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USDA Planning Process for Colorado River Basin Salinity Control

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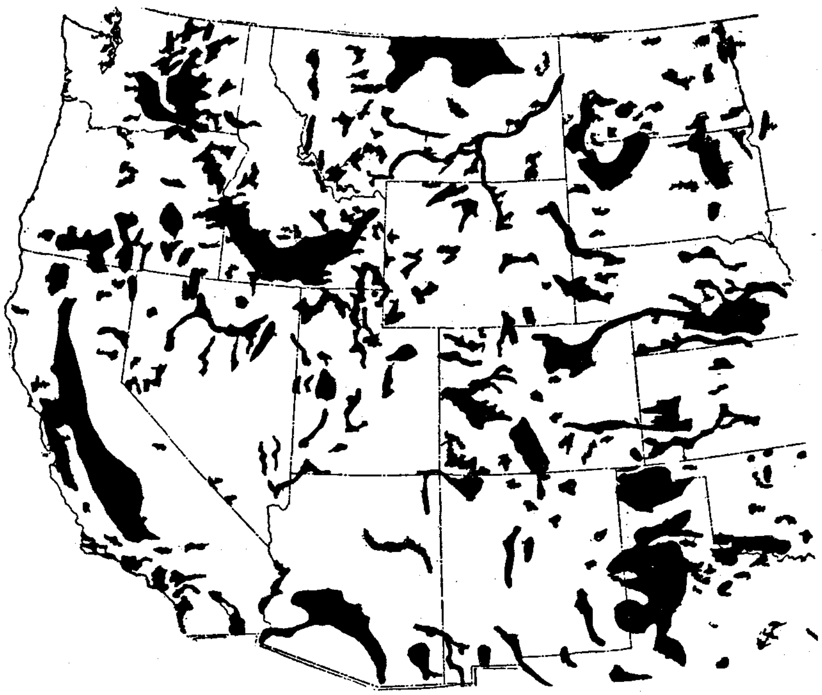
INTRODUCTION

The demise of a number of ancient Mesopotamian civilizations dependent on irrigation, as well as the abandonment 700 years ago of agricultural settlements in the American Southwest, have been traced to salt buildup, drought, and/or erosion. Even today, 550,000 acres (222,750 ha) of irrigated land are going out of production each year due to salt buildup in arid land regions of the world [1]. Cooperative planning by USDA with state and federal agencies has been underway since 1973 to reduce salinity problems in the Colorado River Basin. The experience gained in planning and implementing onfarm salinity control measures will prove valuable in other parts of the country--valuable enough to save dollars, time, farms, and perhaps even portions of our present civilization.

The most important beginning point in any planning effort is to accurately locate and define the magnitude of the problem. Salinity problems are not just a concern for those in the Colorado River Basin. Every state in the West has some high water table problems. Associated with high water table, in many cases, is a soil salinity problem which affects crop production on 10,300,000 irrigated acres (4,171,000 ha) [3]. Salt concentrations are increasing steadily in some of the nation's most productive soils. The rich San Joaquin Valley in California could eventually lose 2 million acres (810,000 ha) to salinization [4]. Other areas with significant problems include the valleys of the Rio Grande and Pecos River, closed river systems in the Great Basin, the Arkansas River, tracts in Texas and Oklahoma, and tributaries of the Upper Missouri. Figure 1 displays the widely dispersed and serious salinity problem. Most commonly, it is associated with irrigated agriculture.

Figure 1. Salt affected cropland soil. Source: Modified from an unpublished draft map by C. A. Bower, 1960's.



THE COLORADO RIVER PREDICAMENT AND PROGRESS

Salinity has long been recognized as one of the major problems of the Colorado River, but in the early 1960's the amount of water delivered to Mexico fell dramatically and the quality deteriorated. In 1964 the Colorado River dried up as it went from the Mexicali Valley of Mexico to the Gulf of California. The river was and still is essentially consumed. Mexico gets the last 10 percent of the Colorado River water to irrigate about 450,000 acres (182,000 ha) of crops and to provide municipal water to about 1.5 million people. The clear snowmelt water originating 1,500 miles (24.15 km) upstream in the Rocky Mountains picks up about 10 million tons of salt a year as it traverses the seven basin states.

Man-caused increases in salinity result from the diversion, consumptive use, and salt loading in return flows. The largest man-induced increase in salinity is caused by the concentrating effect of irrigated agriculture and salt loading associated with it. About 2.6 million acres (1.0 million ha) are irrigated in the Colorado Basin.

A salinity control program to benefit water users in the U.S. as well as Mexico was authorized in the Colorado River Basin Salinity Control Act, Public Law 93-320. The U. S. Department of Interior (USDI) was assigned leadership responsibility and the Bureau of Reclamation (BR) was delegated as the agency to carry out the program. Specific cooperative investigations are conducted under a Memorandum of Understanding between USDI and USDA and Memorandum of Agreement between SCS and BR.

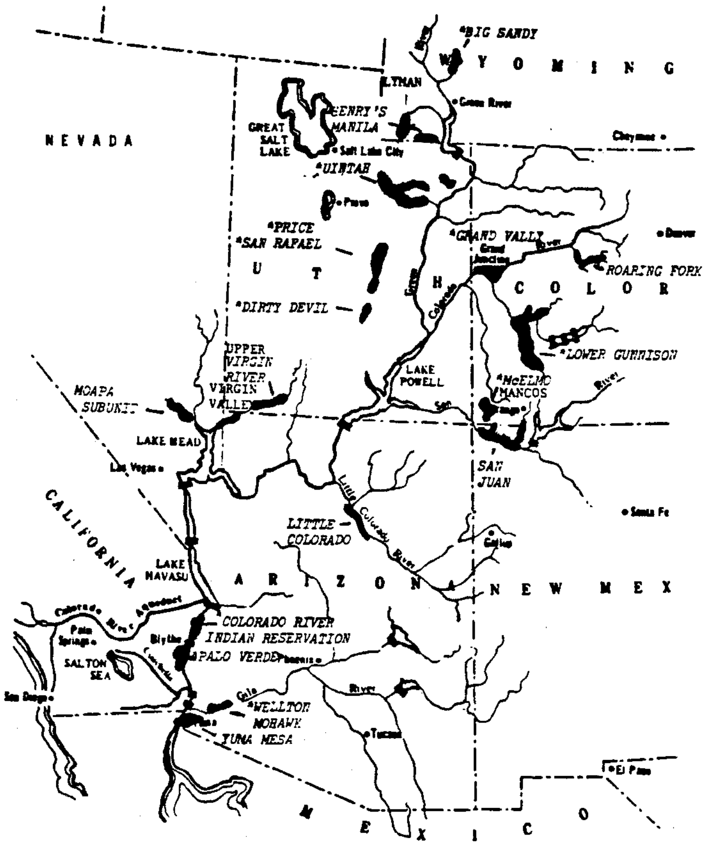
The Act has two major components. Title I is to facilitate water delivery to Mexico of the quantity of water agreed to in 1944 Compact and at the quality standard agreed to August 30, 1973, by Minute 242 of the International Boundary and Water Commission. Title I of the Act includes reducing and treating drainage return flows from the Wellton-Mohawk Irrigation and Drainage District near Yuma, Arizona. The second component of the Act (Title II) deals with the salinity contribution to the river above Imperial Dam and the program necessary to meet U.S. water quality standards while the Basin States continue to develop their compact-apportioned waters.

Specifically, Title II authorized the construction, operation, and maintenance of four salinity-control projects, including the Grand Valley Unit, Colorado; and the expeditious completion of planning reports on 12 other units above Imperial Dam on the Colorado River. For the Grand Valley Unit, Title II states: "The Secretary of Agriculture is directed to cooperate in the planning and construction of onfarm system measures under programs available to that Department." United States Department of Agriculture (USDA) planning reports were completed for the Grand Valley and Uinta Basin in Utah, and USDA implementation and installation of onfarm salinity control measures began in 1979 in the Grand Valley and in 1980 in the Uinta Basin.

The 12 agricultural units studied were those that appeared to have the greatest opportunity to reduce salinity by improving onfarm irrigation systems and management. During the last ten years, SCS has taken the lead to develop USDA plans and reports and has planning completed or in progress in Arizona, California, Colorado, Nevada, New

Mexico, Utah, and Wyoming. Figure 2 shows irrigation salt source areas having potential for salinity control with USDA programs.

Figure 2. Agricultural irrigation salt source areas.



* Identified in PL 93-320

Table 1 shows the planning accomplished and underway, and some key findings.

Table 1. USDA Colorado River Basin Salinity Control Program

Salinity Unit	Planning	Irrigated Area		Potential Salt Reduction
		(acres)	(ha)	(tons)
Wellton-Mohawk, AZ (5)	1973 - Sep. 1974	65,000	26,300	100,000 acft[1]
Yuma Mesa, AZ	Preliminary Eval.	26,000	10,500	80,000 acft[1]
Grand Valley, CO (6)	1973 - Dec. 1977	65,000	26,300	130,000
Lateral Supplement (7)	1979 - Jan. 1980	-	-	100,000
Uinta Basin, UT (8)	1976 - Jan. 1979	205,000	83,000	77,000
Martin Lateral, UT (9)	1978 - Jun. 1981	3,000	1,200	3,000
Big Sandy, WY (10)	1977 - Nov. 1980	16,000	6,500	113,000
Moapa Valley, NV (11)	1978 - Feb. 1981	5,000	2,000	19,000
Little Colorado Rvr, AZ (12)	1978 - Dec. 1981	35,000	14,200	(small)
Lower Gunnison, CO (13)	1977 - Sep. 1981	183,000	74,100	335,000
Virgin Valley, NV,AZ,UT (14)	1980 - Mar. 1982	5,000	2,000	37,000
McElmo Creek, CO (15)	1978 - Feb. 1983	29,000	11,700	38,000
Mancos Valley, CO	1982 - (1984)	(9,000)	3,600	(9,000)
Price-San Rafael, UT	1977 - (1984)	(52,000)	21,100	(122,000)
Colorado Rvr Indian Res., AZ, CA	1979 - (1985)	(75,000)	30,400	(small)
Palo Verde, CA	Draft POW- (1987)	(94,000)	38,100	(75,000)

[1] Return flow reduction

GENERAL PLANNING REQUIREMENTS

Typically, SCS responds to requests for technical assistance from farmers and ranchers to offer solutions to onfarm problems, but the Colorado River Basin Salinity Program is unique within the Soil Conservation Service (SCS) and USDA. The international objective is to plan and implement an onfarm irrigation program which is most cost effective to reduce downstream salinity damages in the Lower Colorado Basin and Republic of Mexico.

Many interagency and USDA staff meetings were held to clarify and define objectives and obtain public participation in view of the National Water Resources Council's Principles and Standards. The following agreements were reached and followed in USDA studies:

1. Defining Clear Objectives

The objective is salt load reduction by achieving water conservation with improved onfarm irrigation water management practices. This achieves both national economic development and protects the environment. The objective can be defined in the national water resources planning framework in two parts as follows:

National Economic Development (NED) - Reduce downstream salinity damages and increase the efficiency of onfarm agricultural production.

Environmental Quality (EQ) - Improve water quality by reducing salinity and achieve water conservation while minimizing adverse effects on fish and wildlife habitat in irrigated areas.

2. Obtaining Public, Farmer, and Agency Participation

Federal and state agencies worked together in frequent meetings to develop plans to solve our international salinity issue. Farmers and the public are working to reach mutual agreements on the use and management of land and water resources, and an understanding of the tradeoffs between onfarm agricultural production and downstream salinity values. Farmers and ranchers are in control of their own destinies and proposed improvement in irrigation systems to reduce salinity must fit practical farm operations and be an integral part of an economically profitable farming operation. Farmers participate throughout planning, as a result they assume responsibility for carrying out decisions. In each salinity unit, a local coordinating committee has been officially formed to guide the study, hold public meetings, and distribute information. Conservation districts have assumed a leadership role in obtaining public participation for USDA planning activities.

THE PLANNING PROCESS

Once the general planning requirements were established, USDA guidelines were prepared for field staffs to use in developing plans for each unit. The process follows basic planning steps. The planning process according to the Principles and Guidelines (16) consists of the following six major steps:

1. Defining the problem
2. Inventory and Analysis
3. Formulation of alternative plans
4. Prepare displays of effects
5. Comparison of alternative plans
6. Selection of recommended plan

Step One: Defining the Problem

It is easy to say the main problem is downstream salinity. It is more difficult to quantify the salinity problem.

The largest man-induced increase in salinity is caused by the salt loading associated with irrigated agriculture. The salinity problem takes into account the international implications with Mexico and treaty obligations. Specific state and local concerns relate to meeting the United States water quality (salinity) standards while the basin states continue to develop their compact allocated water.

Salinity causes millions of dollars of damage to water users of Colorado, Utah, Arizona, Nevada, California, Wyoming, New Mexico, and the Republic of Mexico. It has been estimated that an increase of 1 mg/l of salt loading at Imperial Dam costs downstream water users in 1983 dollars approximately $540,000. Stated in another way, each ton of salt causes $54 worth of downstream damages [2]. Increasing salinity of the Colorado River limits crop production in such highly productive areas as the Imperial Valley which had a half billion dollars in annual sales according to the 1974 Census of Agriculture.

Individual farmers who perceive the problem of reduced yields and high production costs can be helped by the same water conservation efforts needed to reduce salinity.

Step Two: Inventory and Analysis

The potential for onfarm practices to alleviate the salinity problem was determined during inventory and forecasting. The inventory of individual onfarm irrigation management has been the greatest challenge in making field surveys. Important analysis procedures used to evaluate present and future conditions are described in step three.

Step Three: Formulation of Alternative Plans

This requires a determination of treatment opportunities. Technical guides at SCS field offices list alternative irrigation systems and practices that are adapted to specific site conditions. Then alternative plans are formulated and a determination made to measure the contribution each practice makes toward solving the salinity problem. Acceptable alternative plans can be formulated only if plan elements and effects are determined in physical, environmental, and economic terms described as follows:

Physical Analysis

The Soil Conservation Service at its West National Technical Center in Portland has developed several programs to analyze farm irrigation by the furrow, level border, graded border, and contour ditch methods. Programs are based on procedures developed by SCS and published in Chapter 4, Graded Borders and Level Basins, of Section 15, Irrigation, National Engineering Handbook (NEH). Analysis is also based on Chapter 5, Furrows and Corrugations, of Section 15, NEH, and unpublished procedures for contour ditch analysis. One program developed specifically for the salinity program and used in planning seven of the units is the "Irrigation Methods Analysis Program" called IRMA. The IRMA program provides the user an automated data processing technique to quickly, accurately, and economically examine present conditions and evaluate the effects of any number of alternatives such as: (1) Adjusting flow rate or time of set needed to maximize application efficiency and reduce deep percolation and surface runoff, (2) Changing field grade and/or length of run for surface methods, and (3) Changing the method of irrigation.

The program summarizes (1) unit values for each irrigation and annual values of gross water applied, net water to supply crop consumptive use, deep percolation, and surface runoff; (2) structural needs and cost for each field; and (3) annual values of the above for farms or ranches, subproject areas, or project areas, or by crops, soils, canals, etc., as desired by the user.

The determination of seepage and deep percolation reduction is the key to analysis of impacts on salinity. Water and salt budgets are developed to evaluate the effect of irrigation practices on salinity. Most of the saline aquifers underlying the soils have an unlimited salt supply and subsurface return flows will continue to return to the river at about the same concentration as before the improvement program. Each acre-foot (1233m^3) of deep percolating water picks up one to ten tons of salt while in transit back to the river system. The actual amount depends on which subarea is being evaluated. If irrigation systems or water management is improved and irrigation water does not seep

from ditches or percolate from fields into the saline aquifer, salt loading will be reduced proportionally to the reduction in deep percolation and seepage volumes. The USDA analysis is based on our technical ability to accurately estimate the amount of reduction in seepage and deep percolation that occurs with onfarm irrigation improvement and translate this into salinity changes. SCS has worked very closely with the Bureau of Reclamation, which is maintaining a basin-wide model to balance water and salt contributions from each study unit.

Economic Analysis

The economic procedure used to evaluate the salinity program is very similar to those used to evaluate other kinds of water and related land resource developments. Since benefits accrue to two groups, the onfarm water users and the downstream water users, it is important that the magnitude of the benefits accruing to both groups be determined. It is also important to analyze several levels of resource development so that the optimum scale of development can be determined.

Throughout the formulation process, the physical effects of each alternative must be measured and translated into economic terms so that the benefits from each alternative can be compared with its cost.

The optimum level of development can be identified by determining the point of maximum net benefits. Net benefits are maximized when incremental benefits equal incremental cost.

Farmers and ranchers are installing irrigation systems and improving management to reduce labor, energy, fertilizer, and cost of production, conserve short water supplies, and increase yields. In Wellton-Mohawk between 1975 and 1982, 327 applications for assistance were received, in Grand Valley between 1979 and 1982, 1,400 separate requests for assistance have been received, and in the Uinta Basin between 1980 and 1982, 406 applications for assistance were received. The onfarm cost effectiveness of water conservation is the catalyst to obtain farmer participation, while the reduction of downstream salinity damages is realized to the nation.

Environmental Analysis

Planning requires a comprehensive assessment of all natural and human resources and their values. Several environmental concerns and impacts can be identified within a program to improve irrigation water use and management. Improvement in irrigation water use and management to obtain water conservation, make full use of limited water supplies (particularly in time of drought), augment instream flows for fish and wildlife, and reduce downstream water salinity could adversely affect wildlife in artificially created wetlands along canals or within irrigated farms. Improving irrigation could adversely affect riparian vegetation and associated wildlife.

Planning included complete assessment of all the environmental elements (fish and wildlife, threatened and endangered species, cultural resources, prime farmlands, etc.), identification and measurement of the impacts of proposed actions, and a display of the options and tradeoffs. The choices within the environmental sector between salinity and fish and wildlife can then be evaluated by water users, the concerned public, and state and federal agencies.

The SCS and the Bureau of Reclamation published a joint Environmental Impact Statement on the cumulative impacts of the Colorado River Basin Salinity Control Program (17). On individual units, the USDA onfarm program is covered in the EIS prepared by the BR for the Wellton-Mohawk Irrigation and Drainage District in Arizona. The USDA onfarm program for Grand Valley, Colorado is addressed in an EIS prepared by the BR. A detailed evaluation of irrigation - induced wetland was made on the Lower Gunnison River Unit (18). The SCS prepared an EIS for the onfarm and associated lateral portion of the Unita Basin in Utah and the Lower Gunnison River Unit in Colorado (19). The BR also prepared an EIS for the Lower Gunnison Basin. Other environmental documents are now being prepared for the onfarm portion of the Moapa unit in Nevada, and the Virgin unit in Arizona, Nevada, and Utah.

<u>Steps Four and Five</u>: Prepare Displays of Effects and Compare Alternative Plans.

A summary display of significant physical, economic, environmental, and social effects is needed to readily identify the tradeoffs between alternatives. The alternative plans were analyzed to identify which plan tends to:

1. Maximize net onfarm monetary benefits.
2. Maximize net off-farm or downstream benefits.
3. Maximize total (onfarm an downstream) net monetary benefits.
4. Maximize water conservation.
5. Maximize salinity reduction.
6. Minimize adverse environmental effects on fish and wildlife.

Table 2 summarizes the results of four alternative plans very similar to plans already approved. Salt load and salinity concentration reduction and off-farm monetary benefits are used to illustrate salinity improvement.

Summarizing the results of alternative plans in this manner provides a full disclosure of the benefits and costs of the alternatives considered and also provide a basis by which all interest groups can make their decisions on

Table 2. Summary comparison of alternative plans

	ALTERNATIVE PLANS			
Item	A	B	C	D
	National Economic Development			
Annual Benefits				
Onfarm	$ 115,000	160,000	175,000	180,000
Off-farm	$ 100,000	150,000	180,000	190,000
TOTAL	$ 215,000	310,000	355,000	370,00
Annual Cost	$ 100,000	140,000	160,000	180,000
Total Net Benefits	$ 115,000	170,000	195,000	190,000
Net Benefits to Specific Sectors:				
Onfarm[1]	$ 15,000	20,000	15,000	0
Off-farm[2]	$ 0	10,000	20,000	10,000
Cost Effectiveness $ per mg/l reduction	$ 250,000	516,700	507,000	462,500
	Environmental Quality			
Salinity Concentration Reduction @ Imperial Dam (mg/l)	.4	.6	.7	.8
Salt Load Reduction (tons)	4,000	6,000	7,200	7,600
Loss of Wetland (acres)	100	140	160	180
(ha)	(40)	(57)	(65)	(73)
Onfarm Irrigation Efficiency (%)	58	71	78	81

1 Net benefits accruing onfarm when all costs are borne by onfarm interests.
2 Net benefits accruing off-farm when all costs are borne by off-farm interests.

salinity control. Different program decisions will be made depending on how different economic indicators are weighted. Plan A would obtain a nominal amount of salinity reduction at least cost per unit. Plan B would maximize net benefits to the farmer. Plan C would be the NED Plan and maximize total net benefits. Plan D would maximize salinity reduction downstream.

Step Six: Selection of Recommended Plan

A plan of conservation measures is then selected which includes consideration of acceptability by local farmers and ranchers and the obligation to meet national and international water conservation and interstate water quality goals. The recommended onfarm irrigation program includes structural onfarm improvement measures, improved irrigation water management, technical assistance, and cost-share support. In the example in Table 2, Plan C--the NED Plan--would be the plan that USDA recommends for implementation. In addition, it also provides nearly maximum salinity reduction and farmers receive some benefits. The Principles and Guidelines state that an exception would be required if Plan C were not selected.

DEVELOPING AN IMPLEMENTATION PLAN

Several ongoing programs are providing technical and financial assistance to improve irrigation systems and management. Implementation plans will generally include the identification of financial and technical assistance available to the land owner or operator. USDA salinity programs are funded by a variety of authorities.

The Wellton-Mohawk USDA program is fully funded through a transfer of funds from the Bureau of Reclamation. About $15 million in funds have been transferred since 1975 to USDA to cover technical assistance, federal cost-sharing of irrigation practices, research, and extension. Through 1982, 26,400 acres (10,700 ha) have been treated with onfarm improvement practices and complete irrigation water management. About 33,400 acres (13,500 ha) have been or are under contract. Monitoring and evaluation of these improvements has shown that deep percolation has been reduced about 2 acre-feet per acre (6089 m^3/ha).

The Grand Valley and Uinta Basin farmers are receiving Agricultural Conservation Program (ACP) funds from USDA to cost-share onfarm salinity control practices. Funding levels have been about $2 million each year for 1980-82 in the Uinta Basin and $1.7 million each year for 1979-82 in the Grand Valley Unit. Technical assistance by SCS has been through targeting our ongoing programs to these areas. Funding for 1983 for these three units is $7.3 million.

In addition, a land treatment plan (9) was developed on Martin Lateral in the Uinta Basin. Nearly one million dollars in federal funds have been targeted to this area for onfarm irrigation improvement under the PL-566 watershed program.

Implementation of a long-term monitoring and evaluation plan (20) of onfarm improvements is being undertaken this year. The monitoring will evaluate a cross-section of various onfarm irrigation systems and will serve as a basis for determining program impacts. The evaluation will include an estimate of impacts of implementation on water management, deep percolation, salt load reduction, wetland and wildlife habitat, and agricultural monetary returns.

CONCLUSION

The planning and implementation of a Colorado River Salinity Control Program during the last decade has changed the course of history and reversed the degradation of the finite Colorado water supply by salinity. Important policy and costly decisions are being made in attempts to mitigate the impacts of salinity. It is absolutely essential to USDA planning and implementation that the plans with greatest net benefits and with acceptable onfarm practices be selected from a broad array of opportunities. USDA salinity control planning of needed onfarm irrigation improvements on individual units is essentially completed. Implementation is progressing on 3 of the 12 units.

The USDA onfarm salinity control program is receiving positive reviews for cost-effectiveness, and the planning experience gained in this activity will be most helpful in formulating and justifying future salinity control programs. This planning experience should provide know-how to help irrigated agriculture overcome the salinity problem and not follow past civilizations into oblivion.

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