The salinity control story of the Upper Colorado River Basin illustrated by case studies

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The Colorado River system transports approximately 9 million tons1 of salt per year into Lake Mead, the largest man-made reservoir in the United States. This salt load affects almost 30 million people and 4.5 million acres of irrigated lands in nine states within two countries. The Colorado River supports diverse uses, including agriculture and industry, and it underpins the regional economies both inside and outside its natural watershed area. Such intensive use and reliance on this river system has led to significant efforts to control the salinity of this critical water resource.

This paper outlines the sources and distribution of salinity within the Colorado River basin; identifies some current and potential actions to control salinity; and describes some of the lessons learned based upon several salinity control case studies in the Upper Colorado River.

Cooperative programs to address salt-loading in the Colorado River system began more than 30 years ago. These salinity control efforts have addressed both naturally-occurring and human-induced sources of salinity by targeting the improvement of irrigated agriculture, reducing inefficient water practices and controlling natural point sources. Primarily federally-funded, with local and state cost share components, salt control efforts have focused on minimizing deep percolation by increasing the efficiencies of both off-farm delivery systems (e.g., piping and lining ditches and canals) and on-farm application techniques (e.g., conversion to highly efficient sprinkler systems). Additionally, the program has identified opportunities to control natural sources, such as the capture and/or diversion of saline springs and seeps.

The Colorado River Basin, shown in Figure 1, is situated in a diverse regional geologic setting, consisting of three general physiographic provinces: Rocky Mountains, Colorado Plateaus, and Basin and Range. The drainage basin is bound at its upper reaches by mostly crystalline igneous and metamorphic rocks at its headwaters in the Rocky Mountains along the continental divide. The mountains yield to primarily sedimentary rock-dominated plateaus as the river progresses down gradient into the Colorado Plateaus and Basin and Range provinces. Naturally-occurring saline springs can occur throughout the basin and ancient marine deposits of Paleo- and Mesozoic ages provide a vast source of potential salinity. When water is applied to this salt-rich material, it mobilizes and transports salts and trace elements, through dissolution and surface runoff, as well as deep percolation into the ground water system, which can then discharge into the river system.

The Upper Colorado River Basin upstream of the Colorado state line contains both significant natural and human-induced salt loading sources and is responsible for approximately one half of the median annual dissolved-solids load as measured below Lake Powell at Lees Ferry, Arizona (Anning, 2006). Further inspection of these modeled data suggests that approximately 15% of the median salt load at Lees Ferry is attributable to two large irrigation districts in Western Colorado. When combined with the Dotsero-Glenwood Springs complex of natural springs and the Paradox Valley evaporite contributions to groundwater, this percentage increases to 26 percent.

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1 English tons; all units of measure referenced in this paper are English units.
Figure 1: The Colorado River Basin supports 30 million people in the Southwestern United States and Mexico. Although most salinity impacts are felt in the lower basin, where the majority of the population lives, most salinity control efforts are focused in the Upper Basin where the primary salt sources are located.

Due to these significant salt loading percentages, salinity control efforts have focused on these areas and recent studies confirm that salinity control activities in the Lower Gunnison River, the Grand Valley and the Dolores River of Colorado may have reduced median annual salt loads by 531,400 tons/year (Anning, 2006). When compared to total human-induced and controllable sources, this represents a reduction of between 25-55% of the median salt load from these sub-basins.

Specifically, it has been found that salinity loading can be cost-effectively controlled by sealing earthen canals (e.g., installing membrane lining, piping irrigation laterals and/or application of low permeable materials) and converting to highly efficient irrigation practices. The Uncompahgre River Valley (approximately 70,000 irrigated acres) and the Grand Valley (approximately 60,000 irrigated acres) in Western Colorado are salt-rich areas that historically relied upon a large network of earthen canals to distribute large volumes of water over long distances from mainstream diversions to fields that previously utilized low efficiency flood irrigation techniques for a growing season that can extend from March to October.

With federal and state financial assistance, these agricultural producing areas have begun to modernize and salt reduction benefits are becoming realized. Piping of irrigation laterals with PVC is considered to be at least 90 percent effective in reducing water loss to deep percolation. It has also been found that treatment of main canals with water-soluble polymers, such as polyacrylamide or PAM, can be a cost effective alternative to reducing deep percolation from water delivery systems.

Reduction of deep percolation results in a direct reduction of salt-loading to the river and has been documented by several studies. A demonstration project in the Uncompahgre River Basin near Montrose, Colorado was conducted in 1998–2000 to determine the effects on salt loads in a small drainage basin, by replacing 8.5 miles of open-ditch irrigation laterals with 7.5 miles of pipe. The salt load due to deep percolation at the outflow site was approximately 1,980 tons per year less in the post-project period than in the pre-project period, a reduction of approximately 11 percent. When surface water impacts are considered, the salt loading
reduction was 2900 tons per year, a reduction of 16 percent of the pre-project salt load (Butler, 2001).

The conversion to highly efficient irrigation techniques (e.g., center pivots, microjets and drip tape) in Western Colorado has been demonstrated to be a highly effective method of reducing salt-loading to the Colorado River. The United States Natural Resources Conservation Service (US NRCS) estimates that conversion of on-farm flood irrigation to sprinklers can eliminate up to 85 percent of induced deep percolation due to inefficiency (NRCS, 2006).

Another significant contributor to deep percolation, and therefore to salt loading, in Western Colorado is pond construction for water storage. Up to 12 percent of the salt loading to the Uncompahgre River can be attributed to leaky ponds that percolate through the saline subsurface and discharge to the river system (USBR, 2004). The proliferation of ponds is increasing due to urbanization as landowners install small water bodies and water features for primarily aesthetic purposes. To address this issue and reduce saltloading impacts, the introduction of low permeability liners has been proven to be successful. The use of both compacted bentonite clay and geomembranes can effectively eliminate the majority of deep percolation from ponds and are a cost effective solution to reduce salt loading to the Colorado system.

Increasing population and changes in land use have had confounding effects upon salt loading in the Upper Colorado River Basin. Preliminary results from an on-going study indicate that conversion of areas from agricultural to residential uses can reduce deep percolation and related salt loading (Mayo, personal comm., 2007). However, in some areas where land subdivisions have caused large agricultural practices to be reduced into smaller ‘hobby ranchettes,’ it is feared that inefficient water may increase as a result and salt loading may increase. The most significant potential impact of residential growth is in areas that previously have not been irrigated or disturbed. As water is applied to these ‘virgin’ areas via landscape irrigation or even septic systems, a new source of salinity is mobilized that can increase salt loading to the river basin.

Use of Geographic Information Systems (GIS) have proven to be an effective tool in helping manage and target areas for additional water conservation practices and for land use planning to reduce deep percolation. For example, in the Lower Gunnison River Basin, an effort to compile a comprehensive GIS database on land and water uses, soil chemistry and physics and irrigation techniques has begun. When combined with accurate geolocation data, acquired using global positioning systems (GPS), of the vast distribution of irrigation and conveyance improvements, these data will provide planners and policy makers with better information upon which to base educated decisions. It is hoped that this information can be used by local entities to plan for projected future growth with the intent of reducing salinity loading and to minimize related downstream adverse water quality impacts.

Additionally, it is hoped that GIS/GPS will be an aid in the implementation of new technologies. This is especially true in areas where optimal topography can be identified and incorporated into water diversion structure redesign to take advantage of hydrostatic pressures to implement low power, highly efficient sprinkler technologies. It is hoped that some ancillary benefits such as the potential to produce micro hydroelectricity to off set costs can also be attained in the future.

References Cited:
