ECe of about 0.6 dS/m, and well irrigation water of about 1.5 dS/m. The district has also found high sodium levels in water from some irrigation wells.

The salinity program is considered a success at WGSCD and will continue as long as cooperators need it. If any district cooperator in WGSCD would like their farm tested, please call us at (970) 365-8097 ext. 3. A complete salinity analysis costs \$50 per field. If time permits, we will test outside WGSCD. The fee for testing outside WGSCD is \$2.50 per acre with a \$100 minimum charge.

*by Nick Hoban  
West Greeley Soil Conservation  
District*

## Investigating Salinity Issues on the Lower South Platte

**Northern Colorado Water Conservancy District teams with the Bureau of Reclamation to collect and analyze data.**



Irrigating farmers in the lower South Platte River basin are becoming aware of a growing salinity problem. Many growers have asked why their historically productive ground has become less productive without major changes in their farming practices. Salinity is causing growers to abandon certain crops from their operations because of low yields. Growers are searching for answers to their concerns. While the adverse effects of salinity on crop yields have been well documented, additional cooperative efforts must be made to study the scope of the problem and provide information on how to best manage salinity to preserve productive farm ground.

Irrigation Management Service (IMS) of the Northern Colorado Water Conservancy District (NCWCD) and the U.S. Bureau of Reclamation have united to study and research salinity issues throughout the District's

District have generated concerns regarding salinity levels throughout the lower South Platte. This information and their ongoing work in the area has encouraged the NCWCD to become more involved and investigate the problem further.

Starting in spring 2001, the IMS will begin investigating and monitoring salinity levels in irrigation water and soils throughout the District. The IMS plans to monitor salt mass balances throughout the lower South Platte River and its tributaries including the St. Vrain, Little Thompson, Big Thompson and the Cache la Poudre rivers. The IMS will monitor these rivers by utilizing flow data from the current U.S. Geological Service stream gauging stations. IMS will also install up to twenty additional observation wells, intensifying the observations along the river/delivery system. Many of the new data collection sites will be automated

boundaries, which includes most of the lower South Platte region. Information gathered from other institutions such as Colorado State University, the Natural Resource Conservation Service and the West Greeley Soil Conservation

and transmit data via cellular phone. The IMS will also collect soil salinity readings throughout the District with a salinity vehicle to take soil readings in the field easily and quickly. To avoid duplication of data already being collected, the IMS also hopes to work closely with other institutions and agencies already conducting salinity studies. The IMS would like to process this information and make it readily available to the general public via the web.

This salinity study is expected to continue for seven years. The first couple of years will be devoted to collecting data concerning salinity levels throughout the Lower South Platte River. While continuing to take readings from the instrumentation installed during the initial two years, the succeeding years will study salinity with a more site-specific approach. This site-specific plan includes more direct work with growers on managing salinity issues. Salinity is one more problem facing Colorado farmers, and the District hopes the information and findings gathered from this study will help farmers maintain productive operations for many years to come.

*by Alan A. Halley  
Agricultural Resource Specialist  
Northern Colorado Water  
Conservancy District*

# Salinity Assessment In The Laboratory

**Electrical conductivity measurements are the key to salinity evaluation.**

Electrical conductivity (EC) is one of the most frequently measured soil parameters in arid and semi-arid regions. It is commonly grouped with soil fertility testing as part of a package or routine soil test since it is the primary means to evaluate salt problems.

There are several methods that are followed in the laboratory to measure EC. When soil samples are received they are usually air dried and then ground to pass through a 2 mm sieve. For routine analysis, pH and EC can be measured on a 1:1 or 1:5 basis, where one part soil is mixed with one part or five parts water. The mixture is shaken on a rotary shaker for 30 min. with the sample stirred at 15 min. The sample is then removed from the shaker, allowed to settle for 5-10 min and then measured for pH and EC. When measuring EC, the conductivity electrode is immersed in the soil solution and a reading is taken.

If the meter used for measuring EC automatically compensates for ambient temperature, the EC reading can be recorded as the conductivity of the sample. Some meters, however, do not compensate for temperature making it necessary to read a 0.01M KCl solution to determine the effect of temperature. Under ideal conditions at 25°C a 0.01M KCl solution should read as 1.413 dS/m using a conductivity cell (1 cm in diameter).

Some meters have temperature



**A conductivity meter is used to take an soil EC reading.**

probes that can be placed in the sample along with the conductivity cell to compensate for the temperature. However, it would still be a good practice to measure a National Institute of Standards and Technology (NIST) conductivity standard (available from Fisher Scientific) or soil standards available from the North American Proficiency Testing (NAPT) Program that is administered by the American Society of Agronomy. The Soil, Water, and Plant Testing Lab also has a check soil that is used on a daily basis to evaluate the lab's EC readings and is available to those wishing to check their own EC meters.

Another way to evaluate conductivity is to measure the EC of a soil paste extract. Approximately 50-100 g of

ground soil is placed in a plastic cup and enough water is mixed with the soil to create a paste condition. The paste tends to glisten when enough water has been added and usually has the consistency of a thick cake batter. The saturated sample is allowed to stand four hours or overnight to help bring salts into solution. After standing for the necessary amount of time, water is added to the sample to bring it back to saturation, if necessary. The soil paste is then vacuum filtered and the soil extract is measured with the conductivity cell by pouring the extract into the cell (the holes in the cell are plugged to prevent the extract from flowing out).

For routine soil analysis the 1:1 or 1:5 EC readings are faster and

## Salinity Assessment In The Laboratory (Continued)

usually evaluate EC adequately. However, if the EC of a 1:1 or 1:5 soil mixture exceeds certain limits, it may be necessary to evaluate the EC on a paste basis, since there is the possibility that the salts could be high enough to warrant the analysis of a sodium adsorption ratio (SAR).

Paste EC's tend to be higher than EC's done on soil to water ratios. At the Soil, Water, and Plant Testing Lab, the 1:1 EC is evaluated for each sample, and if the 1:1 EC exceeds specific levels (0.8 dS/m in a sandy soil, 1.2 in a sandy clay loam or clay loam, or 1.6 in sandy clay or clay soil), a paste is made and the EC is

evaluated from the paste extract. If the EC from the paste exceeds 7 dS/m, then the sample is analyzed for calcium, magnesium, and sodium to calculate a SAR.

The most recent unit for EC is dS/m (deciSiemens/meter), which is the same as mmhos/cm. However, many labs still express EC readings as mmhos/cm. The mho is actually the inverse of the ohm, which used to be the unit of measure on very old EC meters (yes, we do have one in the lab); however, the readings are very large and cumbersome to work with.

While soil to water ratios are faster to measure and are suited to routine measurements, it is felt that the paste EC more accurately evaluates the salt conditions of the soil since it more closely simulates field conditions. Whether one method is used over the other, EC is one of the most common tests to evaluate soil conditions for plant growth and should be considered when attempting to reclaim salt affected soils or when purchasing topsoils or soil amendments.

*by Jim Self  
Manager, Soil, Plant, and Water  
Testing Laboratory*

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## Meet Dr. Luis Garcia

Dr. Garcia is an associate professor in the Department of Civil Engineering at Colorado State University. He is also the Interim Associate Director of the Colorado Agricultural Experiment station, the Program Leader for the Bioresource and Agricultural Engineering Program at CSU, and the Director of the Integrated Decision Support Group at CSU.

Dr. Garcia's main research interest is in the application of Decision Support Systems (DSS) in natural resource systems, specifically in applications for water resources, irrigation, and drainage. He uses technologies such as Geographic Information Systems (GIS), numerical modeling, and databases to create DSS. In 1992, Dr. Garcia created an interdisciplinary research group called the Integrated Decision Support Group (IDS), part

of the Water Center at CSU (<http://www.ids.colostate.edu>).

In addition to research work in the United States, Dr. Garcia has done international work in the area of water resources and drainage in Italy, the Netherlands, Austria and Egypt. He has worked on a number of DSS projects including a consumptive use module for the Colorado River DSS, a Water Quality Analysis and Simulation Program (WASP), a South Platte Mapping and Analysis Program (SPMAP), a conjunctive irrigation and drainage DSS (CSUID) and a drainage model called ADPP. Dr. Garcia enjoys working with water users around the state. He has a part time appointment in extension and works mainly in the South Platte (Consumptive Use and Salinity) and the Arkansas River Basin (Salinity).



Dr. Garcia's hobbies include golf, fishing, hiking and camping. Curriculum Vitae.



# Mapping Soil Salinity with Electromagnetic Device

Non-invasive tool speeds up processing of spatially quantified soil salinity maps.



**EM-38 quickly measures conductivity in soil.**

For years we have had to collect dozens of soil samples from different quadrants of our cooperators' fields to obtain valuable information in determining salinity or sodicity. Hours of sampling, bagging, transporting to the lab, and waiting for the analyses to return was the norm. Then we questioned the results if the pH, electrical conductivity (EC), or sodium absorption ratio (SAR) values were not representative of the field or to a particular portion of the field. We thought that after we sampled 101 sites in 80 acres we could have an idea of what the salt levels were. Well, guess again! Even after 101 samples you would still not have a spatial relevancy for the samples taken and not be any further along in ascertaining the variability in field salinity levels. Besides that, no grower could afford that kind of sampling regimen.

Dr. James D. Rhoades, retired research leader of the United States Salinity Laboratory (USSL) in Riverside, California, worked with several people in the geophysical measurement arena to devise a new approach to determine salinity levels to a depth of 60 inches. By utilizing conductivity measurements of the soil that coincide with the lab analysis of EC, Rhoades and his fellow scientists determined an accelerated method to measure conductivity in the field.

This more recent approach to determining salinity with electromagnetic induction methods allows rapid measurements with an electro-magnetic (EM) tool, along with statistical sampling and lab analyses, to determine the spatial variability of salts across the field. How does this work? The scientist travels across the field placing the

EM-38 tool (from Geonics Ltd.) on the surface in two positions. These two dimensions allow the tool to measure resistance or conductance of the soil medium. In the horizontal dipole position, the EM tool emits an electromagnetic frequency of 14,600 Hz into the soil medium approximately 30 inches. A receiving magnet reads the in-phase residual signal of apparent conductivity in mS/m. In the vertical dipole position the EM tool sends the electromagnetic signal about 60 inches, and the receiving magnet reads the remaining signal and displays it on the units readout in mS/m. These two readings, coupled with a GPS X-Y coordinate are recorded into a data logger or onto a log sheet for future manipulation into a computer model constructed by scientists at USSL.

In consultation with the producer, local conservationists, soil survey information, and topographical maps, a modified grid design of the growers' field(s) is set. The landscape positions, size of field, water flow direction, irrigation type and soil delineations are considered in designing a grid spacing for the em survey. Each time that the EM tool is used, it must be calibrated. Locating a starting point and using a GPS receiver, scientists can walk or ride an all-terrain vehicle (ATV) from one X-Y grid coordinate to the next while recording data from the EM-38.

## Mapping Soil Salinity with Electromagnetic Device (Continued)

It is important to note that one must be a minimum of 45-90 ft. from overhead electrical lines, and 12-15 ft. away from the ATV to minimize attenuated signals. Also when initializing the unit, keep clear of pickups, tractors, power lines, underground pipelines and electric fences. USSL scientists suggest a minimum of 50 data points from both the vertical and horizontal dipole positions of the EM tool to obtain a reasonable data set for the modeling software to offer statistically valid results. This dictates the grid spacing for any field(s) to the field scientist.

After the field data is collected, it can be loaded into the ESAP software. The frequency and soil sampling locations for verification samples are determined and samples are taken for lab analysis. Alternatively, a Hach Chemical Co. SIM Kit can be used. The number of samples and location is very important to assist in the

modeling process. Then the values are loaded into SURFER software (Golden Software Co.) and an isobar two-dimensional map is developed. The grower can use the map to determine the best course of action with the consulting agronomist.

This methodology is reasonably quick; it offers growers very reasonable estimates of salt levels and the location of salt problems in

their fields. Salinity is a growing problem in many irrigated areas of Colorado. Growers want to know why their crops are detrimentally affected. If salts are a yield limiting factor, this mapping device can help diagnose the extent of the problem.

*by Michael Petersen  
Area Resource Soil Scientist  
USDA-NRCS*

**Certified Crop Adviser Exam  
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# Understanding Irrigation Water Quality

**Irrigation water quality is a critical factor in managing salt-affected soils to maintain long term productivity.**

The development of salt-affected soils depends upon a wide range of factors including: soil type, field slope and drainage, irrigation system type and management, fertilizer and manuring practices, and other soil and water management practices. In Colorado, perhaps the most critical factor in predicting, managing, and mitigating salt-affected soils is the quality of irrigation water being used. Besides affecting crop yield and soil physical conditions, irrigation water quality can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long term productivity.



Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants.

## Salinity hazard

The most influential water quality parameter on crop productivity is the salinity hazard (as measured by EC). The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher

the EC, the less water is available to plants, even though a field may appear wet. Because plants can only transpire “pure” water, usable plant water in the soil solution decreases dramatically as EC increases. The amount of water transpired through a crop is directly related to yield and therefore irrigation water with high EC reduces yield potential (Table 1). Beyond effects on the immediate crop being irrigated, is the long-term impact of salt loading through the irrigation water. Water with an EC of only 1.15 dS/m contains 2,000 pounds of salt for every acre foot of water. You can use conversions e. and f. in Table 2 to make this calculation for other water EC levels.

Water quality is relatively inexpensive to assess when costs are calculated on a per acre basis. A complete analysis from a laboratory will range from \$30 to \$70. Because irrigation water (especially ground water) is less variable over time than soil, sampling every year is unnecessary once the quality of an irrigation water source is determined. Water quality results can also be used to direct soil analysis needs. Potential problems in the soil can be predicted and monitored when first detected in the irrigation water.

In spite of these reasons for assessing irrigation water quality, most Colorado producers do not use this practice. Although 66% of producers

reported in a 1997 statewide irrigation survey that they soil sampled, only 7% of respondents reported sampling their irrigation water.

## Criteria

Soil scientists use the following categories to describe irrigation water effects on crop production and soil quality:

- Salinity hazard - electrical conductivity (EC) or total dissolved solids (TDS)
- Sodium hazard - expressed as SAR or ESP
- pH and alkalinity - (carbonate and bicarbonate)
- Specific ions: chloride (Cl<sup>-</sup>), sulfate (SO<sub>4</sub><sup>2-</sup>), boron (B), and nitrate-nitrogen (NO<sub>3</sub>-N).

the EC, the less water is available to plants, even though a field may appear wet. Because plants can only transpire “pure” water, usable plant water in the soil solution decreases dramatically as EC increases. The amount of water transpired through a crop is directly related to yield and therefore irrigation water with high EC reduces yield potential (Table 1). Beyond effects on the immediate crop being irrigated, is the long-term impact of salt loading through the irrigation water. Water with an EC of only 1.15 dS/m contains 2,000 pounds of salt for every acre foot of water. You can use conversions e. and f. in Table 2 to make this calculation for other water EC levels.

## Understanding Irrigation Water Quality (Continued)

Other terms used to report salinity hazard are: salts, salinity, electrical conductivity (EC), or total dissolved solids (TDS). These terms are all comparable and all quantify the amount of dissolved “salts” (or ions, charged particles) in a water sample. However, TDS is a direct measurement of dissolved ions and EC is an indirect measurement of ions by an electrode (See article by [Jim Self](#)). For simplicity, we will use EC for the remainder of this article. Although people frequently confuse salinity with common table salt or sodium chloride (NaCl), EC measures salinity from all the ions dissolved in a sample. This includes negatively charged ions (eg. Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>,) and positively charged ions (eg. Ca<sup>2+</sup>, Na<sup>+</sup>). Another common source of confusion is the variety of unit systems used with EC. The

**Table 1. Potential Yield reduction from saline water for selected irrigated crops.<sup>1</sup>**

| Crop                    | % yield reduction |     |     |     |
|-------------------------|-------------------|-----|-----|-----|
|                         | 0%                | 10% | 25% | 50% |
| Barley                  | 5.3               | 6.7 | 8.7 | 12  |
| Wheat                   | 4.0               | 4.9 | 6.4 | 8.7 |
| Sugar beet <sup>3</sup> | 4.7               | 5.8 | 7.5 | 10  |
| Alfalfa                 | 1.3               | 2.2 | 3.6 | 5.9 |
| Potato                  | 1.1               | 1.7 | 2.5 | 3.9 |
| Corn (grain)            | 1.1               | 1.7 | 2.5 | 3.9 |
| Corn (silage)           | 1.2               | 2.1 | 3.5 | 5.7 |
| Onion                   | 0.8               | 1.2 | 1.8 | 2.9 |
| Beans                   | 0.7               | 1.0 | 1.5 | 2.4 |

<sup>1</sup>Adapted from “Quality of Water for Irrigation.” R.S. Ayers. Jour. Of the Irrig.and Drain. Div., ASCE. Vol 103, No. IR2, June 1977, p. 140.

<sup>2</sup> EC = electrical conductivity of the irrigation water in dS/m at 25°C.

<sup>3</sup> Sensitive during germination. EC<sub>e</sub> should not exceed 3 dS/m for garden beets and sugar beets

preferred unit is deciSiemens per meter (dS/m), however millimhos per centimeter (mmhos/cm) and micromhos per centimeter (µmhos/cm) are still frequently used. Conversions to help you change between unit systems are provided in [Table 2](#).

**Table 2. Useful conversion factors for understanding irrigation water quality laboratory reports.**

| Component   | To Convert                  | Multiply By | To Obtain                         |
|---|-----------------------------|-------------|-----------------------------------|
| a Water nutrient or TDS   | mg./L                       | 1.0         | ppm                               |
| b Water salinity hazard   | 1 dS/m                      | 1.0         | 1 mmhos/cm                        |
| c Water salinity hazard   | 1 mmhos/cm                  | 1,000       | 1 umhos/cm                        |
| d Water salinity hazard   | EC (dS/m)<br>for EC <5 dS/m | 640         | TDS (mg/L)                        |
| e Water salinity hazard   | EC (dS/m)<br>for EC >5 dS/m | 800         | TDS (mg/L)                        |
| f Water NO <sub>3</sub> -N, SO <sub>4</sub> -S, B or other iron | ppm                         | 0.23        | lb per acre inch of water applied |
| g Irrigation water  | acre inch                   | 27,150      | gallons of water                  |

**Key**

- mg/L milligrams per liter
- ppm parts per million
- dS/m deciSiemens per meter
- mmhos/cm millimho per centimeter
- meq/L millequivalents per liter
- (meq/l = mg/l divided by atomic weight of iron divided by ionic charge)

## Understanding Irrigation Water Quality (Continued)

### Sodium hazard

While EC is an assessment of all soluble salts in a sample; sodium is defined separately because of its detrimental effects on soil permeability and tilth. The sodium hazard is defined by an index called the sodium adsorption ratio (SAR). This is the proportion of sodium (Na<sup>+</sup>) to calcium (Ca<sup>2+</sup>) and magnesium (Mg<sup>2+</sup>) ions in a sample. Calcium will flocculate (hold together soil particles), while sodium disperses soil and causes crusting and permeability problems. (The differences between saline and sodium affected soils are explained in the June 1998, Vol. 12, Issue 6. Agronomy News). Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler applied. Crops vary in their susceptibility to this type of damage as shown in Table 3.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

\*Sodium Adsorption ratio (SAR) (concentrations in meq/L)

### pH and alkalinity

The acidity or basicity of an irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pH's are an uncommon problem, but may cause accelerated equipment corrosion. High pH's above 8.5 are often caused by high bicarbonate (HCO<sub>3</sub><sup>-</sup>) and carbonate (CO<sub>3</sub><sup>2-</sup>) concentrations (alkalinity). High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify sodic soil conditions. In these cases, a lab will calculate an adjusted SAR to reflect the increased sodium hazard.

### Chloride

Chloride is a common ion in Colorado irrigation waters. Although chloride is essential to plants in low amounts, it can cause toxicity to sensitive crops at high concentrations (Table 3). Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation (Table 4). Leaf burn under sprinkler from both sodium and chloride can be reduced by night

time irrigation or application on cool, cloudy days. Drop nozzles and drag hoses are also recommended when applying any saline irrigation water through a sprinkler system to avoid direct contact with leaf surfaces.

### Boron

Boron is another element that is essential in low amounts, but toxic at higher concentrations (Table 5). In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 ppm. Although some yield response to boron fertilization on alfalfa has been claimed in Colorado, many irrigation waters contain enough B that additional B fertilizer is not required. Because B toxicity can occur at such low concentrations, an irrigation water analysis is advised for ground water before applying additional B to crops.

### Sulfate

The sulfate ion is a major contributor to EC in many of Colorado irrigation waters. However, toxicity usually is not an issue, except at very high concentrations where high sulfate can interfere with uptake of other nutrients. As with boron, sulfate in irrigation water has fertility

**Table 3. Susceptibility ranges for selected crops to foliar injury from saline sprinkler water.**

|                         | -----Na or Cl concentration (mg/L) causing foliar injury----- |         |         |            |
|-------------------------|---|---------|---------|------------|
| <b>Na concentration</b> | <46   | 46-230  | 231-460 | >460       |
| <b>Cl concentration</b> | <175  | 175-350 | 351-700 | >700       |
|                         | Apricot   | Pepper  | Alfalfa | Sugar beet |
|                         | Plum  | Potato  | Barley  | Sunflower  |
|                         |   | Tomato  | Corn    |            |
|                         |   |         | Sorghum |            |

Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for day-time irrigation. Source: Mass (1990) Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. Pp. 262-304.

**Table 4. Chlorine classification of irrigation water.**

| -----Concentration----- |           |  |
|-------------------------|-----------|--|
| meq/L                   | ppm       | Effect on Crops                        |
| Below 2                 | Below 70  | General safe for all plants            |
| 2-4                     | 70-140    | Sensitive plants show injury           |
| 5-10                    | 141-350   | Moderately tolerant plants show injury |
| Above 10                | Above 350 | Can cause severe problems              |

Chloride tolerance of selected crops. Listing in order of increasing tolerance: (low tolerance) dry beans, onion, carrot, lettuce, pepper, corn, potato, alfalfa, sudangrass, zucchini squash, wheat, sorghum, sugar beet, barley (high tolerance).  
 Source: Mass (1990) Crop salt tolerance. In: Agricultural Salinity Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. Pp 262-304.

benefits and irrigation water in Colorado often has enough sulfate for maximum production on most crops. Exceptions are sandy fields with < 1% organic matter and < 10 ppm SO<sub>4</sub>-S in irrigation water.

**Nitrogen**

The nitrate ion often occurs at higher concentrations than ammonium in irrigation water. Nitrogen in irrigation water (N) is largely a fertility issue and nitrate-nitrogen (NO<sub>3</sub>-N) can be a significant N source in the S. Platte, San Luis

Valley, and parts of the Arkansas River basins. Waters high in N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can usually be overcome by good fertilizer and irrigation management. Regardless of the crop, nitrate should be credited toward the fertilizer rate whenever the concentration exceeds 10 ppm NO<sub>3</sub>-N. Table 2 provides conversions from ppm to pounds per acre inch.

In many areas of Colorado, irrigation water quality can influence crop productivity more than soil fertility, hybrid, weed control and other factors that receive much more attention. Farm managers should be encouraged to get a chemical analysis of their irrigation sources. This basic knowledge is essential in making the right decisions for their irrigated production.

*Troy Bauder  
 Extension Water Quality Specialist*

**Table 5. Boron sensitivity of selected Colorado Plants.**

| -----Sensitive-----                              |            | Moderately Sensitive | Moderately Tolerant | Tolerant   |
|--|------------|----------------------|---------------------|------------|
| -----B concentration (mg L <sup>-1</sup> )*----- |            |                      |                     |            |
| 0.5 - 0.75                                       | 0.76 - 1.0 | 1.1 - 2.0            | 2.1 - 4.0           | 4.1 - 6.0  |
| Peach  | Wheat      | Carrot               | Lettuce             | Alfalfa    |
| Onion  | Barley     | Potato               | Cabbage             | Sugar beet |
|  | Sunflower  | Cucumber             | Corn                | Tomato     |
|  | Dry Bean   |                      | Oats                |            |

Source: Mass (1987) Salt tolerance of plants. In: CRC Handbook of Plant Science in Agriculture. B.R. Christie (ed.). CRC Press Inc.

\*Maximum concentrations tolerated in soil-water or saturation extract without yield or vegetative growth reductions. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

# Reducing Salinity Through Fertilizer Management

## Wise fertilizer decisions can reduce salt injury to your crop.

Fertilizers are salts. Therefore, when salinity is a concern, it is critical to pay close attention to how much fertilizer you apply, what kind of fertilizer you apply, where you apply fertilizer, and when you apply fertilizer.

Apply only the amount of fertilizer that will achieve maximum economic yield. Additional fertilizer will increase soil salt content and cost more, but will not increase yield. Base fertilizer application rates on annual soil sampling. This practice will help you know how much fertilizer you actually need and prevent over-application. Use a reputable laboratory that understands your salinity management goals. Avoid unnecessary application of potash or micronutrient fertilizers.

Different fertilizer forms have different salt indices. In other words, you can apply the same amount of nitrogen using different fertilizers and apply vastly different amounts of salt in the process. Choose fertilizers that will supply the crop's needs and have the lowest salt indices. Anhydrous ammonia has the lowest salt index of all nitrogen fertilizers (Table 1). Among phosphorus fertilizers, triple superphosphate has the lowest salt index, considerably lower than monoammonium phosphate (MAP) or diammonium phosphate (DAP). If you need potassium fertilizer, potassium sulfate has a much lower salt content than potassium chloride (muriate of potash).

The closer that fertilizer is applied to seeds or growing plants, the greater the risk of salt burn. Do not apply fertilizer with the seed if the crop yield is already below optimum due to salts. Never apply urea or ammonium fertilizers directly with the seed. Banding phosphorus fertilizer doubles its efficiency. Therefore, banding keeps fertilizer rates down and helps to avoid excess salts. Be careful to avoid banding too close to the seed. Use Table 2 to determine how close you can put the fertilizer band without causing a salt burn. You will need to know the soil texture and the amount of N and K<sub>2</sub>O you intend to apply.

**Table 1a. Salt indices of nitrogen fertilizers.**

|                       | Salt Index per unit of N |
|-----------------------|--------------------------|
| anhydrous ammonia     | 0.6                      |
| ammonium nitrate      | 3.0                      |
| ammonium sulfate      | 3.3                      |
| ammonium thiosulfate  | 7.0                      |
| urea                  | 1.6                      |
| urea-ammonium-nitrate | 2.3                      |

**Table 1b. Salt indices of phosphorus fertilizers.**

|                        | Salt Index per unit of P <sub>2</sub> O <sub>5</sub> |
|------------------------|--|
| diammonium phosphate   | 0.6  |
| monoammonium phosphate | 0.5  |
| monocalcium phosphate  | 0.3  |
| simple superphosphate  | 0.4  |
| triple superphosphate  | 0.2  |

**Table 1c. Salt indices of potassium fertilizers.**

| Fertilizer                 | Salt Index per unit of K <sub>2</sub> O |
|----------------------------|---|
| potassium chloride         | 1.9                                     |
| potassium nitrate          | 1.6                                     |
| potassium sulfate          | 0.9                                     |
| potassium thiosulfate      | 2.6                                     |
| sulfate of potash-magnesia | 2.0                                     |

**Table 2. Maximum safe levels of fertilizer salt (N = K<sub>2</sub>O in lbs/acre) to apply as a function of soil texture and placement.**

| Placement<br>(distance from seed) | Sandy | Loamy | Clay  |
|-----------------------------------|-------|-------|-------|
|                                   | Soils | Soils | Soils |
| -----lbs/acre-----                |       |       |       |
| in direct contact                 | 6     | 8     | 10    |
| 1/4 - 1/2 inch                    | 10    | 15    | 20    |
| 1-2 inches                        | 20    | 30    | 40    |
| > 2 inches                        | 25+   | 38+   | 50+   |

## Reducing Salinity Through Fertilizer Management (Continued)

Crops are most sensitive to salts when they are in the seedling stage. Salinity also reduces germination. Therefore, it is wise to avoid fertilizer application during the early growth stages. If you have salinity problems, avoid starter fertilizers and apply as much of the N as a sidedress as possible, eliminating pre-plant N applications. Coated fertilizers can reduce early season salinity by gradually releasing nutrients into the soil. Fertilization is a good

practice in saline soils because it allows you to spoon feed the N in small doses through the sprinkler system. However, do not pump anhydrous ammonia into irrigation furrows because this will increase the Sodium Adsorption Ratio (SAR) of the irrigation water and increase the sodicity risk.

Applying fertilizer only at required rates, choosing fertilizers with low salt indices, banding fertilizer away

from the seed, and delaying fertilizer application until after plants are established will help to protect your crop from excess salinity due to fertilizer application.

*by Jessica G. Davis  
Extension Soil Specialist*

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### VISIT THIS WEB SITE!

## **Transgenic Crops: An Introduction and Resource Guide**

[http://www.colostate.edu/programs/lifesciences/Transgenic Crops/](http://www.colostate.edu/programs/lifesciences/Transgenic%20Crops/)

by

Pat Byrne -- Sarah Ward -- Ann Fenwick -- Lacy Fuller

### **Topics:**

History of Plant Breeding  
What are Transgenic Plants?  
How to make Transgenic Plants: Animation Deni  
Evaluation & Regulations  
Current Transgenic Products  
Future Transgenic Products  
Risks & Concerns  
News Updates



# High-value Crops Have Low Salinity Tolerance

## Study evaluates onion varieties for salinity tolerance.

Crops differ in their ability to tolerate salinity. For example, barley and sugarbeet are known for their strong tolerance of salinity. Wheat, sorghum, alfalfa, and corn have moderate salinity tolerance. Peppers, onion, dry bean, and carrot have very low salinity tolerance. Hence, these high-value crops suffer the most under saline conditions. As salinity increases, growers may be forced to grow lower-value crops that have greater salinity tolerance. This shift may have severe consequences for agricultural profitability.

We started an experiment this year at the CSU Arkansas Valley Research Center which compares the response of different onion varieties to soil salinity. The variety evaluation included three yellow onion varieties (Colorado 6, Vision, and Daytona), one red onion variety (Redwing), and one white variety (Blanco Duro). We are testing these onion varieties at three different salinity levels. The three salinity treatments are low, medium, and high. The low level is the natural salinity level in the field area, and Epsom salt ( $MgSO_4$ ) was applied to achieve the medium and high salinity levels.

Yields were measured from each plot and graded by size, and data were analyzed in a split-block design. Salinity levels had no effect on total market yield or grade, but varieties were significantly different as shown in the table. Colorado 6 had the highest colossal and jumbo yields. Colorado 6 and Vision had the highest total market weight, but Colorado 6 also had the greatest cull weight, while Vision had the lowest cull weight. Blanco Duro had the lowest total market weight, while Daytona and Redwing market yields were moderate.

The interaction between variety and salinity levels was not statistically significant. In other words, the trends described above were true at all salinity levels. Next year we will increase salt application rates so that we get soil salinity levels which are high enough to have a significant impact on onion yields.

by Mike Bartolo

Extension vegetable crop specialist

Orren Doss

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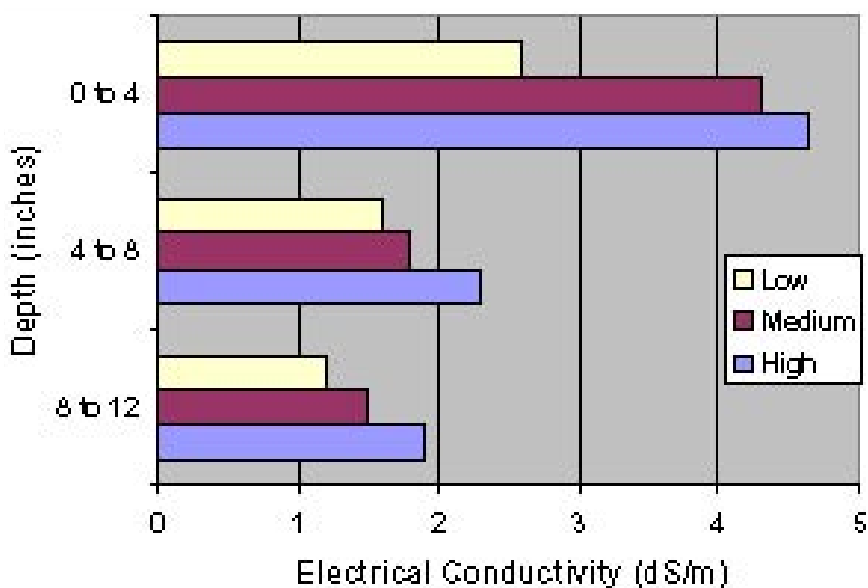


Figure 1. Soil salinity levels in onion variety plots.

Table 1. Total market yield and grade of onion varieties averaged across salinity levels.

| Variety            | Colossal Weight | Jumbo Weight | Medium Weight | Pre-Pack Weight | Total Market Weight | Cull Weight |
|--------------------|-----------------|--------------|---------------|-----------------|---------------------|-------------|
| -----cwt/acre----- |                 |              |               |                 |                     |             |
| Colorado 6         | 7 A             | 296 A        | 131 C         | 8 BC            | 8 BC                | 62 A        |
| Vision             | 0 B             | 146 B        | 273 A         | 12 AB           | 431 A               | 10C         |
| Daytona            | 0 B             | 66 C         | 247 AB        | 13 AB           | 326 B               | 30 B        |
| Redwing            | 0 B             | 60 C         | 236 B         | 16 A            | 311 B               | 10 C        |
| Blanco Duro        | 2 B             | 138 B        | 95 D          | 6 C             | 241 C               | 13 C        |

## Web Sites

<http://wrri.nmsu.edu/publish/techrpt/abstracts/abs198.html>

Evaluation of salinity tolerance of Russian thistle to determine its potential for forage production using saline irrigation water.

<http://www.ussl.ars.usda.gov/>

George E. Brown Salinity Laboratory. A National Laboratory for basic research on the chemistry, physics, and biology of salt-affected soil-plant-water systems. There are two pages of interest:

<http://www.ussl.ars.usda.gov/salinity.htm>

Frequently Asked Questions about salinity

<http://www.ussl.ars.usda.gov/answers/cropsali>

Maintaining low salinity may not be economically feasible, but judicious crop selection that produces satisfactory yields under saline conditions and using special management practices to minimize salinity may make the difference between success or failure.

[http://www.hiddenvegas.com/mastergardeners/Salinity\\_Effects.html](http://www.hiddenvegas.com/mastergardeners/Salinity_Effects.html)

This an archival page sponsored by The University of Nevada Cooperative Extension and the Master Gardeners of Southern Nevada. Select Publication Index from the menu, Fact Sheet 91-54, Salinity and its effects on landscape plants.

<http://www.usbr.gov/niwqp/>

The National Irrigation Water Quality Program is an inter-bureau program managed by the Department of the Interior.

<http://agpublications.tamu.edu/pubs/eengine/b1667.pdf>

Irrigation Water Quality, Texas Agricultural Extension Service publication #B-1667. Texas Agricultural Extension Service web site.

<http://ag.arizona.edu/OALS/IALC/soils/aridsoils/>

From index on this page, select "saline.html", to get Soils of Arid Regions of the U.S. and Israel: "Classification, Properties, and Management of Aridisols".

<http://www.statlab.iastate.edu/survey/SQI/>

NRCS' Soil Quality Institute's page. There are links to current projects, products and education resources.

<http://www.ext.usu.edu/publica/agpubs/salini.htm>

A Utah State University Extension publication on salinity and plant tolerance.