USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: DESCRIPTION AND INTERPRETATION OF SALINIZATION IN THE LOWER ARKANSAS RIVER VALLEY, COLORADO

Focus Categories: WQL, GW, AG

Keywords: Salinity, saline soils, drainage, water quality, groundwater quality, data analysis, data storage and retrieval

Duration: 3/00 - 2/01 (With extension to be requested for two additional years)

Funds Requested:

Federal Funds:	$17,571 Direct		
Nonfederal Funds:	$19,750 Direct	$15,392 Indirect	$35,142 TOTAL

Principal investigators name(s) and university:

Principal Investigators:

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Co-Principal Investigators:

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James C. Valliant, Extension Irrigation Specialist, Cooperative Extension, Colorado State University

Congressional district: 4th

Statement of critical regional or state water problems

Salinity and drainage problems usually appear in intensively-irrigated alluvial valleys within a few decades to a few hundred years of the commencement of large-scale irrigation. Sooner or later, the artificially high rate of application of water to land exceeds the natural rate of drainage, the water table rises, and artificial drainage is needed to regain an acceptable water and salt balance (Gates and Grismer 1989). In the lower Arkansas river valley in Colorado, saline high water tables began to appear in the early part of the twentieth century. Installation of subsurface drains in the 1930s seemed to assuage the problems for awhile (USDA-NRCS, Rocky Ford Field Office, personal communication). However, water tables began to rise again in the late 1970s. Watts and Lindner-Lundsford (1992) suggested that the blame be placed on increased diversions from the river for irrigation application and associated reduction in groundwater pumping. Indeed, in the 1950-70's, two reservoirs began operations that have drastically changed the river. Flushing from floods was substantially reduced and controlled releases were made from the reservoirs. This allowed year-round, or at least prolonged, supplies of water to the canals on the perimeter of the valley. Seepage from these canals and lower velocity in the river have caused the river channel to widen, sediments to deposit on the bed, and the river level to rise. Recent investigations by the principal investigators of water levels in the reach of the Arkansas River upstream of John Martin Reservoir indicate an increasing trend since about 1989. The overall rise in the river level (of about 0.6 m) may have significantly reduced the gradient that drives drainage flows from the irrigated land to the river. Since 1991, irrigation water supplies from snow pack and rainfall have been far above average. Many of the large supply canals in the area have diverted more water in each of the last three years than in their 100+ year histories and have increased seepage throughout the basin. Also, in response to the recent Kansas-Colorado court ruling, groundwater pumping in the valley, which serves to reduce water table levels, has diminished.

These factors contribute to a growing body of evidence that the irrigated lands of the lower Arkansas are subjected to forces that are elevating the severity of waterlogging and salinization. At a time when conjecture about the main causes and prognosis of the problems is growing, some people feel that conditions already have reached a crisis stage. Informal and anecdotal evidence abounds: salt crusting on soil surfaces, seepage and wet spots in selected fields, stunted growth of crops, and reduced crop yields. Such losses threaten the economic wellbeing of the rural communities in the Valley and, by extension, diminish the agricultural base of the state. Until recently, however, scientific investigations of the problems have been sparse. Furthermore, studies often are limited in their scopes and piecemeal in their approaches, failing to provide a coherent understanding of the extent and severity of the problems.

Statement of results or benefits

There is an acute need to place the diagnosis of salinity and waterlogging problems in the Arkansas Valley on a sound scientific footing. Furthermore, beyond the need to accurately describe the problems for farmers and for state and regional agencies, a reliable database will be needed to aid in prescribing solutions. This project proposes to strengthen the data foundation needed to characterize salinization problems in the lower Arkansas river valley and to guide the search for answers. The output will be a report that assesses the scope and severity of the problems. The report will consider soil salinity, water table depth and salinity; river level, flow, and salinity; water levels, flows, and salinity in canals and drains; irrigation practices; hydraulic conductivity of surface soils; well pumping; and crop yields. Plausible causes and promising directions for addressing the problems also will be addressed. The report will be accompanied by a digital spatially-referenced (ArcView™ GIS format) database.

The results of the proposed project should prove a valuable resource in support of decision-making and intervention in the Valley. Without sound and timely intervention, it appears that the Valley will eventually succumb, at least in a large part, to the ill effects of salinization. Solutions based upon accurate knowledge of field conditions will be needed to insure sustainability of the Valley's productive agricultural base and preservation of its rural communities.

NATURE, SCOPE AND OBJECTIVES OF RESEARCH

Methods, procedures, and facilities:

Compilation and Evaluation of Past Data

Data from past studies in the Valley will be pulled together, transformed into a compatible and accessible format, compared, and interpreted. Comprehensive library research will be conducted to find pertinent published articles. Both file reports and published reports also will be sought directly from agencies working in the Valley [e.g. U.S. Geological Survey (USGS) Subdistrict Office, Colorado Division of Water Resources, U.S. Department of Agriculture (USDA) – Natural Resources Conservation Servie (NRCS) Area Office]. Internet searches will be conducted to identify data and reports available on the World Wide Web. Historic data considered will include land topography and topology of hydraulic systems, field and crop layouts, general hydrology, subsurface geology and lithology, water table depth and salinity, groundwater well locations and pumping rates, river water levels and salinity, soil textures and classifications, irrigation practices, and county-wide crop yields.

Collection of New Field Data

New data will be collected to fill gaps in the knowledge base. The data collection effort will focus on a representative region of the Valley between Manzanola in Otero County to Las Animas in Bent County (Figure 1). *Much of the data will be collected directly by project personnel, while some will be collected in cooperation with partnering agencies. Furthermore, the funding requested under this project will be supplemented with funding from other projects (described under "Related Research" below) in order to support the entire effort described herein.* Cooperation with area farmers will be facilitated by the Colorado State University Cooperative Extension Office in Rocky Ford.

It is desirable to collect the data over a *several-year period* to ascertain temporal variability and trends. The following field measurements will be made:

(1) *Soil Salinity*. About 50 fields (10 to 30 acres in size) will be broadly surveyed for soil salinity. The fields will be selected as a representative distribution over

the study region. Each of the 50 fields will be surveyed once during the early part of the irrigation season and once during the late part of the season. Electromagnetic induction probes (Geonics^{TM} EM-38) will be used to collect samples at about 60 locations within each field. Two of the probes will be made available through a cooperative agreement with the USDA-NRCS Area Office in La Junta (see attached letter from Lorenz Sutherland, NRCS Area Agronomist). In a subset of five fields, each sample will be located with a survey-quality global positioning system (GPS) (Trimble^{TM} Model 4600 LS Surveyor) owned by the Civil Engineering Department. This will allow calculation of spatially-referenced correlation of salinity to crop yield measurements taken at the end of the season (see below).

(2) *Water Table Depth and Salinity*. Observation wells will be drilled inside each of the 50 surveyed fields and at additional locations throughout the study region. The USDA-NRCS Area Office in La Junta has committed the availability of two Giddings^{TM} drill rigs for this purpose. We also hope to acquire a small portable engine-driven auger for use in cropped fields. Water levels and salinity will be measured in the wells every 10 days throughout the irrigation season. Specific conductance meters (Hach^{TM} Model 44600 and Orion^{TM} Model 128) owned by the Civil Engineering Department and the USDA-NRCS Area Office will be used to measure electrical conductivity for correlation to total dissolved solids.

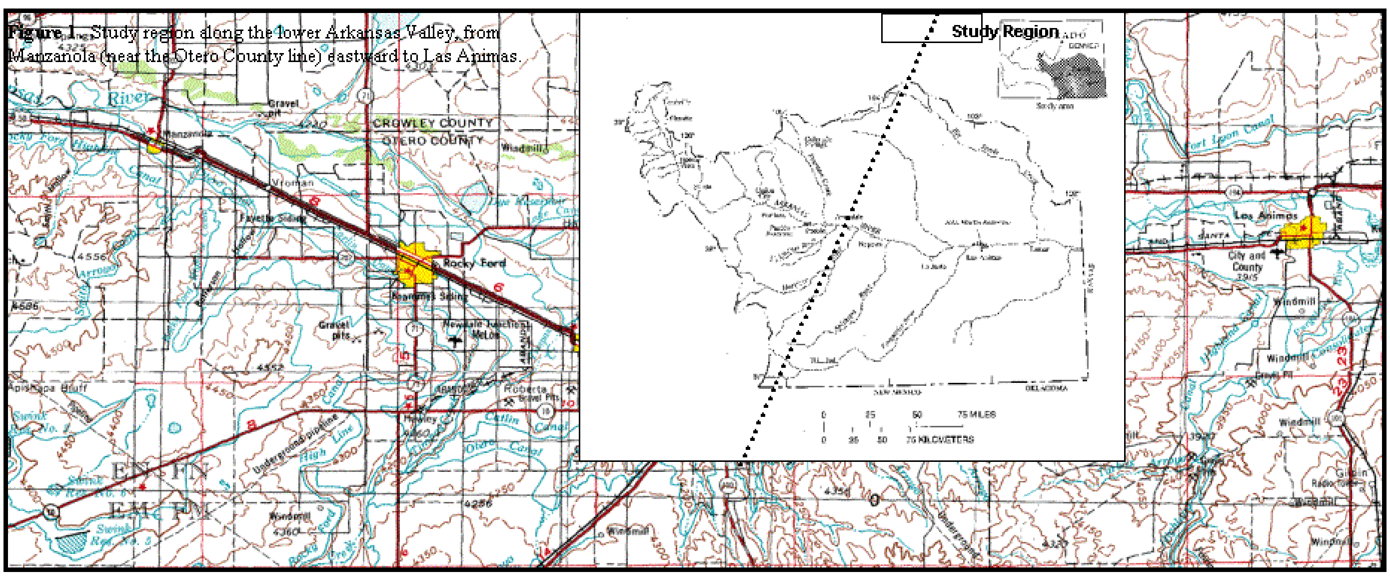

Figure 1. Study region along the lower Arkansas Valley, from Manzanola (near the Otero County line) eastward to Las Animas.

(3) *River Water Level and Salinity*. Water level and salinity are measured periodically at a few selected sites (e.g. Timpas Creek gage, La Junta gage, and Las Animas gage) along the Arkansas River by the USGS Subdistrict Office in Pueblo and the District 2 Office of the Colorado Division of Water Resources. The proposed project will cooperate with these agencies to obtain these data. Additional data will be collected (using specific conductance meters and the GPS system) near the upstream and downstream boundaries of the study region and in the vicinity of the diversions to the main canals.

(4) *Water Levels and Salinity in Irrigation Canals and Drains*. Water levels and salinity will be measured periodically at selected locations along the length of the major canals and drains in the study region. The sampling interval will be about 800 m.

(5) *Hydraulic Conductivity of Near-Surface Soils*. Subsurface drainage investigations will require estimates of the horizontal hydraulic conductivity in the top three meters below the soil surface. These estimates will be made using auger hole tests conducted in the observation wells to be drilled over the region. These tests are conducted by drilling below the water table, removing the water from the well with a hand-pump, measuring the rate of rise of the water table in the well (and the associated time-varying hydraulic gradient), and calculating the approximate average horizontal hydraulic conductivity around the annulus of the well.

(6) *Crop Yields*. Crop yields will be measured at the end of the crop season on a subset of the fields surveyed for salinity and water table depth. A significant consideration in this work is that some fields, as well as specific areas within given fields, are more affected by salinity build-up than others. Therefore, crop yield data from several different farms, as well as from different locations within selected fields, will be obtained.

Bulk crop yield will be obtained for all fields on which salinity measurements are taken. This bulk yield data will be obtained from grower records. Detailed yield maps will be made on five fields that show significant within-field variability in salinity distribution. Within-field yield measurements will be taken on corn fields using a GPS-based yield mapping combine tractor or from individual grain truck weights over specific field areas.

This data will allow the correlation of average soil salinity with crop yield, the estimation of the magnitude of yield reduction between low and high-salinity fields, and the evaluation of the impact of site-specific salinity conditions on the overall yield performance of individual fields. Moreover, the data will be available for future calibration and application of a water use-salinity-yield model.

Data Synthesis and Problem Identification

Old and new data must be synthesized and properly interpreted to describe trends and variability in salinity-related factors. Analysis will be conducted to provide descriptive statistics of each data element. Correlation and non-linear regression will be used to estimate relationships between variables. Dependence of data statistics on space and time structures will be explored. This will provide understanding of how salinization processes change (over time and from location to location within the study region) and insight into the relationships between such changes.

Preparation of Accessible Database for Analysis and Modeling

Data elements will be stored for access and display through a spatially-referenced database with time-varying layers. Base images of the Valley, field layouts, and regional hydrography already have been assembled by the principal investigators using the ESRI ArcView™ format. This convenient and widely-used format also will be adopted for use in the proposed project. In addition, data will be stored in standard spreadsheet format with a structure amenable to direct analysis and access by computational models.

A Cooperative Effort

The data-intensive study described above is believed to be essential to arresting salinization in the lower Arkansas Valley. However, it will be time-consuming and costly, and can only be accomplished with the assistance of other interested parties in the Valley and with funding supplemented by other projects as described below. In their recent work in the Arkansas Valley, the principal investigators have established partnerships with Southeastern Colorado Water Conservancy District, the USDA-NRCS Area Office, the Pueblo Subdistrict Office of the USGS, the Eastern Colorado Area Office of the U.S. Bureau of Reclamation (USBR), the District 2 Office of the Colorado Division of Water Resources, the USDA Farm Services Agency, and the Bent County Soil Conservation Board. Continued cooperation from these agencies will be sought in the proposed project. Letters of support for the proposed project have been provided by the Southeastern Colorado Water Conservancy District, the USDA-NRCS Area Office, and the Colorado Water Conservation Board (see attachments). The principal investigators also are seeking cooperation from the Arkansas Valley Ditch Association. Toward this end, a meeting is scheduled in Rocky Ford in early March with the Catlin Ditch Company.

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