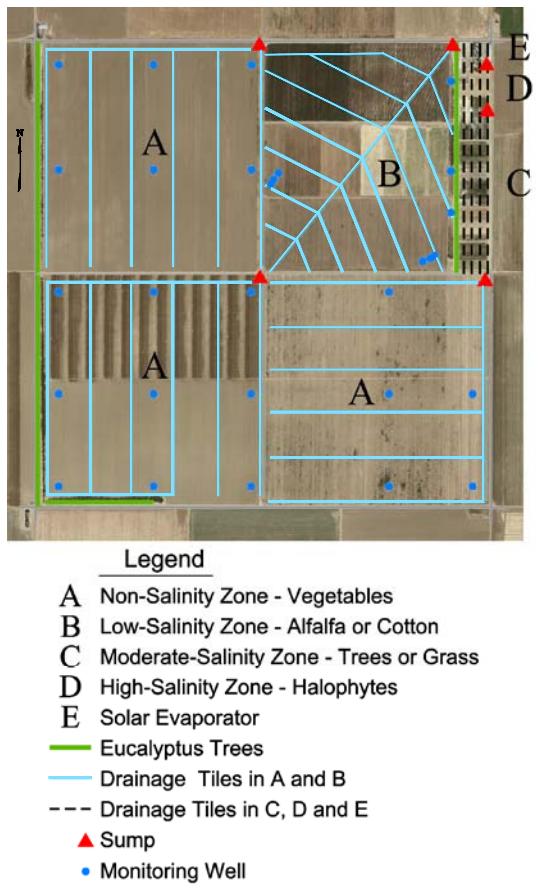
Agricultural Drainage Research Development and Demonstration (RD&D) Activities:

source control, reuse, drainage water treatment, plant materials, biomass utilization, and ground-water management

IFDM

Design of the Integrated on-Farm Drainage Management (IFDM) System at Red Rock Ranch (RRR)

Agencies: California Department of Food and Agriculture; California Department of Water Resources; California State University, Fresno; Center for Irrigation Technology; Red Rock Ranch, Inc.; University of California, Davis; U.S. Bureau of Reclamation; USDA-Natural Resource Conservation Service; Westlands Water District; Westside Resource Conservation District



IFDM is a farming system that sequentially reuses subsurface drainage water to grow salt-tolerant crops. The area of land in the RRR-IFDM system consists of one section, approximately 1 mi by 1 mi or 640 acres. An estimated 590 acres of land are presently under irrigation.

Section A and a portion of Section B (west ½ of B-Middle, and all of B-South) are the salt sensitive areas and makes up approximately 86 percent of the farm. Salt sensitive crops, such as tomatoes, onions, wheat, and corn, are irrigated with good quality water supplied by Westlands Water District with TDS concentrations averaging 250 PPM. A 1,800-ft deep groundwater well is used for irrigation when surface irrigation water is not available.

Section B (B-North and east ½ of B-Middle), Sections C, and D are all irrigated fields for reuse. Drainage water collected from Section A is applied to Section B, 10 percent of the acreage, which is made up of salt-tolerant commercial crops such as alfalfa, cotton, tall wheat grass, and creeping wild rye. Drainage water, from Section B, is then applied to salt-tolerant trees and grasses on Section C which represents about two percent of the farm. Drainage water from this area is then applied to Section D which represents one percent of the farm that is planted in halophytes such as saltgrass, iodine bush, cordgrass and salicornia. Each sequential reuse reduces the volume of drainage water and increases the salt concentration.

Drainage water too saline for irrigation is applied to the solar evaporator using timed spray sprinklers. An enhanced evaporation system (solar evaporator) is the terminus of the system and has a zero-liquid discharge. The solar evaporator is operated within the design discharge capacity. The daily water application rates to the solar evaporator are determined according to the climatic data, such as, air temperature, humidity, wind speed, evaporation by pan, and solar radiation. The solar evaporator was developed as an economic, simple, and environmentally safe method to evaporate concentrated subsurface drainage water and store salts at the terminal point of the IFDM system. The solar evaporator also allows for the recovery of salts for beneficial use.

Engineers and scientists are transferring the technology developed at Red Rock Ranch to individual farms and district areas.

Solar evaporator (vertically orientated nozzles at riser height=1.00 ft).

Forages

Biomass Yield and Nutritional Quality of Forage Species under Long-Term Irrigation with Saline-Sodic Drainage Water: Field Evaluation, Animal Feed Science and Technology

Agencies: Department of Plant Science, California State University, Fresno; Department of Animal Science, University of California, Davis; Department of LAWR, University of California, Davis; USDA-ARS Salinity Laboratory, Riverside, CA

Selection of salt-tolerant forages for quality and productivity

The objective of this study was to evaluate the biomass production and nutritional quality of six forages: *'Jose'* tall wheatgrass, creeping wildrye, alkali sacaton, 'Alta' tall fescue, puccinellia and *'Salado/801S'* alfalfa. These forages were grown in clay soils near Five Points, CA and most fields were in their fourth and fifth year of irrigation with saline-sodic drainage water. The forage field soil salinities were higher than 12 dS/m EC_e and also had high levels of boron (B), selenium (Se) and sodicity (high sodium (Na)) relative to calcium and magnesium.

Forage Yield and Quality:

* *'Jose'* tall wheatgrass and creeping wildrye had dry matter (DM) production of 7.0 and 11.5 MT/ha/yr. (= 3. 1 and 5.1 tons/acre/yr.) under highly saline conditions of 19 and 13 dS/m EC_e, respectively.
* Alfalfa produced 16-20 MT/ha/yr. (= 7.1-8.9 tons/acre/yr.) of DM under low salinity conditions of <7.0 dS/m EC_e.
* Metabolizable energy (ME) contents of 7.9-9.9 MJ/kg DM; except alkali sacaton (6.7 MJ/kg DM).
* Selenium levels varied from 4.4 to 10.7 mg/kg DM (for forages receiving 4-5 years of drainage water application).

Forages at the high end of selenium range could cause Se toxicity in ruminants when used as a sole source of forage, but they could also be used as a Se supplement if fed at a rate of 20-40 g/kg in the Se-deficient areas in eastern San Joaquin Valley. Current research is examining how grazing systems should be managed to accommodate high selenium in the forage.

Suyama, H., et al., Biomass yield and nutritional quality of forage species under long-term irrigation with saline-sodic drainage water: Field evaluation, Animal Feed Science and Technology (2006), doi:10.1016/j.anifeedsci.2006.08.010.

Creeping wildrye transplanted into cracking clay soil [at Red Rock Ranch]. This same field is later shown in photo below middle.

'Jose' tall wheatgrass, the most salt-tolerant of the forages tested.

Creeping wildrye irrigated with saline-sodic DW and growing in a field with salinity averaging 13 dS/m ECe.

Black angus beef cattle grazing on a 20-acre (9 ha) creeping wildrye field.

Brine Shrimp

Reducing Selenium Loads and Ecotoxic Risk in IFDM Systems Using Solar Evaporator Basins that Combine Invertebrate Harvest with Algal Volatilization of Selenium

Agencies: Department of Land, Air and Water Resources, University of California, Davis; California Department of Water Resources; Red Rock Ranch, Inc; Novalek, Inc.

Objective: To investigate interrelationship of algal abundance, brine shrimp growth, and Se volatilization

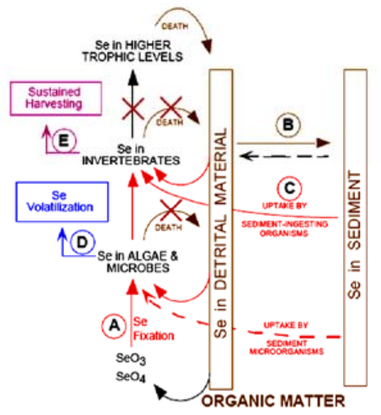
Integrated on-Farm Drainage Management (IFDM) is a promising strategy for reducing the volume of contaminated water that is often produced as a consequence of irrigation in the San Joaquin Valley, yet the problem with accumulation of high concentrations of naturally occurring salt and selenium exists. The aim of the ongoing research at the Red Rock Ranch (RRR) field site is to reduce selenium ecotoxic risk associated with exposure to contaminated agricultural drainage water. The proposed mechanism of selenium bioremediation is through a combination of natural microalgal volatilization and food chain disruption. We are assessing the effects of fertilizer and other inputs on algal dynamics for optimizing the harvest of brine shrimp, as well as Se volatilization so that both total and bioavailable Se are reduced. In addition we will be evaluating the ecotoxic status in harvested basins, including sediment/detritus status, so that reduced ecotoxic risk can be maintained.

The field site consists of six, 30'x 6'x 1.5' concrete basins that are enclosed within a plastic greenhouse. RRR drainage water in the basins has salt and selenium concentrations of approximately 120 ppt and 10-12 ppm, respectively. Algae, from the Tulare Lake Drainage District, were introduced to the basins in March, 2006. Once a stable community of algae was established, brine shrimp, Artemia franciscana, were introduced into the system. On a daily basis, pH, electrical conductivity, dissolved oxygen and temperature are monitored. Monthly, samples are taken for water selenium concentrations, microalgal tissue selenium concentrations, chlorophyll a, microscopy, and DNA extractions for microalgal community profiling.

Laboratory microcosms examining the key factors that play a role at the field site.

The results from this field study and ongoing laboratory microcosms will provide valuable information for design strategies in optimizing selenium remediation and reducing ecotoxic risk associated with exposure to agricultural drainage water.

Brine Shrimp, *Artemia franciscana* (W. Wurtsbaugh)



Conceptual model of reducing selenium ecotoxic risk in drainage basins by invertebrate harvest and natural volatilization.

Concrete basins containing agricultural drainage water at Red Rock Ranch.

Salt

Sulfate in Glass Making

Agencies: Department of Geology, Department of Biological and Agricultural Engineering, University of California, Davis; California Department of Water Resources; U.S. Environmental Protection Agency

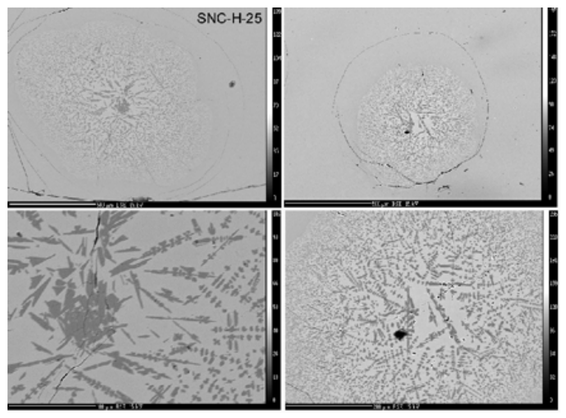
Scientists from UC Davis are participating in the development of potential uses of salt products derived from agricultural drainage water and marketing opportunities for such products. This study investigated the process of vitrification of salts to make commercial glass products.

In this study, experimental glass samples were produced with salts collected from agricultural drainage water. Salt was collected from two sources: 1) evaporation pond salt composed of 85% (by weight) of thenardite (Na_2SO_4) and minor amounts of blodite ($Na_2Mg[SO_4]_2.4H_2O$), and halite (NaCl), and 2) a purified sodium sulfate separated from agricultural drainage water using a pilot solar concentration and salt crystallization system.

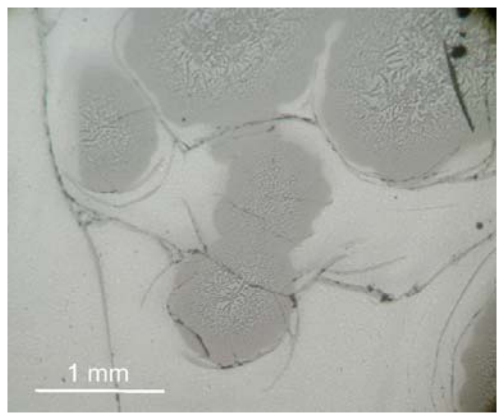
Devitrification

The study found that the ease with which devitrification occurs suggests that interaction between sodium sulfate melt and crystalline grains during melting may severely restrict dissolution and thus promotes nucleation during cooling. Devitrification may be a fundamental property of sulfate-rich glass mixtures that should be further explored. It is possible that properties of the glass ceramic material for some applications might be advantageous.

Thy, P., et al., Use of sodium sulfate separated from agricultural drainage water in glass making, Final Report 2006.



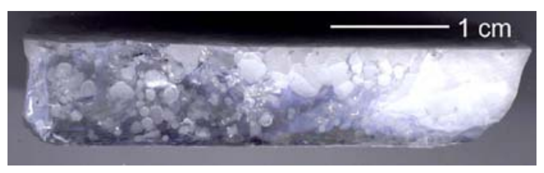
Close-ups of devtrification cells in SNC-H-25



Close-up of the devitrification spheres in SNC-H-25. Top is toward the surface of glass mass. Note the decrease in grain-size from the centers toward devitrification margin (=front) for each cell. Concentric contraction cracks surround the devitrification cells.

Glass batch made from 3 kg flat glass mixture based on purified natural sodium sulfate as source of sodium. Fired for 4 days at 1300 °C. The container is 12 cm in diameter and 15.5 cm deep and filled to 2 cm from the top rim.

The experimental product SNC-H-25 in a large thin walled alumina container. The results revealed partial devitrification in glass with clear glass preserved in the center at the surface (see cross section below).



Cross section of partially devitrified glass in SNC-H-25.