Report for 2004CO99B: Salt Chemistry Effects on Indirect Field Salinity Assessment in the Arkansas River Valley, Colorado

- Conference Proceedings:
  - Wittler, J.M., G.E. Cardon, and C.A. Cooper, 2005, "Regional calibration of the EM-38 for salinity assessment," poster presentation at American Acadamy for the Advancement of Science Annual Meeting, Feb 17-22, 2005. Washington, DC.
  - Wittler, J.M., G.E. Cardon and C.A. Cooper, 2004, "Regional calibration of the EM-38 for salinity assessment in the Arkansas Valley," presentation at Soil Science Society of America 68th Anual Meeting, Seattle, WA, 31 October to 4 November 2004.
- Other Publications:
  - Cooper, C.A., G.E. Cardon and J.M. Wittler, 2005, "Influence of salt chemistry on direct and indirect salinity measurement in the Arkansas River Basin, Colorado," presented at International Salinity Forum, Riverside, California, 25-27 April 2005.
  - Wittler, J.M., G.E. Cardon, T.K. Gates, C.A. Cooper, and P.L. Sutherland, 2005, "Calibration of electromagnetic sensors for regional salinity assessment in an irrigated river valley," poster presented at International Salinity Forum, Riverside, California, 25-27 April 2005.
  - Cooper, C.A., G.E. Cardon and J.M. Wittler, 2004, "Salinity chemistry in high plains irrigated agriculture, Arkansas River Valley, Colorado, " poster presentation at Soil Science Society of America, 68th Annual Meeting. Seattle, WA, 31 October to 4 November 2004.

Report Follows

Problem and research objectives:

Salinity in the Arkansas River Basin is causing decreased productivity; with potential salinity sources being, geologic, waterlogging, urban and agricultural return flows. However, there was little chemical soil data to describe accurately and specifically, the type of salinity. Field observation suggested that the primary soil salinity is calcium-based (gypsum or calcite), and this type of salinity may be a factor in the difficulty of calibrating electromagnetic induction probes for in-field salinity assessment.

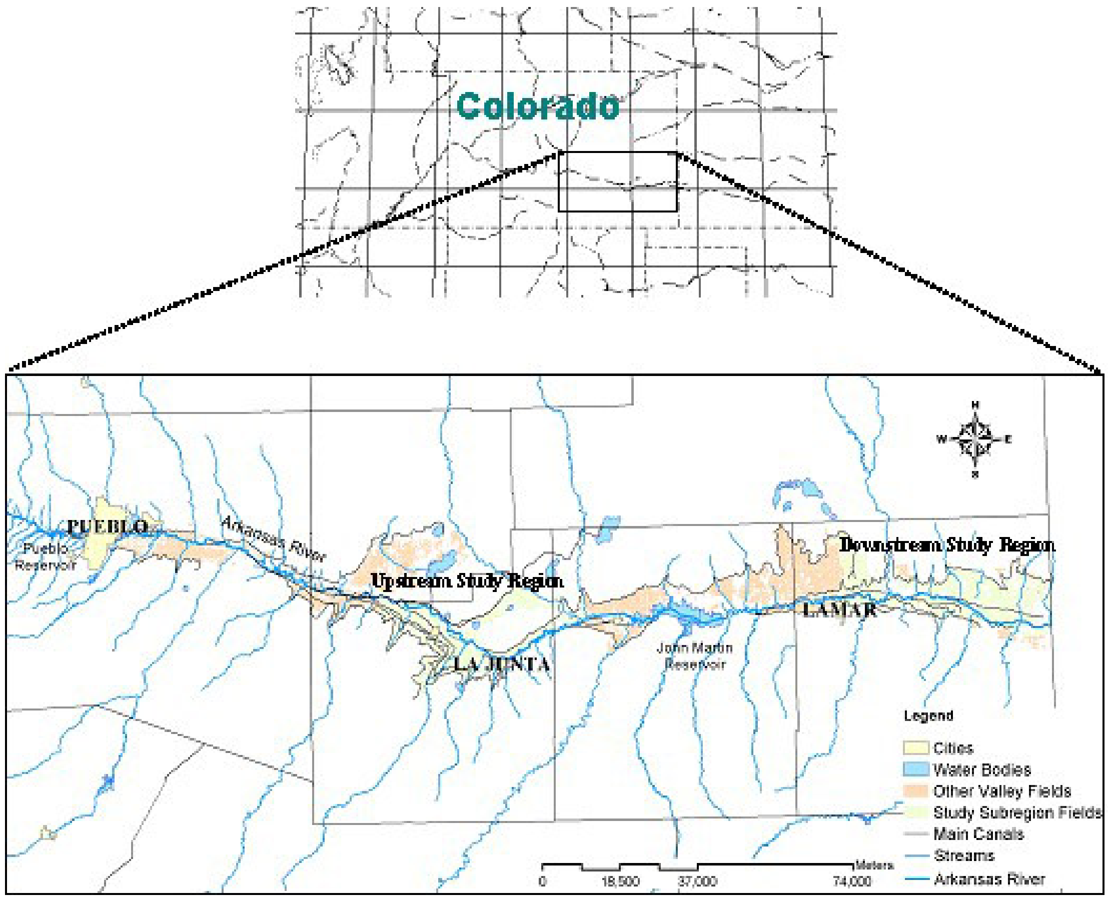

Figure 1. Upstream and Downstream Study Sub-regions on the Lower Arkansas River

Methodology:

Project goals to collect baseline soil chemical data have been completed. Field sampling in the Arkansas River Valley was completed in the summer of 2004. Overall, 24 fields were sampled in the upstream region and 27 fields in the downstream region. Samples were typically collected to a depth of 1.2 meters, spanning a range of salinities. Samples were then processed for saturated paste extracts with the extract waters being tested at the Soil, Water and Plant Testing Lab on the Colorado State University Campus. Additionally, chemical analysis was run on pore water extract waters and for a multiple extract testing. Method tests are also being conducted for in-laboratory procedures and the effects on the electrical conductivities.

Principal Findings and significances:

Data for the baseline chemistry are currently being analyzed, but preliminary results reveal that there are relationships between extract water electrical conductivity (EC) and the sodium concentrations (Figure 2), which is also true for the magnesium, and sulfate concentrations. This relationship is not found in the calcium concentrations in the extract waters. It is surmised that this is because $CaSO_4$ (typically as gypsum) and $CaCO_3$ (typically as calcite) are slightly to limited in their solubilities in near neutral pH conditions (Figure 2). However, some soils also appear to have a reserve of calcium attached either to colloids or in the soil solution that influences the EC/calcium relationship above an EC of approximately 3.0 dS m^{-1}.

The chloride relationship to EC is also unclear, presumably due to the different hydrological regimes on how the soils were "salted up." In fields in which the salt source is from the top down it is expected that chloride, which typically behaves as a conservative chemical species, should be leached to the deeper samples or to below the rootzone. However, in waterlogged fields it is expected that with an upwelling gradient for groundwater flow that the chloride will become concentrated near the soil surface due to evapotranspiration. Statistical analysis of these hydrologic regimes is planned for the summer of 2005.
Pore water extract waters were sampled from the Research Station in Rocky Ford, CO. Irrigation was applied on Day 0, and with *in-situ* extractions occurring on Days 1 – 4. Pore waters were sampled through multiple tubes each with a ceramic cup at either 1, 2, 3, and 4 foot depths using suction induced with a pump. Sample waters were not available at the 3 and 4 foot depths on Day 1. In Figure 3. the irrigation water sodium concentration and the saturated paste extract concentrations are presented as reference points. A combination of leaching, dilution of the pore waters and the movement of the wetting front through the soil profile are shown in Figure 3. These data are also paired with EM-38 measurements which suggest that there is a change in the overall bulk conductivity as the wetting front expands through the soil profile.

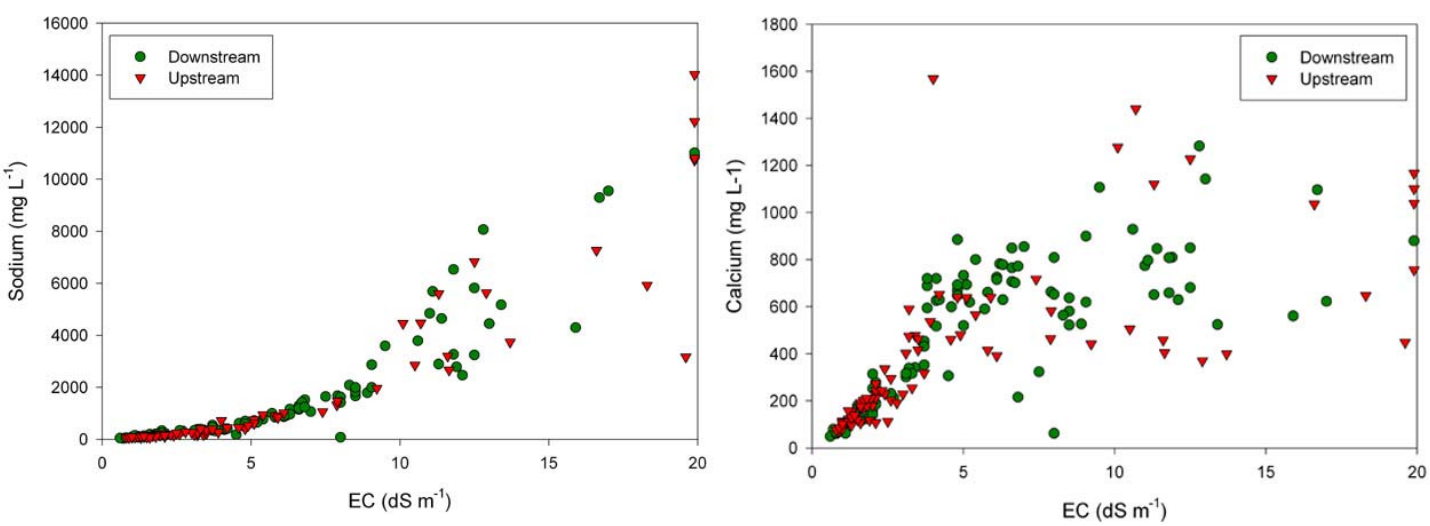

Figure 2. Sodium and Calcium extract concentrations (mg/L)

Multiple extracts of a single soil sample were completed in January 2005. This sample was repeatedly processed in a manner equivalent to all the other soil samples for saturated paste extracts. The chemical results of the repeated testing are in Figure 4. From these results the initial flush of sodium from the soil and a subsequent decrease in the EC of the extract waters are apparent in the first six extractions. This result suggests that the EC is strongly influenced by sodium, which is highly soluble. As the multiple extracts proceeded, minor decreases in the magnesium concentrations occurred, but the calcium concentrations are essentially the same between the first extract and the 14th extract, which suggests that the soils and EC are "buffered" by gypsum and calcite mineral precipitates that cannot be readily leached from agricultural fields. Fourteen extractions were not sufficient to decrease the extract EC significantly below 4 dS m^{-1}. Implications of this research support leaching studies of soil cores by David Huber and Dr. Greg Butters. The data have not yet been completely examined for management recommendations of calcium-salt affected fields.

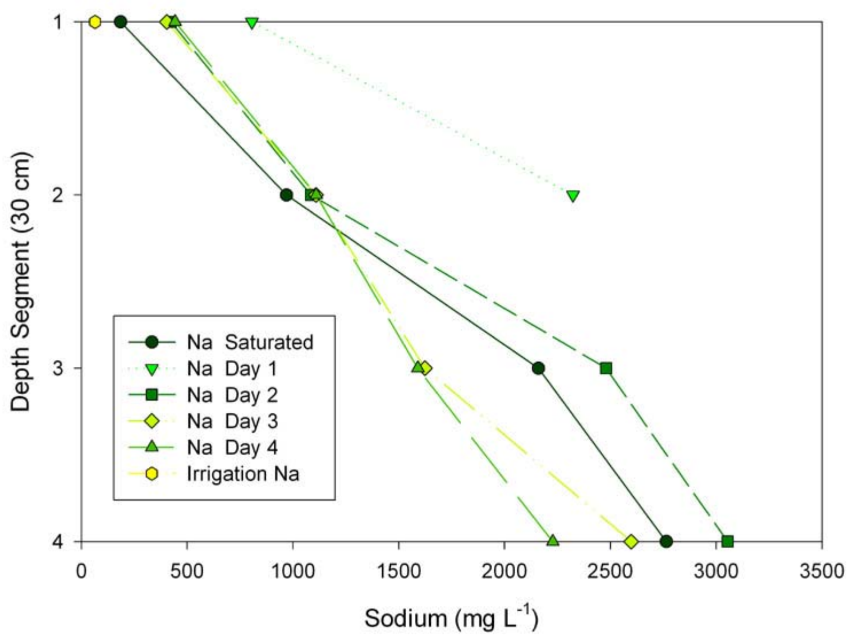

Figure 3. Sodium Concentrations in Pore Water Extracts

Testing of the EC laboratory methods is on-going. Since there are manipulations to collected soil samples as part of developing saturated paste extracts, such as drying, grinding and mixing of soils and pastes, there is a potential to influence the EC measurements. Grinding of nodules of calcium sulfate, calcium carbonate minerals/precipitates and of soil aggregates can increase the surface area available for dissolution and thereby change the overall EC measurement by making more salts available for dissolution than are available *in-situ* under typically irrigation processes. Preliminary data suggests that extract waters taken from soil samples retaining their aggregates, and not stirred during the saturation process, have a lower EC than those samples that are manipulated. The use of surrogate irrigation water in creating the saturated paste has preliminary results suggesting that the EC between the soils and the water is not additive. It is expected that the additional tests may offer clues/answers as to the why and how the two EC's become intermixed.

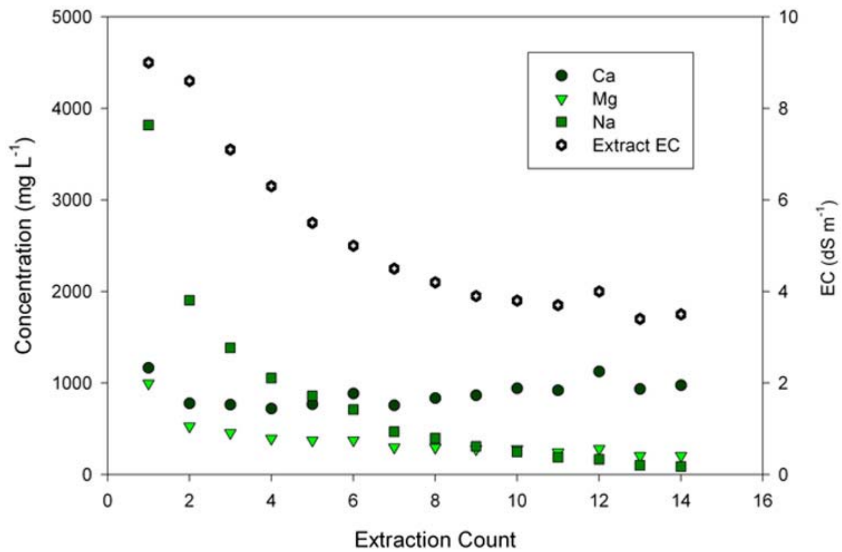

Figure 4. Multiple Extraction Results

Planned analysis for Summer 2005, include, but are not limited to:

1) Beta testing of an updated WATSUIT model by Dr. Jim Oster, Emeritus Soil and Water Specialist, University of California, Riverside.
2) Refining the calibration equations to the EM-38 electromagnetic sensor by utilizing chemical data. Equations were created by James Wittler as part of an ongoing Masters research at Colorado State University.
3) Continue working with other researchers on efforts related to salinity in the Arkansas River Basin. Data has already been used to direct monitoring and modeling efforts of Yaun-Win Lin and Roberto Arranz (graduate students of Dr. Garcia). The implication of the calcium chemistry/mineralogy in the soils has impacted assumptions of chemical transport and removal mechanisms.
4) Spatial statistically analysis of the chemical data regionally and between regions to determine locations with greater concentrations of salts, being sodium, calcium, magnesium, etc.
5) Normal versus inverted soil salinity profiles to determine the effects of waterlogging.
6) Variability in the chemical constituent concentrations as a function of EC groupings.
7) Chemical data is providing clues as to why current EC-Crop guidance manuals are not accurate for these saline systems and research/analysis will following up on this information.
8) Examination of available models, including Hydrus 1D 3.0 (with Unsatchem), and continuing use of Visual Minteq to help model chemical changes with the removal of pure water through evapotranspiration.

Assistance in this research came from five undergraduates working in the Irrigation Laboratory in Plant Sciences Building on the Colorado State University Campus. Additional assistance was provided by Dr. Tim Gates in Civil Engineering, Dr. Luis Garcia, Eric Morway and others involved directly with the Arkansas River Valley Project examining salinity and waterlogging. In particular, much of this current work is only possible because of the work done by James Wittler in examining and calibrating the EM-38 sensor and developing the pore water study.

Salary for Curtis Cooper was provided by the USDA, in the form of a three year National Needs Fellowship. The Colorado Water Resources Research Institute provided funding for the presentation of abbreviated forms of this research at the Soil Science Society of America, 68th Annual Meeting, Seattle, WA (November 2004) and at International Salinity Forum, Riverside, CA (April 2005). In April 2005, Curtis Cooper was offered a position in the 2005 Summer Doctoral Fellows Program at Washington State University, Pullman WA, in part due to his research of salinity.

Funding for the research was supplied by the Colorado Water Resources Research Institute and Agricultural Experiment Station.