SALINITY MANAGEMENT OPTIONS FOR THE COLORADO RIVER

Damage Estimates and Control Program Impacts

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ABSTRACT

Rivers draining arid basins increase in salinity content in the downstream area to the point where water users are often significantly damaged. The problem in some cases can be ameliorated by altering upstream water and land use practices. An economic trade off exists between the cost of such upstream efforts and the downstream benefits achieved. This report examines options for salinity management in the Colorado River Basin.

The study sought to provide additional information to estimate 1) economic damages caused by various salt concentrations to agricultural and municipal water users and 2) economic costs of salinity control measures by upstream water users. Damages were estimated for high salinity levels to provide guidelines to project future conditions. Control costs were estimated with a physical model developed to predict the response of soil, water, and crop factors. Input-output models were used to estimate indirect economic impacts.

Agricultural damages for each milligram per liter of salt concentration at Imperial Dam in the 900 to 1400 range were estimated to be $33,100 annually. Of the total, $28,200 are in the Imperial Valley and decreasing amounts occur respectively in the Palo Verde, Yuma, Colorado River Indian Reservation, San Diego, Coachella, and Central Arizona areas. Salinity caused damages to plumbing and appliances in the Los Angeles area were estimated to be about $112,000 per mg/l. Comparable estimates were $11,200 for Central Arizona and $11,400 for the Las Vegas area. As for controlled costs, 80 percent of the initial salt load could theoretically be at an incremental cost of less than $2.20 per ton. The comparison of the reduction measures showed on-farm practices to be the least expensive alternative for reducing salinity. Based on an approximation that 1 mg/l at Imperial Dam is equivalent to 10,000 tons of salt, the above estimated benefits of salinity reduction would be about $17 per ton. Salinity control projects at Paradox Valley and acreage retirements in the Grand and Uncompaghre Valleys were found to be economically justified but lining the Grand Valley Canal was not.

The above estimates are approximations obtained from available data and can be improved by further studies to cover additional cost and benefit effects or by more comprehensive data on the effects covered.

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PREFACE

Water in the Colorado River becomes increasingly saline from the headwaters to downstream reaches. Upstream agricultural and municipal water uses affect the quantity and salinity of water available to downstream users, and that quantity and salinity affects the value of the water for downstream users. In effect measures to reduce the salinity of upstream flows benefit those downstream by reducing salinity damages to agriculture and municipalities. The purpose of this study was to provide information on costs of implementing proposed upstream salinity control measures on the Colorado River and on benefits of reduced damages to downstream water users.

The study addressed a wide variety of economic effects in order to make these estimates. Researchers were often faced with uncertain data. Some of the data used in the study has been changed by more recent findings even while the report has been in preparation and publication. Other quantities are still a legitimate matter of debate.

As an example of the problems encountered, "indirect costs" were suspected to be a significant component of total costs for remedial measures. At the same time, it was recognized that a definitive study of indirect costs would be outside the scope of time and effort provided by the project budget. Believing that it would be better to bring the subject into focus rather than to ignore it altogether, Professor Howe was called upon to undertake this part of the study. It was fortunate that Professor Howe was able and willing to do it because he had already completed several studies of a closely related nature covering the Colorado River Basin. His challenge was to adapt his previous studies and the analytical tools developed in them, along with results of relevant studies by others, to the specific questions of the salinity control remedial program. The principal investigators would like to compliment him on an outstanding product.

It must be pointed out, however, that his effort was under serious constraint by the fact that the details of salinity control remedial measures to be implemented in the upper basin were not known. It was therefore necessary to make certain assumptions concerning possible remedial measures and their costs. Furthermore, it seemed the purpose of the project would be best served by assuming sufficient precision in the available data in order to introduce a sequence of forward linkages into the analysis. Thus, it was possible to indicate the nature and relative magnitude of indirect costs in a more comprehensive way than would otherwise be possible.

The reader is therefore cautioned to view the indirect cost estimates as no more than illustrative of the nature and magnitude of such costs. More definitive estimates would require 1) fully identified remedial measures and a quantitative understanding of their effectiveness in reducing salt load, and 2) a very expensive and time consuming field data collection effort. The investigators feel that such a study should be made, but that it is unlikely that both the foregoing conditions can be met. In the first place, remedial measures are being planned incrementally rather than as larger projects. Uncertainties as to the effectiveness of some of the proposed remedial measures will probably not be resolved until they are actually tried. It is equally unlikely that Congress or anyone else will provide the level of funding necessary to accomplish a fully refined indirect cost assessment.

It seems, therefore, that the indirect cost of the Colorado River Salinity Control Program will remain in the realm of rough estimation, and/or speculation. The assessment of this project is presented here with the expectation that it will serve as a guide to decision-makers as the remedial program unfolds. The approximations provided should certainly be useful in tempering the judgment of planners and decision-makers.

The estimates of the direct costs of remedial measures should be conditioned with the same kinds of remarks. Here again, the specific remedial measures to be implemented in the upper basin were not identified at the time of the study, nor were accurate estimates available concerning the effectiveness of each measure. Rather than ignore important direct cost components in the total economics of salinity control, the investigators considered it profitable to incorporate a representative analysis. Again, inadequate funds were available to do more than this.

Much the same reasoning also pertains to the damage estimates. The principal thrust of this project is to examine damages due to additions of dissolved salts in the water of the Colorado River. The focus is therefore on agricultural and municipal/industrial water users in the lower basin. The major effort was invested in estimation of crop yield reduction in irrigated agriculture and of the municipal/industrial damages associated with salts in the water. The availability and willingness to participate of veteran scientists with previous experience in studies of this type in the lower basin states was a major factor in making it possible for this study to achieve as much as it did.

CHAPTER I

INTRODUCTION

Control of the salinity in large river basins in arid areas is an interesting and difficult challenge to policy makers. All rivers contain dissolved salts acquired by leaching from soils and substrata or from inflows of saline water from underground sources. Normal urban and industrial development in areas adjacent to river basins further contribute to the salinity concentration through evaporation in reservoirs and return flows from irrigation, urban, and industrial withdrawals. Increased concentrations of dissolved salts usually have a detrimental effect on production and costs. Such detriments affect agriculture, industry, and households most noticeably in terms of increased costs of operation. There is also an indication of some adverse health affects. Nowhere in the United States are the problems of salinity management more sharply defined than in the Colorado River Basin. Furthermore, the water of the Lower Colorado Basin, with constantly increasing levels of salt concentration, flows into Mexico.

It is imperative that measures to correct this problem are well-founded and based on sound concepts and information. It is contended that economic tools be employed to match the problem to policy decision criteria. Economically, the problem is that the well-being of some users of the river conflicts with the well-being of others. A perfectly competitive economy would yield allocation of resources such that no alternative pattern of resource use would make anyone better off without making someone worse off. It is evident that this ideal market situation does not exist in the allocation of water or in managing water quality for at least two reasons. First, prices do not correctly reflect the social value of resources and commodities. The individual decision-maker has no incentive to take all the costs or benefits into account in making a resource allocation decision. This implies that a misallocation of resources may occur. Second, producers of "public goods" such as improved water quality are unable to collect all the revenues from the beneficiaries, since users cannot be excluded for non-payment of price. Consequently, each user may expect to reap benefits from these public goods whether or not he pays the cost.

The salinity problem in the Colorado River exhibits both of these aspects of market failure. It is estimated that at least 50 percent of the salinity concentration in the river is due to external causes. This level of salinity, due to man-made influences, constitutes a negative externality imposed on downstream users. A private market approach would not succeed in attaining the most socially desired level of salinity because the producers of the improvements would be unable to collect the appropriate revenues from the downstream beneficiaries.

In this research, the various aspects of an economically efficient program are identified and measured. Models involving river hydrology, agricultural responses, municipal and industrial water uses, and interrelationships among these sectors are used to develop a socially optimal program. Irrigation management practices to control salinity problems are not discussed individually in this study but include the following methods: Ditch linings, soil management, salt leaching, and special bedding. This research will serve as a basis for evaluating a plan which has been submitted by the basin states to maintain salinity standards within the basin.

In order to determine a socially optimal management program, it was first necessary to estimate the losses due to the increasing levels of salinity.

OBJECTIVES

This comprehensive report of the salinity management options for the Colorado River was conducted with five specific objectives in mind. The first was to estimate the direct economic damages to agricultural users associated with specific alternative salinity levels in the basin water. The second was to estimate the direct economic damages associated with specific alternative levels of salt concentration for municipal water users in the basin. Objective three was to estimate the direct economic impact of possible salinity control measures on Upper Basin water users. The fourth objective was to estimate the indirect economic impacts associated with various salinity levels on agricultural, municipal, and industrial water users. Included in this objective was an estimate of indirect economic impacts associated with possible salinity control measures. The fifth objective was to express the results of the study in terms that would assist the United States Bureau of Reclamation (USBR) in economic evaluation of the alternative salinity control measures.

RESEARCH PROCEDURES

An approach was taken to evaluate the reaction of agricultural, municipal, and industrial entities to increasingly concentrated saline water found in the Lower Colorado River Basin. This included an examination of the response to high salinity levels in the past and a projection of these responses into the future to serve as a guide for salinity control proposals. An aggregation of damages and costs of corrective measures were examined. This study was designed to correlate new information and update past information in order to assist in decisions of alternative remedial measures.

The initial segment of the research was designed to estimate the direct agricultural damage due to various salinity levels. This included identification of the areas affected by the salinity problem, recognition of problem severity classes, definition of management alternatives, estimation of the cost of various management alternatives, estimation of yield responses due to specific salt concentration levels, and an aggregation of the agricultural damage function for the basin. Dr. Frank Robinson, Water Scientist, Imperial Valley Field Station of the University of California, and Dr. Ernest B. Jackson, Agronomist at the Arizona Agricultural Experiment Station served as co-leaders for the agricultural damage segment of the study. The United States Bureau of Reclamation (USBR), under the direction of Dr. Alan P. Kleinman, Chief, Economic Resources Branch, Lower Colorado Region, U.S. Bureau of Reclamation, conducted extensive research in estimating direct agricultural damages in the areas identified above. Their work, included in the study, summarizes much of the work submitted by Dr. Frank Robinson and Dr. Ernest Jackson and provides some estimates of the costs of crop losses due to various salinity levels.

In meeting the second objective of the study, research was conducted to estimate direct municipal and industrial damage. This involved the identification of the specific areas affected and the type of damage relevant to each. Management alternatives were defined and their respective costs were estimated, aggregated, and expanded to represent the basin. Two specific areas were identified and examined. Dr. Ralph C. d'Arge, University of California, Riverside and later at University of Wyoming, concentrated on two locations in the Los Angeles region of California.

Next, research was conducted to provide an estimate of the direct economic impacts of controlling the Upper Basin. Included was an examination of direct loading by agriculture, municipal, and industrial users, as well as natural diffuse sources. An estimation of the control costs for the specific levels of salt concentration was calculated. The research in this section was under the co-leadership of Dr. R.A. Young, Colorado State University, and Dr. Jay C. Andersen, Utah State University. Dr. Young examined the loading problems of the area, while Dr. Andersen was responsible for the development of two models to be used in estimating the direct economic impacts of the Upper Basin. A physical model was developed to predict the response of soil, water, and crop factors to irrigation, which was necessary to supply the basic data. Then an economic model was developed to predict the cost effectiveness of various programs. A multi-year analysis of management practices was subsequently developed.

The final segment of the study involved an estimation of indirect economic impacts. It was necessary to assemble input-output models and operate these models to obtain indirect economic impacts for specific levels of salt concentration. Dr. Charles W. Howe, University of Colorado, conducted this research.

Special appreciation is due Dr. Norman A. Evans, Director, Environmental Resources Center, Colorado State University, and Dr. L. Douglas James, Director, Utah Water Research Laboratory, and Director, Utah Center for Water Resources Research. They have given liberally of their time to correlate the work of the many researchers involved in this project.

Because of the tremendous size of the finding of this research, only summaries of the individual studies are included in the main body of the text. The complete reports are contained in the Appendices. Placement of the individual studies corresponds to the order of the objectives. The identification of the leader or co-leaders prefaces each report with a complete list of the contributors for specific study areas prefacing their respective reports in the appendices.

CHAPTER II

ESTIMATES OF AGRICULTURAL DAMAGES

INTRODUCTION

This chapter is limited to an estimation of crop yield losses due to increasing salinity of the irrigation water in areas below Lee Ferry served by the Colorado River. Areas presently receiving Colorado River water are considered in detail, and a few irrigation districts which might receive water from the Central Arizona Project are considered hypothetically. In the latter instance, some possible blends of Colorado River water with that presently supplied to the districts concerned are used for estimating the crop yields to be expected as the salinity of the Colorado River increases. Expected blends of Colorado River water with northern California water were used in estimating crop yields in the Pacific Coast area.

These estimates are based upon: 1) yield decrement to be expected for certain crops due to the salinity of the soil solution, as worked out by the U.S. Salinity Laboratory and modified by a University of California Committee of Consultants; 2) the salinity expected to develop in soils having a given infiltration rate and drainage capability and irrigated with water having a given salt content, as determined on the Imperial Valley Field Station: 3) soil drainage classes and acreages in the areas involved, as determined from maps of soil series and associations prepared by the U.S. Soil Conservation Service; and 4) annual crop reports of the irrigation districts.

In each irrigation district, the cropland was divided into "well," "moderate," and "poor" drainage classes (based upon infiltration rate and drainage capability) and equated to similar soils on the Imperial Valley Field Station for which mean salinity levels (electrical conductivity of soil extracts) to be expected had been established under irrigation with given water quality (TDS), given irrigation intensity, and best cultural practice for the soil. The principal crops were then partitioned on the different soil classes and projected on the basis of irrigation practice and expected salinity of the irrigation water as it progresses to about 1,200 mg/l TDS predicted for the river by the year 2000.

Estimates of yield reduction for a given crop were obtained by imposing the effective soil solution conductivity expected for the drainage class, salinity level of the irrigation water, and irrigation practice upon the yield declination curve supplied by the California Committee of Consultants. For the areas which receive all of their water from the river, crop yields were computed directly on the expected river salinities. For the areas which may receive water from the Central Arizona Project or the Metropolitan Water District facilities, yields were computed on salinities of possible blends of water with that presently available to the irrigation districts concerned.

Gila and Yuma Projects

The Gila and Yuma projects comprise a total of approximately 150,000 acres of irrigated cropland which was divided into 109,210 acres of well drained, 14,580 acres of moderately drained, and 25,020 acres of poorly drained soil (Appendix 1). Yield losses to be expected for the 10 major crops are projected on the basis of salinity level and irrigation method and summarized over soil drainage classes in Table 1.

Colorado River Irrigation Project
(Colorado River Indian
Reservation, Parker, Arizona)

A total of 105,734 acres of the Colorado River flood plain has been mapped and will be under cultivation within 15 years. Expected crop losses from increasing salinity are based upon this projection broken down into 57,096 acres of well drained, 32,778 moderately drained, and 15,860 poorly drained soil. Yield losses for the different salinity levels and irrigation methods, averaged over drainage classes, are shown in Table 2.

Central Arizona Project

The CAP is expected to deliver an annual average of 1,200,000 acre feet of Colorado River water from Lake Havasu through the Granite Reef Aqueduct to the area of Central Arizona generally between Phoenix and Tucson. The present indication is that the major portion of this water will be required for municipal and industrial uses. But for the purpose of indicating how the Colorado salinity might affect crop production if CAP water is used for agriculture, some probable allotments are assumed for irrigation

Table 1. Summary of yield losses in the Gila and Yuma projects due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice—thousand tons.

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Cotton 19,880 Ac.	16					0.10	0.29
Alfalfa Hay 33,410 Ac.	16	7.96	10.06	14.82	17.79	20.97	24.23
	22	5.87	7.96	9.89	12.83	15.82	18.80
	29	5.03	6.92	8.80	10.73	13.83	16.65
	35	3.77	5.24	6.92	8.38	10.48	12.41
	Sprinkler		2.51	4.82	6.29	8.17	10.06
Lettuce 13,250 Ac.	16	7.36	9.80	12.52	14.44	18.48	22.03
	22	4.73	6.85	9.08	10.84	14.62	19.05
	29	3.84	4.73	7.74	9.39	13.18	16.37
	35	2.80	4.05	5.39	7.08	10.22	13.31
	Sprinkler		1.87	3.53	4.88	6.43	8.33
Cantaloupes 7,630 Ac.	16	2.42	3.31	4.51	5.85	6.66	7.78
	22	1.69	2.42	3.16	3.82	4.87	5.89
	29	1.32	2.06	2.79	3.38	4.23	5.16
	35	0.88	1.47	2.06	2.64	3.38	3.96
	Sprinkler		0.44	1.25	1.83	2.50	3.23
Wheat 29,060 Ac.	16		0.18	0.54	0.84	1.20	1.56
	22			0.12	0.48	0.72	1.02
	29				0.24	0.54	0.84
	35					0.24	0.48
	Sprinkler						0.18
Grain Sorghum 12,130 Ac.	16	0.06	0.19	0.32	0.43	0.56	0.71
	22		0.06	0.17	0.26	0.39	0.50
	29			0.11	0.20	0.32	0.43
	35				0.09	0.20	0.30
	Sprinkler					0.07	0.19
Grapefruit 2,300 Ac.	16	0.06	0.13	0.23	0.33	0.44	0.53
	22			0.07	0.13	0.21	0.30
	29			0.02	0.07	0.14	0.21
	35					0.02	0.07
Oranges and Tangerines 17,600 Ac.	16	0.21	0.47	0.65	1.20	1.67	1.96
	22			0.26	0.47	0.78	1.64
	29			0.08	0.26	0.52	0.78
	35					0.08	0.26
Lemons 10,700 Ac.	16	0.39	0.88	1.62	2.26	3.04	3.68
	22			0.49	0.88	1.47	2.06
	29			0.15	0.49	0.98	1.47
	35					0.15	0.49

districts supplied by the Salt River and San Carlos projects, and for one small independent district which is supplied entirely from groundwater.

Salt River Project

In 1973 the SRP supplied full irrigation service to 120,136 acres of Salt River Valley Water Users Association crop land, and supplemental irrigation to 16,249 acres of crop land outside of the SRVWUA under special contracts. In addition to this service, 5.6 percent of the surface water diverted at Granite Reef Dam went to the Roosevelt Water Conservation District which irrigated 28,188 acres.

The average annual flow of the Salt and Verde Rivers is approximately 850,000 ac ft with an average quality of 467 mg/l TDS. Average annual groundwater pumpage is approximately 200,000 ac ft with an average quality of 980 mg/l TDS. The normal SRP water supply, therefore, is approximately 1,050,000 ac ft with an average TDS of 565 mg/l. If the SRP were given an annual allotment of 150,000 ac ft as the Colorado River salinity increased from the current 775 mg/l above Parker Dam to about the expected 1,200 mg/l, the resulting CAP-SRP blend would go from 591 mg/l to 660 mg/l TDS.

Table 2. Summary of yield losses on the Colorado Indian Reservation lands due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice, projected on the basis of completed project acreage.

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Alfalfa Hay	16	5.41	9.24	13.97	17.50	21.17	24.59
(1000 Tons)	22	3.99	5.41	7.15	10.24	14.21	17.75
28,490 Ac.	29	3.42	4.70	5.98	7.71	11.56	14.78
	35	2.56	3.56	4.70	5.69	7.11	8.85
	Sprinkler		1.71	3.27	4.27	5.55	6.83
Cotton	16					0.11	0.39
(1000 Bales)							
25,510 Ac.							
Wheat	16		0.13	0.39	0.61	0.86	1.12
(1000 Tons)	22			0.09	0.26	0.52	0.65
20,520 Ac.	29				0.20	0.39	0.61
	35					0.20	0.35
	Sprinkler						0.13
Grain Sorghum	16	0.04	0.08	0.20	0.27	0.36	0.49
(1000 Tons)	22		0.04	0.11	0.17	0.25	0.32
7,500 Ac.	29			0.07	0.13	0.20	0.27
	35				0.06	0.13	0.19
	Sprinkler					0.05	0.12
Cantaloupes	16	14.78	20.94	33.91	44.56	56.55	66.32
(1000 Crates)	22	10.30	14.78	19.26	24.08	34.84	45.49
1,580 Ac.	29	8.06	12.54	17.02	20.61	27.74	36.63
	35	5.38	9.16	12.54	16.13	20.61	24.19
	Sprinkler		3.14	7.62	11.20	15.23	19.71
Lettuce	16	379.39	541.18	726.40	826.21	1072.38	1272.97
(1000 Cartons)	22	182.11	309.13	463.36	579.02	782.37	979.42
8,680	29	140.01	235.80	352.83	482.28	678.05	855.70
	35	102.17	147.58	196.77	285.00	457.36	612.31
	Sprinkler		68.11	128.66	177.85	234.62	330.41
Onions	16	3.076	4.834	5.242	5.569	7.202	9.080
(1000 Tons)	22	1.117	2.750	4.382	4.834	5.406	5.977
1,580 Ac.	29	0.539	1.862	3.434	4.589	5.161	5.645
	35	0.373	0.826	1.617	2.920	4.508	5.079
	Sprinkler		0.249	0.498	1.203	2.447	3.936

Salt River Valley Water Users Association. The 134,225 acres of SRVWUA crop land was divided into 73,815 acres well drained, 48,325 acres moderately drained, and 12,085 acres poorly drained. Only minor yield losses on the poorly drained soil would result from the CAP salinity and these losses would be due primarily to irrigation practice as is shown in Table 3.

The SRP Supplemental Irrigation Service. The SRP Supplemental contracts include Fort McDowell Indian Reservation, Salt River Indian Reservation, and the irrigation districts of Gila Crossing, Maricopa Colony, Peninsular Horowitz, and St. Johns for a total of 16,249 acres irrigated in 1973. This was divided into 8,937 acres well drained, 5,850 acres moderately drained, and 1,462 acres poorly drained. The only yield reduction would occur in alfalfa on the poorly drained soil, Table 4.

The Roosevelt Water Conservation District. The RWCD has 34,703 acres of cultivated crop land, of which 28,188 acres were irrigated in 1973. Their water supply averages approximately 50,000 ac ft of surface water from the SRP and 100,000 ac ft of groundwater. If an allotment of 50,000 ac ft CAP water is assumed, 50,000 ac ft of groundwater would still have to be pumped to meet needs. The CAP water could be delivered either directly to the RWCD or mixed with the SRP surface water above Granite Reef Dam and then delivered to RWCD. The first alternative would result in a blend of 603 mg/l initially which would increase to 681 mg/l. The second alternative would result in a blend of 672 mg/l initially which would increase to 880 mg/l. In either event, yield reductions would result principally on the 7,877 acres of poorly drained soil, as summarized in Tables 5 and 6.

Roosevelt Irrigation District

The RID has a total irrigable area of 38,152 acres irrigated entirely from groundwater. Their estimated

Table 3. Summary of yield losses on the Salt River Valley Water Users Association lands due to increasing salinity of irrigation water from the Central Arizona Project and irrigation method as compared with present water quality and best irrigation practice, projected on the basis of 150,000 acre feet per year of CAP water and 1,050,000 acre feet of SRP water.

Crop	Irrigations Per Year	T.D.S. of S.R.P. Water 565	Total Dissolved Solids in C.A.P. Water, mg/l		
			900	1100	1400
			T.D.S. in C.A.P. - S.R.V.W.U.A. Blend		
			607	632	669
Alfalfa (Tons)	16		460	1380	2300
43,655 Ac.	22			230	1380
	29				690
Lettuce (Cartons)	16	3170	4120	6020	7920
750 Ac.	22	1270	2220	3640	6020
	29	480	1270	2690	4590
	35			950	2690
Onions (Tons)	16	15	82	212	149
945 Ac.	22		45	67	112
	29		22	52	90
	35			35	35
Grapefruit (Tons)	16	56	169	169	254
1,550 Ac.	22		21	70	169
	29			35	106
	35				35
Oranges and Tangerines (Tons)	16	99	161	297	446
3,090 Ac.	22		37	124	297
	29			62	186
	35				62
Carrots (Tons)	16	175	205	265	490
865 Ac.	22	115	145	190	265
	29	75	115	160	220
	35	20	60	115	160
	Sprinkler				

Table 4. Summary of yield losses in the SRP supplemental area due to increasing salinity of irrigation water from the CAP blended into the SRP irrigation system, and irrigation method as compared with present water quality, and best irrigation practices.

Crop	Irrigations Per Year	T.D.S. of S.R.P. Water 565	T.D.S. in C.A.P. Water, mg/l		
			900	1100	1400
			T.D.S. in C.A.P. - S.R.P. Blend, mg/l		
			607	632	669
Alfalfa (Tons)	16		30.0	91.0	152.0
2,560 Ac.	22			15.0	91.0
	29				46.0

pumpage is 160,000 ac ft with an average TDS of 1,300 mg/l. If they were allotted 40,000 ac ft of CAP water, they could eliminate some of their worst wells which with the CAP water would improve their water quality at least until the CAP water reaches 1,300 mg/l. Their blend would then go to 1,325 mg/l when the CAP water reaches 1,400 mg/l.

The RID crop land is mostly well drained (35,000 acres well, 2,280 acres moderate, and 330 acres poor) and therefore would be little affected by the salinity of CAP water. Yield losses, due principally to irrigation methods, are summarized in Table 7.

San Carlos Project

The San Carlos Project encompasses 100,000 acres of Indian and non-Indian lands. The water supply averages approximately 190,000 ac ft of surface water and 75,000 ac ft of groundwater annually. This irrigates, after system losses, approximately 50,000 acres with less than 4 feet of water per year. If they were allotted 150,000 ac ft of CAP water and allowed to pump 50,000 ac ft by lining the canals and laterals they could irrigate approximately 80,000 acres with 4 feet of water per year.

Table 5. Summary of yield losses in the Roosevelt Water Conservation District due to increasing salinity of CAP water delivered above Granite Reef Dam and the resulting blend delivered to the RWCD, and irrigation method as compared with present water quality and best irrigation practices.

Crop	Irrigations Per Year	R.W.C.D. Blend Without C.A.P., T.D.S.	T.D.S. of C.A.P. Water, mg/l			
			775	1000	1200	1400
			T.D.S. of C.A.P. - S.R.P. - R.W.C.D. Blend[a]			
		617	603	632	657	681
Alfalfa (Tons) 10,370 Ac.	16	500	300	800	1100	1500
	22			100	400	700
	29				100	400
Grapefruit (Tons) 1,390 Ac.	16	460	330	610	760	1020
	22	200	80	250	380	510
	29	80		130	250	380
	35				80	130
Oranges and Tangerines (Tons) 3,190 Ac.	16	690	500	920	1150	1540
	22	310	120	380	580	770
	29	120		190	380	580
	35				120	190

[a] On the basis of 900,000 ac ft S.R.P. surface water with 470 mg/l T.D.S. blended with 200,000 ac. ft. of C.A.P. water which is increasing in salinity, and subsequent delivery of 100,000 ac. ft. of this blend to the R.W.C.D. to be further blended with 50,000 ac ft of groundwater with an average salinity of 765 mg/l.

Table 6. Summary of yield losses in the Roosevelt Water conservation District due to increasing salinity of CAP water delivered directly into the RWCD system and irrigation method as compared with present water quality and best irrigation practices.

Crop	Irrigations Per Year	T.D.S. of R.W.C.D. Water	T.D.S. of 50,000 ac. ft of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of 100,000 ac. ft of C.A.P. - R.W.C.D. Blend, mg/l						
		620	672	713	747	780	813	847	880
Alfalfa (Tons) 10,370 Ac.	16	500	1400	1700	1800	1800	2000	2300	2500
	22		500	1000	1100	1200	1500	1700	2000
	29			700	800	1000	1200	1500	1700
	35			100	300	400	700	1000	1200
Grapefruit (Tons) 1,390 Ac.	16	460	910	1170	1240	1320	1420	1650	2050
	22	200	460	690	760	840	1020	1170	1420
	29	80	330	510	610	690	840	1020	1170
	35		130	250	330	380	510	690	840
	Sprinkler								200
Oranges and Tangerines (Tons) 3,190 Ac.	16	690	1380	1770	1880	2000	2150	2500	2765
	22	310	690	1040	1150	1270	1540	1770	2150
	29	120	500	770	920	1040	1270	1540	1770
	35		190	380	500	580	770	1040	1270
	Sprinkler								310

The average salinity of project water is approximately 910 mg/l. With the introduction of CAP water as stipulated above the blend would begin at 858 mg/l and reach 1,098 mg/l with CAP water at 1,400 mg/l.

District (non-Indian) lands consist of approximately 16,450 acres well drained, 12,800 acres moderately drained, and 20,750 acres poorly drained. Crop losses due to salinity and irrigation method, projected on the basis of 40,000 irrigated acres, are summarized in Table 8.

The Indian lands consist of approximately 24,390 acres well drained, 12,170 acres moderately drained

Table 7. Summary of yield losses in the Roosevelt Irrigation District due to increasing salinity of CAP water delivered directly into the RID system and irrigation method as compared with present water quality and irrigation practice.

Crop	Irrigations Per Year	T.D.S. of R.I.D. Water 1300	T.D.S. of 20,000 ac. ft. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of 160,000 ac ft of C.A.P. - R.I.D. Blend, mg/l						
			1169	1200	1225	1250	1275	1300	1325
Alfalfa Hay (Tons) 9,189 Ac.	16	630	460	490	510	570	590	630	650
	22	310	120	160	200	230	270	310	350
	29	200		20	80	120	160	200	240
	35								
Alfalfa Seed (Tons) 4,071 Ac.	16	390	280	300	320	350	360	390	400
	22	190	70	100	120	150	170	190	220
	29	120		20	50	70	100	120	150
	35								
Irrigated Pasture (Animal Unit Months) 312 Ac.	16	570	400	440	460	510	530	570	600
	22	320	130	170	210	240	280	320	360
	29	220	40	80	110	150	190	220	250
	35	60		10	30	30	50	60	60
	Sprinkler								20
Lettuce (Cartons) 221 Ac.	16	2980				1490	1490	2980	4470
	22	2980				1490	1490	2980	4470
	29	2980				1490	1490	2980	4470
	35	2980				1490	1490	2980	4470
	Sprinkler								

Table 8. Summary of yield losses on the district part of the San Carlos irrigation project due to increasing salinity of CAP water delivered directly into the San Carlos irrigation system and method of irrigation as compared with present water quality and best irrigation practice projected on the basis of 80,000 irrigated acres in the entire project.

Crop	Irrigations Per Year	T.D.S. of San Carlos Water 910	T.D.S. of 50,000 ac ft of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of 390,000 ac ft of C.A.P. - San Carlos Blend, mg/l						
			858	906	945	983	1022	1060	1098
Alfalfa Hay (Tons) 7,344 Ac.	16	2340	2068	2340	2795	3083	3509	3983	4465
	22	1810	1487	1810	2004	2198	2340	2715	2924
	29	1487	1228	1487	1681	1874	2068	2340	2585
	35	1164	776	1164	1357	1422	1616	1810	2004
	Sprinkler				259	517	776	1164	1357
Safflower (Tons) 1,435 Ac.	16							4	11
Wheat (Tons) 3,225 Ac.	16					29	57	86	128
Maize (Tons) 4,435 Ac.	16	64	16	64	111	143	176	223	271
	22					32	64	111	143
	29						16	64	95
Grapes (Tons) 85 Ac.	16	16.3	12.8	16.3	19.8	22.1	24.4	27.9	31.9
	22	9.9	7.0	9.9	11.6	13.9	16.3	19.8	22.1
	29	7.0	4.7	7.0	8.7	11.0	12.8	16.3	18.6
	35	3.5	0.9	3.5	5.2	6.4	8.1	9.9	11.6
	Sprinkler						0.9	3.5	5.2

and 5,130 acres poorly drained. Crop losses due to salinity and irrigation method, projected on the basis of 40,000 irrigated acres, are shown in Table 9.

Imperial Valley Irrigation District. The Imperial Valley Irrigation District is comprised of about 470,000 acres of irrigated crop land which was divided into 59,500 acres of well drained, 87,500 acres of moderately drained, 222,000 acres of poorly drained, and 101,000 acres of very poorly drained soils (Appendix 2). Yield losses to be expected for the 13 major crops are projected on the basis of salinity level and irrigation method and summarized over soil drainage classes in Table 10.

Coachella Valley County Irrigation District. The 44,000 major crop irrigated acres of the Coachella Valley were partitioned into 38,030 acres of well drained, 2,450 acres of moderately drained, 3,270 acres of poorly drained, and 250 acres of very poorly drained soils. The expected yield decrements due to increasing salinity in the irrigation water are summarized over soil drainage classes in Table 11.

Palo Verde Irrigation District. The Palo Verde Valley has about 95,700 acres of 10 major crops divided into 28,100 acres of well drained, 26,700 acres of moderately drained, 22,500 acres of poorly drained, and 18,400 acres of very poorly drained soils. The impact of increasing salinity on each crop is summarized in Table 12.

Pacific Coast Areas. Colorado River water used in the coastal areas is pumped through the Colorado aqueduct of the Metropolitan Water District of Southern California. The study of yield effects of increased salinity narrows to the region served by the first San Diego aqueduct because of substantial water blending in other areas. The areas expected to be impacted by Colorado River salinity comprise 34,821 irrigated acres of which 9,054 acres of well drained soils, 17,739 acres of moderately drained soils, and 8,028 acres of poorly drained soils. Salinity impacts on the 10 major crops are summarized over soil drainage classes in Table 13.

VALUE OF DAMAGES IN AGRICULTURE

The waters of the Colorado River are progressively increasing in salinity. Some principal dissolved constituents in the Colorado River waters are calcium, magnesium, sodium, sulfate, chloride, and bicarbonate. These and small amounts of other dissolved constituents, are commonly referred to as salinity.

At the headwaters, the average salinity in the river is less than 50 milligrams per liter (mg/l) and progressively increases downstream until, at Imperial Dam, the present condition is about 865 mg/l. Projections of future salinity suggest values between 1200 and 1400 mg/l at Imperial Dam by 2000. Should such salinity increases be realized, severe economic impacts would affect all users in the Lower Basin.

The objective of the portion of the research reported here is to project changes in cropping patterns, physical output for each crop, changes in farm management, and dollar impacts in terms of net profit (Appendix 3). The damage estimates may be

Table 9. Summary of yield losses on the Indian part of the San Carlos Irrigation Project due to increasing salinity of CAP water delivered directly into the San Carlos irrigation system and method of irrigation, as compared with present water quality and best irrigation practice, projected on the basis of 80,000 irrigated acres in the entire project.

Crop	Irrigations Per Year	T.D.S. of San Carlos Water 910	T.D.S. of 150,000 ac. ft. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of 390,000 ac. ft. of C.A.P. - San Carlos Blend, mg/l						
			858	906	945	983	1022	1060	1098
Alfalfa Hay (Tons) 2,760 Ac.	16	321	278	321	447	505	623	748	873
	22	243	199	243	269	295	321	365	423
	29	199	165	199	226	252	278	321	347
	35	156	104	156	182	191	217	243	269
	Sprinkler				34	69	104	156	182
Wheat (Tons) 2,195 Ac.	16					5	11	16	23
	22								
Maize (Tons) 1,810 Ac.	16	5	1	5	9	11	14	17	21
	22					2	5	9	11
	29							5	7
Watermelon (Tons) 425 Ac.	16	103	90	103	139	155	182	221	252
	22	77	64	77	85	92	103	113	136
	29	64	51	64	72	80	90	103	110
	35	46	33	46	54	59	67	77	85
	Sprinkler				18	26	33	46	54

Table 10. ***Summary of yield losses in the Imperial Valley due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice—thousand tons.***

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Alfalfa	16	130	180	244	327	371	481
158,000 Ac.	22	100	129	170	280	302	343
	29	81	110	145	177	226	314
	35	59	87	111	138	173	205
	Sprinkler		43	76	104	137	168
Asparagus	16	0.20	0.44	0.72	1.12	1.48	2.56
4,000 Ac.	22		0.20	0.44	0.60	0.96	1.28
	29		0.08	0.32	0.48	0.72	1.12
	35			0.08	0.28	0.48	0.72
	Sprinkler					0.24	0.44
Barley	16				0.4	1.2	3.8
49,000 Ac.	22					0.8	1.2
	29						
	35						
	Sprinkler						
Cantaloupe	16	4.0	5.4	7.5	9.5	12.0	14.0
12,000 Ac.	22	2.8	4.0	4.9	6.1	7.9	10.0
	29	2.1	3.3	4.4	5.4	6.5	8.4
	35	1.4	2.3	3.3	4.2	5.2	6.1
	Sprinkler		0.7	1.9	3.0	4.2	4.9
Carrot	16	3.4	5.1	7.9	11.0	15.2	18.2
4,000 Ac.	22	1.7	3.1	4.2	6.0	9.0	12.8
	29	0.3	2.3	3.4	5.1	7.9	9.8
	35			1.4	3.2	5.7	7.7
	Sprinkler					0.9	2.3
Cotton	16			0.14	0.36	0.59	2.15
38,000 Ac.	27				0.07	0.42	0.42
	29					0.15	0.36
	35						0.15
	Sprinkler						0.07
Lettuce	16	51.5	71.2	93.2	109.9	136.0	156.9
36,000 Ac.	22	29.5	46.5	61.6	79.0	100.6	124.4
	29	24.3	38.7	53.7	65.5	89.2	107.2
	35	17.8	25.6	34.6	46.4	65.5	83.9
	Sprinkler		11.0	23.0	32.1	39.8	54.2
Onions	16	1.3	1.8	2.5	3.1	5.7	7.5
2,000 Ac.	22		0.7	1.4	1.8	2.7	3.6
	29		0.3	0.9	1.4	2.3	3.1
	35				0.3	1.2	2.1
	Sprinkler						0.3
Sorghum	16	1.8	4.2	6.2	8.1	10.3	15.5
50,000 Ac.	22	0.8	1.7	3.5	5.7	7.7	9.3
	29	0.5	1.2	3.2	4.3	6.4	8.1
	35	0.2	0.5	1.2	2.4	4.3	6.2
	Sprinkler			0.5	1.2	2.6	4.5
Sugar Beets	16			12	33	60	132
63,000 Ac.	22				6	27	45
	29					12	33
	35						12
	Sprinkler						6
Tomatoes	16	0.92	1.15	1.58	1.99	2.80	3.88
2,000 Ac.	22	0.61	0.92	1.15	1.31	1.73	2.28
	29	0.38	0.77	1.00	1.23	1.54	1.84
	35	0.16	0.46	0.77	1.00	1.23	1.46
	Sprinkler			0.31	0.69	0.92	1.15
Wheat	16	2.1	3.9	7.5	10.2	13.5	22.2
49,000 Ac.	22	0.4	2.1	3.9	6.2	10.7	12.1
	29		1.3	3.0	4.9	7.6	10.2
	35			1.7	3.0	4.9	7.1
	Sprinkler			0.4	1.3	3.0	4.8

Table 11. Summary of yield losses in the Coachella Valley due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice—thousand tons.

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Carrot	16						
7,000 Ac.	22						
	29						
	35						
	Sprinkler						
Dates	16						
3,440 Ac.	22						
	29						
	35						
	Sprinkler						
Grapes	16	0.2	0.3	0.5	0.6	0.8	1.0
7,480 Ac.	22	0.1	0.2	0.3	0.4	0.5	0.7
	29	0.1	0.2	0.3	0.3	0.4	0.5
	35	0.1	0.1	0.2	0.3	0.3	0.4
	Sprinkler			0.1	0.1	0.2	0.3
Grapefruit	16	2.4	3.5	7.3	7.5	7.7	7.9
7,700 Ac.	22	1.7	2.4	3.2	7.1	7.3	7.4
	29	1.5	2.1	2.7	3.3	7.1	7.3
	35	1.0	1.5	2.1	2.6	3.3	6.9
	Sprinkler		0.6	1.3	1.9	2.6	3.3
Lemon & Lime	16	0.3	0.3	0.7	0.8	0.8	0.8
2,000 Ac.	22	0.2	0.3	0.3	0.7	0.7	0.7
	29	0.2	0.2	0.3	0.3	0.7	0.7
	35	0.1	0.2	0.2	0.3	0.3	0.7
	Sprinkler		0.1	0.2	0.2	0.3	0.3
Onions	16					0.1	0.4
320 Ac.	22					0.1	0.4
	29					0.1	0.4
	35					0.1	0.4
	Sprinkler						
Orange & Tangerine	16	1.0	1.4	2.9	2.9	3.0	3.1
7,460 Ac.	22	0.7	1.0	1.2	2.8	2.9	2.9
	29	0.6	0.8	1.1	1.3	2.8	2.9
	35	0.4	0.6	0.8	1.0	1.3	2.7
	Sprinkler		0.3	0.5	0.8	1.0	1.3
Sweet Corn	16	0.9	1.3	1.6	3.5	3.6	3.7
4,900 Ac.	22	0.5	0.8	1.1	1.3	1.7	3.5
	29	0.4	0.6	0.9	1.1	1.6	1.7
	35	0.3	0.4	0.6	0.8	1.1	1.3
	Sprinkler		0.2	0.4	0.6	0.7	1.1
Alfalfa	16	0.6	1.4	1.5	2.3	2.6	2.8
3,600 Ac.	22	0.4	0.6	0.9	1.1	2.1	2.4
	29	0.4	0.6	0.8	0.9	1.3	2.2
	35	0.3	0.4	0.6	0.6	0.8	1.2
	Sprinkler	0.3	0.4	0.4	0.5	0.7	0.8

used in conjunction with a simulation model of the Colorado River. As the simulation model is run under varying assumptions and conditions, major economic impacts related to salinity changes can be observed. Such economic evaluation will provide some of the basis both for evaluating salinity mitigation proposals and for measuring negative external impacts of future water resource development projects. This type of analysis is presently required by the Office of Management and Budget on all federally sponsored projects.

Continuing work is expected to encompass all agricultural and M and I users in both the Upper and Lower Basins as well as the most promising salinity mitigation measures, in order to provide guidance as to the future development and management of water resources in the basin.

Table 12. Summary of yield losses in the Palo Verde Irrigation District due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice—thousand tons.

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Alfalfa	16	22.3	29.4	42.9	76.1	82.0	88.0
38,000 Ac.	22	16.2	21.7	29.9	36.8	72.4	77.6
	29	13.2	18.8	25.4	31.1	40.3	73.7
	35	9.4	14.3	19.3	23.4	30.3	36.6
	Sprinkler		7.2	13.6	18.5	25.0	30.3
Cantaloupe	16			6	9	14	17
1,400 Ac.	22				1	4	8
	29					1	4
	35						
	Sprinkler						
Watermelon	16			0.31	0.49	0.76	0.93
1,300 Ac.	22				0.05	0.22	0.44
	29					0.05	0.22
	35						
	Sprinkler						
Cotton	16			0.48	1.06	2.12	5.24
13,900 Ac.	22				0.33	1.25	1.32
	29					0.49	1.06
	35						0.49
	Sprinkler						0.21
Grapefruit	16	4	9	16	21	31	36
810 Ac.	22			5	9	15	19
	29				5	10	15
	35						5
	Sprinkler						
Lettuce	16					44	88
7,000 Ac.	22					44	88
	29					44	88
	35					44	88
	Sprinkler						
Lemon	16	6	12	21	28	41	48
3,300 Ac.	22			7	12	20	26
	29				7	13	20
	35						7
	Sprinkler						
Onion	16					0.4	1.7
3,500 Ac.	22					0.4	1.7
	29					0.4	1.7
	35					0.4	1.7
	Sprinkler						
Sorghum	16	0.08	0.19	0.27	0.35	0.44	0.68
6,500 Ac.	22	0.05	0.09	0.16	0.26	0.34	0.40
	29	0.03	0.07	0.15	0.19	0.28	0.35
	35	0.02	0.03	0.07	0.12	0.19	0.27
	Sprinkler			0.03	0.07	0.13	0.21
Wheat	16	0.50	0.91	1.52	2.32	3.07	3.77
20,000 Ac.	22		0.50	0.91	1.43	2.45	2.75
	29		0.31	0.71	1.14	1.74	2.32
	35			0.41	0.71	1.14	1.63
	Sprinkler				0.31	0.71	1.12

Study Procedures

The agricultural areas modeled are all in the Lower Basin: San Diego coastal area, Coachella Valley, Imperial Valley, Yuma area, Palo Verde Irrigation District, Colorado River Indian Reservation, and the Central Arizona Project (CAP) service area. Agricultural yield decrements and alternative management practices which might be implemented by farmers as salinity levels increase were evaluated by researchers of the University of Arizona and the University of California. These physical data were

Table 13. Summary of yield losses in the Pacific Coast area due to increasing salinity of irrigation water from the Colorado River and irrigation method as compared with present water quality and best irrigation practice—thousand tons.

Crop	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Avocados	Surface				0.6	1.7	2.8
13,256 Ac.	Sprinkler						0.6
	Trickler						
Grapefruit	Surface	0.55	0.80	1.06	1.36	1.55	4.50
655 Ac.	Sprinkler	0.16	0.40	0.69	0.93	1.24	1.60
	Trickler						
Lemons	Surface	3.5	5.1	6.8	8.6	9.8	21.1
3,158 Ac.	Sprinkler	1.0	2.5	4.4	5.9	7.9	10.2
	Trickler						
Naval Oranges	Surface	0.55	0.82	1.08	1.39	1.58	3.39
1,145 Ac.	Sprinkler	0.15	0.40	0.70	0.94	1.26	1.63
	Trickler						
Valencia Oranges	Surface	4.48	6.52	8.64	11.09	12.64	27.14
9,465 Ac.	Sprinkler	1.30	3.26	5.63	7.58	10.11	13.05
	Trickler						
Potatoes	Surface					0.06	0.27
625 Ac.	Sprinkler						
	Trickler						
Strawberry	Surface				0.29	0.64	0.99
635 Ac.	Sprinkler						
	Trickler						
Tangerine	Surface	0.78	1.13	1.49	1.92	2.19	4.70
1,070 Ac.	Sprinkler	0.22	0.56	0.97	1.31	1.75	2.26
	Trickler						
Summer Tomatoes	Surface	0.11	0.29	0.49	0.64	0.80	0.97
330 Ac.	Sprinkler			0.21	0.42	0.59	0.77
	Trickler						
Fall Tomatoes	Surface	0.74	1.88	3.28	3.75	5.16	6.56
3,135 Ac.	Sprinkler			1.41	2.81	3.98	5.16
	Trickler						
Spring Tomatoes	Surface	0.2	0.8	1.4	1.6	2.2	14.3
1,019 Ac.	Sprinkler			0.6	1.2	1.7	2.2
	Trickler						
Limes	Surface	0.22	0.32	0.42	0.54	0.61	1.31
325 Ac.	Sprinkler	0.06	0.16	0.27	0.37	0.49	0.63
	Trickler						

then used as inputs to a linear programming profit maximization model, wherein the optimal farmer response to salinity change was delineated. From this optimization for salinity levels from 900 to 1,400 mg/l, a damage function was defined for each impact area. This linear programming work was carried out by personnel of the Bureau of Reclamation.

The Linear Programming Model

The linear programming routine (APEX-I), utilized for analysis, was a program supplied by Control Data Corporation and run on the CDC Cyber 74/28 system of the Bureau of Reclamation in Denver. This LP package has sufficient capacity and flexibility to allow modeling of all sizes of irrigation districts.

The model was designed to maximize net returns to all farmers in a district above variable production costs and new capital investments subject to resource and production constraints. Detailed enterprise budgets for the crops representative of conditions in each irrigated area were used to develop the input for the linear programming model.

The crops used were alfalfa hay, cotton, sugar beets, sorghum, wheat, barley, lettuce, tomatoes, asparagus, onions, watermelon, carrots, and cantaloupe which account for about 90 percent of the acreages. Each of these crop activities was defined on four soil drainage conditions: very poorly drained, poorly drained, moderately well drained, and well drained. The combination of each crop under each soil condition was then defined for six irrigation activities which include variations in frequency of water application as well as partial and full sprinkler systems. Available to each of the above combinations was a number of management activities. These activities were options open to the manager which he might employ, at a cost, in the face of rising salinity to mitigate the detrimental influence upon net returns. These activities include ditch lining, land leveling, deep plowing, tiling, special bedding practices, and leaching irrigations. Various combinations of crops were defined to allow more than one crop on each acre per year. The program was then run for six salinity levels from 900 to 1,400 mg/l with the difference in the value of the objective function indicative of the damage associated with the salinity change.

Model Constraints

The number of acres available for crop production was limited to the available land including double cropping and excluding the historical pattern of fallow land. The quantity of water available for crop use had an upper limit associated with the water rights. Various categories of labor were constrained or simply accounted for to provide labor use information. Fertilizer rows were utilized as well as rows for new capital investment. Existing management improvements such as land presently tilled were inserted as data in the model. In order to restrict the production of high valued specialty crops, constraints were applied to total production of each commodity which serves as a proxy for the magnitude of market demand.

The decrease in net profit available to farmers as a result of salinity impacts was estimated through repeated running of the linear programming model.

Results—Imperial Valley

In order to indicate the predictive ability of the model, a comparison of selected factors is given in Table 14. The approximation of the existing situation by using 900 mg/l shows a very good correlation between historical trend and model results.

Table 15 shows, on a crop-by-crop basis, a comparison between actual data and model results for yields, acres, and production for the Imperial Valley.

Table 14. Selected factor comparison historic and LP Model 900 mg/l.

Factor	Historic	L.P. Model
Water Use - Acre-Feet	2,838,558	2,692,167
Gross Output - Dollars	284,242,000	269,822,804
Sprinkler to Establish Stand - Acres	56,600	69,973
Full-Time Sprinkler - Acres	0	0

Table 15. Comparison of actual conditions for Imperial Valley in 1974 with LP Model solution at 900 mg/l.

Crop	Historic Yield	Confidence Interval	Model Production	Historic Production	Model Acres	Historic Acres	1974 Yield	1974 Production	1974 Acre
Asparagus	1.53 Tons	±0.16	4,533	6,568 ± 2,035	2,963	4,170	1.63	7,500	4,600
Alfalfa	7.45 Tons	±0.33	1,072,288	1,203,934 ±131,646	150,726	176,051	9.00	1,089,000	121,000
Watermelon	9.80 Tons	±1.42	29,846	25,777 ± 4,068	3,046	3,192	7.25	29,000	4,000
Tomato	7.68 Tons	±2.85	19,018	16,951 ± 2,068	2,529	2,401	12.93	38,800	3,000
Onion	13.70 Tons	±2.41	81,752	64,846 ±16,906	5,967	4,231	12.00	36,000	3,000
Carrot	14.00 Tons	±3.42	67,254	56,462 ±10,792	4,804	4,657	18.86	111,300	5,900
Cantaloupe	5.88 Tons	±0.59	77,504	61,866 ±15,638	14,028	10,567	7.53	62,500	8,300
Sugar Beets	22.00 Tons	±3.36	1,459,281	1,615,143 ±155,862	66,331	69,193	26.80	1,742,000	65,000
Sorghum	2.25 Tons	±0.27	91,101	100,934 ± 14,048	67,736	50,417	2.30	74,000	32,000
Barley	1.90 Tons	±0.21	52,606	95,500 ± 42,894	27,687	51,766	2.14	12,000	5,600
Wheat	2.14 Tons	±0.29	131,182	125,191 ± 80,945	61,300	51,477	2.53	263,000	104,000
Cotton	2.43 Bales	±0.80	100,182	74,722 ± 25,460	41,199	36,625	2.38	215,800	87,000
Lettuce	10.83 Tons	±1.01	6,411,159	515,815 ±125,345	59,202	42,771	11.65	571,000	49,000

The results of all model runs are then used to define a damage function. Alternative functional forms are shown in Table 16 and data are shown graphically in Figure 1. As can be seen, the exponential form provides a close approximation of the data generated by the model runs.

Results—Other Areas

Similar functions have been generated for all major areas of agricultural water use in the Lower Basin. Table 17 shows the results of the LP runs for each area and salinity level. As can be seen, the total annual damages over the 500 mg/l range result in an average impact per mg/l of $28,167 for Imperial, $73 for Coachella, $139 for San Diego, $2,654 for Palo Verde, $756 for Colorado River Indian Reservation, $1,334 for the Yuma area, and $11 for the Central Arizona Project area. The total for all agricultural areas considered in the Lower Basin is $33,133 per mg/l annually. These numbers are only averages over the range and should be used cautiously. A more accurate application is through the use of individual damage function.

Table 16. Agricultural damage function estimates, Imperial Valley.

Unit: $1,000

Imperial Dam mg/l	Model Estimate	Quadratic Fit[a]	Exponential Fit[b]
900 - 1,000	1,906	2,145	1,728
1,000 - 1,100	2,702	2,246	2,857
1,100 - 1,200	4,294	4,226	4,722
1,200 - 1,300	7,539	8,085	7,806
1,300 - 1,400	14,084	13,822	12,903

[a] Estimated by the equation: $D = a + bx + cx^2$ where $a = 104{,}465{,}155$, $b = -196{,}257$, and $c = 93.94$; $R^2 = 0.96$.

[b] Estimated by the equation: $D = be^{mx}$ where $b = 11{,}343$, $e = 2.71828$, and $m = 0.0050262$, $R^2 = 0.99$.

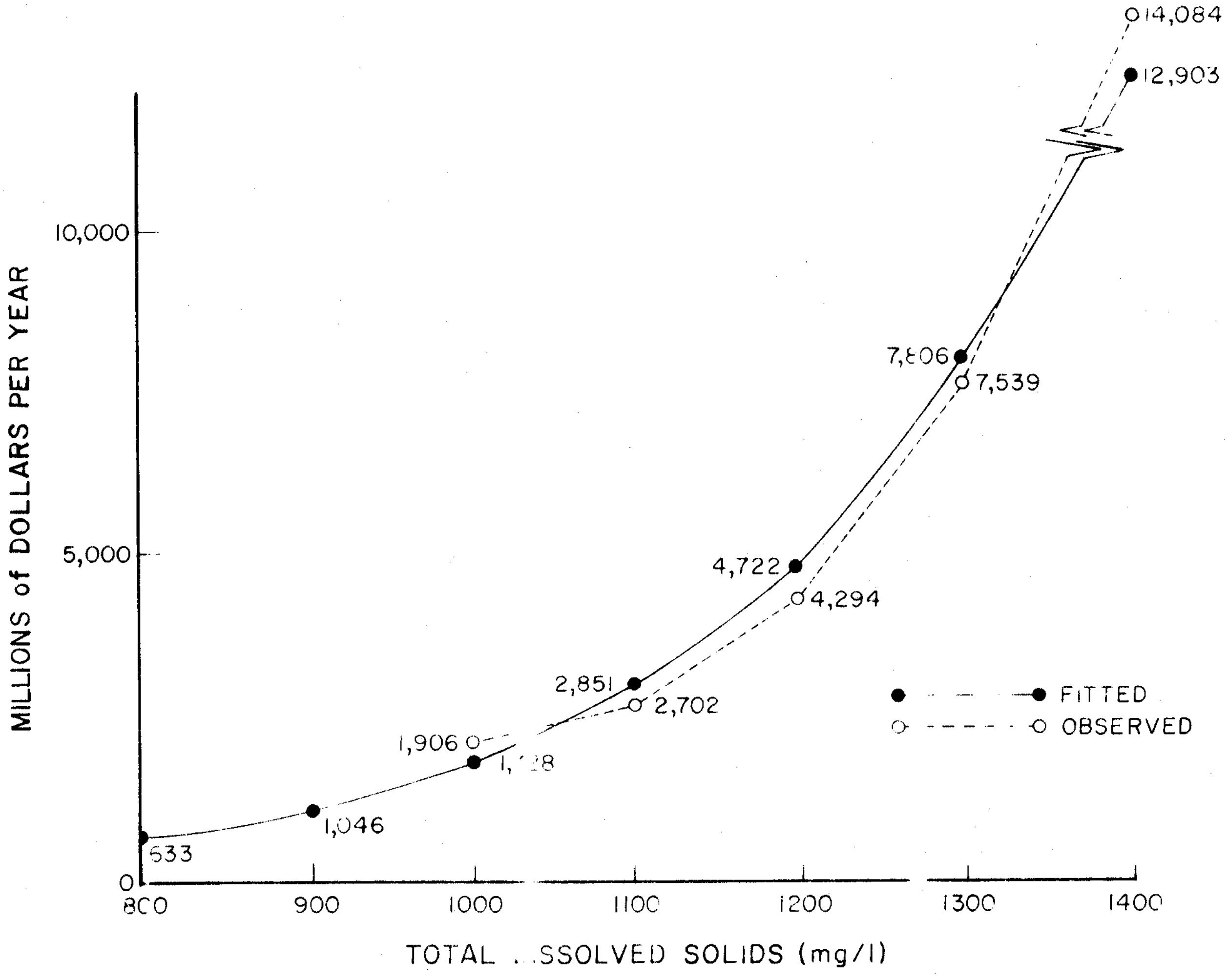

Figure 1. Observed data with fitted damage function—Imperial Valley.

Table 17. Agricultural damages by irrigated area ($/year).

Salinity Range mg/l	Imperial	Coachella	Palo Verde	C.R.I.R.	Coastal	Yuma	C.A.P.	Range Total	$/mg/l
900 - 1,000	1,906,439	277	73,759	17,676	3,746	34,687	368	2,036,952	20,370
1,000 - 1,100	795,414	14,332	218,895	9,743	—	18,430	1,486	1,058,300	10,583
1,100 - 1,200	1,592,172	476	177,691	17,433	5,867	15,812	423	1,819,874	18,199
1,200 - 1,300	3,245,149	10,272	274,423	143,416	—	309,337	1,560	3,984,157	39,842
1,300 - 1,400	6,544,502	11,041	582,141	189,966	59,661	278,641	1,506	7,667,458	76,675
Total	14,083,676	36,398	1,326,909	378,234	69,274	666,907	5,343	16,566,741	
Range Average $ per mg/l	28,167	73	2,654	756	139	1,334	11		33,133

Table 18 indicates the combined damages for all agricultural areas modeled and the predicted values using the exponential functional form. The function appears to provide a good estimate of the real damage function as the R^2 equals .99. The data are plotted in Figure 2. These models will provide, at a low cost, information relative to the economic impact of any number of alternative operating, management, and structural policies which we may wish to evaluate in order to provide guidance for the "best" solutions to the salinity problems of the Colorado River.

Application of Results

The use of the damage estimates in project evaluation is summarized in Table 19.

Suppose project "A," a salinity control project, is being investigated. Studies indicate that with the project the salinity level will be 885 mg/l, a reduction of 65 mg/l. Solving the damage equation results in an annual dollar impact of $601,600. This value becomes a "benefit" estimate for economic justification of the proposal. Similarly project "E," an upstream development scheme, is found to increase the salinity level from 1,350 to 1,400 mg/l. Evaluating the 50 mg/l increase results in an annual dollar impact of $3,322,500 which becomes a cost chargeable to the proposed development. In like manner, any development on the river can be evaluated in dollar terms if indeed farmers respond to increasing salinity in a profit maximizing manner. Because of uncertainties surrounding data available to the farm operator, adjustments probably would not be as great as specified by the model runs. Hence, the estimates given here should be viewed as biased downward or on the conservative side. Actual losses in profit available to farmers are likely to be much greater if projected salinity levels are reached on the Colorado River in the absence of any mitigation measures.

Table 18. Total agricultural damages.

mg/l At Imperial Dam	Unit: Dollars Per Year Observed	Predicted[a]
700		
		661,138
800		
		1,117,401
900		
	2,036,952	1,888,541
1,000		
	3,096,252	3,191,858
1,100		
	4,915,126	5,394,618
1,200		
	8,899,283	9,117,544
1,300		
	16,566,741	15,409,730
1,400		

[a] Estimated by the equation: $D = be^{mx}$ where $b = 12{,}910$, $e = 2.71828$, and $m = 0.0052$; $R^2 = 0.99$.

Table 19. Application of agricultural damage estimates to project evaluation.

Project	Salinity mg/l At Imperial Dam		Total Salinity Impact	Annual Dollar Impact	Average Impact Per mg/l
	With	Without			
A (Control)	885	950	-65	$ 601,600	$ 9,260
B (Control)	980	1,050	-70	$1,082,800	$15,470
C (Control)	1,050	1,150	-100	$3,035,100	$30,350
D (Control)	1,225	1,250	-25	$1,577,500	$63,100
E (Development)	1,400	1,350	+50	$3,322,500	$66,450

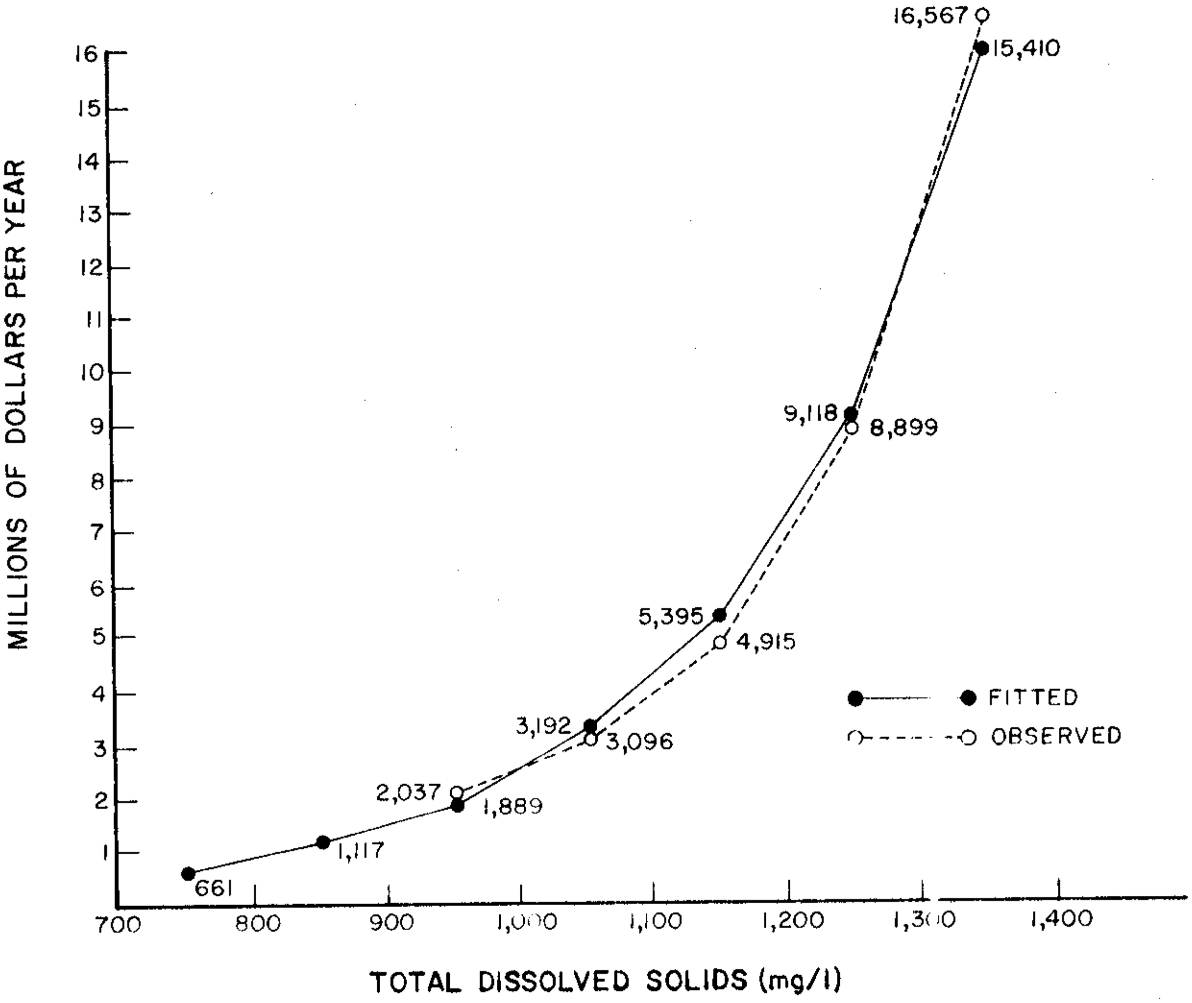

Figure 2. Observed data with fitted damage function—total.

CHAPTER III
MUNICIPAL DAMAGE ESTIMATES

THE CALIFORNIA INVESTIGATION

It has been recognized for some time that variations in the chemical constituents of water may induce differences in corrosion rates, thereby affecting the lifetimes of household water conveyance systems as well as household appliances using water. In this study, an attempt was made to measure economic losses associated with various salinity levels in household water (Appendix 4). Losses were measured for galvanized wastewater pipes, galvanized water pipes, brass faucets, dishwashers, washing machines, and garbage disposals. A statistical analysis was undertaken to compare estimated mean lifetimes for households in two locations in the Los Angeles area of California.

Procedure

Two municipal locations in the Los Angeles area, San Fernando Valley and Costa Mesa-Newport Beach, were divided according to socio-economic units based on differences in median home value, median contract rent, number of persons per household, age of structure, etc. A third area, Long Beach, was also included in portions of the analysis. Plumbing contractors serving each of these areas for at least 12 years were also contacted along with local appliance dealers. This survey was designed to provide a distribution of lifetime estimates by type of plumbing fixtures or appliances. A regression analysis examining the relationship between estimated lifetime, total dissolved solids (TDS), and the socio-economic variable was conducted.

A Conceptual Model

There are basically two approaches to analyzing consumer or household decision-making with respect to water quality. One is to assume that sufficient low-cost information is available to home buyers such that preferred locations, those with the higher water quality, are valued more highly by consumers. Another assumption is that information costs are relatively high and water quality characteristics are considered insignificant to the home buyers when compared with other locational considerations (travel time to work, depreciation rates, socio-economic attributes of the neighborhood, etc.).

Since the aggregate cost of water softening devices, bottled water, acid rinses for swimming pools, additional detergents, and other direct consumer expenditures for reducing the effect of poor water quality are typically less than 2-3 percent of income, it would appear more realistic to presume that information costs on water quality exceed the expected benefits of such information. It was assumed that the home buyer makes his purchase decision independent of variations in water quality except for an estimate of the corrosion of faucets and pipes, and perhaps a query on the age and condition of appliances. Once location is selected, then the consumer considers combinations of defensive expenditures designed to achieve a desired level of water quality. Many of these defensive expenditures might be partially or completely capitalized into property values.

Defensive expenditures undertaken by the individual household would partially reflect economic losses associated with direct physical damages or loss of palatability due to poorer water quality. In consequence, it was anticipated that actual marginal damages (WL_D) would exceed measured physical damages (WL_W), but were either greater or less than the losses capitalized in property values. That is,

$$WL_p \geqslant WL_D > WL_W$$

When the quality of water delivered to the household could not be altered, it was anticipated that the consumer would then make decisions designed to achieve suitable water quality through various water use activities. Those decisions included the purchase and use of a water softener, bottled water purchases, increased lawn and shrub watering, etc. Since the household cannot directly purchase water of varying quality, a demand function is not observable. The approach taken in this study was to estimate physical damages in terms of expected lifetimes and assume that the household would be willing to pay up to the economic value of those physical damages to avoid them. Clearly, this estimate does not consider how the household might, acting individually, avoid some or all of the consequences of poor water quality.

Data Collection

A survey questionnaire was developed and applied to plumbers and appliance servicemen in areas for which there were differing concentrations of salinity in water supplies in an attempt to obtain useful estimates of typical lifetimes of those goods suspected to be affected by salinity. Questions were aimed primarily at obtaining estimated typical lifetimes for various capital-cost items that had been identified in previous studies as being affected by salinity concentrations. In addition, the questionnaires attempted to obtain estimates of repair or replacement costs.

For the estimates of this study to be comparable to other work in this area, TDS was used as an appropriate measure of salinity. In order to generate data that could be applied to regression studies, it was necessary to find various locations for which the TDS concentration differed. The primary criteria for acceptance of various Los Angeles neighborhoods as possible survey locations were based upon the length of time that the area in question had received a single source of water, the extent to which the area had received a single source, the nature of differing water sources, and the availability of water records. With these qualifications in mind, three major locations were selected: San Fernando Valley, Costa Mesa-Newport Beach, and Long Beach. Each location had a constant water supply source for at least twenty years and a long time series of water quality data were available. Each area had a different TDS level: San Fernando Valley, 210 mg/l; Costa Mesa-Newport Beach, 728 mg/l; Long Beach, 759 mg/l and 457 mg/l from two different locations.

A list of potential respondents was developed from current telephone books and calls were made to set appointments for a field researcher to go through the survey with the respondent. This was necessary to restrict the response to a single socio-economic unit. A major problem with this survey procedure was the difficulty in arranging appointments and persuading the respondent to give up the time necessary to complete the survey form. In view of this problem, a second approach was used wherein survey questionnaires, with complete instructions, were mailed to the respondent. As a result of the two procedures, a total of 87 responses were received.

Statistical Tests

Since the sample size in each of the areas was approximately 30, it was appropriate to use a t-Statistic. The calculations for statistical significance are recorded in Table 20. These tests did not take into account alternative distributions or socio-economic variables. However, the results did conform with previous data in that there is no substantial TDS related corrosion in pipes with the exception of galvanized pipes. The major impacts of higher salinity levels are upon household appliances, faucets, and water heaters.

The next statistical test involved the use of multiple regression analyses designed to examine the relationship between water salinity and the estimated lifetimes of various appliances or water conveyance systems and the effect of certain socio-economic variables upon this relationship (Table 21). In general, TDS tended to be the most significant predictor of lifetimes, but appeared to have little influence on copper piping, toilet flushing mechanisms, and cast iron wastewater pipes.

None of the socio-economic variables was consistently significant although "number of persons per unit" and "percent renter occupied" were often important. Conceivably, these variables reflect the level of use that an item receives. In general, there was evidence that the physical damage due to salinity is significant and that this damage may not be strictly linear over the 200-700 mg/l range of TDS.

Economic Damage Computations

Damage cost functions were developed by estimating costs for each water affected appliance or pipe identified earlier. Cost estimates were assumed to have a time horizon equal to the economic lifetime of a typical housing unit. As such, the present value of any given cost would be related to TDS through the relationship between the lifetime of an article and the TDS concentration.

Summary

A comparison of the distribution between Costa Mesa (728 mg/l TDS) and San Fernando Valley (210 mg/l) indicated a statistically significant difference in estimated mean lifetimes. The Costa Mesa-Newport Beach area had a shorter estimated mean lifetime for dishwashers, washing machines, garbage disposals, brass faucets, water heaters, and galvanized pipes at the 10 percent level of significance. No significant difference was found for the other water conveyance systems or fixtures at that same level of significance.

The regression analysis, which examined the relationship between estimated lifetime, total dissolved solids, and the socio-economic variables, found none of the socio-economic variables to be significant other than the number of persons per household. This result may have been due to a lack of substantial variation in household characteristics across the two locations or an incorrect specification of the relevant economic variables. Further research is needed before it could be concluded that differences in socio-economic characteristics have no impact on physical deterioration of household water systems.

Estimated economic losses for a typical Los Angeles household, with the discount rate having been set at 8 percent, ranged from $620 to $1,010 in present value terms for an increase in TDS from 200 mg/l to 700 mg/l. The estimated economic losses are two to three times higher than those previously reported in water resource literature. Aggregate damages to households in the Los Angeles metropolitan area due to utilization of Colorado River water can be estimated by extrapolation to be between $880 million and $1.44 billion in present value terms, or approximately $70 to $115 million as an annual cost. An improvement of 10 mg/l TDS in the Colorado River water delivered to Los Angeles residences, by implication, would lead to a cost saving of approximately $14 million in present value terms of $1.12 million per year. This estimate is likely to be downward biased because it does not include all types of household savings such as on purchases of soaps, detergents, acid rinses for swimming pools, and others. On the other hand, it is likely to be upward biased because it does not include potential technological advances that partially ameliorate the physical damages at costs less than economic losses.

THE CENTRAL ARIZONA AND LAS VEGAS AREA INVESTIGATION

The Bureau of Reclamation elected to conduct onsite surveys in order to establish a broader statistical base from which to estimate damages attributable to salinity for the Phoenix, Tucson, and Las Vegas areas. The same questionnaire used in Los Angeles was also used for plumbing contractors and appliance dealers in the corresponding standard metropolitan statistical areas of the above three locations.

As a result of the analysis, pecuniary estimates of damages were derived for the following household items: galvanized water pipes, water heaters, toilet flushing mechanisms, dishwashers, and garbage disposals. A statistical analysis compared the estimated mean lifetime of these items between two municipal groups of differing water qualities. One group was comprised of the SMSA of Phoenix plus the Boulder City and Henderson areas from the SMSA of Las Vegas. The second group contained the remaining portion of the Las Vegas SMSA plus the SMSA of Tucson. The water quality of the first group is estimated to average 735 mg/l while the second was observed to have a somewhat better quality of 500 mg/l.

Plumbing contractors and appliance dealers serving each of the above areas were contacted to provide estimates of average lifetimes for various plumbing fixtures and water using household appliances.

These estimates enabled a distribution to be constructed of average years of life by type of plumbing fixtures and appliances. A comparison of lifetime estimates between the two groups indicated that the following items had a statistically significant difference (longer average lifetime for Las Vegas-Tucson lower TDS area): galvanized water pipes, toilet flushing mechanisms, water heaters, dishwashers, and garbage disposals. No statistically significant difference was found for cast iron wastewater pipes, brass faucets, washing machines, and evaporative coolers.

A typical household was constructed for these areas based on the percentage of homes containing the various water related items. Estimated economic costs for the representative household was derived in present value terms, utilizing an 8 percent discount rate for the damages in the range in water quality from 500 to 735 mg/l.

Data Collection

Primary data were collected in the SMSA's of Las Vegas, Phoenix, and Tucson by asking similar questions as used in the Los Angeles area. Plumbers and appliance people were contacted and asked to provide estimates centered around the effect of salinity on the lifetimes of water related consumer goods.

Table 20. Test for significantly different sample means.

	Estimated Mean Lifetime (Years)		
	San Fernando Valley (210 mg/l)	Costa Mesa-Newport Beach (728 mg/l)	Statistical Significance
Water Heater	8.74	5.22	Different at 0.005
Galvanized Wastewater Pipes	30.94	10.14	Different at 0.005
Galvanized Water Pipes	17.28	11.25	Different at 0.100
Toilet Flushing Mechanism	7.68	6.63	No difference
Copper Water Pipes	44.08	47.50	No difference
Plastic Water Pipes	48.33	60.00	No difference
Copper Wastewater Pipes	43.82	43.78	No difference
Plastic Wastewater Pipes	42.50	53.00	No difference
Dishwashers	9.60	6.50	Different at 0.005
Washers	8.50	7.38	Different at 0.100
Garbage Disposals	8.47	6.86	Different at 0.100
Brass Faucets	10.40	6.00	Different at 0.050

Table 21. Regression estimates for length of average lifetime and salinity.

Water Heaters:

$$\ln L = 5.43771 - \underset{(4.967)^{a,b}}{0.42435} (\ln TDS) - \underset{(3.925)^{b}}{0.99322} (\ln \#PERS/UNIT) + \underset{(2.406)^{b}}{0.36828} (DUMMY)$$

$F = 13.34^{b}$

$R^2 = 0.60$

Galvanized Wastewater Pipes:

$$\ln L = 7.42425 - \underset{(4.227)^{b}}{0.79571} (\ln TDS) + \underset{(3.248)^{b}}{1.05941} (DUMMY)$$

$F = 11.23^{b}$

$R^2 = 0.51$

Galvanized Water Pipes:

$$L = 16.56015 - \underset{(1.584)}{0.00666} (TDS) - \underset{(1.883)}{3.78336} (DUMMY)$$

$F = 3.94^{c}$

$R^2 = 0.23$

Brass Faucets:

$$\ln L = 6.35863 - \underset{(1.351)}{0.69277} (\ln TDS) + \underset{(1.420)}{1.28617} (DUMMY)$$

$F = 1.4$

$R^2 = 0.15$

Dishwashers:

$$\ln L = 4.05324 - \underset{(3.175)^{b}}{0.34538} (\ln TDS) + \underset{(1.870)}{0.42955} (DUMMY)$$

$F = 5.18^{c}$

$R^2 = 0.30$

Washers:

$$L = 9.62161 - \underset{(1.933)}{0.00360} (TDS) + \underset{(1.305)}{1.45762} (DUMMY)$$

$F = 2.07$

$R^2 = 0.15$

Garbage Disposals:

$$\ln L = 2.82352 - \underset{(1.013)}{0.13076} (\ln TDS) + \underset{(0.145)}{0.03794} (\ln DUMMY)$$

$F = 0.55$

$R^2 = 0.05$

[a] The values in parentheses are T-Statistics.

[b] Denotes statistically different from zero at the 99% level of a 1-tailed test.

[c] Denotes statistically different from zero at the 95% level of a 1-tailed test.

With the completion of the Central Arizona Project in the mid-1980s municipal water from the Colorado River will be delivered to Phoenix, Tucson, and the respective surrounding areas. Since both locations will potentially be affected by the salinity content of Colorado River water, it is important to assess the magnitude of economic impacts reasonably expected under present and future conditions. The salinity content of municipal water currently used in the Phoenix area was estimated to average 735 mg/l while Tucson's average was much lower at 550 mg/l. Results from the SMSA of Las Vegas indicated that varying water qualities exist for different locations. For example, Las Vegas (including North Las Vegas) was estimated to average 450 mg/l while Boulder City and Henderson had poorer quality water at about 680 mg/l.

Table 22 contains the number of responses tabulated from plumbers and appliance dealers in each of the five locations. In order to improve the statistical analysis, two groups were formed. One group consisted of the SMSA of Phoenix and the locations of Boulder City and Henderson. The water quality of these locations is approximately in the same range; therefore, in order to increase the usefulness of the small number of observations in Boulder City and Henderson, these three locations were combined to form one group with estimated average water quality of 735 mg/l.

The second group was composed of Tucson and the remainder of the Las Vegas SMSA. These areas average between 450-550 mg/l and have approximately an equal number of observations. An average water quality of 500 mg/l was assumed to be representative of this group.

Table 22. Tabulated responses.

	Plumbing	Appliances
Phoenix	126	21
Tucson	38	31
Las Vegas	30	21
Boulder City	6	4
Henderson	3	4
Total Responses Obtained	173	60

Statistical Significance

A test was used to determine statistical significance of mean lifetimes between the two groups. Table 23 lists each of the household items surveyed and the resulting mean lifetimes. Statistical significance was found to exist between the two groups for galvanized water pipes, water heaters, toilet flushing mechanisms, dishwashers, and garbage disposals. No significant differences were found for galvanized wastewater pipes, brass faucets, clothes washers, and evaporative coolers. In the cases where a significant difference exists, mean lifetimes of items at the lower salinity level are longer which support the hypothesis that poorer quality water reduces the economic usefulness of certain items.

Economic Damage Computations

Estimation of monetary losses (additional costs) for a typical household was derived by calculating the

Table 23. Test for significantly different sample means.

Item	Estimated Mean Lifetime (Years) Phoenix - Boulder City - Henderson (735 mg/l)	Las Vegas - Tucson (500 mg/l)	Statistical Significance
Galvanized Wastewater Pipes	42.23	40.15	No difference
Galvanized Water Pipes	16.39	19.85	Different at 0.05
Water Heater	7.79	9.66	Different at 0.02
Toilet Flushing Mechanisms	6.18	8.02	Different at 0.10
Brass Faucets	9.48	10.28	No difference
Clothes Washers	8.69	8.63	No difference
Dishwashers	7.28	9.01	Different at 0.02
Evaporative Coolers	8.96	7.23	No difference
Garbage Disposals	6.03	7.58	Different at 0.05

present worth of differing lengths of life attributable to different levels of TDS. The objective of this procedure was to determine the annual costs of replacement required to maintain the services of a certain household item over a 60-year period. Damages were based on the capital replacement costs of household items in 1975 using an 8 percent discount rate. The results are in 1975 dollars which enables a direct comparison to be made with the estimates for the Los Angeles area.

Cost streams were calculated for each significant item in Table 23 at both 500 mg/l and 735 mg/l following the same assumptions used in the Los Angeles study. Replacement was considered to occur at the end of the lifetime of the previous unit. Costs were adjusted for the final replacement period to equal 60 years which reflected actual costs incurred for this less than full life segment. For example, in the case of water heaters, lump sum costs of replacement occurred every 9.66 years after the initial investment, thus, replacing the unit five times covering 57.96 years of the 60-year household life. Costs for the remaining 2.04 years (less than the average economic lifetimes) were based on the relationship of replacement costs for this segment to costs required for a full economic life of 9.66 years and discounted in the same manner as previous lump sums.

The present value of the cost streams for galvanized water pipes, toilet flushing mechanisms, water heaters, dishwashers, and garbage disposals are presented in Table 24. The difference between the resulting present value sum at 735 mg/l and 500 mg/l is considered to be amount of additional costs per unit over a 60-year period due to the increasing TDS.

Since different households may or may not contain some or all of the items, a typical household for each area was construed. Table 25 shows the number of units per household considered to be typical for the Central Arizona service area (SMSA's of Phoenix and Tucson) and the lower mainstem of the Colorado River (Las Vegas SMSA and municipal communities along the river to the Mexican border).

Total lifetime replacement costs were converted to costs per mg/l by dividing 235 (735-500) into the difference of the cost streams displayed in Table 24. These values were multiplied by the weighing factors

Table 24. Present value of replacing significant household items over 60-year life (8 percent, 1975 dollars).

Item	Phoenix - Boulder City - Henderson (735 mg/l)	Las Vegas - Tucson (500 mg/l)	Difference
Galvanized Water Pipes	827.11	758.63	68.48
Toilet Flushing Mechanisms	65.38	53.72	11.66
Water Heaters	351.18	301.90	49.28
Dishwashers	519.22	445.17	74.05
Garbage Disposals	173.33	145.59	27.74

Table 25. Typical household unit for selected items: CAP and lower mainstem.

Item	CAP (Units)	Lower Mainstem (Units)
Galvanized Water[a] Pipes	0.50	0.38
Toilet Flushing[b] Mechanisms	1.60	1.61
Water Heaters[a]	0.985	0.985
Dishwashers[b]	0.20	0.25
Garbage Disposals[a]	0.61	0.74

[a] Mean values of survey data.

[b] Census of Housing, 1970, U.S. Census Bureau (U.S. GPO, Washington, D.C., 1974).

contained in Table 25 with the results reflecting expected costs per mg/l per household. Next, the cost per mg/l per household was capitalized over the 60-year period at 8 percent in order to estimate the corresponding annual costs. These values are contained in Table 26 along with an estimate of number of household units for the CAP and lower mainstem areas.

The number of households for both areas is the annual equivalent amount of the present worth of households for the 60-year period in question. Since costs are on an annual equivalent basis also, direct multiplication results in total annual area damages per unit per mg/l shown in the last two columns of Table 26.

Table 26. Annual cost per household per mg/l TDS and total cost per mg/l TDS—Central Arizona Project service area and lower mainstem.

	Item	Household Annual Cost/mg/l CAP ($)	Household Annual Cost/mg/l LMS ($)	CAP Household Units	LMS Household Units	Total Annual Cost/mg/l CAP ($)	Total Annual Cost/mg/l LMS ($)
1.	Galvanized Water Pipe Systems	0.0118	0.0089	245,000	250,100	2,891	2,226
2.	Toilet Flushing Mechanisms	0.0064	0.0065	245,000	250,100	1,568	1,626
3.	Water Heaters	0.0167	0.0167	245,000	250,100	4,092	4,177
4.	Dishwashing Machines	0.0051	0.0064	245,000	250,100	1,250	1,601
5.	Garbage Disposals	0.0058	0.0071	245,000	250,100	1,421	1,776

CHAPTER IV

ECONOMIC IMPACTS OF SELECTED SALINITY CONTROL MEASURES

THE GRAND VALLEY COLORADO CASE STUDY

Salinity (dissolved solids) in water supplies causes significant economic damages to agricultural, municipal and industrial water users in the Lower Colorado River Basin. Salinity is due to both natural causes (salt springs, surface runoff) and man-made causes (agriculture and industry). Total salt contributions from irrigation in the Upper Basin have been estimated to account for about 38 percent of the total damages which accrue to downstream water users. The saline irrigation return flow problem in the Upper Basin is unusual, in that substantial amounts of salt are "picked up" from ancient marine deposits beneath the irrigated lands in addition to the more typical fertilizer leaching and concentration of dissolved solids via evapotranspiration.

This report focuses on the economic costs to water users of nonstructural methods of controlling saline irrigation return flows in the Upper Colorado River Basin (Appendix 5). The Grand Valley in western Colorado is used for a case study.

The Grand Valley is located in west central Colorado at the confluence of the Gunnison and Colorado Rivers. The elevation is about 4,400 feet, and the normal growing season averages about 190 days. With an annual rainfall seldom exceeding 10 inches, irrigation is necessary to maintain a viable commercial agriculture in the valley. Approximately 57,000 acres of land is presently irrigated. Major crops grown include corn, alfalfa, sugar beets, small grains, and permanent pasture. Slightly less than 15 percent of the irrigated acreage is planted to pome and deciduous orchards and other specialty crops.

The primary source of salinity comes from extremely saline aquifers (as high as 10,000 mg/l) overlying a marine-deposited Mancos shale formation. Lenses of salts contained in the shale are dissolved by water entering and coming into chemical equilibrium with the shale formation before returning to the river channel. Water enters the aquifers by seepage from delivery canals, laterals and drains (about 55 percent of the total), and from deep percolation from fields associated with application of irrigation water (about 45 percent). Average annual salt pickup attributable to irrigated agriculture in the Grand Valley is estimated at 600,000 tons, or about 10 tons per irrigated acre.

Engineering studies have recommended that return flow control programs begin with lining irrigation water conveyance systems. Such structural measures would be effective, but are relatively expensive. The Bureau of Reclamation's proposed canal lining and drainage program may cost in excess of $60 million (1973 prices), or over $1,000 per acre. In the hope that nonstructural measures, involving changes in the institutional system (incentives, constraints, penalties) could do part of the job less expensively, several modifications of present irrigation practices were examined.

Assumptions

Two practices hypothesized which influence the amount of deep percolation (drainage water) and hence salt pickup, are analyzed. First, irrigators may modify traditional irrigation practices by varying the rate of water applied per unit area in the crop season. Previous research by agricultural engineers has revealed that soil infiltration rates in the study area are high in the early part of the irrigation season, but drop to low levels as the season progresses. Hence, if most of the deep percolation is thought to occur in the first two irrigations, salt percolation losses can be minimized merely by changing a) the length of time water is allowed to run in each furrow, and/or b) the rate of application by adjusting the size or number of siphon tubes, and/or c) spacing of furrows, and/or d) use of basin irrigation.

Crops typically vary as to deep percolation losses, even with similar irrigation practices. A second method of reducing deep percolation can be achieved by cutting back the acreage of crops which are high contributors in favor of those which are less of a problem. Both of these alternatives involves increased costs or decreased income to affected farmers.

The Economic Model

Linear programming models of representative farm situations provide the basis for deriving estimates of the economic costs of nonstructural salinity controls. Data for the models were collected by personal interviews with 98 farmers, or 28 percent of commercial crop farmers in the study area. The models form a valley-wide characterization of farm sizes, resource levels, cropping patterns and irrigation practices. Measures designed to reduce salt pickup are analyzed in the model by introducing processes with varying water supplies, application rates, timing or irrigation methods.

The linear program is a conventional short-run land and water allocation model with constraints on cropland, water and acreages of specified crops. The objective function is net return (defined as gross crop sales minus operating costs). Each crop production activity includes a coefficient representing annual deep percolation per acre. The model is solved to find the net income-maximizing situation for each of a number of constraints on deep percolation losses. It is assumed that salt is picked up at the rate of 5 tons of dissolved solids per acre foot of deep percolating water. This rate represents an average for the valley and reflects a compromise among conflicting estimates.

It could not be conclusively established that crop yields would be adversely affected by the more efficient irrigation practices, so no such cost is included. The 15 percent of the acreage in deciduous fruit orchards and other specialty crops are omitted from the analysis reported here. Net income losses due to hypothesized imposition of discharge standards are computed.

Results

Some of the more important results of the analysis are summarized in Table 27. The initial solution or "bench mark condition" with respect to salt pickup, net crop income, and irrigation water applied to crops is reported in part A. From the results summarized in part B, given our assumptions, it is readily apparent that improved irrigation efficiency can inexpensively bring about substantial reductions in that portion of salt pickup due to on-farm irrigation. The model indicates that about 80 percent of the initial salt load in return flows due to percolation from fields can be avoided at an incremental cost of less than $2.20 per ton.

The results of crop substitution on salt pickup, summarized in part C, show appreciably higher estimated costs. Only about 40 percent of the initial salt load can be removed, and the incremental cost exceeds $60 per ton at that level of removal. By comparison, recent cost estimates of control by canal lining in the Grand Valley range from $14 to $100 per ton. Program benefits (present downstream damages avoided) are summarized elsewhere in this report.

No detailed study of the important issues concerning the incidence of control costs or the mechanisms for financing abatement programs was undertaken. In generalities, the costs estimated here of crop substitution and much of those for changing irrigation practices would be borne by farmers themselves. Some portion (up to 75 percent) of the cost of changing irrigation systems can usually be obtained through ASCS cost sharing programs. The administrative and enforcement costs would be absorbed by either the state or federal enforcement agency.

Table 27. Consequences of implementing on-farm, nonstructural salinity controls in the Grand Valley: Selected results of the linear programming model.

Salt Discharge in Irrigation Return Flows	Total Net Farm Income	Irrigation Water Requirement[a]	Incremental Direct Cost of Salt Removal
-TONS--	--$--	--Acre Feet--	--$ Per Ton--
A. Initial Condition (Both Cases)			
146,510	5,962,301	214,745	
B. Case I, More Efficient Irrigation Practices Adopted:			
137,500	5,949,651	212,469	1.40
100,000	5,897,019	202,995	1.40
75,000	5,858,839	196,177	1.53
50,000	5,807,160	180,015	2.07
37,500	5,779,383	170,015	2.22
C. Case II, Modification of the Cropping Pattern:			
125,000	5,797,679	219,012	7.65
112,500	5,563,304	221,185	18.75
100,000	4,854,002	227,348	56.74
87,500	4,014,064	232,673	67.20

[a] Includes crop consumptive use, on-farm losses, and system delivery losses.

Conclusions

Several limitations should be recognized in interpreting this analysis. First, neither the amount of drainage water associated with specified irrigation practices nor the rate of salt pickup per unit of drainage water are well established. In fact, considerable disagreement is found on these points among hydrology and soils specialists. Second, it may not be possible to increase irrigation efficiency to the degree assumed without some sacrifice in crop yield. Finally, the regulatory and social costs of imposing water quality standards have not been dealt with where the effluent of individual irrigators is not identifiable. Present water distribution policies in the area and Colorado water law do not provide any incentive for reducing return flows, and relatively drastic measures might be required to implement nonstructural controls. These and other political/administrative aspects remain to be studied. The structural measures may be expensive, but they would be relatively straightforward to implement within present institutions.

Of the nonstructural control measures examined, a simple modification in present irrigation practices would apparently achieve a substantial reduction in salt pickup at a cost relatively low in comparison to other alternatives. However, this alternative might be difficult and expensive to implement, monitor, and administer. Substituting crops to avoid salt loading would be more costly and limited in scope.

MODELING THE SOIL-WATER-PLANT RELATIONSHIPS: CASE STUDY IN UTAH

Before it is concluded that modifications which reduce salinity leaching are really a valuable management tool, it is necessary to explore the actual response of crop, soil, and water factors to irrigation practices and the cost effectiveness of proposed irrigation practices. Specifically stated, this portion of the study involved the development of a physical model to predict the response of soil, water, and crop factors to irrigation and the development of an economic model which, using the physical model for basic data, predicted the cost effectiveness of irrigation management as related to return flow salinity (Appendix 6). These models were originally developed to determine optimal cropping and irrigation strategies subject to certain constraints for a one-year period. A multi-year analysis was subsequently developed by using the final conditions of a given year for the initial soil salinity conditions of the following year subject to the assumptions of the physical model. The physical and economic models are discussed separately for purposes of organization and convenience to the reader.

The Physical Model

The model used in this study is concerned with the soil water flow in response to varying irrigation management inputs. The general equation for water flow is given as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial H}{\partial z}\right) + a(z) \cdots\cdots\cdots(1)$$

in which θ is the water content, t is time, K is the hydraulic conductivity, H is the matrix potential, z is depth, and a(z) is the root extraction term.

The salt flow portion of the model is given as follows:

$$\frac{\partial C\theta}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial C}{\partial z}\right) - \frac{d(Cq)}{dz} \cdots\cdots\cdots(2)$$

in which C is the salt concentration, D includes the combined diffusion and dispersion coefficients, and q is the mass flux of water.

To determine the influence of salinity on the crop yield, another component must be added to the model. This is done by assuming the relative yield was related to relative transpiration as follows:

$$\frac{Y}{Y_p} = \frac{T}{T_p} \cdots\cdots\cdots\cdots\cdots\cdots(3)$$

in which Y is the dry matter yield of a given crop for the season, T is the transpiration for the same crop for the same season, Y_p is the potential yield for the same crop and season where soil water or salinity did not reduce yields, and T_p is the potential transpiration for the same crop and season where soil water or salinity did not reduce yields. The ratio of actual yield to potential yield under "ideal" conditions is an important component of the model and because of the stated assumptions may be represented also as the ratio T/T_p. The ratio is shown to vary considerably among various irrigation management practices and initial soil salinity levels. Since variation in the ratio reflects variation in agricultural productivity, it will be of interest to agricultural water users and policy makers.

The procedure followed was to compute various consequences of a given irrigation management sequence for a typical season as a function of soil and crop conditions for that season. Three important factors were varied and the outputs predicted which resulted from the variation. The three factors were irrigation, initial soil salt concentration, and cropping variables. Irrigation was applied in the simulations according to the frequency used on the experimental farm in the Colorado River Basin during 1971. The amount of water applied was varied from zero to sufficient to cause considerable drainage. The initial salt concentration in the soil was assumed to be uniform at the beginning of the season at 20, 50, or 200 millequivalents per liter. The 20 meq/l concentration represents present conditions on the experimental farm. The 50 meq/l and 200 meq/l are used to simulate salt buildup that would occur over several years if proper drainage, or insufficient leaching were not achieved.

Three crops were simulated: alfalfa, corn, and oats. The variation of the crop component amounted to varying the root zone dimensions and the ratio of actual transpiration to potential transpiration. The only situations deemed relevant for this presentation are those in which the depth of alfalfa roots is assumed to be greater than the depth of corn roots. Crop management variables are to be introduced in the discussion of the economic model.

Table 28 shows the results of varying the water application rate and initial soil salt concentration level in the cultivation of corn, alfalfa, and oats. Table 28 data show that the T/T_p ratio for corn and alfalfa increased in value as the irrigation level increased until it reached 1.0 between the 40.8 and 56.4 centimeter levels. T/T_p did not reach 1.0 for oats. However, the pattern of increase through the water application levels was similar to that of corn and alfalfa. The smaller values of T/T_p for oats are due chiefly to a more shallow root depth. The data show a more significant decrease in T/T_p for alfalfa than for corn in the lower irrigation rates. This is due to a longer season of active water use by alfalfa and for a much greater proportion of transpiration to evapotranspiration for alfalfa than for corn.

There was relatively little difference between the T/T_p values of the two lower initial salt concentration

Table 28. Comparison of T/T_p and final salt concentration for corn, alfalfa, and oats at various levels of water application and initial salt concentration.

Irrigation and Rain cm	T/T_p			Initial Salt Concentration meq/liter	Final Salt Concentration meq/liter		
	Corn	Alfalfa	Oats		Corn	Alfalfa	Oats
5.6	0.81	0.52	0.29	20	62	43	33
5.6	0.77	0.50	0.28	50	127	97	78
5.6	0.48	0.33	0.18	200	305	277	248
10.3	0.89	0.61	0.37	20	60	42	33
10.3	0.86	0.58	0.36	50	120	94	76
10.3	0.55	0.42	0.24	200	296	269	242
15.0	0.97	0.68	0.46	20	56	43	33
15.0	0.93	0.66	0.44	50	116	94	76
15.0	0.64	0.49	0.32	200	296	268	242
22.0	0.98	0.80	0.59	20	40	41	43
22.0	0.98	0.78	0.58	50	95	92	76
22.0	0.78	0.63	0.46	200	291	263	240
40.8	0.99	1.00	0.89	20	27	30	26
40.8	0.98	1.00	0.88	50	64	64	58
40.8	0.97	0.93	0.80	200	227	228	208
56.4	1.00	1.00	0.97	20	23	24	24
56.4	1.00	1.00	0.93	50	50	52	52
56.4	1.00	1.00	0.93	200	189	195	185
66.7	1.00	1.00	0.99	20	20	20	22
66.7	1.00	1.00	0.99	50	42	44	43
66.7	1.00	1.00	0.99	200	153	158	157

levels, but there was a marked difference when the concentration was 200 meq/l.

The results showing final salt concentration levels indicate a buildup of salts in the soil profile for each crop until the water application reaches a high level. This buildup could have serious effects on yields if it were maintained over a long period of time. However, at the 56.4 and 66.7 centimeter levels, salt is leached from the soil and the buildup ceases.

The data in Table 29 also demonstrate the buildup of salts that occurs in the lower four annual water application rates. The drainage figures show an upward flow of water until irrigation reaches 56.4 centimeters, especially for the longer-rooted corn and alfalfa. The salt flow to groundwater figures show the amount of salts in millequivalents that transfer from the soil to the irrigation return flow. The negative values in the lower water application rates indicate a buildup of salts which occurs because of the evapotranspiration process. At the two highest water application levels, the values are positive and indicate some transfer of salts from the soil into the return flow.

The single point values relating water added to the T/T_p are somewhat unrealistic in a real field situation because water is not distributed uniformly. Even with the best irrigation system there are parts of the field that receive more water than others. To account for this, a uniformity coefficient Cu has been defined as follows:

$$Cu = 1 - \frac{D}{M}$$

in which M is the average irrigation rate and D is the average deviation (sign ignored) about the average irrigation rate. When Cu = 1, water application is completely uniform. For the sprinkler irrigation simulation the coefficient used in the model was equal to 0.88. The value was 0.42 for flood irrigation. The values of T/T_p and final salt concentration were adjusted for these variations in Cu to increase the accuracy of the model. The data showing the variation of T/T_p will not be presented in this work but are included as part of the economic model.

The Economic Model

The economic model is designed to suggest ways to maximize profits at various levels of salt outflow from the farm operation. This is done through the use of a linear programming procedure designed to minimize the income losses imposed by restraints on the salt outflow from the irrigation return flow. It is based on the physical model and on a set of cost and

Table 29. Comparison of drainage and salt outflow to groundwater for corn, alfalfa, and oats at various levels of water application and initial salt concentration.

Irrigation and Rain cm	Drainage in Centimeters			Initial Salt Concentration Meq/Liter	Salt Flow to Groundwater in Millequivalents		
	Corn	Alfalfa	Oats		Corn	Alfalfa	Oats
5.6	-14.2	-9.7	-3.8	20	-284	-195	-74
5.6	-14.2	-9.4	-3.8	50	-710	-472	-191
5.6	-11.6	-7.8	-3.6	200	-2320	-1561	-718
10.3	-14.1	-9.5	-3.8	20	-282	-189	-76
10.3	-14.0	-9.3	-3.8	50	-700	-466	-190
10.3	-11.4	-7.7	-3.5	200	-2280	-1860	-700
15.0	-14.0	-9.3	-3.8	20	-280	-154	-76
15.0	-13.9	-9.2	-3.8	50	-695	-458	-189
15.0	-11.4	-7.6	-3.5	200	-2280	-1840	-700
22.0	-13.6	-9.4	-3.8	20	-272	-148	-76
22.0	-13.5	-9.2	-3.8	50	-675	-461	-190
22.0	-11.3	-7.5	-3.3	200	-2260	-1840	-660
40.8	-8.7	-7.4	-2.5	20	-174	-148	-50
40.8	-7.1	-6.7	-2.4	50	-355	-370	-120
40.8	-6.2	-5.6	-1.2	200	-1240	-1340	-240
56.4	0.9	0.0	1.3	20	19	0	26
56.4	1.0	0.4	1.3	50	49	22	66
56.4	1.1	0.3	2.5	200	214	61	490
66.7	10.5	8.8	10.0	20	210	178	198
66.7	10.6	9.3	10.0	50	532	467	495
66.7	10.8	9.4	9.9	200	2160	1882	1975

return data for the farm. The beginning point is to assume that any amount of salt can be allowed to leave the farm. The model is set to maximize net income under this assumption, then it is successively constrained to allow smaller and smaller amounts of salt outflow. Of primary concern is the reduction of income which accompanies this constraint on resource use. Also of concern are the cropping and irrigation management alternatives as they affect income and salt outflow.

As the salt outflow and income incrementally change, the model develops as a by-product the marginal relationship between salt outflow and income. From this relationship a shadow price is derived which reflects the value of an additional ton of salt outflow in terms of net income, or the amount of the income loss that occurs as salt outflow is incrementally reduced. This value can be compared with alternative ways of reducing salinity in the river or compensating the damages that accrue to downstream users.

The linear programming model used in this study is a profit maximizing model which has the algebraic form:

$$\begin{aligned} \text{Maximize} \quad & Z = CX \\ \text{Subject to} \quad & AX \gtreqless B \\ & X \geqslant 0 \end{aligned}$$

in which Z is net income or profit, C is the row vector of net revenue per unit of activity, X is the set of activities or production processes, A is the matrix of technical coefficients or production relationships, and B is the column vector of constraints on resource availability.

Linear programming and the economic concepts involved were applied to the present study as follows:

1. **The optimal combination of crops to be produced is selected subject to constraints on certain fixed inputs such as land.**
2. **Many of the inputs are not fixed, therefore, the optimal combination of these inputs can be selected by considering their relative productivity and cost.**
3. **The optimal level of output per acre is defined and selected at the point where the value of the incremental unit of production or output equals the cost of the incremental unit of input.**

Using the multi-year calculation of soil salinity during a given year where the initial soil salinity level depends on the final salinity of the previous year, a simple recursive program was adopted to calculate and maximize net income over a 6-year period. Instead of using stochastic processes to estimate supply relationships by the prices of commodities and their major competitors, we began with the technical structure of the decision-making process and derived from it the relationships connecting production to prices, costs, acreage controls, and technological changes. This technique was adapted to maximize net revenue subject to salinity constraints over a 6-year period.

Decision options were analyzed which included cropping choices, water application alternatives of sprinkling or flooding, and variations in the quantity of water applied during the season. Several combinations of these alternatives were used in this study as shown in Table 30, except that flood irrigation was not used on the lowest three levels of water application. It would be impossible to distribute these small amounts of water uniformly over the season by flooding.

It was assumed that the farm under study had 10 acres of each of the three soil salinity characteristics described previously: 20, 50, and 200 meq/l. There were also constraints to provide for crop rotation in order to allow for nurse crops for alfalfa seedlings and for disease control in corn production.

Table 30. Management decision options utilized in the analysis of salinity outflow.

Crop	Water Application Plus Rain	Irrigation Method
Corn	10.3 cm	Sprinkler
Oats	15.0	Flooding
	22.0	
Alfalfa	40.8	Flooding
	56.4	
	66.7	

Results

Two main sets of results were desired for the single year and multi-year analyses. The first was the set of production activities that would maximize farm profits at each level of salt outflow. The second calculation desired was of the loss in income from not allowing an additional ton of salt to flow out. As has been explained, the mirror image of this is the shadow price or the value to the farm of allowing an additional ton of salt outflow.

A number of different situations were modeled to determine the manifold effects of variations in irrigation methods, rates of water application, and restrictions on the cropping combinations. Of the several situations that were simulated, two are deemed relevant for this presentation. In both cases corn is restricted to one-half of the acreage with alfalfa roots assumed deeper than corn roots. One case simulates the conditions associated with sprinkler irrigation. The other shows the effects of flood irrigation. Optimal cropping and irrigation strategies were calculated for both strategies for levels of salt output from zero to 12 tons per acre. These strategies were then simulated at each level of salt output and revenue figures were derived for the farm enterprise.

In the first situation where sprinkler irrigation was used, the optimal cropping pattern for all levels of initial soil salinity and salt output was to allow the maximum corn cultivation of half of the acreage with the remaining acreage devoted to the cultivation of alfalfa except for the restriction that oats be used as a nurse crop on one-tenth of the land. The higher water application levels dominate the irrigation strategy. The lowest two levels are never shown to be optimal for any crop in any situation.

The pattern of net revenue and the shadow price of salt outflow for the first situation are shown in Figure 3 and Figure 4. The results indicate that at the very lowest levels of salt outflow the reduction in net revenue for the farm is considerable while the income loss is not great at a level of 80 tons for the 30 acres and becomes less significant at higher levels. It can be concluded by viewing these results that a zero output would be very costly if not entirely impossible.

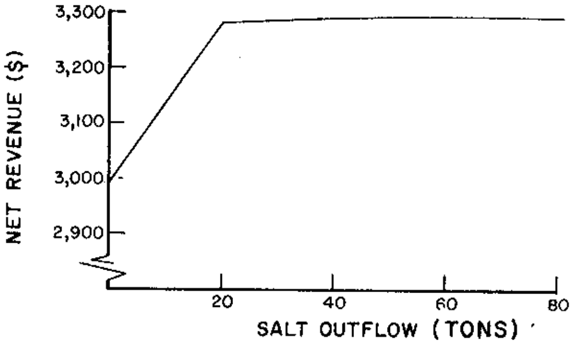

Figure 3. Net revenue by amount of salt outflow (sprinkler) for the 30 acres.

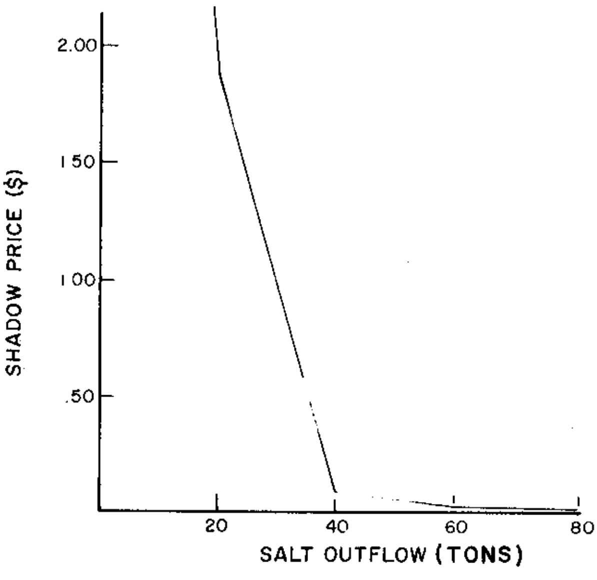

Figure 4. Shadow price or value of an additional ton of salt outflow (sprinkler), for 30 acres.

When flood irrigation is used instead of sprinkling, alfalfa dominates the cropping pattern completely (again with an allowance for the oats as a nurse crop), in the levels of salt output less than 6 tons per acre. In the low salt soil, the maximum allowed corn cultivation is shown to be optimal at the higher levels of salt outflow while some corn would be cultivated at the high salt outflow levels for the soil of higher initial salt concentrations. Only the three highest irrigation levels would be utilized under this situation with the highest level used at the higher levels of salt outflow.

The net revenue and shadow price patterns are illustrated in Figure 5 and Figure 6. Essentially the same pattern is shown for this situation as for sprinkler irrigation except that the shadow price of salt outflow drops to a very low level at a lower salt outflow level.

A number of interesting but somewhat expected results occurred in the multi-year simulations of irrigation management practices and optimal cropping patterns. The lowest level of water application (20 cm) resulted with a salt buildup in the soil profile which tended to taper off in the last few years of the 6-year period. This tapering was due to the effect of the optimal cropping strategy which let a few acres remain idle allowing a heavier water application for the remaining land which leached the salt from the profile of that part of the land. The heavier water application rates resulted in no extreme change in soil salinity over time. For the soil of high initial soil salt concentration, (50 and 200 meq/l), the highest water application rates brought an actual decline in soil salinity over time. As might be expected, the heavy applications flush the salt through the soil while the lighter applications result in less outflow but also lead to a severe degree of salt buildup in the soil.

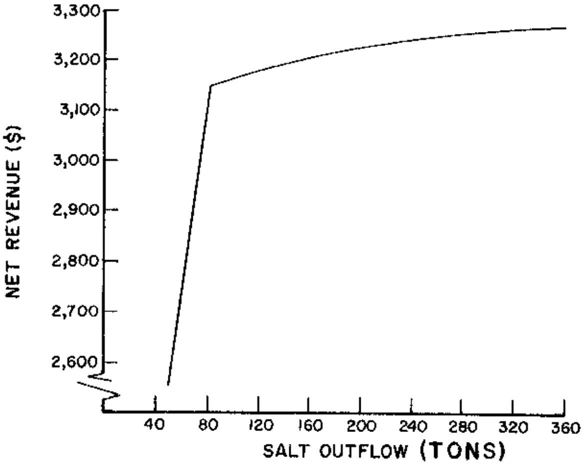

Figure 5. Net revenue by amount of salt outflow for the 30 acres.

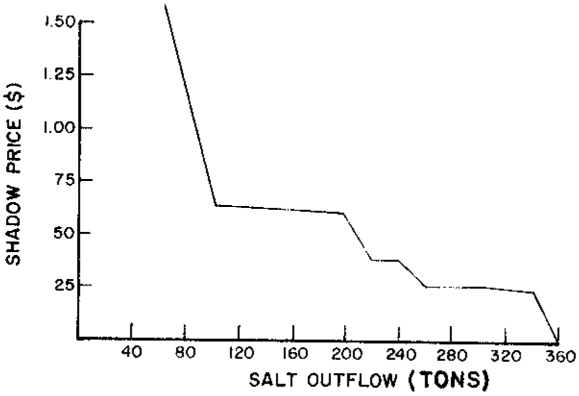

Figure 6. Shadow price or value of an additional ton of salt outflow for the 30 acres (flood).

According to the results from the profit maximizing model associated with the multi-year analysis, alfalfa combined with the necessary nurse crop of oats dominates the cropping pattern where minimum water application is allowed with sprinkler irrigation indicated as the optimal water application method. Corn with flood irrigation dominates the high water application method as well as the situations for maximization of profits.

The lower water application rates cause very little salt outflow during the first few years, but the outflow increases during the final 2 years. The higher application rates are associated with high salt outflow which increases at a decreasing rate.

The level of profits is maintained fairly constant in the two highest water application rates, but the profits are shown to decline in the lower rates as productivity declines due to salt buildup in the soil profile. In view of this result, the shadow prices indicated in the single year analysis are rendered less than an accurate reflection of the value to the farm of allowing higher levels of salt outflow.

Summary and Policy Implications

The costs of reducing salt outflows through irrigation management include the actual costs of improvements (i.e. sprinkler systems, ditch lining, etc.), and the reduction of income which results from falling yields when salts are allowed to accumulate in the soil profile. When these costs are considered, it is evident that a reduction in salt outflow to a level of 1 or 2 tons per acre (30 to 60 tons on the figures) is less expensive than any other current alternative for reducing salinity in the Colorado River. However, because of the salt buildup that would occur in the soil profile over time when salt outflow is low, the long-run costs are greater than might be supposed through the use of 1-year analysis. A policy of zero output of salt from agricultural operations would be extremely costly if even possible.

CHAPTER V
ESTIMATION OF ECONOMIC IMPACTS FROM SALINITY REDUCTION IN THE COLORADO RIVER BASIN

The second and third chapters have estimated regional income losses for the Lower Colorado River Basin (Arizona-California) stemming from agricultural and municipal damages imposed by salinity. Appendix 7 provides estimates of regional income losses to the Upper Colorado River Basin (in particular, the Upper Main Stem Subbasin) which might follow the phasing out of certain economically marginal acreages. The fourth chapter describes the costs and other economic impacts of salinity control measures. This section combines these data with data from other sources to construct marginal cost and benefit schedules for varying quantities of salt load reduction. These schedules identify currently justifiable projects or programs for salinity control as accurately as was possible within the limitations of the available data.

Data are available on the following projects or programs for salinity control:

1. Paradox Valley of the Dolores River (Bureau of Reclamation Project). It is estimated that 180,000 tons/year can be eliminated by undertaking a groundwater pumping and evaporation scheme which would reduce water contact with huge salt domes. The project will cost approximately $16 million. If we assumed indefinite life for the project facilities and a 10 percent interest rate, the annual cost of $1.6 million implies a cost per ton removed of $8.90. An increase in consumptive water use will also occur. We have assumed this loss to be 10,000 ac ft per year. Afterwards, the Bureau estimated this to be 3900 ac ft annually, and this would reduce the costs of tons of salt removed by Paradox Valley.
2. Grand Valley (part of Upper Main Stem Subbasin) canal lining scheme (Bureau of Reclamation). It is estimated that canal lining and better irrigation scheduling can reduce the salt load by 200,000 tons per year. The cost is estimated to be $59 million, implying a cost of $30 per ton removed. Canal losses of about 40,000 ac ft per year will be avoided, and we assume that no more than 20,000 ac ft of this represents actual saving of water which would not have returned to streams for further use.
3. Improved on-farm irrigation practices. Leathers and Young have estimated that about 110,000 tons/year could be avoided at costs averaging $2/ton. These practices would also save 45,000 ac ft of consumptive use in the Grand Valley.[1]
4. Modified cropping patterns I. Leathers and Young have estimated that salt loadings of 21,500 tons per year could be avoided in the Grand Valley at costs of about $8/ton plus 4300 ac ft of added consumptive use.
5. Modified cropping patterns II. Leathers and Young estimate that further modifications could avoid an added 12,500 tons/year at costs of about $19/ton and 2200 ac ft of added consumptive water use.
6. Howe and Young (Appendix 7) estimate that phasing out 8800 acres of cropland in the Grand Valley would involve a regional income loss of $163 per acre per year, but saving 10 tons of salt per acre and reducing consumptive use by 14,800 ac ft per year.
7. Howe and Young (Appendix 7) also estimate that phasing out 10,200 acres in the Uncompaghre Valley (part of the Upper Main Stem Subbasin) would also involve a regional income loss of $163 per acre, saving an assumed 10 tons of salt per acre per year and reducing consumptive use by 16,000 ac ft per year.

These data were used to rank these projects or programs in terms of cost per ton of salt removed in order to develop a marginal cost schedule for different quantities removed. There are, however, two difficulties in proceeding to construct that schedule. The first is that a joint product is being produced by most of these activities: salt reduction and a reduction in consumptive use of water (activities 1, 4, and 5 actually increase consumptive use of water). The waters of the Colorado River are fully utilized at the present time, so that water has a positive scarcity value. An acre foot freed from one use will be used beneficially at another location. An added acre foot of water consumed deprives downstream parties of its use. The opportunity cost has been estimated to be about $10 per acre foot, but that figure needs to be increased to $15 to allow for inflation in the cost of agricultural commodities since 1970.

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[1] Leathers, K.L., and R.A. Young (Appendix 5).

Thus, in costing out salt reductions, it is possible to subtract from (add to) the cost per ton removed the value of water simultaneously released from (added to) consumptive use and valued at $15 per ac ft.

The second problem is that the quantities of salt associated with the various projects or programs listed above are not strictly additive. For example, if canal lining is undertaken, the salt reductions available through improved on-farm irrigation practice may be reduced. It is probably the case that the full benefits from such irrigation improvements could not be realized after modification of cropping patterns. Finally, it is clear that acreage reductions in the Grand Valley will reduce the areas to which improved irrigation practice and cropping patterns can be applied.

To deal with this problem, we make the following assumption:

> The potential salt savings from activities 2, 3, 4, and 5 (as listed earlier and all being in the Grand Valley) will be reduced in proportion to any acreage phased-out in the Grand Valley.

Since there are 8800 candidate acres in the Grand Valley out of a total (non-orchard irrigated acreage of 57,000 acres, this would represent a 15 percent reduction, or a reduction to 85 percent of the levels achievable without acreage phase-out. Thus if a cost schedule is constructed which contains Grand Valley acreage phase-out, the potential salt savings from activities 2, 3, 4, and 5 must be reduced by 15 percent. The Paradox Valley point source project and the phase-out of acreage in the Uncompaghre Valley are independent of the other activities.

Table 31 gives the results of these calculations, with the various activities listed in ascending order of cost per ton of salt removed. Indirect downstream effects are also evaluated. See methods described in Appendix 7.

The Colorado River is used both for irrigation and for municipal and industrial purposes (M&I). This study has dealt only with the regional damages which occur via agriculture. The small portion of M&I use (less than 5 percent of total withdrawals) inflicts some damage to residential public, commercial, and industrial equipment. These damages would have to be added to the benefit schedule, but the small amounts of water withdrawn for M&I uses imply that the M&I benefits (damages saved) per ton of salt removed would be small.

Benefits from salinity reduction take the form of damages avoided. Several cases were considered for various TDS intervals, 900-1100 mg/l, 1100-1200 mg/l, etc. The current TDS level at the major diversion point, Imperial Dam, is approximately 865 mg/l. It has been estimated that the TDS level at Imperial Dam will approach 930 mg/l by 1980, 1100 mg/l by 1990, and 1200 mg/l by 2000 in the absence of salinity control programs, given the trends in Upper Basin water uses. For present analyses, it seems reasonable, therefore, to confine our attention to the salinity intervals 900-1100 mg/l and 1100-1200.

The relationship between a change in salt loading in the upper basin and the TDS concentration at Imperial Dam is that approximately 10,000 tons equals 1 ppm.[2] This permits the conversion of the loss data into (1974) dollars per ton of TDS. These data are presented in Table 32.

Table 33 presents annual benefits for the various activities under the different unit benefit values. Potential salt removal savings have been calculated assuming Grand Valley acreage reduction. Again, it is felt that the "no forward linkage" (defined on page 314, Appendix 7) cases most closely approximate reality, but forward linkages cannot be ruled out without

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[2] This is an average value taken from Bureau of Reclamation studies and given to the present author by John T. Maletic.

Table 31. Calculation of net cost of salinity reduction by activity.

Activity	Independent Salt-Saving Potential (Tons/Year)	Salt Saving Potential c/G.V. Acre. Ret. (Tons/Year)	Project Cost Per Ton of Salt Extracted	Water Saved	Value of Water Saved Per Ton of Salt Extracted	Net Cost Per Ton of Salt Extracted
On-farm Practices	110,000	93,500	$ 2.00	44,700	$ 6.10	$- 4.10[a]
Paradox Valley	180,000	153,000	8.90	-10,000	-0.80	9.70
Modified Crops I	21,500	18,300	8.00	- 4,300	-3.00	11.00
G.V. Acreage Ret.	–	88,000	16.30	14,800	2.50	13.80
Uncom. V. Acre. Ret.	102,000	102,000	16.30	16,000	2.30	14.00
Modified Crops II	12,500	10,600	19.00	- 2,200	-2.60	21.60
Grand Valley Canals	200,000	170,000	30.00	20,000	1.50	28.50
Total	626,000	635,400	–	–	–	–

[a] This negative sign indicates the high desirability of undertaking these activities. Project costs may be somewhat understated. See Leathers and Young (Appendix 5).

Table 32. Annual benefits[a] per ton of salt load reduction: Alternative cases and salinity levels (1974 dollars/tons).

Salinity Level At Imperial Dam	No Forward Linkage[c]		Forward Linkage[c]	
	Case 1[d]	Case 2[e]	Case 1[d]	Case 2[e]
900-1100 ppm	8	0[b]	81	0[b]
1100-1200 ppm	24	20	54	55

[a] Damages avoided.

[b] This is interpreted as no significant damage.

[c] Forward linkages, p. 314, Appendix 7.

[d] Long run.

[e] Short run.

further study. In fact, Tables 31, 32, and 33 clearly indicate the critical need for knowledge about forward linkages: if there are none, the unit benefit range is $0 to $8. If we really don't know, the range is $0 to $81. Most decision-makers would not find the latter statement of much help.

Figure 7 provides a visual summary of the data on the costs of salinity control projects and benefits from salinity reduction. Figure 7 shows clearly that on-farm practices which mitigate salinity and reduce consumptive use are by virtue of their negative cost economically worthwhile quite aside from the reduction of salinity damages. The value of the water saved, evaluated in a basin context, is more than the cost of the steps taken. However, at present there is no motivation for the private farm manager to undertake these steps since the benefits accrue to other water users. As one moves to the right on Figure 7, the Paradox Valley project is shown to be justified only if benefits exceed the $8/ton figure estimated for the first case with no forward linkages and a salinity level of 900 to 1100 ppm. Since the upper bound on unit benefits in the absence of forward linkages is $24 per ton (Table 32), it is clear that the second round of crop modification and the Grand Valley canal lining program are not economically feasible, unless long-term forward linkages can be demonstrated. It appears quite likely that carefully designed irrigated acreage retirements and the Paradox Valley project are economically feasible.

Table 33. Total annual salinity reduction benefits by projects at various unit benefit levels.

Activity	Tons Saved Per Year	Total Annual Benefits (000) When Benefits Per Ton Are:					
		0	8	20	24	55	81
On-farm Practices	93,500	0	748	1,870	2,244	5,143	7,574
Paradox Valley	153,000	0	1,224	3,060	3,672	8,415	12,393
Modified Crops I	18,300	0	146	366	439	1,007	1,482
G.V. Acreage Ret.	88,000	0	704	1,760	2,112	4,840	7,128
Uncom. V. Acre. Ret.	102,000	0	816	2,040	2,448	5,610	8,262
Modified Crop II	10,600	0	85	212	254	583	8,586
Grand Valley Canals	170,000	0	1,360	3,400	4,080	9,350	13,770
Totals	635,400	0	5,083	12,708	15,250	34,947	51,467

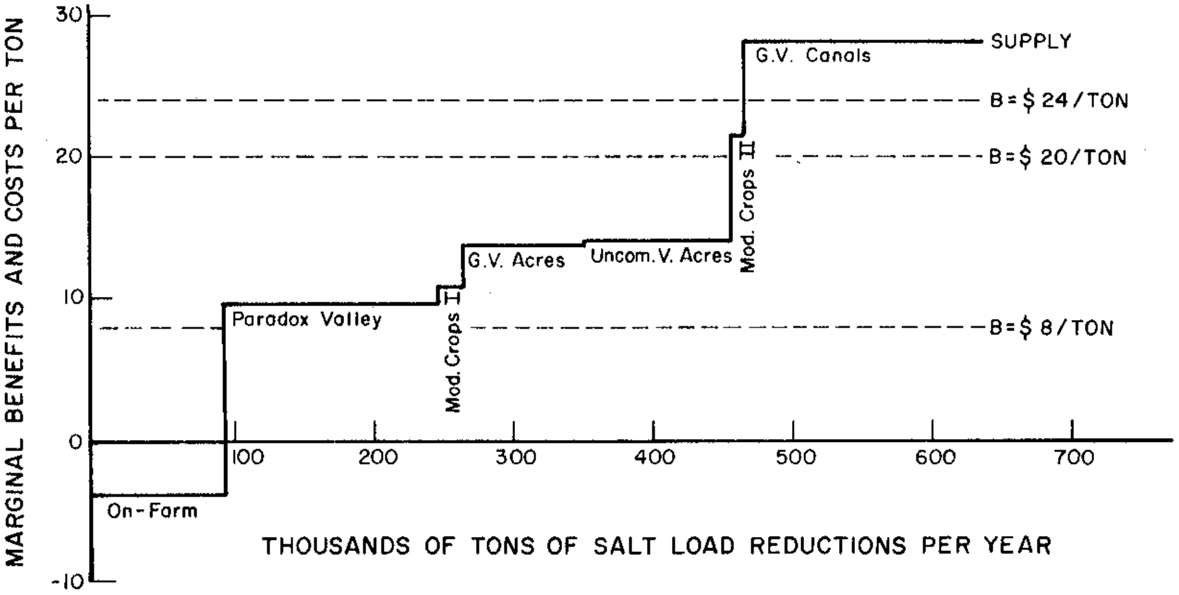

Figure 7. Comparison of the costs and benefits of salinity reduction.

CHAPTER VI
SUMMARY

This research was designed to provide an evaluation of the reaction of agricultural, municipal, and industrial users to the increasing levels of salinity in the Colorado River Basin. Initially, agricultural users were identified and damages assessed.

For the purposes of this study, estimates of crop yield losses due to various salt concentrations were based upon the salinity of the soil solution, the level of salinity expected to develop in soils with various infiltration rates and drainage capacities, soil drainage classes and acreages, and the crop reports of the irrigation districts. The principal crops were partitioned on the different soil classes and yields projected on the basis of irrigation practices and the changing salinity levels of the irrigation water which is expected to reach the 1,400 mg/l TDS level by the year 2000. Variations in blends of water sources were taken into account where applicable. Most of the area surveyed in Arizona gave little indication of extreme yield declinations, but this was attributed to the different water blends and the small proportion of poorly drained soil in relation to the total acreage. Currently on 90,000 acres of land in the Central Arizona Project, Yuma area, and the Colorado Indian Reservation are classified as poor drainage soils. This constitutes only about 17 percent of the 531,000 acres under irrigation at the present time. The California region indicated a much higher yield loss, principally because there is a much larger proportion of the irrigated soils which are classed as poorly drained or very poorly drained. Of the 650,000 acres of land under consideration more that 350,000 or 55 percent of the irrigated land was classified as poorly or very poorly drained.

There are two options available in dealing with the problem of rising salinity levels. The first is to accept the damages in the form of declining yields and reduced acreages which ultimately will inhibit production. The second option is to practice one or more of the management options currently available to reduce salinity levels. Naturally, these options are not without cost. Some current management practices include ditch lining, land leveling, slip and moldboard plowing, leaching irrigation, and drip irrigation installations.

These management practices require substantial additional investment in farm operations, ranging from $50/acre for land leveling up to $600/acre for sprinkler irrigation. If farmers do not have access to the large amount of capital required for such investments, they may be forced to change to more salt tolerant crops. For example, canteloupe, watermelon and barley showed little effect from the increased salinity levels in the Imperial Valley of California.

As previously noted, well drained soil was least affected, in terms of crop losses, by the increased salinity levels. This is also shown by the relatively stable production of the well drained land as salinity concentrations increased. It is worthwhile to note that the relative production of the other land classes declined as salt levels increased from 900 mg/l to 1,400 mg/l. However, when the levels actually reached 1,400 mg/l, the relative of all land classes decreased.

The annual damages for all agricultural areas considered in the lower basin was approximately $33,133 per mg/l of TDS. Any development on the river can be evaluated in dollar terms if, as we hypothesized, farmers do respond to increasing salinity in a profit maximizing manner. The actual losses to farmers are likely to be much higher if the alternative management practices are not applied.

Next, municipal damages were evaluated and costs estimated for increased salinity levels. It has been recognized for sometime that variations in the chemical constituents of water may affect the lifetimes of household water conveyance systems and appliances using water. Economic losses associated with variation in water use by households were measured for water heaters, various types of water pipes, brass faucets, dishwashers, washing machines, and garbage disposals.

Two locations in the Los Angeles area of California were included with each location being divided according to socio-economic units based on differences in median home value, median contract rent, number of persons per household, age of structure, etc. Plumbing contractors, along with local appliance dealers were contacted to provide estimates of the average lifetimes for the various plumbing fixtures and appliances.

A regression analysis examining the relationship between estimated lifetime, total dissolved solids

(TDS), and the socio-economic variables was conducted. None of the socio-economic variables were found to be statistically significant in variation in estimated lifetimes other than the number of people per household.

Estimated economic losses for a typical Los Angeles household, utilizing an 8 percent discount rate, ranged from $620 to $1,010 in present value terms with an increase in TDS from 200 to 700 mg/l. The estimated economic losses developed in this study are two to three times higher than those previously reported in the water resource literature. Aggregate damages to households in the Los Angeles metropolitan area due to increased salinity levels can be estimated to be between $880 million and $1.44 billion in present value terms. An improvement of 10 mg/l TDS in the Colorado River water delivered to Los Angeles residences would lead to a cost savings of approximately $14 million in present value terms, or $1.12 million per year. This estimate is likely to be downward biased since it does not include all types of household savings. On the other hand, it does not take into account technological advances such as using new types of pipe or water softening devices.

An additional area relevant to this research, an estimation of direct economic impacts of the upper basin, was also examined. This included an inspection of the origin of the salinity problem and the impact of current users in complicating this problem. Salinity is due in part to natural causes (salt springs, natural runoff) and in part to man-made causes (agriculture and industry). Salt contributions due to irrigation in the upper basin have been estimated to account for about 38 percent of the total damage which accrues to downstream water users. A substantial amount of salt is accumulated from ancient marine deposits beneath irrigated land which is in addition to the usual fertilizer leaching and evapotranspiration that occurs. The economic costs to water users of nonstructural methods of controlling saline irrigation return flows were examined as opposed to the structural methods. Nonstructural methods included changes in the institutional system (incentives, constraints, penalties) to modify current irrigation practices. It is possible to influence the amount of deep percolation by varying the amount and rate of water applied through the course of a normal growing season. Two specific practices include altering the length of time water is allowed to run in each furrow and/or adjusting the quantity of water in each furrow. It is also possible to vary deep percolation losses by cutting back the acreage of crops which traditionally are high contributors in favor of those which are less of a problem. Both of these methods involve increased costs or decreased income.

It could not be established conclusively that crop yields would be reduced by more efficient irrigation practices, so this cost was not included. From the results obtained, it is apparent that improved irrigation efficiency can bring about a 75 percent decrease in salt discharge for a cost of $2.22 per ton of salt removals with only a 3 percent loss in total net farm income. While 40 percent of the initial salt load can be removed by the use of crop substitution, it is at a cost of $60 per ton of salt removal. It was also noted that the evidence surrounding these conclusions are not without question. For instance, there is considerable disagreement as to the rate of salt pickup per unit of drainage water. Also, it may not be possible to increase irrigation efficiency without some sacrifice in crop yield. Finally, there is no analysis of the regulatory costs or social costs necessary to improve water quality standards.

In a further attempt to define the damages due to various salinity levels, a physical model was constructed to predict the response of soil, water, and crop factors to irrigation. Various consequences of a given irrigation management sequence for a typical season were computed. Three important factors were varied, including irrigation practices, initial salt concentrations, and cropping procedures. This model provided evidence that the elimination of salt leaching from irrigated land was accompanied by rather dramatic changes within the soil profile. Final salt concentration levels indicated a buildup of salts within the soil which implied that there could be a serious effect on crop yields if that level of salinity were maintained. However, when the irrigation level reached 66.7 cm, salt was leached from the soil and the buildup ceased. At the highest water application levels, there is an indication of some transfer of salts from the soil into the return flow.

Given the information concerning salt buildup and leaching, an economic model was developed to suggest ways to maximize profits at various levels of salt outflow from the farm operation. A shadow price of the salt outflow, determined with the use of linear programming procedures, reflected a value of additional salt removal or outflow. The determination of this value allowed a comparison of alternative methods of reducing salinity in the river or compensating the damages that accrue to downstream users.

The level of profits for farmers remained fairly constant at high water application rates, but profits declined at the lower rates as productivity fell due to the salinity buildup.

The actual costs of implementing improvement practices and the reduction of income resulting from declining yields as salts are maintained were included in determining costs of reducing salt outflows through irrigation management. When the total costs were taken into account, it was evident from a one-year analysis that a reduction in salt outflow to a level of one or two tons per acre was less expensive than the other viable alternatives. However, because of the potential salt buildup that would subsequently occur, the long run costs were greater than was indicated in the one year analysis. This implied that a policy of zero output of salt would be prohibitive if possible at all.

In conclusion, these data were combined with data from other sources to construct cost and benefit schedules for varying quantities of salt load reduction. These schedules were designed to permit the identification of justifiable projects or programs for salinity control. The data available provided the essential ingredients of a marginal cost schedule for different quantities removed.

In general this study dealt with damages which occur because of agricultural use since agriculture accounted for 95 percent of the total water withdrawn from the river. Damages to municipal and industrial users were identified and costs assessed as noted earlier in the study. Those damages were not included in the benefit schedule since the relatively small withdrawals for municipal and industrial purposes added little to benefits per ton of salt removed. Benefits from salinity reduction take the form of damages avoided. It was estimated that a change of 10,000 tons of salt in the upper basin resulted in a change of 1 mg/l in the salinity level for the lower basin.

On-farm practices which mitigate salinity and reduce consumptive water may be **economically worthwhile** quite aside from the reduction in salinity damages. The value of the water saved, evaluated in a basin context, is more than the cost of the corrective actions taken. It is more important to realize that at the present time, there is no motivation for the private farm manager to undertake these steps since all benefits accrue to the Lower Basin.

Since the upper bound on benefits is $24/ton in the absence of forward linkages, it is clear that the second round of crop modification and canal lining in the Upper Basin is not economically feasible unless the predominance of long-term forward linkages can be demonstrated.

APPENDIX 1
AGRICULTURAL CONSEQUENCES FROM SALINITY IN ARIZONA

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GILA AND YUMA PROJECTS

The soils of the Gila and Yuma irrigation projects on the Colorado River in southwestern Arizona have been divided, generally, into series and associations by the Soil Conservation Service. They estimated the occurrence of the different series in the Wellton-Mohawk Valley by means of soil profile studies made in holes dug on a 1/2 mile grid. The North Gila, South Gila, and Yuma valleys are maped more generally as associations, principally C-2 and C-3. C-2 is the Gilman-Vint Association which consists of 45 percent Gilman series, 25 percent Vint series and 35 percent soils of the Maripo, Agualt, Glenbar, and Imperial series in approximately equal proportions. C-3 is the Imperial-Glenbar Association which consists of about 40 percent Imperial clay, 30 percent Glenbar soils, and 30 percent Holtville, Gadsden and Cashion in about equal proportions. Brea is found in small areas but not named in either association.

Since these valley soils were laid down by the Colorado and Gila Rivers, they occur in various intermingled patterns, often small irregular strips. For this reason, the valleys are cropped without regard for soil type unless experience has shown that a given area is unsuited to a given crop. Apparently, no attempt has been made to report any distribution of crops by soils.

The soils of the Yuma and Wellton mesas are sandy and generally uniform with little variation. The Wellton Mesa is 95 percent, or more, classed as the Wellton series. The Yuma Mesa is entirely the Superstition series.

With the assistance of Earl Champerlain of the SCS Soil Survey group at Yuma, estimates of the occurrence of the different soils were made as shown in Tables 1-1 and 1-2. These were assigned to three drainage groups by means of the soil series descriptions and equated to the drainage classifications shown by Robinson (Appendix 2, p. 83). Abbreviated soil series textural descriptions and permeabilities (where available) are also shown in Tables 1-1 and 1-2.

Yields and acreages of the major crops in the Gila and Yuma projects were obtained from crop census data worksheets prepared by the Yuma Projects office of the U.S. Bureau of Reclamation. Weighted average yields for the Project are summarized over six years in Table 1-3.

Since crop acreages of the major crops have steadily shifted toward the acreages now grown, the 1972 acreages, rather than averages, were used in the projections for estimating future crop declination to be expected from increasing salinity of the irrigation water. The partitioning of crop acreages into drainage classifications is shown in Table 1-4.

The effective values of soil saturation extract conductivities for the three drainage classes as worked out by Robinson and explained in his Imperial Valley report (Appendix 2, Procedure, p. 88) are shown in Table 1-5. These data with the yield declination data from the California Committee of Consultants, shown in Table 1-6, were used in calculating the projected yields for the ten major crops shown in Table 1-7. Values of the ten major crops from 1967 to 1973 are shown in Table 1-8, and costs of irrigation water are shown in Table 1-9.

COLORADO RIVER IRRIGATION PROJECT (COLORADO RIVER INDIAN RESERVATION PARKER, ARIZONA)

The Bureau of Indian Affairs has classified the Arizona bottom land soils of the Colorado River Indian Reservation into four general classes. Classes 1, 3, and 4 were, more or less, carefully delineated, leaving the soils which did not fall into these three classes in class 2. Billy Martin, Indian Service Soil Conservationist in the Parker office, equated the four classes to the SCS soil series classifications as follows: Class 1 is well drained loam similar to the Gilman series. Class 3 is well drained with medium textured topsoils and coarser textured subsoils similar to the Vint series. Class 4 is very well drained and includes loams and sandy loams underlaid with coarse sands similar to the Brios series. Class 2 includes the heavier less well drained fine textured soils. Approximately two-thirds

Table 1-1. Assignment of soil series to drainage groups.[a]

Soil Series	Soil Texture	Permeability[b] in./hr.	Drainage Classification Acres			Estimated Percent
			Well	Moderate	Poor	
	North Gila, South Gila, and Yuma Valleys					
Agualt:	0-27" Loam, 27-60" Sand	0.63-2.0	3,150			5
Brios:	0-14" Sandy Loam, 14-22" Coarse Sand, 22-50" Stratified Coarse Sand	2.0 -6.0	3,150			5
Cashion:	0-27" Clay, 27-29" Very Fine Sandy Loam, 39-42" Light Silt Loam	0.06-0.2			3,150	5
Gadsden:	0-43" Clay, 43-60" Clay Loam	0.06-0.2			3,150	5
Gilman:	0-13" Loam, 13-60" Very Fine Sandy Loam	0.63-2.0	12,600			20
Glenbar:	0-27" Clay Loam, 27-56" Silty Clay Loam, 56-60" Clay Loam	0.2 -0.6		11,340		18
Holtville:	0-17" Silty Clay Loam, 17-24" Silty Clay, 24-35" Silt Loam, 35-72" Loamy Very Fine Sand	"Slow"			3,150	5
Imperial:	0-60" Silty Clay	"Slow"			12,600	20
Maripo:	0-34" Sandy Loam, 34-60" Gravelly Sand	2.0 -6.3	3,150			5
Vint:	0-25" Loamy Fine Sand, 25-27" Silt Loam, 27-33" Loamy Fine Sand, 33-36" Very Fine Sandy Loam, 36-42" Loamy Fine Sand, 42-45" Fine Sandy Loam, 45-60" Loamy Sand	6.3 -20.0	7,560			12
	Yuma Mesa					
Superstition:	0-60" Loamy Fine Sand	6.0 -	21,000			100

[a] From U.S.D.A. S.C.S. descriptions.

[b] Permeability of most restricting layer.

of this classification is similar to the moderately well drained Glenbar series, and approximately one-third is similar to the poorly drained Gadsden or Imperial series (Series descriptions are shown in Tables 1-1 and 1-2).

A total of 105,734 acres of the Colorado River flood plain has been mapped and will eventually be brought under cultivation. The annual crop reports (USDI, 1969-1973) show an increase from 51,149 acres cropped in 1969 to 62,748 acres in 1973. At this rate, all of the project acreage should be under cultivation within 15 years.

At present, the lighter soils are cropped principally with alfalfa, but there has been no effort to determine the distribution of crops on the different soil types. For this reason, the crop acreages shown in Table 1-12 were arbitrarily assigned to the drainage classes on the basis of the percentage figures shown in Table 1-10, adjusted after assuming that approximately two-thirds of the alfalfa acreage is on the lighter soils of classes 3 and 4.

Since the 105,734 acre project will all be under cultivation by the year 2000, the 1973 acreages shown in Table 1-12 were projected on that basis, as shown in Table 1-13. These are the acreages used for estimating future crop declination from increasing salinity of the irrigation water (Table 1-15). The yield declination data shown previously in Table 1-6 and used in calculating the projected yields did not include that for onions which is shown in Table 1-14. Values of the seven major crops from 1969-1973 are shown in Table 1-16. Cost of irrigation water is shown in Table 1-17.

CENTRAL ARIZONA PROJECT AREA

The Bureau of Reclamation awarded the first construction contract of the Central Arizona Project in April of 1973. Groundbreaking ceremonies were held on the shores of Lake Havasu on May 6, 1973, and it is anticipated that water will be flowing through the Granite Reef Aqueduct by 1980. This gives the Arizona Water Commission less than 5 more years to complete the task of allocating CAP water to the many potential users. They have "expressions of interest" from approximately a hundred sources. These include between 16 and 20 old established irrigation and drainage districts, newly formed districts, utility companies, mining companies, water companies, municipalities, military posts, ranches, individuals, and others. It is obvious that any sort of equitable distribution will be extremely difficult.

In the course of negotiations which finally resulted in authorization of the CAP, the Department of the Interior assured Congress that there would be a water supply adequate to deliver an annual average of 1,200,000 acre feet to the CAP during the 50-year project cost repayment period. However, in any year in which there should be too little water available to deliver the minimum allotments to California, Nevada, and Arizona, it is agreed that the shortage will be borne first by the CAP. By the same token, CAP will share in any surplus above these minimums.[1]

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[1] Lower Basin allotments: California 4,400,000 acre feet; Nevada 300,000; Arizona 2,800,000.

Table 1-2. Assignment of soil series to drainage groups.[a]

Soil Series	Soil Texture	Permeability[b] in./hr.	Drainage Classification			Estimated Percent
			Well	Moderate	Poor	
	Wellton-Mohawk Valley					
Agualt:	0-27" Loam, 27-60" Sand	0.63-2.0	8,920			16.5
Brios:	0-14" Sandy Loam, 14-22" Coarse Sand, 22-50" Stratified Coarse Sand	2.0 -6.0	4,590			8.5
Gilman:	0-13" Loam, 13-60" Very Fine Sandy Loam	0.63-2.0	9,450			17.5
Glenbar:	0-27" Clay Loam, 27-56" Silty Clay Loam, 56-60" Clay Loam	0.2 -0.6		1,890		3.5
Holtville:	0-17" Silty Clay Loam, 17-24" Silty Clay, 24-35" Silt Loam, 35-72" Loamy Very Fine Sand	"Slow"			2,430	4.5
Indio:	0-10" Very Fine Sandy Loam, 10-60" Stratified Very Fine Sandy Loam and Silt Loam	"Moderate"	5,400			10.0
Maripo:	0-34" Sandy Loam, 34-60" Gravelly Sand	2.0 -6.3	8,910			16.5
Meloland:	18-26" Silt Loam, 26-71" Silty Clay	"Slow"		1,350		2.5
Niland:	0-23" Stratified Gravelly Sand and Sand, 23-48" Silty Clay	"Slow"			540	1.0
Ripley:	0-12" Silty Clay Loam, 12-20" Coarse Silt Loam, 20-32" Very Fine Sandy Loam, 32-60" Fine Sand	"Moderate"	1,620			3.0
Vint:	0-25" Loamy Fine Sand, 25-27" Silt Loam, 27-33" Loamy Fine Sand, 33-36" Very Fine Sandy Loam, 36-42" Loamy Fine Sand, 42-45" Fine Sandy Loam 45-60" Loamy Sand	6.3 -20.0	8,910			16.5
	Wellton Mesa					
Coolidge:	0-63" Sandy Loam	2.0 -6.3	270			2.5
Dateland:	0-10" Loamy Fine Sand, 10-17" Fine Sandy Loam, 17-33" Loam, 33-66" Sandy Clay Loam	2.0 -6.0	270			2.5
Wellton:	0-6" Loamy Sand, 6-17" Light Sandy Loam, 17-28" Gravelly Sandy Loam, 28-46" Gravelly Loam, 46-56" Coarse, Sandy Loam, 56-70" Gravelly Sandy Loam	2.0 -6.0	10,260			95.0

[a] From U.S.D.A. S.C.S. descriptions, holes on ½ mile grid.

[b] Permeability of most restricting layer.

Table 1-3. Yields of major crops in the Gila and Yuma Irrigation Projects.[a]

Crop	1967	1968	1969	1970	1971	1972	95% Confidence Interval
Cotton	1.96	2.69	2.54	1.83	2.25	2.20	2.25 ± 0.30 Bales
Alfalfa	6.08	5.88	6.82	6.68	6.77	6.83	6.51 ± 0.38 Tons
Lettuce	8.17	5.13	5.33	7.03	4.30	4.86	5.80 ± 1.35 Tons
Cantaloupes	6.37	7.29	7.40	8.22	7.09	7.64	7.34 ± 0.56 Tons
Wheat	1.99	2.10	2.09	2.13	2.32	2.33	2.16 ± 0.12 Tons
Grain Sorghum	2.00	1.86	1.72	2.00	2.22	1.90	1.95 ± 0.15 Tons
Grass Seed	7.42	8.65	7.22	6.83	7.36	6.97	7.41 ± 0.59 cwt.
Grapefruit	12.44	14.50	14.51	14.39	14.07	15.56	14.25 ± 0.93 Tons
Oranges and Tangerines	8.83	8.21	11.25	8.00	7.59	8.30	8.70 ± 1.20 Tons
Lemons	15.20	19.94	15.94	11.93	10.70	10.47	14.03 ± 3.37 Tons

[a] Weighted average yields from the Wellton-Mohawk, North Gila, South Gila, and Yuma valleys, and the Wellton and Yuma mesas.

Table 1-4. ***Partition of crop acreage on different soil drainage classifications—Gila and Yuma projects.***

Crop	Drainage Classification		
	Well	Moderate	Poor
Cotton	13,030	2,520	4,330
Alfalfa	23,140	3,830	6,440
Lettuce	7,720	1,950	3,580
Cantaloupes	4,530	1,100	2,000
Wheat	20,140	3,360	5,560
Grain Sorghum	9,000	1,230	1,900
Grass Seed	7,820	1,330	2,230
Grapefruit	2,200	100	
Oranges and Tangerines	17,000	600	
Lemons	10,000	700	

Table 1-5. ***Effective values of soil saturation extract conductivities in three soil drainage classes, six TDS levels, and five irrigation management treatments.***[a]

TDS	Irrigations Per Year	Drainage Classification		
		Well	Moderate	Poor
900	16	0.4	2.0	4.3
	22	0.4	1.4	3.7
	29	0.4	1.1	3.4
	35	0.4	0.7	3.0
	Sprinkler	0.0	0.0	2.1
1000	16	0.7	2.4	5.0
	22	0.7	1.7	4.3
	29	0.7	1.5	4.0
	35	0.7	1.0	3.5
	Sprinkler	0.0	0.2	2.7
1100	16	0.9	2.9	5.7
	22	0.9	2.1	4.9
	29	0.9	1.8	4.6
	35	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3
1200	16	1.2	3.3	6.3
	22	1.2	2.4	5.4
	29	1.2	2.1	5.1
	35	1.2	1.5	4.5
	Sprinkler	0.0	0.8	3.8
1300	16	1.5	3.8	7.0
	22	1.5	2.8	6.1
	29	1.5	2.5	5.7
	35	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
1400	16	1.7	4.2	7.7
	22	1.7	3.2	6.7
	29	1.7	2.8	6.3
	35	1.7	2.1	5.6
	Sprinkler	0.4	1.5	5.0

[a] From Robinson, F. E., 1974, Appendix 2, Table 2-8.

The Arizona Water Commission estimates that by the year 2000 municipal and industrial uses will take at least 400,000 acre feet, leaving approximately 800,000 for agriculture. This will fall far short of meeting the needs. One large irrigation district alone has asked for more than 500,000 acre feet of CAP water. Thus it is clear that if only the established irrigation districts are considered in the allocation of water, few can expect to receive as much as half of what they have asked for. Exceptions might be such districts as the Salt River and San Carlos projects which have surface water supplies, storage facilities and distribution

Table 1-6. Yield decrement to be expected for certain crops due to the level of salinity in the soil solution as shown by the electrical conductivity of the saturation extract in millimhos per centimeter.[a]

Crop	0% mmho/cm	10% mmho/cm	25% mmho/cm	50% mmho/cm
Cotton	6.7	10.0	12.0	16.0
Alfalfa	2.0	3.0	5.0	8.0
Lettuce	1.3	2.0	3.0	5.0
Cantaloupes	2.3	3.5	No Data	No Data
Wheat	4.7	7.0	10.0	14.0
Grain Sorghum	4.0	6.0	9.0	12.0
Bermuda Grass	8.7	13.0	16.0	18.0
Grapefruit	1.7	2.5	No Data	5.0
Oranges and Tangerines	1.7	2.5	No Data	5.0
Lemons	1.7	2.5	No Data	5.0
Onions	1.3	2.0	3.5	4.0

[a]From the California Committee of Consultants (1974).

Table 1-7. Projected yields of cotton in the Gila, North Gila, Wellton-Mohawk and Yuma valleys with four levels of surface irrigation and sprinkler on three soil drainage classes.

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
		Cotton in 1000 Bales					
Well 13,030 Acres	16	All Values 29.32					
	22						
	29						
	35						
	Sprinkler						
Moderate 2,520 Acres	16	All Values 5.67					
	22						
	29						
	35						
	Sprinkler						
Poor 4,330 Acres	16	All Values 9.74					
	22						
	29						
	35						
	Sprinkler						
		Alfalfa Hay in 1000 Tons					
Well 23,140 Acres	16	All Values 150.64					
	22						
	29						
	35						
	Sprinkler						
Moderate 3,830 Acres	16	24.93	23.93	22.69	21.81	20.94	20.19
	22	24.93	24.93	24.68	23.93	22.94	22.06
	29	24.93	24.93	24.93	24.68	23.68	22.94
	35	24.93	24.93	24.93	24.93	24.93	24.68
	Sprinkler	24.93	24.93	24.93	24.93	24.93	24.93
Poor 6,440 Acres	16	33.54	31.44	28.92	26.83	24.52	22.01
	22	35.63	33.54	31.86	29.97	27.67	25.57
	29	36.47	24.58	32.70	31.02	28.92	26.83
	35	37.73	36.26	34.58	33.12	31.02	29.34
	Sprinkler	41.50	38.99	36.68	35.21	33.33	31.44
		Lettuce in 1000 Tons					
Well 7,720 Acres	16	44.78	44.78	44.78	44.78	43.44	42.32
	22	44.78	44.78	44.78	44.78	43.44	42.32
	29	44.78	44.78	44.78	44.78	43.44	42.32
	35	44.78	44.78	44.78	44.78	43.44	42.32
	Sprinkler	44.78	44.78	44.78	44.78	44.78	44.78

[a]Yields based on Yuma Mesa–Yuma Valley history.

Table 1-7. ***Continued.***

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Moderate 1,950 Acres	16	10.18	9.50	8.65	8.09	7.35	6.79
	22	11.14	10.69	10.01	9.50	8.82	7.07
	29	11.31	10.97	10.52	10.01	9.33	8.82
	35	11.31	11.31	11.31	10.97	10.52	10.01
	Sprinkler	11.31	11.31	11.31	11.31	11.31	10.97
Poor 3,580 Acres	16	12.14	10.38	8.51	6.95	5.19	3.32
	22	13.81	12.14	10.59	9.34	7.58	6.02
	29	14.53	12.98	11.42	10.28	8.51	6.95
	35	15.57	14.32	12.98	11.63	10.28	8.82
	Sprinkler	18.37	16.50	14.84	13.49	11.94	10.38
		Cantaloupes in 1000 Tons					
Well 4,530 Acres	16	All Values 33.25					
	22						
	29						
	35						
	Sprinkler						
Moderate 1,100 Acres	16	8.07	7.99	7.67	7.38	7.06	6.82
	22	8.07	8.07	8.07	7.99	7.75	7.46
	29	8.07	8.07	8.07	8.07	7.95	7.75
	35	8.07	8.07	8.07	8.07	8.07	8.07
	Sprinkler	8.07	8.07	8.07	8.07	8.07	8.07
Poor 2,000 Acres	16	10.24	11.45	10.57	9.84	9.03	8.15
	22	12.99	10.24	11.52	10.94	10.13	9.40
	29	13.36	12.62	11.89	11.30	10.57	9.84
	35	13.80	13.21	12.62	12.04	11.30	10.72
	Sprinkler	14.68	14.24	13.43	12.85	12.18	11.45
		Wheat in 1000 Tons					
Well 20,140 Acres	16	All Values 43.50					
	22						
	29						
	35						
	Sprinkler						
Moderate 3,360 Acres	16	All Values 7.26					
	22						
	29						
	35						
	Sprinkler						
Poor 5,560 Acres	16	12.01	11.83	11.47	11.17	10.81	10.45
	22	12.01	12.01	11.89	11.55	11.29	10.99
	29	12.01	12.01	12.01	11.77	11.47	11.17
	35	12.01	12.01	12.01	12.01	11.77	11.53
	Sprinkler	12.01	12.01	12.01	12.01	12.01	11.83
		Grain Sorghum in 1000 Tons					
Well 9,000 Acres	16	All Values 17.55					
	22						
	29						
	35						
	Sprinkler						
Moderate 1,230 Acres	16	2.40	2.40	2.40	2.40	2.40	2.38
	22	2.40	2.40	2.40	2.40	2.40	2.40
	29	2.40	2.40	2.40	2.40	2.40	2.40
	35	2.40	2.40	2.40	2.40	2.40	2.40
	Sprinkler	2.40	2.40	2.40	2.40	2.40	2.40
Poor 1,900 Acres	16	3.65	3.52	3.39	3.28	3.15	3.02
	22	3.71	3.65	3.54	3.45	3.32	3.21
	29	3.71	3.71	3.60	3.51	3.39	3.28
	35	3.71	3.71	3.71	3.62	3.51	3.41
	Sprinkler	3.71	3.71	3.71	3.71	3.64	3.52

[a] Yields based on Yuma Mesa–Yuma Valley history.

Table 1-7. ***Continued.***

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
		Grass Seed in 1000 Cwt					
Well	16	All Values 57.95					
7,820 Acres	22						
	29						
	35						
	Sprinkler						
Moderate	16	All Values 9.86					
1,330 Acres	22						
	29						
	35						
	Sprinkler						
Poor	16	All Values 16.52					
2,230 Acres	22						
	29						
	35						
	Sprinkler						
		Grapefruit in 1000 Tons[a]					
Well	16	All Values 31.35					
2,200 Acres	22						
	29						
	35						
	Sprinkler						
Moderate	16	1.36	1.29	1.19	1.09	0.98	0.89
100 Acres	22	1.42	1.42	1.35	1.29	1.21	1.12
	29	1.42	1.42	1.40	1.35	1.28	1.21
	35	1.42	1.42	1.42	1.42	1.40	1.35
	Sprinkler	1.42	1.42	1.42	1.42	1.42	1.42
		Oranges and Tangerines in 1000 Tons[a]					
Well	16	All Values 147.90					
17,000 Acres	22						
	29						
	35						
	Sprinkler						
Moderate	16	5.01	4.75	4.36	4.02	3.55	3.26
600 Acres	22	5.22	5.22	4.96	4.75	4.44	3.58
	29	5.22	5.22	5.14	4.96	4.70	4.44
	35	5.22	5.22	5.22	5.22	5.14	4.96
	Sprinkler	5.22	5.22	5.22	5.22	5.22	5.22
		Lemons in 1000 Tons[a]					
Well	16	All Values 140.30					
10,000 Acres	22						
	29						
	35						
	Sprinkler						
Moderate	16	9.43	8.94	8.20	7.56	6.78	6.14
700 Acres	22	9.82	9.82	9.33	8.94	8.35	7.76
	29	9.82	9.82	9.67	9.33	8.84	8.35
	35	9.82	9.82	9.82	9.82	9.67	9.33
	Sprinkler	9.82	9.82	9.82	9.82	9.82	9.82

[a] Yields based on Yuma Mesa–Yuma Valley history.

Table 1-8. Crop values on the Yuma and Gila projects 1967-1973 (weighted averages).[a]

Crop	Value Per Acre						
	1967	1968	1969	1970	1971	1972	1973
Cotton	274.97	348.81	227.28	250.68	428.35	375.43	625.56
Alfalfa	179.67	160.16	182.38	186.98	205.63	233.33	305.41
Lettuce	789.29	817.56	776.00	708.07	1333.73	932.71	1100.01
Cantaloupes	746.44	717.83	709.52	821.44	878.61	935.58	1040.69
Wheat	105.04	91.26	102.49	102.46	119.76	137.35	206.55
Grain Sorghum	85.74	73.08	82.66	109.44	108.21	117.88	172.86
Grass Seed	193.41	221.06	180.68	199.30	442.62	414.92	588.75
Grapefruit	550.84	1160.52	645.93	545.33	770.79	896.49	363.19
Oranges and Tangerines	890.48	418.22	413.13	163.99	271.16	344.13	353.11
Lemons	1063.22	1207.56	715.75	917.35	1052.37	795.67	949.29

[a] Total value, Yuma Valley, North Gila Valley, South Gila Valley, Yuma Mesa, and Wellton-Mohawk District over total acres.

Table 1-9. Costs of irrigation water on the Yuma and Gila projects.

Irrigation District	Base Allotment Per Acre		Cost Per Acre Foot in Excess of Base Allotment				
	Acre Ft.	Cost[a]	1st 2 Feet	2nd 2 Feet	2rd 2 Feet	4th 2 Feet	All Additional
			1974				
Yuma Mesa	9	13.50	1.55	1.55	1.55	1.55	1.55
Unit B (Mesa)	6	18.00	3.50	3.50	3.50	3.50	3.50
Yuma Valley	5	16.00	3.20	3.20	3.20	3.20	3.20
North Gila	5	8.50	No additional for excess				
South Gila	5	16.00	3.20	3.20	3.20	3.20	3.20
Wellton-Mohawk	4	11.00	3.00	3.00	3.00	3.00	3.00
			1975				
Yuma Mesa	9	22.50	3.00	5.00	7.50	7.50	7.50
Unit B (Mesa)	6	24.00	4.25	4.25	5.00	5.00	5.00
Yuma Valley	5	20.00	4.00	4.00	4.00	4.00	4.00
North Gila	5	10.00	No additional for excess				
South Gila	5	16.00					
Wellton-Mohawk	4	11.00	4.50	4.50	5.20	10.00	15.00

[a] The base allotment charge is the minimum.

Table 1-10. Assignment of soil classes to drainage groups. Potential acreage for cultivation by 2000 A.D.

Class[a]	Drainage Classification			Estimated Percent
	Well	Moderate	Poor	
1	16,917			16
2		32,778		31
2			15,860	15
3	20,512			19.4
4	19,667			18.6
	57,096	32,778	15,860	100

[a] Land classification map, Colorado River Irrigation Project, Colorado River Indian Reservation, Arizona; Branch of Land Operations, Bureau of Indian Affairs U.S.D.I., Phoenix Area Office, 1964.

Table 1-11. Acre yields of major crops in the Colorado River (Indian Reservation) project.[a]

Crop	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa	8.00	8.00	8.00	8.25	8.50	8.15 ± 0.23 Tons
Cotton	2.75	2.25	2.25	2.75	3.00	2.60 ± 0.34 Bales
Wheat	1.80	2.25	2.10	2.40	2.80	2.27 ± 0.37 Tons
Grain Sorghum	1.50	1.50	2.04	2.00	1.60	1.73 ± 0.27 Tons
Cantaloupes	250	250	300	250	350	280 ± 45 Crates
Lettuce	400	600	500	500	380	476 ± 89.4 Ctn.
Onions	15.0	18.0	11.5	12.0	8.3	12.96 ± 3.7 Tons

[a] Annual irrigation crop report No. 55-13F. Branch of Land Operations, Bureau of Indian Affairs, U.S.D.I.

Table 1-12. Partition of 1973 crop acreage on different soil drainage classes.[a]

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	16,100	4,290	2,020
Cotton	5,740	4,960	2,410
Wheat	5,240	4,520	2,200
Grain Sorghum	1,920	1,650	800
Cantaloupes	390	340	160
Lettuce	2,190	1,880	920
Onions	400	340	160

[a] Annual irrigation crop report No. 55-13F, Branch of Land Operations, Bureau of Indian Affairs, U.S.D.I. 1969-1973.

systems in operation that could be greatly enhanced by allotments of CAP water which would be inadequate for comparable areas that depend entirely upon groundwater.

Salt River Project

The Salt River Project irrigation system serves approximately 261,246 acres of land in the Salt River Valley of central Arizona. It supplies full service to the Salt River Valley Water Users Association (238,264 acres), supplemental service to special contractors (22,982 acres), and 5.6 percent of the surface water diverted at Granite Reef Dam to the Roosevelt Water Conservation District.

In 1973 the acreage under full and supplemental irrigation (not including RWCD) consisted of 101,370 acres of urban and suburban residential, commercial, and industrial lands; 9,414 acres of farmsteads, roads, ditches and drains; and 150,462 acres of cultivated crop land. Of the crop land, 136,385 acres were irrigated (Annual Crop Production Report, Salt River Project).

In general, the Salt River Project includes: 1) the Verde River with its two reservoirs above Horseshoe Dam and Bartlett Dam; 2) the Salt River and its reservoirs above Stewart Mountain Dam, Mormon Flat Dam, Horseshoe Mesa Dam; 3) Granite Reef diversion dam at the confluence of the two rivers; 4) the distribution system which includes the Arizona Canal, Grand Canal, Tempe Canal, Western Canal, Consolidated Canal, Eastern Canal, and their laterals; and 5) drainage and pumping works with 252 active wells.

The Salt River Project also generates electrical power with the releases or flows from the dams on the Salt and Verde Rivers. These hydro-electric plants are not necessarily a part of this report except as they affect the quality of water which reaches the farms and cities. This effect may not be of great importance because of the relatively low salt content of the two rivers. However, water quality varies between the rivers and with the amount of natural flow. Operation of the power generating plants helps determine which water source is released or stored at any given time and therefore is a factor to consider. This will be especially true if Orme Dam is built and different proportions of SRP and CAP waters are stored there at different times of the year.

There are other possibilities that could affect the quality of water they might be delivered to the SRP, as well as to other contractors for CAP water: 1. Orme Dam may or may not be built. This would affect the water quality for any user below this point in the CAP system. 2. The SRP may have to make exchanges with other CAP water contractors. The amount of SRP water involved would affect the

Table 1-13. Acreage of the seven major crops projected to the year 2000, when all of the project land will be under irrigation.

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	27,600	7,400	3,490
Cotton	9,830	8,560	4,120
Wheat	8,990	7,720	3,810
Grain Sorghum	3,280	2,850	1,370
Cantaloupes	630	630	320
Lettuce	3,810	3,280	1,590
Onions	630	630	320
TOTAL	54,770	31,070	15,020

mixture of CAP and SRP waters. 3. The quantities of water allocations to the Indians. 4. The allocation between various contractors for CAP water and their diversion point locations (Teeples, per communication). For the purposes of this report, the following assumptions are made: 1) Continued surface water supply based on a 10 year average; 2) possible CAP allocations; 3) groundwater pumpage to maintain the minimum balance required to meet SRP obligations; and 4) uniform mixing of all water sources.

Water quality stations for which records are published on the surface water of the project are downstream from Bartlett Dam on the Verde River and the Stewart Mountain Dam on the Salt River. The 9 year average flow (1964-1972) of the Verde River was 372,000 ac ft with a weighted average of 288 mg/l TDS, while that of the Salt River was 533,000 ac ft with 591 mg/l TDS (Arizona Water Commission files, Hubbard, personal communications). The project is presently pumping 252 wells. Over the 10 year period ending in 1970 they pumped an average of 400,000 acre feet per year while the depth to water in selected wells dropped an average of 13 feet per year (Arizona Water Commission files). In 1970 the U.S. Geological Survey estimated that a safe groundwater yield for the SRP area is 300,000 ac ft per year, including that pumped by others within the SRP boundaries.

It is estimated that by 1980 SRP obligations will be 766,000 acre feet for agriculture, 190,000 for municipal and industrial, and 239,000 (20 percent) transportation and storage losses (Arizona Water Commission files). With a continued supply of 850,000 ac ft of surface water and curtailed pumping of 200,000 ac ft, minimum balance to meet this obligation would be 150,000 ac ft of CAP water.

The salinity in the active wells ranges from around 300 mg/l to 2,897 mg/l TDS with an average of 980 mg/l (Hubbard, personal communication). Since CAP water is supposed to replace groundwater on a one-to-one basis, the highest salt content wells could be eliminated to bring this average down to somewhere near the present 775 mg/l of the Colorado River at Parker Dam. However, for the purposes of this report, an average groundwater quality of 980 mg/l TDS is used.

If a continued supply of 850,000 ac ft of surface water and curtailed pumping of 275,000 ac ft is assumed, an allotment of 75,000 ac ft of CAP water would meet the minimum balance needed to fill SRP obligations. The project water before addition of CAP water would then have an average salinity of around 600 mg/l TDS which would be increased only slightly by the addition of CAP water at its present level, and only another 40 mg/l when the CAP reaches 1400 mg/l (Table 1-17). If the SRP were allotted the 150,000 ac ft CAP water they have requested, the salinity of the blend would be slightly lower initially and only 26 mg/l higher when CAP water reaches 1400 mg/l (Table 1-18). This is because of the trade off of groundwater for CAP water. Since this is the case, crop declinations are figured on the basis of the higher allotment.

The soils of the general area served by the Salt River Project irrigation system are assigned to drainage groups in Table 1-19. This breakdown was made from a general soils map of Maricopa County and Salt River Indian Reservation prepared by the U.S. Soil Conservation Service. The proportions of different soil classes as shown here are used for both the SRVWUA and areas of supplemental irrigation service.

Yields of major crops in the areas served by the SRP irrigation system were taken from the annual crop reports of the SRP and are shown in Table 1-20.

Costs of SRP water to the user in 1975 are based on the following formula: 1. Assessment to each user $5.75. This provides 2 ac ft per acre. 2. Stored and developed, and normal flow $2.00 per acre foot (1 acre foot per acre allotted for 1975). 3. Pump water $8.00 per acre foot (maximum of 2 acre feet per acre for 1975). Cost to a specific water user will vary depending on the land's water right and the amount of water used.

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Acreages planted to major crops in the SRVWUA are shown in Table 1-21, and assigned to drainage classes in Table 1-22. The average acreages of wheat, sorghum, and barley taken from Table 1-21 were adjusted to more realistic figures in Table 1-22, based upon recent trends away from sorghum and barley, and the increased planting of wheat as a result of the higher yield potential of the new stiff-strawed varieties from Mexico.

Effective values of soil saturation extract conductivities for the three soil drainage classes were worked out for the levels of salinity to be expected after CAP water is blended into the SRP system (Table 1-23). These values with the expected yield decrements shown in Table 1-24 were used to determine the projected crop yields shown in Tables 1-25 and 1-26.

Table 1-14. Crop yields on the Colorado River Indian Reservation lands projected on the basis of completed project acreage, as influenced by irrigation method and salinity of the irrigation water.

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
		Alfalfa Hay in 1000 Tons					
Well 27,600 Ac.	16	All Values 224.94					
	22						
	29						
	35						
	Sprinkler						
Moderate 7,400 Ac.	16	60.31	57.90	54.88	52.77	50.66	48.85
	22	60.31	60.31	59.71	57.90	55.49	53.37
	29	60.31	60.31	60.31	59.71	57.29	55.49
	35	60.31	60.31	60.31	60.31	60.31	59.71
	Sprinkler	60.31	60.31	60.31	60.31	60.31	60.31
Poor 3,490 Ac.	16	22.75	21.33	19.62	18.20	16.64	14.93
	22	24.17	22.75	21.61	20.33	18.77	17.35
	29	24.74	23.46	22.18	21.05	19.62	18.20
	35	25.60	24.60	23.46	22.47	21.05	19.91
	Sprinkler	28.16	26.45	24.89	23.89	22.61	21.33
		Cotton in 1000 Bales					
Well	16	All Values 25.56					
	22						
	29						
	35						
	Sprinkler						
Moderate	16	All Values 22.26					
	22						
	29						
	35						
	Sprinkler						
Poor	16	10.71	10.71	10.71	10.71	10.60	10.39
	22	10.71	10.71	10.71	10.71	10.71	10.71
	29	10.71	10.71	10.71	10.71	10.71	10.71
	35	10.71	10.71	10.71	10.71	10.71	10.71
	Sprinkler	10.71	10.71	10.71	10.71	10.71	10.71
		Wheat in 1000 Tons					
Well 8,990 Ac.	16	All Values 29.40					
	22						
	29						
	35						
	Sprinkler						
Moderate 7,720 Ac.	16	All Values 17.52					
	22						
	29						
	35						
	Sprinkler						
Poor 3,810 Ac.	16	8.65	8.52	8.26	8.04	7.79	7.53
	22	8.65	8.65	8.56	8.39	8.13	8.00
	29	8.65	8.65	8.65	8.45	8.26	8.04
	35	8.65	8.65	8.65	8.65	8.45	8.30
	Sprinkler	8.65	8.65	8.65	8.65	8.65	8.52
		Grain Sorghum in 1000 Tons					
Well 3,280 Ac.	16	All Values 6.61					
	22						
	29						
	35						
	Sprinkler						
Moderate 2,850 Ac.	16	4.93	4.93	4.93	4.93	4.93	4.88
	22	4.93	4.93	4.93	4.93	4.93	4.93
	29	4.93	4.93	4.93	4.93	4.93	4.93
	35	4.93	4.93	4.93	4.93	4.93	4.93
	Sprinkler	4.93	4.93	4.93	4.93	4.93	4.93

Table 1-14. ***Continued.***

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Poor 1,370 Ac.	16	2.33	2.25	2.17	2.10	2.01	1.93
	22	2.37	2.33	2.26	2.20	2.12	2.05
	29	2.37	2.37	2.30	2.24	2.17	2.10
	35	2.37	2.37	2.37	2.31	2.24	2.18
	Sprinkler	2.37	2.37	2.37	2.37	2.32	2.25
		Cantaloupes in 1000 Crates					
Well 630 Ac.	16	All Values 176.40					
	22						
	29						
	35						
	Sprinkler						
Moderate 630 Ac.	16	176.40	175.17	167.58	161.41	154.35	149.06
	22	176.40	176.40	176.40	175.17	169.34	163.17
	29	176.40	176.40	176.40	176.40	173.75	169.34
	35	176.40	176.40	176.40	176.40	176.40	176.40
	Sprinkler	176.40	176.40	176.40	176.40	176.40	176.40
Poor 320 Ac.	16	74.82	69.89	64.51	60.03	55.10	50.62
	22	79.30	74.82	70.34	66.75	61.82	57.34
	29	81.54	77.06	72.58	68.99	64.51	60.03
	35	84.22	80.64	77.06	73.47	68.99	65.41
	Sprinkler	89.60	86.46	81.98	78.40	74.37	69.89
		Lettuce in 1000 Cartons					
Well 3,810 Ac.	16	1813.56	1813.56	1813.56	1813.56	1768.22	1713.81
	22	1813.56	1813.56	1813.56	1813.56	1768.22	1713.81
	29	1813.56	1813.56	1813.56	1813.56	1768.22	1713.81
	35	1813.56	1813.56	1813.56	1813.56	1768.22	1713.81
	Sprinkler	1813.56	1813.56	1813.56	1813.56	1813.56	1813.56
Moderate 3,280 Ac.	16	1405.15	1311.48	1194.38	1147.54	1014.83	936.77
	22	1545.67	1475.41	1381.73	1311.48	1217.80	1131.93
	29	1561.28	1522.25	1451.99	1381.73	1288.06	1217.80
	35	1561.28	1561.28	1561.28	1522.25	1451.99	1381.73
	Sprinkler	1561.28	1561.28	1561.28	1561.28	1561.28	1522.25
Poor 1,590 Ac.	16	446.54	378.42	310.30	257.33	189.21	121.09
	22	503.30	446.54	385.99	340.58	276.25	219.48
	29	529.79	473.03	416.26	367.07	310.30	257.33
	35	567.63	522.22	473.03	423.83	367.07	336.79
	Sprinkler	669.80	601.69	541.14	491.95	435.18	378.42
		Onions in 1000 Tons					
Well 630 Ac.	16	8.165	8.165	8.165	8.165	8.083	7.920
	22	8.165	8.165	8.165	8.165	8.083	7.920
	29	8.165	8.165	8.165	8.165	8.083	7.920
	35	8.165	8.165	8.165	8.165	8.083	7.920
	Sprinkler	8.165	8.165	8.165	8.165	8.165	8.165
Moderate 630 Ac.	16	7.838	7.634	7.389	7.104	6.695	6.369
	22	8.124	7.961	7.798	7.634	7.430	7.185
	29	8.165	8.083	7.920	7.798	7.593	7.430
	35	8.165	8.165	8.165	8.083	7.920	7.798
	Sprinkler	8.165	8.165	8.165	8.165	8.165	8.083
Poor 320 Ac.	16	3.193	2.074	0.581	0	0	0
	22	3.442	3.193	2.281	1.244	0	0
	29	3.566	3.318	2.903	1.866	0.581	0
	35	3.732	3.525	3.318	3.110	1.866	0.809
	Sprinkler	3.960	3.815	3.608	3.401	3.152	2.074

Table 1-15. Crop values on the Colorado River Indian Reservation irrigation project.[a]

Crop	Average Market Value Per Acre				
	1969	1970	1971	1972	1973
Alfalfa	240.00	224.00	232.00	264.00	425.00
Cotton[b]	447.00	493.00	393.00	462.00	579.00
Wheat	210.00	121.00	120.00	140.00	210.00
Grain Sorghum	96.00	75.00	96.00	93.00	96.00
Cantaloupes	2625.00	1625.00	2100.00	1375.00	2625.00
Lettuce	1140.00	900.00	1500.00	1500.00	1140.00
Onions	282.00	630.00	368.00	15.00	282.00

[a] Annual irrigation crop report No. 55-13F, Branch of Land Operations, Bureau of Indian Affairs, U.S.D.I. 1969-1973.

[b] Includes lint and seed.

Table 1-16. Cost of irrigation water on the Colorado River Indian Reservation project.

Base Allotment Per Acre			Cost of All Water in Excess of The Base Allotment
Acre Feet	Cost		
5	11.00	1974	$2.00 Per Acre Foot
5	14.00	1975	$3.50 Per Acre Foot

Table 1-17. Effects of increasing salinity of CAP water when it is blended into the Salt River project water (Assuming an allotment of 75,000 ac ft of CAP water).

850,000 Ac. Ft Salt and Verde Rivers Water[a]	275,000 Ac. Ft Groundwater	1,125,000 Ac. Ft. Salt River Project Water	75,000 Ac. Ft C.A.P. Water	1,200,000 Ac Ft Blended C.A.P. and S.R.P. Water
TDS mg/l	TDS mg/l	TDS mg/l	TDS mg/l	TDS mg/l
467[b]	980[c]	592	775[d]	604
467	980	592	900	612
467	980	592	1,000	618
467	980	592	1,100	624
467	980	592	1,200	630
467	980	592	1,300	637
467	980	592	1,400	643

[a] Nine year average flow (1964-1972) of 905,000 acre feet less 5.6% to the Roosevelt Water Conservation District, leaves 854,000 Ac Ft surface water.

[b] The nine year average flow of the Verde River below Barlett Dam was 372,000 acre feet with an average of 288 mg/l T.D.S., while that of the Salt River below Stewart Mountain Dam was 533,000 acre feet with an average of 591 mg/l T.D.S.

[c] Average salinity of active S.R.P. wells. Figure supplied by the Salt River Project Office. T.D.S. of individual wells ranges from 200 to 3,000 mg/l. Volumetric average varies according to which wells are being pumped.

[d] Present salinity of Colorado River water of the C.A.P. diversion point above Parker Dam.

Table 1-18. Effects of increasing salinity of CAP water when it is blended into the Salt River project water (assuming allotment of the 150,000 ac ft requested).

850,000 Ac Ft Salt and Verde Rivers Water TDS mg/l	200,000 Ac Ft Pumped Water TDS mg/l	1,050,000 Ac Ft Salt River Project Water TDS mg/l	150,000 Ac Ft C.A.P. Water TDS mg/l	1,200,000 Ac Ft Blended C.A.P. and S.R.P. Water TDS mg/l
467	980	565	775	591
467	980	565	900	607
467	980	565	1,000	619
467	980	565	1,100	632
467	980	565	1,200	644
467	980	565	1,300	657
467	980	565	1,400	669

Table 1-19. Assignment of soil series to drainage groups for lands served by the Salt River project—full and supplemental.[a]

Soil Series	Soil Texture	Permeability[b] in./hr.	Drainage Classification			Estimated Percent
			Well 55%	Moderate 36%	Poor 9%	
Antho:	0-36" Sandy Loam, 36-47" Loamy Sand, 47-60" Light Sandy Clay Loam	2.0 -6.0	16,460			6.3
Avondale:	0-12" Clay Loam, 12-37" Heavy Loam 37-55" Very Fine Sandy Loam	0.2 -0.6		13,060		5.0
Cashion:	0-27" Clay, 27-29" Very Fine Sandy Loam, 29-42" Light Silt Loam				3,920	1.5
Contine:	0-12" Clay Loam, 12-38" Clay Loam-Clay, 38-60" Loam-Clay Loam	0.06-0.2			16,720	6.4
Coolidge:	0-63" Sandy Loam	2.0 -6.3	16,720			6.4
Estrella:	0-24" Loam, 24-48" Clay Loam, 48-55" Gravelly Light Clay Loam	0.2 -0.6		23,250		8.9
Gadsden:	0-43" Clay, 43-60" Clay Loam	0.06-0.2			3,920	1.5
Gilman:	0-13" Loam, 13-60" Very Fine Sandy Loam	0.6 -2.0	73,670			28.2
Glenbar:	0-27" Clay Loam, 27-56" Silty Clay Loam, 56-60" Clay Loam	0.2 -0.6		3,920		1.5
Laveen:	0-60" Loam	0.6 -2.0	35,000			13.4
Mohall:	0-10" Coarse Sandy Loam, 10-19" Sandy Clay Loam, 19-27" Clay Loam, 27-37" Loam, 37-76" Gravelly Sandy Loam, 76-98" Gravelly Coarse Loamy Sand	0.2 -0.63		46,500		17.8
Rillito:	0-2" Loam, 2-10" Fine Sandy Loam, 10-32" Gravelly Loam, 32-41" Gravelly Sandy Loam, 41-59" Gravelly Loam, 59-75" Gravelly Sandy Loam	0.6 -2.0	1,830			0.7
Valencia:	0-26" Sandy Loam, 26-31" Light Sandy Clay Loam, 31-48" Clay Loam, 48-60" Sandy Clay Loam	0-2 -0.6		6,270		2.4
			143,680	93,000	24,560	

[a] Acreages estimated from maps supplied by the S.R.P. and U.S.S.C.S. Phoenix.

[b] Permeability of the most restricting horizon.

Salt River Project Supplmental Irrigation Service

The SRP supplemental irrigation contracts and acres irrigated in 1973 are: Fort McDowell Indian Reservation, 315 acres; Gila Crossing District, 687; Maricopa Colony District, 1,094; Peninsular Horowitz District, 2,070; Salt River Indian Reservation, 10,797; and St. Johns Irrigation District, 1,286. The crop yields and values were reported in the SRP crop reports and therefore are the same as for the SRVWUA.

Average acreages of major crops grown in the supplemental irrigation areas are partitioned into soil drainage classes in Table 1-27. Projected crop yields, as affected by increasing salinity of the CAP ater are shown in Tables 1-28 and 1-29. Crop values are shown in Tables 1-39 and 1-40.

Table 1-20. Yields of major crops in the Salt River project.[a]

Crop	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	5.4	5.3	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	5.86 ± 0.19 Ton
Upland Cotton	2.25	2.30	1.50	1.75	2.50	2.25	2.00	2.25	2.43	2.55	2.18 ± 0.24 Bale
Upland Cotton Seed	1.00	1.00	0.60	0.80	1.00	1.00	1.00	1.00	1.10	1.10	0.96 ± 0.11 Ton
Barley	2.04	1.92	1.80	1.99	1.97	1.70	1.99	2.04	2.14	2.21	1.98 ± 0.11 Ton
Wheat							2.25	2.55	2.70	2.82	2.58 ± 0.39 Ton
Sorghum	1.85	2.13	2.13	2.38	2.24	2.18	2.24	1.82	2.18	2.35	2.15 ± 0.13 Ton
Carrots	13.0	13.0	13.0	13.5	13.5	13.5	10.5	12.0	13.0	10.0	12.5 ± 0.91 Ton
Lettuce	418	474	526	400	378	410	409	512	473	525	452.5 ± 40.1 Ctn.
Onions (Dry)	300	300	300	300	300	375	360	375	450	450	351.0 ± 43.9 Cwt.
Grapefruit	203	159	192	123	360	248	440	209	198	216	234.8 ± 68.0 Cwt.
Oranges and Tangerines				137	118	201	275	134	168	206	177.0 ± 50.7 Cwt.
Sugar Beets				18.0	20.0	19.0	15.0	21.4	22.5	23.0	19.8 ± 2.8 Ton

[a] Yields taken from annual crop reports of the S.R.P., full and supplemental irrigation service.

Table 1-21. Acreages planted to major crops, SRVWUA area.

Crop	1967	1968	1969	1970	1971	1972	1973	Average
Alfalfa	40,719	44,038	41,790	45,567	42,734	44,954	45,780	43,655
Upland Cotton	26,567	29,518	31,556	29,449	23,415	25,851	23,564	27,131
Barley	28,585	27,915	27,047	26,587	25,827	9,614	6,102	21,668
Wheat	3,464	3,626	3,568	7,772	11,503	17,309	16,972	9,173
Sorghum	37,171	31,235	24,143	18,943	17,617	9,293	12,962	21,623
Lettuce	1,163	720	286	117	283	1,386	1,270	746
Onions (Dry)	2,102	1,825	940	156	219	1,309	63	945
Grapefruit	1,581	1,575	1,629	1,528	1,636	1,175	1,320	1,349
Oranges & Tangerines	2,936	2,925	3,329	3,342	3,052	2,872	3,151	3,087
Sugar Beets	4,303	4,815	8,460	5,705	1,698	1,960	884	3,975
Carrots	1,254	1,294	590	818	385	800	907	864
							Total	134,216

Table 1-22. Partition of crop acreages of the SRVWUA into three soil drainage classes.

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	24,000	15,725	3,930
Upland Cotton	14,920	9,770	2,440
Barley	9,170	6,000	1,500
Wheat	10,550	6,900	1,720
Sorghum	9,140	5,980	1,500
Lettuce	410	270	70
Onions (Dry)	520	340	85
Grapefruit	740	490	120
Oranges & Tangerines	1,700	1,110	280
Sugar Beets	2,190	1,430	360
Carrots	475	310	80

***Table 1-23.** Effective values of soil saturation extract conductivities (ECe x 10^{3}) in three soil drainage classes, four TDS levels, and five irrigation treatments.*

TDS	Irrigations Per Year	Drainage Classification		
		Well	Moderate	Poor
500	16	0	0.3	1.5
	22	0	0	1.2
	29	0	0	1.0
	35	0	0	0.8
	Sprinkler	0	0	0
600	16	0	0.7	2.2
	22	0	0.3	1.8
	29	0	0.1	1.6
	35	0	0	1.3
	Sprinkler	0	0	0.3
700	16	0	1.4	3.3
	22	0	0.8	2.7
	29	0	0.6	2.5
	35	0	0.2	2.1
	Sprinkler	0	0	1.2
800	16	0.1	1.5	3.5
	22	0.1	1.0	3.0
	29	0.1	0.8	2.8
	35	0.1	0.4	2.4
	Sprinkler	0	0	1.4

***Table 1-24.** Yield decrement to be expected for the major crops in Central Arizona at different levels of soil salinity as measured in millimhos of electrical conductivity per centimeter (ECe x 10^{3}).*[a]

Crop	Yield Decrement			
	0% mmho/cm	10% mmho/cm	25% mmho/cm	50% mmho/cm
Alfalfa	2	3	5	8
Barley	8	12	16	18
Cantaloupes	2.3	3.5	No Data	No Data
Carrots	1	1.5	2.5	4
Cotton	6.7	10	12	16
Grapefruit	1.7	2.5		5
Grapes	2.7	4		8
Lettuce	1.3	2	3	5
Onions	1.3	2	3.5	4
Oranges and Tangerines	1.7	2.5		5
Safflower	5.3	8	11	14
Sorghum	4	6	9	12
Sugar Beets	6.7	10	13	16
Watermelons	2	No Data	No Data	No Data
Wheat	4.7	7	10	14

[a] From the California Committee of Consultants (1974).

Table 1-25. ***SRVWUA crop yields projected on the basis of 150,000 ac ft per year of CAP water blended with 1,050,000 ac ft of SRP water, as affected by increasing salinity of the CAP water, soil type, and irrigation method.***

		Total Dissolved Solids in Irrigation Water, mg/l			
			C.A.P. Water		
Drainage Classification	Irrigations Per Year	S.R.P. Water	900	1100	1400
			Blend		
		565	607	632	669
		Alfalfa in 1000 Tons			
Well	16	All Values 140.6			
24,000 A	22				
	29				
	35				
	Sprinkler				
Moderate	16	All Values 185.53			
15,725 A	22				
	29				
	35				
	Sprinkler				
Poor	16	23.03	22.57	21.65	20.73
3,930 A	22	23.03	23.03	22.80	21.65
	29	23.03	23.03	23.03	22.34
	35	23.03	23.03	23.03	23.03
	Sprinkler	23.03	23.03	23.03	23.03
		Lettuce in 1000 Cartons			
Well	16	All Values 185.53			
410 A	22				
	29				
	35				
	Sprinkler				
Moderate	16	All Values 122.18			
270 A	22				
	29				
	35				
	Sprinkler				
Poor	16	28.51	27.56	25.66	23.76
70 A	22	30.41	29.46	28.04	25.66
	29	31.20	30.41	28.99	27.09
	35	31.68	31.68	30.73	28.99
	Sprinkler	31.68	31.68	31.68	31.68
		Onions in Tons			
Well	16	All Values 9,126			
520 A	22				
	29				
	35				
	Sprinkler				
Moderate	16	All Values 5,967			
340 A	22				
	29				
	35				
	Sprinkler				
Poor	16	1,477	1,410	1,380	1,343
85 A	22	1,492	1,447	1,425	1,380
	29	1,492	1,470	1,440	1,402
	35	1,492	1,492	1,470	1,440
	Sprinkler	1,492	1,492	1,492	1,492

Table 1-25. Continued.

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l			
			C.A.P. Water		
		S.R.P. Water	900	1100	1400
				Blend	
		565	607	632	669
		Grapefruit in Tons			
Well 740 A	16	All Values 8,688			
	22				
	29				
	35				
	Sprinkler				
Moderate 490 A	16	All Values 5,753			
	22				
	29				
	35				
	Sprinkler				
Poor 120 A	16	1,353	1,240	1,240	1,155
	22	1,409	1,388	1,339	1,240
	29	1,409	1,409	1,374	1,303
	35	1,409	1,409	1,409	1,374
	Sprinkler	1,409	1,409	1,409	1,409
		Oranges in Tons			
Well 1,700 A	16	All Values 15,045			
	22				
	29				
	35				
	Sprinkler				
Moderate 1,110 A	16	All Values 9,824			
	22				
	29				
	35				
	Sprinkler				
Poor 280 A	16	2,379	2,317	2,181	2,032
	22	2,478	2,441	2,354	2,181
	29	2,478	2,478	2,416	2,292
	35	2,478	2,478	2,478	2,416
	Sprinkler	2,478	2,478	2,478	2,478
		Carrots in Tons			
Well 475 A	16	All Values 5,938			
	22				
	29				
	35				
	Sprinkler				
Moderate 310 A	16	3,875	3,875	3,875	3,720
	22	3,875	3,875	3,875	3,875
	29	3,875	3,875	3,875	3,875
	35	3,875	3,875	3,875	3,875
	Sprinkler	3,875	3,875	3,875	3,875
Poor 80 A	16	825	795	735	665
	22	885	855	810	735
	29	925	885	840	780
	35	980	940	885	840
	Sprinkler	1,000	1,000	1,000	1,000

Table 1-26. Projected acreages and yields of major crops of the SRVWUA not affected by increases in salinity of the CAP water to 1400 mg/l.

Crop	Drainage Classification					
	Well		Moderate		Poor	
	Acres	Yield	Acres	Yield	Acres	Yield
Barley	9,170	18,157 Tons	6,000	11,880 Tons	1,500	2,970 Tons
Cotton (Upland)	14,920	32,526 Bales	9,770	21,299 Bales	2,440	5,319 Bales
Cotton Seed (Upland)		14,323 Tons		9,379 Tons		2,342 Tons
Sorghum	9,140	19,651 Tons	5,980	12,857 Tons	1,500	3,225 Tons
Sugar Beets	2,190	43,362 Tons	1,430	28,314 Tons	360	7,128 Tons
Wheat	10,550	27,219 Tons	6,900	17,802 Tons	1,720	4,438 Tons

Table 1-27. Partition of major crop acreages of the SRP supplemental irrigation areas into soil drainage classes.

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	1,300	1,000	260
Barley	1,190	780	190
Cotton	1,910	1,250	320
Lettuce	2,350	770	
Onions	310		
Sorghum	1,600	1,100	300
Sugar Beets	500	400	170
Wheat	1,000	1,000	740

Table 1-28. Yields of major crops in the SRP supplemental irrigation area projected on the basis of increasing salinity of CAP water when it is blended into the SRP irrigation system, as influenced by irrigation method and soil drainage class.

Drainage Classification	Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l			
			C.A.P. Water		
		S.R.P. Water	900	1100	1400
			Blend		
		565	607	632	669
		Alfalfa in Tons			
Well	16	All Values 7,618			
1,300 Ac.	22				
	29				
	35				
	Sprinkler				
Moderate	16	All Values 5,860			
1,000 Ac.	22				
	29				
	35				
	Sprinkler				
Poor	16	1,524	1,494	1,433	1,372
260 Ac.	22	1,524	1,524	1,509	1,433
	29	1,524	1,524	1,524	1,478
	35	1,524	1,524	1,524	1,524
	Sprinkler	1,524	1,524	1,524	1,524

Table 1-29. Projected acreages and yields of major crops in the SRP supplemental irrigation areas not affected by increases in salinity of the CAP water to 1400 mg/l.

Crop	Drainage Classification					
	Well		Moderate		Poor	
	Acres	Yield	Acres	Yield	Acres	Yield
Barley	1,190	2,356 Tons	780	1,544 Tons	190	376 Tons
Cotton (Upland)	1,910	4,164 Bales	1,250	2,725 Bales	320	698 Bales
Cotton Seed (Upland)		1,834 Tons		1,200 Tons		307 Tons
Lettuce	2,350	106,338 Ctn.	770	348,425 Ctn.		
Onions	310	5,441 Tons				
Sorghum	1,600	3,400 Tons	1,100	2,365 Tons	300	645 Tons
Sugar Beets	500	9,900 Tons	400	7,920 Tons	170	3,366 Tons
Wheat	1,000	2,580 Tons	1,000	2,580 Tons	740	1,909 Tons

The Roosevelt Water Conservation District

The Roosevelt Water Conservation District is on the east side of and adjacent to the SRVWUA district. It has a total irrigable area of 39,415 acres. In 1973 this acreage consisted of 116 acres of urban and suburban residential, commercial, and industrial lands; 1,211 acres of farmsteads, roads, ditches, and drains; and 34,703 acres of cultivated cropland, of which 28,188 acres were irrigated (Annual Crop Production Records, Roosevelt Water Conservation District).

The water supply consists of 5.6 percent of the surface water diverted at Granite Reef Dam by the SRP, and 55 active wells. The wells are pumped directly into the distribution system which consists of 141 miles of concrete lined canals and laterals (Hubbard, personal communications). The average surface water supply from SRP has been approximately 50,000 ac ft per year[2], and the average pumpage has been approximately 100,000 ac ft per year (Arizona Water Commission files). If an allotment of 50,000 ac ft of CAP water is assumed (RWCD request was 75,000 ac ft), they would still have to continue pumping 50,000 ac ft to meet their needs.

No specific data on the salinity of the wells being pumped is available, but an estimate can be made by averaging the published analysis made on wells within the district area (Table 1-30). How much the increasing salinity of CAP water might affect the RWCD water will depend upon how it is delivered to the district. If the CAP water is mixed with the SRP surface water above Granite Reef Dam (or Orme Dam) the dilution will be very beneficial to RWCD, as shown in Table 1-31. But if the CAP water is delivered directly to the RWCD system, the resulting blend will be significantly higher in TDS as shown in Table 1-32.

The soils of the RWCD are assigned to drainage groups in Table 1-33. Acreages of major crops are partitioned into drainage classes in Table 1-34. Average yields are shown in Table 1-35. Projected crop yields as affected by increasing salinity of CAP water are shown for the two possible blends in Tables 1-36 and 1-37. Crops not affected by increases in salinity of CAP water to 1400 mg/l are shown in Table 1-38. Crop values for the RWCD, SRVWUA, and SRP supplemental are shown in Tables 1-39 and 1-40.

Water costs in the RWCD for 1975 are $11 per ac ft plus $15 service charge on each active account. In 1973 there were 628 active accounts for a total of $9,420 service charge on 28,188 irrigated acres or $0.33 per acre. From March 1 to October 1 irrigation water supply is limited to 2.5 ac ft per acre of land, except that water right may be transferred from one account to another, either under the same or different owners. The RWCD office estimates water use at 3.4 ac ft per acre over the entire year.

Roosevelt Irrigation District

The Roosevelt Irrigation District is in western Salt River Valley and includes an area approximately 20 miles long and 3 miles wide along the north side of the old Gila River channel between the Agua Fria and Hassayampa Rivers. The total irrigable area is 38,152 acres. In 1973 this was broken down into 2,250 acres of farmsteads, roads, ditches, and drains; 660 acres of urban and suburban residential, commercial, and industrial; and 31,663 acres irrigated for harvest or pasture (Annual Crop Production Reports, Roosevelt Irrigation District).

The irrigation water is entirely from wells pumped into a concrete-lined distribution system (Arizona Water Commission files). The estimated pumpage is 160,000 ac ft per year from 106 active wells. Some of the water comes from wells within the western boundaries of the Salt River Valley Water Users Association, some from wells along the Agua Fria River but to the east of the old river bed, and some from wells within the RID boundaries. Nearly all are high in salt content as is shown by published analysis of a few selected wells (Table 1-41) (Teeples, personal communication). Water samples taken directly from the main canals have run around 1300 mg/l TDS (McLouth, personal communication). If this

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[2] 5.6 percent of 900,000 ac ft (9-year average flow of the Salt and Verde Rivers).

Table 1-30. ***Water quality of selected wells in the Roosevelt Water Conservation District.***[a]

Twp	Range	Section	Sample Date	EC x 10^3	TDS mg/l	SAR	Water Class
1 N	6 E	4	1966	1.2	780	4.7	C3-S1
		4	1960	1.2	835	4.9	C3-S1
		15	1963	1.7	931	4.1	C3-S1
		17	1959	1.5	740	5.5	C3-S2
		22	1961	1.1	639	8.6	C3-S2
		26	1959	1.1	734	8.5	C3-S2
		26	1959	1.2	655	9.4	C3-S2
		34	1967	0.8	520	4.7	C3-S1
1 S	6 E	10	1961	1.7	931	2.8	C3-S1
		13	1956	1.2	850	1.3	C3-S1
		21	1959	1.3	641	2.8	C3-S1
2 S	6 E	2	1950	1.0	681	1.6	C3-S1
		2	1950	1.4	993	1.5	C3-S1
		9	1950	1.4	977	1.9	C3-S1
		28	1951	0.9	638	2.5	C3-S2
		32	1957	0.8	693	7.0	C3-S2
Average				1.2	765	4.5	C3-S1

[a] Smith, H. V., G. E. Draper, and W. H. Fuller. 1964. The quality of Arizona Irrigation Waters. University of Arizona Experiment Station, Report 223.

Table 1-31. ***Effects of increasing salinity of CAP water when it is blended with SRP surface water before being delivered to the RWCD (assuming an allotment of 200,000 ac ft—150,000 SRP and 50,000 RWCD—delivered above Granite Reef Dam).***

900,000 Ac. Ft Salt and Verde Rivers Water TDS mg/l	200,000 Ac Ft of C.A.P. Water TDS mg/l	100,000 Ac Ft of Blended S.R.P.-C.A.P. TDS mg/l	50,000 Ac. Ft R.W.C.D. Groundwater TDS mg/l	150,000 Ac Ft Blended C.A.P., S.R.P., R.W.C.D. Groundwater TDS mg/l
470	775	522	765	603
470	900	548	765	620
470	1,000	566	765	632
470	1,100	585	765	645
470	1,200	603	765	657
470	1,300	621	765	669
470	1,400	639	765	681

Table 1-32. ***Effects of increasing salinity of CAP water when it is blended into the RWCD water (assuming an allotment of 50,000 ac ft of CAP water) delivered directly into the RWCD system.***

50,000 Ac. Ft Salt and Verde Water[a] TDS mg/l	50,000 Ac Ft Groundwater TDS mg/l	100,000 Ac Ft R.W.C.D. Water TDS mg/l	50,000 Ac Ft. C.A.P. Water TDS mg/l	150,000 Ac Ft Blended C.A.P. and R.W.C.D. Water TDS mg/l
470	765	620	775[a]	672
470	765	620	900	713
470	765	620	1,000	747
470	765	620	1,100	780
470	765	620	1,200	813
470	765	620	1,300	847
470	765	620	1,400	880

[a] Present salinity of the Colorado River water at the C.A.P. diversion point above Parker Dam.

Table 1-33. Assignment of Roosevelt Water Conservation District soils to drainage groups.[a]

Series	Permeability In./Hour	Drainage Classification		
		Well	Moderate	Poor
Antho	2.0 - 6.0	1,388		
Avondale	0.2 - 0.6		1,353	
Contine	0.06 - 0.2			6,975
Coolidge	2.0 - 6.3	763		
Estrella	0.2 - 0.6		2,533	
Gadsden	0.06 - 0.2			
Gilman	0.6 - 2.0	7,461		
Glenbar	0.2 - 0.6		416	
Laveen	0.6 - 2.0	1,631		
Mohall	0.2 - 0.6		11,001	
Rillito	0.6 - 2.0	104		
Valencia	0.2 - 0.6		174	
Vecont	0.06 - 0.2			486
		11,347	15,477	7,877

[a]Acres irrigated in 1973	30,720
Idle cropland	3,981
Total area in irrigation rotation	34,701

Table 1-34. Partition of major crop acreages of the Roosevelt Water Conservation District into soil drainage classes.

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	3,510	4,580	2,280
Barley	1,100	1,430	710
Cotton	2,570	3,350	1,670
Sorghum	395	510	255
Sugar Beets	395		
Wheat	520	670	340
Lettuce	200		
Watermelon	540		
Grapefruit	400	660	330
Oranges & Tangerines	1,000	1,410	780

Table 1-35. Yields of major crops in the Roosevelt Water Conservation District.[a]

Crop	1968	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	6.0	6.0	6.0	6.0	6.0	6.0	6 ± 0 Ton
Barley	1.97	1.70	1.99	2.04	2.14	2.16	2 ± 0.19 Ton
Wheat	1.86	1.86	2.25	2.55	2.70	2.76	2.33 ± 0.46 Ton
Sorghum	1.92	2.18	2.24	1.82	1.71	2.16	2.01 ± 0.25 Ton
All Cotton	2.23	2.17	1.92	2.14	2.01	1.96	2.07 ± 0.14 Bale
All Cotton Seed	0.90	0.95	0.97	0.95	0.85	0.88	0.92 ± 0.05 Ton
Carrots	13.50	13.50	9.00	12.00	6.50	13.00	11.25 ± 3.31 Ton
Lettuce	4.72	10.25	10.23	12.83	7.75	13.50	9.88 ± 3.75 Ton
Watermelon	14.00	14.00	8.50	12.00	13.00	10.00	11.92 ± 2.58 Ton
Sugar Beets	20.00	19.00	15.00	21.40	22.50	23.00	20.15 ± 3.37 Ton
Grapefruit	18.00	12.40	22.00	10.45	18.75	10.80	15.40 ± 5.54 Ton
Lemons and Limes			19.25	10.9	19.25	15.30	16.18 ± 7.31 Ton
Oranges & Tangerines	5.93	10.05	13.75	6.7	12.35	10.30	9.85 ± 3.52 Ton

[a]Yields prior to 1972 from Salt River Project crop reports.

Table 1-36. Yields of major crops in the RWCD projected on the basis of CAP water delivered above Granite Reef Dam, and the resulting blend then delivered to RWCD.

Drainage Classification	Irrigations Per Year	R.W.C.D. Blend Without C.A.P. T.D.S.	T.D.S. of C.A.P. Water, mg/l			
			775	1000	1200	1400
			T.D.S. of C.A.P. - S.R.P. Blend			
			522	566	603	639
			T.D.S. of C.A.P. - S.R.P. - R.W.C.D. Blend			
		617	603	632	657	681
		Alfalfa in 1000 Tons				
Well 3,510 Ac.	16 22 29 35 Sprinkler	All Values 21.1				
Moderate 4,580 Ac.	16 22 29 35 Sprinkler	All Values 27.5				
Poor 2,280 Ac.	16	13.2	13.4	12.9	12.6	12.2
	22	13.7	13.7	13.6	13.3	13.0
	29	13.7	13.7	13.7	13.6	13.3
	35	13.7	13.7	13.7	13.7	13.7
	Sprinkler	13.7	13.7	13.7	13.7	13.7
		Grapefruit in 1000 Tons				
Well 400 Ac.	16 22 29 35 Sprinkler	All Values 6.16				
Moderate 660 Ac.	16 22 29 35 Sprinkler	All Values 10.16				
Poor 330 Ac.	16	4.62	4.75	4.47	4.32	4.06
	22	4.88	5.00	4.83	4.70	4.57
	29	5.00	5.08	4.95	4.83	4.70
	35	5.08	5.08	5.08	5.00	4.95
	Sprinkler	5.08	5.08	5.08	5.08	5.08
		Oranges and Tangerines in 1000 Tons				
Well 1,000 Ac.	16 22 29 35 Sprinkler	All Values 9.85				
Moderate 1,410 Ac.	16 22 29 35 Sprinkler	All Values 13.89				
Poor 780 Ac.	16	6.99	7.18	6.76	6.53	6.14
	22	7.37	7.56	7.30	7.10	6.91
	29	7.56	7.68	7.49	7.30	7.10
	35	7.68	7.68	7.68	7.56	7.49
	Sprinkler	7.68	7.68	7.68	7.68	7.68

Table 1-37. ***Yields of major crops in the RWCD projected on the basis of CAP water delivered directly into the RWCD distribution system.***

Drainage Classifications	Irrigations Per Year	R.W.C.D. Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of C.A.P. - R.W.C.D. Water, mg/l						
		620	672	713	747	780	813	847	880
			Alfalfa in 1000 Tons						
Well	16	All Values 21.1							
3,510 Ac.	22								
	29								
	35								
	Sprinkler								
Moderate	16	All Values 27.5							
4,580 Ac.	22								
	29								
	35								
	Sprinkler								
Poor	16	13.2	12.3	12.0	11.9	11.9	11.7	11.4	11.2
2,280 Ac.	22	13.7	13.2	12.7	12.6	12.5	12.2	12.0	11.7
	29	13.7	13.4	13.0	12.9	12.7	12.5	12.2	12.0
	35	13.7	13.7	13.6	13.4	13.3	13.0	12.7	12.5
	Sprinkler	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
			Grapefruit in 1000 Tons						
Well	16	All Values 6.16							
400 Ac.	22								
	29								
	35								
	Sprinkler								
Moderate	16	10.16						10.16	9.91
660 Ac.	22								10.16
	29								
	35								
	Sprinkler								
Poor	16	4.62	4.17	3.91	3.84	3.76	3.66	3.43	3.28
330 Ac.	22	4.88	4.62	4.39	4.32	4.24	4.06	3.91	3.66
	29	5.00	4.75	4.57	4.47	4.39	4.24	4.06	3.91
	35	5.08	4.95	4.83	4.75	4.70	4.57	4.39	4.24
	Sprinkler	5.08	5.08	5.08	5.08	5.08	5.08	5.08	4.88
			Oranges and Tangerines in 1000 Tons						
Well	16	All Values 9.85							
1,000 Ac.	22								
	29								
	35								
	Sprinkler								
Moderate	16	13.89						13.89	13.54
1,410 Ac.	22								13.89
	29								
	35								
	Sprinkler								
Poor	16	6.99	6.30	5.91	5.80	5.68	5.53	5.18	4.95
780 Ac.	22	7.37	6.99	6.64	6.53	6.41	6.14	5.91	5.53
	29	7.56	7.18	6.91	6.76	6.64	6.41	6.14	5.91
	35	7.68	7.49	7.30	7.18	7.10	6.91	6.64	6.41
	Sprinkler	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.37

Table 1-38. Projected acreages and yields of major crops of the RWCD not affected by increases in salinity of CAP water to 1400 mg/l.

Crop	Drainage Classification					
	Well		Moderate		Poor	
	Acres	Yield	Acres	Yield	Acres	Yield
Barley	1,100	2,200 Tons	1,430	2,860 Tons	710	1,420 Tons
Cotton (Upland)	2,570	5,320 Bales	3,350	6,935 Bales	1,670	3,457 Bales
Cotton Seed (Upland)	2,570	2,364 Tons	3,350	3,082 Tons	1,670	1,536 Tons
Sorghum	395	794 Tons	510	1,025 Tons	255	513 Tons
Sugar Beets	395	7,959 Tons				
Wheat	520	1,212 Tons	670	1,561 Tons	340	792 Tons
Lettuce	200	1,976 Tons				
Watermelon	540	6,437 Tons				

Table 1-39. Crop values on SRP lands, including SRVWUA, SRP Supplemental, and RWCD.[a]

Crop	Market Value Per Unit						
	1968	1969	1970	1971	1972	1973	
Alfalfa	26.00	28.00	32.00	33.54	35.00	55.00	Ton
Barley	45.42	50.84	50.00	57.92	57.92	111.68	Ton
Carrots	60.00	94.00	78.40	164.60	168.80	180.00	Ton
Cotton (Upland)	125.00	107.00	115.00	141.31	163.20	287.40	Bale
Cotton Seed (Upland)	52.00	40.00	60.00	60.00	50.00	110.00	Ton
Grapefruit	62.00	74.60	49.40	54.00	58.60	25.60	Ton
Lettuce	4.58	3.54	2.13	3.38	3.05	3.32	Carton[b]
Onions (Dry)	42.00	70.00	86.00	74.00	108.80	227.50	Ton
Oranges & Tangerines	158.00	80.40	38.80	54.40	48.60	56.80	Ton
Sorghum	40.71	47.50	83.56	51.42	59.99	107.84	Ton
Sugar Beets	12.12	10.75	13.18	13.50	12.60	18.00	Ton
Wheat	43.67	49.67	82.33	58.67	56.67	124.00	Ton

[a] Salt River Project annual crop reports.

[b] One carton = 50 pounds.

Table 1-40. Crop values on SRP lands, including SRVWUA, SRP Supplemental, and RWCD.[a]

Crop	Market Value Per Acre					
	1968	1969	1970	1971	1972	1973
Alfalfa	156.00	168.00	192.00	201.24	210.00	330.00
Barley	89.38	86.62	99.60	114.75	123.71	246.56
Carrots	810.00	1,269.00	705.60	1,975.20	2,194.40	1,800.00
Cotton (Upland)	312.50	240.75	230.00	317.95	396.58	732.87
Cotton Seed (Upland)	52.00	40.00	60.00	60.00	55.00	125.67
Grapefruit	1,116.00	924.00	1,086.80	564.30	580.14	276.48
Lettuce	865.08	1,451.11	871.17	1,738.84	1,445.60	1,741.28
Onions (Dry)	630.00	1,313.00	1,548.00	1,387.50	2,448.00	4,836.50
Oranges and Tangerines	936.15	808.00	533.50	364.48	408.24	585.04
Sorghum	91.20	103.74	187.20	93.60	131.04	253.68
Sugar Beets	242.40	204.25	197.70	288.90	283.50	414.00
Wheat	81.22	92.38	185.25	149.50	153.00	349.68

[a] Salt River Project annual crop reports.

figure is too low, as might be indicated by Table 1-41, the replacement of RID groundwater by CAP water could eliminate the worst wells and help bring the water from the remaining wells to somewhere near this estimate.

The soils of the RID are predominantly well drained (Table 1-42). This has made it possible to use the present water supply which has a relatively high salt content. Whatever CAP water is allotted to them will serve to improve their water quality by dilution, at least until the CAP water reaches 1300 mg/l TDS. Since the RID has requested 75,000 ac ft, it may not be too far off to assume an allotment of 40,000-50,000 ac ft. If they are allotted 40,000, they will still have to pump 120,000 ac ft of groundwater to meet their commitments.

Table 1-41. Water quality of selected wells which serve the Roosevelt Irrigation District.[a]

Twp	Range	Section	Sample Date	EC x 10^3	TDS mg/l	SAR	Water Class
1 N	1 E	1	1963	1.7	1,019	2.6	C3-S1
1 N	2 E	7	1963	2.0	1,258	4.3	C3-S2
		9	1963	2.5	1,524	6.9	C4-S2
2 N	1 E	4	1963	0.9	539	1.2	C3-S1
1 N	1 W	7	1960	2.0	1,223	4.7	C3-S1
		10	1959	1.4	850	1.3	C3-S1
1 N	2 W	8	1963	2.6	1,554	2.7	C4-S1
		13	1963	5.5	4,581		
		15	1963	3.0	2,081	5.6	C4-S2
		20	1963	4.9	3,694	7.7	C4-S2
1 N	3 W	13	1963	6.3	4,570		
		19	1963	7.2	4,933		
		27	1963	5.5	4,358		
		28	1963	6.2	4,824		
		31	1963	5.5	4,324		
1 N	4 W	20	1963	2.4	1,563	9.6	C4-S1
		27	1963	7.0	4,985		
		30	1963	4.7	3,981		
		33	1963	6.4	5,469		
		36	1963	5.5	4,324		
2 N	1 W	25	1963	0.6	407	3.0	C2-S1
		26	1963	0.6	337	3.6	C2-S1
				3.8	2,836		

[a] Smith, H. V., G. E. Draper, and W. H. Fuller. 1964. The Quality of Arizona Irrigation Waters. University of Arizona Experiment Station, Report 223.

Table 1-42. Assignment of Roosevelt Irrigation District soils to drainage groups.[a]

Series	Permeability In./Hr.	Drainage Classification		
		Well Acres	Moderate Acres	Poor Acres
Antho	2.0 - 6.0	2,340		
Avondale	0.2 - 0.6		330	
Cashion				165
Coolidge	2.0 - 6.3	10,895		
Estrella	0.2 - 0.6		515	
Gadsden	0.06 - 0.2			165
Gilman	0.6 - 2.0	3,645		
Glenbar	0.2 - 0.6		165	
Laveen	0.6 - 2.0	16,310		
Mohall	0.2 - 0.63		1,810	
Rillito	0.6 - 2.0	1,810		
		35,000	2,820	330

[a] Map: M7-E-23122-N, U.S.D.A. S.C.S.

[b] Permeability of most restricting horizon.

Table 1-43 shows the effect of increasing salinity in the CAP water on the resulting blend. If they are allotted 50,000 ac ft and pump 110,000, the blend will be only slightly lower in TDS with the present level of Colorado River water at the diversion point and approximately the same when the Colordo reaches 1400 mg/l (1135, 1175, 1206, 1237, 1269, 1300, and 1331 respectively). Therefore, possible crop declinations are computed on the basis of a 40,000 ac ft allotment of CAP water.

Yields of major crops are shown in Table 1-44. Planted acreages are shown in Table 1-45, and partitioned into soil drainage classes in Table 1-46. These data with the effective values of soil saturation extract conductivities for the levels of salinity expected in the blend (Table 1-47), and yield declination percentages from the California Committee of Consultants (Table 1-24 was used in calculating the projected yields in Tables 1-48 and 1-49. Crop values are shown in Tables 1-50 and 1-50a.

The cost of irrigation water to the farmer in 1975 is $9.50 per acre foot, with an average usage of around 5 acre feet per acre per year.

Table 1-43. Effect of increasing salinity of CAP water when it is blended into the Roosevelt Irrigation District water (assuming an allocation of 40,000 acre feet of CAP water).

120,000 Acre Feet R.I.D. Groundwater TDS mg/l	40,000 Acre Feet of C.A.P. Water TDS mg/l	160,000 Acre Feet Blended Water TDS mg/l
1,300	775	1,169
1,300	900	1,200
1,300	1,000	1,225
1,300	1,100	1,250
1,300	1,200	1,275
1,300	1,300	1,300
1,300	1,400	1,325

Table 1-44. Yields of major crops in the Roosevelt Irrigation District.[a]

Crop	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	6.0	6.0	6.0	6.0	6.0	6.0 ± 0 Ton
Ensilage (Sorghum or Corn)	35.0	22.0	28.0	20.0	25.0	26.0 ± 7.29 Ton
Barley	1.70	1.99	2.11	2.14	2.26	2.04 ± 0.26 Ton
Wheat	1.86	2.25	2.55	2.70	3.24	2.52 ± 0.64 Ton
Upland Cotton	2.25	2.00	2.20	2.40	2.40	2.25 ± 0.21 Bale
Upland Cotton Seed	1.00	1.00	1.00	1.00	1.10	1.02 ± 0.06 Ton
Sugar Beets	19.00	15.0	23.1	22.5	22.5	20.42 ± 4.27 Ton
Irrigated Pasture	6.3	6.0	6.1	6.0	6.1	6.1 ± 0.17 AUM[b]
Lettuce	411	410	528	450		449.75 ± 88.13 Ctn.
Sorghum	2.18	2.24	1.82	1.65	2.35	2.05 ± 0.37 Ton
Alfalfa Seed	2.00	2.00	1.00			1.67 ± 1.06 Cwt

[a] Data from R.I.D. annual crop reports.

[b] Animal unit month.

Table 1-45. Major crop acreages on the Roosevelt Irrigation District.[a]

Crop	1969	1970	1971	1972	1973	Average
Alfalfa Hay	8,405	8,611	8,323	9,348	11,906	9,319
Alfalfa Seed	6,738	6,712	7,111			4,112
Ensilage (Sorghum)	1,554	1,612	3,149	404	779	1,500
Irrigated Pasture	369	368	18,573	14,752	19,667	10,746
Barley	5,446	5,896	4,178	3,367	3,716	4,521
Wheat	713	3,706	5,281	1,602	3,239	2,908
Sorghum	637	540	343	409	130	412
Upland Cotton	9,716	8,077	8,224	9,180	10,310	9,101
Sugar Beets	2,122	1,807	490	833	898	1,230
Lettuce	587	400	38	80		221

[a] Roosevelt Irrigation District Annual Crop Reports. Prior to 1969, crop acreages were included in the S.R.P. crop reports.

Table 1-46. Partition of major crop acreages of the Roosevelt Irrigation District into soil drainage classes.

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa Hay	8,573	652	
Alfalfa Seed	3,783	288	
Ensilage	1,380	105	
Irrigated Pasture	9,583	729	330
Barley	4,159	316	
Wheat	2,675	204	
Sorghum	379	29	
Upland Cotton	8,373	637	
Sugar Beets	1,132	86	
Lettuce	221		

Table 1-47. Effective values of soil saturation extract conductivities for levels of salinity to be expected in the blended water of the RID as the salinity of CAP water increases to 1400 mg/l (based on an allotment of 40,000 acre feet of CAP water).

T.D.S. of R.I.D. - C.A.P. Blend	Irrigations Per Year	Drainage Classification		
		Well	Moderate	Poor
1169	16	1.1	3.2	6.1
	22	1.1	2.3	5.2
	29	1.1	2.0	4.9
	35	1.1	1.4	4.3
	Sprinkler	0	0.7	3.6
1200	16	1.2	3.3	6.3
	22	1.2	2.4	5.4
	29	1.2	2.1	5.1
	35	1.2	1.5	4.5
	Sprinkler	0	0.8	3.8
1225	16	1.3	3.4	6.5
	22	1.3	2.5	5.6
	29	1.3	2.2	5.3
	35	1.3	1.6	4.7
	Sprinkler	0.1	0.9	4.0
1250	16	1.4	3.6	6.7
	22	1.4	2.6	5.8
	29	1.4	2.3	5.4
	35	1.4	1.7	4.8
	Sprinkler	0.1	1.0	4.1
1275	16	1.4	3.7	6.8
	22	1.4	2.7	5.9
	29	1.4	2.4	5.6
	35	1.4	1.7	5.0
	Sprinkler	0.2	1.1	4.3
1300	16	1.5	3.8	7.0
	22	1.5	2.8	6.1
	29	1.5	2.5	5.7
	35	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
1325	16	1.6	3.9	7.2
	22	1.6	2.9	6.3
	29	1.6	2.6	5.9
	35	1.6	1.9	5.2
	Sprinkler	0.3	1.3	4.6

*Table 1-48. **Yields of major crops in the RID projected on the basis of CAP water delivered directly into the RID distribution system.***

Drainage Classification	Irrigations Per Year	R.I.D. Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of E.I.D. + C.A.P. Water, mg/l						
		1300	1169	1200	1225	1250	1275	1300	1325
		Alfalfa Hay in 1000 Tons							
Well 8,573	16	All Values 51.44							
	22								
	29								
	35								
	Sprinkler								
Moderate 652	16	3.28	3.45	3.42	3.40	3.34	3.32	3.28	3.26
	22	3.60	3.79	3.75	3.71	3.68	3.64	3.60	3.56
	29	3.71	3.91	3.89	3.83	3.79	3.75	3.71	3.67
	35	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
	Sprinkler	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
		Alfalfa Seed in Tons							
Well 3,783	16	All Values 315.9							
	22								
	29								
	35								
	Sprinkler								
Moderate 288	16	20.4	21.5	21.3	21.1	20.8	20.7	20.4	20.3
	22	22.4	23.6	23.3	23.1	22.8	22.6	22.4	22.1
	29	23.1	24.3	24.1	23.8	23.6	23.3	23.1	22.8
	35	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
	Sprinkler	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
		Irrigated Pasture in 1000 AUM[a]							
Well 9,583	16	All Values 58.46							
	22								
	29								
	35								
	Sprinkler								
Moderate 729	16	4.09	4.19	4.17	4.16	4.13	4.12	4.09	4.08
	22	4.27	4.38	4.36	4.34	4.32	4.29	4.27	4.25
	29	4.34	4.45	4.43	4.41	4.38	4.36	4.34	4.32
	35	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
	Sprinkler	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Poor 330	16	1.60	1.67	1.65	1.64	1.62	1.61	1.60	1.58
	22	1.67	1.75	1.73	1.71	1.70	1.69	1.67	1.65
	29	1.70	1.77	1.75	1.74	1.73	1.71	1.70	1.69
	35	1.75	1.81	1.80	1.78	1.78	1.76	1.75	1.75
	Sprinkler	1.81	1.87	1.85	1.84	1.83	1.81	1.81	1.79
		Lettuce in 1000 Cartons							
Well 221	16	96.41	99.39	99.39	99.39	97.90	97.90	96.41	94.92
	22	96.41	99.39	99.39	99.39	97.90	97.90	96.41	94.92
	29	96.41	99.39	99.39	99.39	97.90	97.90	96.41	94.92
	35	96.41	99.39	99.39	99.39	97.90	97.90	96.41	94.92
	Sprinkler	99.39	99.39	99.39	99.39	99.39	99.39	99.39	99.39

[a] Animal unit month.

Table 1-49. Acreages and yields of major crops in the Roosevelt Irrigation District not affected by increasing salinity of CAP water to 1400 mg/l.

Crop	Drainage Classification			
	Well		Moderate	
	Acres	Yield	Acres	Yield
Ensilage[a]	1,380	35,880 Tons	105	2,730 Tons
Barley	4,159	8,478 Tons	316	665 Tons
Wheat	2,675	6,741 Tons	204	514 Tons
Sorghum	379	777 Tons	29	59 Tons
Upland Cotton	8,373	18,839 Bales	637	1,433 Bales
Upland Cotton Seed	8,373	8,540 Tons	637	650 Tons
Sugar Beets	1,132	23,115 Tons	86	1,756 Tons

[a] Sorghum ensilage.

Table 1-50. Crop values in the Roosevelt Irrigation District.[a]

Crop	Market Value Per Unit, Dollars				
	1969	1970	1971	1972	1973
Alfalfa Hay	28.00	32.00	33.54	35.00	55.00 Ton
Alfalfa Seed	45.00	45.00	34.00		Cwt
Ensilage	5.00	6.00	7.00	6.50	7.00 Ton
Irrigated Pasture	6.00	7.00	13.42	14.13	22.00 AUM[b]
Barley	50.83	50.00	56.25	57.92	96.25 Ton
Wheat	49.67	82.33	58.67	56.67	96.33 Ton
Sorghum	47.50	83.57	83.57	60.00	107.86 Ton
Upland Cotton	107.00	115.00	141.31	160.00	225.00 Bale
Upland Cotton Seed	40.00	60.00	60.00	50.00	110.00 Ton
Sugar Beets	10.75	13.18	13.50	12.96	17.28 Ton
Lettuce	3.57	3.59	3.91	3.50	Ctn[c]

[a] Data from R.I.D. annual crop reports.

[b] Animal unit month.

[c] Ctn = 50 pounds.

Table 1-50a. Crop values in the Roosevelt District.[a]

Crop	Market Value in Dollars Per Acre				
	1969	1970	1971	1972	1973
Alfalfa Hay	167.99	192.00	201.24	210.00	330.00
Alfalfa Seed	90.00	90.00	34.00		
Ensilage	175.00	132.00	196.00	130.00	175.00
Irrigated Pasture	37.81	42.00	81.63	84.28	134.20
Barley	86.63	99.60	118.12	123.71	217.14
Wheat	92.38	185.25	149.60	153.00	312.12
Sorghum	103.74	187.20	152.10	99.00	253.68
Upland Cotton	240.76	230.00	310.89	384.00	540.00
Upland Cotton Seed	40.00	60.00	60.00	50.00	121.00
Sugar Beets	204.27	197.70	311.85	291.60	389.32
Lettuce	1,474.99	1,471.90	2,064.47	1,575.00	

[a] From R.I.D. Annual crop reports.

SAN CARLOS PROJECT

The San Carlos Project is located in the lower Santa Cruz River Basin, between Florence and Casa Grande, Arizona, and includes 100,000 acres of Indian and non-Indian land. All project facilities are operated jointly. They include: 1) Coolidge Dam and San Carlos Reservoir with a capacity of 948,584 ac ft at spillway level; 2) Ashurst-Hayden diversion dam on the mainstream of the Gila River 10 miles east of Florence; 3) Picacho Reservoir with a capacity of 18,000 ac ft used to store and regulate the delivery of water; 4) Florence-Casa Grande Canal, Pima Lateral, and sublaterals which serve both Indian and non-Indian lands; and 5) drainage and pumping works with 110 producing wells.

Over the last 5 years the water supply has consisted of approximately 70 percent surface water and 30 percent groundwater. The surface water comes from the natural flow of the Gila River and releases from the San Carlos Reservoir, plus the erratic flows of the San Pedro River. The groundwater is pumped into the system from wells scattered throughout the project area. During the last 20 years, pumping for both project and non-project lands has resulted in a progressive lowering of the water table at an average rate of 8 feet per year to its present level of approximately 236 feet (Babcock, 1973).

Since 1934, the project has pumped an average of 89,000 ac ft per year, but for the last 10 years the average has been approximately 75,000 ac ft per year (Records of the San Carlos Irrigation Project). However, the rapidly lowering water table indicates that this rate of pumping cannot be maintained. Yearly diversions of surface water from the river at the Ashurst-Hayden dam has averaged 190,000 ac ft, so this is a reasonable expectation for the future.

There has been no decision on how much CAP water the project will get. They have asked for 240,000 ac ft which would enable them to irrigate the entire 100,000 acres of land with a minimum of 4.0 ac ft per acre after allowing for losses, which they hope to minimize by lining all canals and laterals. For the purposes of this study, it seems reasonable to assume an allotment of no more than 150,000 ac ft to the San Carlos Project. Water sources for the project would then be 150,000 ac ft Colorado River water, 190,000 ac ft Gila River water and possibly 50,000 ac ft of groundwater.

The salinity of the Gila River ranges from 510 mg/l to around 1000 mg/l "mean annual" TDS (Water Resources Data for Arizona), or an average 775 mg/l. Salinity of the groundwater ranges from around 500 mg/l TDS for the best wells to a high of 3957. Records on 64 wells are summarized in Table 1-51 (University of Arizona). The average of these 64 wells is 1510 mg/l TDS. If we assume 50,000 ac ft of groundwater with 1500 mg/l TDS and 190,000 ac ft of surface water with 755 mg/l TDS, the project water, before addition of the Colorado River water, would have an average salinity of around 910 mg/l TDS. This can be expected to remain fairly constant except for the possibly small effect of changes in groundwater salinity due to continued lowering of the water table. This would have very little effect due to the proportion of groundwater involved. As the CAP water increases in salinity, the proportionate increase in the project water would be as shown in Table 1-52.

The canals and laterals of the project are unlined and losses in the system are estimated to be 30 percent or more. This means that the 50,000 acres presently being irrigated are receiving less than 4 ac ft of water per acre. If the losses can be cut to 15 percent by lining the canals and laterals, approximately 330,000 ac ft would reach the farms to irrigate 80,000 acres with a minimum of 4 ac ft per year. Apparently, any crop yield declination due to increasing salinity of the CAP water would be more than offset by the additional acres irrigated. However, since this study is concerned with crop declination due to increasing salinity of the CAP water, projections to the year 2000 will be based upon the acreage to be irrigated after the CAP water is brought into the project (80,000 acres assumed).

Water costs to the farm are based upon total operating expenses within the system and are not broken down into costs of surface water or groundwater. In the San Carlos Irrigation and Drainage District, the base charge to the farm for the 1974-1975 season is $13.70 per acre, which pays for the first 2 acre feet of water. Charges for additional water are $0.50 for the third acre foot and $1.50 each for the fourth and fifth acre feet. Charges to the Indian part of the project are something less because of some government subsidy. There is no way of estimating costs after the introduction of CAP water.

Acreages of the different soil types or series were estimated from a general soil map of Pinal County prepared in March 1971 by the USDA Soil Conservation Service (Adams, 1971) as shown in Tables 1-53 and 1-54.

Yields and acreages of the major crops in the San Carlos Project were obtained from the annual crop reports published by the project. Since those reports are broken down into "District Part" and "Indian Part," the yield projections are treated separately.

Table 1-51. Groundwater quality, San Carlos Irrigation Project.

Sample Date	Well No.	Twp South	Range East	Section	Quadrant	EC x 10^3	TDS mg/l	SAR	Water Class
3-11-67	2	4	10	29	DAA	1.5	975		
8- -63	6	4	11	7	A	1.6	1176		
8- -63	9	4	9	28	CCA	2.2	1682		
8- -63	10	4	9	28	DAD	2.0	1441		
8- -63	12	4	10	16	ACC	1.1	767	4.0	C3-S1
1972	13	5	8	1	CBB	3.2	2103	4.56	C3-S1
1972	15	5	7	1	DDD	2.35	1600		
8- -63	17	5	9	30	CBB	1.0	661		
2- 3-67	23	5	8	23	CBB	2.5	1667		
8- -63	25	5	9	20	DAD	0.8	559		
1972	27	5	7	17	BBB	1.8	1174	3.96	C3-S1
1972	30	5	8	17	DDA	1.8	1175	3.59	C3-S1
1972	31	5	8	17	AAB	2.1	1386	3.15	C3-S1
1972	32B	5	8	18	BBB	1.6	1014	5.38	C3-S1
1972	33	5	8	2	AAB	2.5	1459	3.82	C3-S1
1972	34	5	7	1	AAC	2.5	1712	4.25	C3-S1
1972	35	4	7	36	DCD	2.5	1797	3.59	C3-S1
1972	36	4	7	35	DAD	1.6	1014	4.18	C3-S1
1972	37	4	7	34	DAB	1.95	1125	2.69	C3-S1
1972	39	4	7	36	CAC	1.5	923	6.39	C3-S2
1972	41	5	7	9	ADA	0.74	499		
1972	43B	4	6	4	AAA	1.4	893	8.74	C3-S2
1972	44	4	6	7	CCA	2.0	1439	3.44	C3-S1
1972	45	4	6	18	AAC	1.9	1244	4.92	C3-S1
1972	46	4	6	24	AAB	2.0	1355	4.05	C3-S1
1972	47	4	6	23	AAB	1.45	912	5.48	C3-S1
1972	48	4	6	3	BBC	2.1	1388	6.0	C3-S1
1972	49	4	5	12	AAA	2.4	1723	3.03	C3-S1
1963	50	5	8	10	CCA	1.6	1034	5.30	C3-S2
1972	51	4	5	10	AAA	2.4	1732	2.65	C3-S1
1972	52	5	7	22	BAC	4.0	2880	4.27	C4-S2
1972	55	4	6	8	DDD	1.95	1266	5.40	C3-S1
1972	56	4	6	7	AAD	1.95	1337	4.94	C3-S1
1972	58	4	5	15	BDA	4.5	3811	7.91	C4-S2
1972	59	3	5	29	BCA	1.75	1153	4.09	C3-S1
1972	60	3	5	31	CBA	1.6	1049	4.36	C3-S1
1972	62	3	5	30	CCC	2.2	1421	4.48	C3-S1
1972	64	4	6	21	BBB	3.2	2309	6.37	C4-S2
1972	65	3	6	19	DDD	1.6	1014	8.21	C3-S1
1972	67	3	6	31	DDA	1.6	924	4.28	C3-S1
1972	69	3	5	24	CBA	3.0	2079	5.79	C4-S3
1972	70	5	7	22	DDA	1.95	1337	4.94	C3-S1
1972	71	5	7	15	CCB	5.0	3624	4.55	C4-S2
1972	72	5	7	9	ADB	3.5	2480	4.67	C4-S2
1963	81	6	8	28	DBB	0.9	615	4.20	C3-S1
1972	86	4	7	28	DAA	1.3	735	14.63	C3-S3
1967	89	5	9	14	CBB	2.5	1667	5.94	C3-S2
1967	90	7	6	1	CCC	1.0	707	3.26	C3-S1
1972	94	3	5	4	ADA	2.3	1387	5.26	C3-S1
1972	95	3	5	4	BCB	5.6	3957	10.10	C4-S3
1972	98A	5	7	12	CCB	4.0	2974	4.47	C4-S2
1972	98B	5	7	22	AAA	3.4	2507	5.49	C4-S2
1963	102	6	6	34	CCB	2.8	1893		
1967	107	6	5	23	CDA	2.4	1739		
1972	109	4	5	10	DCC	4.0	3160	9.23	C4-S2
1972	110	5	9	12	BBC	1.0	736		
1972	120	5	8	5	CBA	2.1	1444	4.84	C3-S1
1972	121	4	5	3	CCC	3.1	2455	3.58	C4-S1
1972	123	4	4	1	CCC	1.5	934	4.36	C3-S1
1972	125	4	5	6	CCB	1.8	1176	4.96	C3-S1
1972	130	5	8	5	CBA	2.4	1533	3.89	C3-S1
1972	131	3	4	34	BBC	1.5	947	4.23	C3-S1
1972	132	5	8	5	BAB	1.5	849	2.07	C3-S1
1972	134	4	6	15	BAC	1.4	927	3.51	C3-S1
				Average		2.19	1510		

Table 1-52. Effects of increasing salinity of CAP water when it is blended into the San Carlos Project system.

190,000 Ac Ft Gila River Water TDS mg/l	50,000 Ac Ft. Groundwater TDS mg/l	240,000 Ac Ft San Carlos Water TDS mg/l	150,000 Ac Ft C.A.P. Water TDS mg/l	390,000 Ac Ft Blended Water TDS mg/l
755	1500	910	775[a]	858
755	1500	910	900	906
755	1500	910	1,000	945
755	1500	910	1,100	983
755	1500	910	1,200	1,022
755	1500	910	1,300	1,060
755	1500	910	1,400	1,098

[a] Present salinity of Colorado River water of the C.A.P. Diversion point above Parker Dam.

Table 1-53. Assignment of soil series to drainage groups—San Carlos Project—District Part.[a]

Soil Series	Textures	Permeability[b] in./hr.	Drainage Classification			Estimated Percent
			Well	Moderate	Poor	
Antho:	0-13" Light Sandy Loam, 13-36" Sandy Loam, 36-47" Loamy Sand, 47-60" Light Sandy Clay Loam	2.0 -6.0	4,750			9.5
Casa Grande:	0-3" Heavy Loam, 3-7" Light Clay Loam, 7-15" Clay Loam, 15-23" Light Clay Loam, 23-48" Loam, 48-60" Sandy Loam	0.06-0.2			11,550	23.1
Gadsden:	0-43" Clay, 43-60" Clay Loam	0.06-0.2			750	1.5
Gilman:	0-13" Loam, 13-60" Very Fine Sandy Loam	0.6 -2.0	7,200			14.4
La Palma:	0- Loam with Hard Pan	0.06-0.2			3,250	6.5
Laveen:	0-60" Loam	0.63-2.0	1,800			3.6
Mohall:	0-10" Coarse Sandy Loam, 10-19" Sandy Clay Loam, 19-27" Clay Loam, 27-37" Loam, 37-76" Gravelly Sandy Loam, 76-98" Gravelly Loamy Sand	0.2 -0.6		12,800		25.6
Pimer:	"Entire Profile Heavy Loam to Light Clay Loam" Loam, Silt Loam, Silty Clay Loam	0.2 -2.0	2,700			5.4
Vecont:	0-60" Clay Loam or Clay	0.06-0.2			5,200	10.4
			16,450	12,800	20,750	

[a] General Soil Map, Pinal County by D. E. Adams, U.S.D.A. S.C.S. March 1971, revised April 1972 and San Carlos Project Irrigation Systems map by A. L. Wathen and H. V. Clotts, U.S. Indian Service, Irrigation Division.

Net area irrigated (6 year average)	33,780 acres
Idle crop land not irrigated	16,220 acres

[b] Permeability of most restricting horizon.

San Carlos Irrigation-Drainage District (Non-Indian)

Acreages of the major crops are averaged over 6 years in Table 1-55, assigned to soil drainage classes in Table 1-56, and projected to include the lands to be brought under irrigation by the introduction of CAP water in Table 1-57. The effective values of soil saturation extract conductivities for the three drainage classes and expected levels of salinity in the blended CAP—San Carlos Project water are shown in Table 1-58. These data with the yield decrement data (Table 1-59), crop yields (Table 1-60), and salinities of the blended water (Table 1-52) were used to calculate the projected yields for those crops which would be affected (Table 1-61).

Table 1-54. Assignment of soil series to drainage groups—Indian Part.[a]

Soil Series	Textures	Permeability[b] in./hr.	Drainage Classification			Estimated Percent
			Well	Moderate	Poor	
Antho:	0-13" Light Sandy Loam, 13-36" Sandy Loam, 36-47" Loamy Sand, 47-60" Light Sandy Clay Loam	2.0 -6.0				8.0
Casa Grande:	0-3" Heavy Loam, 3-7" Light Clay Loam, 7-15" Clay Loam, 15-23" Light Clay Loam, 23-48" Loam, 48-60" Sandy Loam	0.06-0.2			3,170	7.6
Gadsden:	0-43" Clay, 43-60" Clay Loam	0.06-0.2			380	0.9
Gilman:	0-13" Loam, 13-60" Very Fine Sandy Loam	0.6 -2.0	3,750			9.0
Laveen:	0-60" Loam	0.63-2.0	9,800			23.5
Mohall:	0-10" Coarse Sandy Loam, 10-19" Sandy Clay Loam, 19-27" Clay Loam, 27-37"Loam, 37-76" Gravelly Loamy Sand, 76-98" Gravelly Loamy Sand	0.2 -0.6		12,170		29.2
Pimer:	0-60" Loam, Silt Loam, Silty Clay Loam, "Entire Profile Heavy Loam to Light Clay Loam"	0.2 -2.0	1,580			3.8
Rillito:	0-10" Loam to Fine Sandy Loam, 10-32" Gravelly Loam, 32-41" Gravelly Sandy Loam, 41-59" Gravelly Loam, 59-75" Gravelly Sandy Loam	0.6 -2.0	5,920			14.2
Vecont:	0-60" Clay Loam or Clay	0.06-0.2			1,580	3.8
			24,390	12,170	5,130	

[a] General Soil Map of Pinal County by D. E. Adams U.S.D.A. S.C.S., March 1971, Revised April 1972, and San Carlos Project Irrigation Systems map by A. L. Wathen and H. V. Clotts, U.S. Indian Service, Irrigation Division.

Net area irrigated (6 year average)	16,100 acres
Idle crop land not irrigated	25,590 acres

[b] Permeability of most restricting horizon.

Table 1-55. Acreages planted to major crops San Carlos Project—District Part.[a]

Crop	1968	1969	1970	1971	1972	1973	Average
Alfalfa Hay	5,056	4,407	4,785	4,492	3,631	5,111	4,580
Barley	11,669	9,631	8,784	6,578	7,494	6,553	8,452
Safflower	25	921	201	698	1,817	1,703	894
Wheat	665	221	2,090	1,638	2,987	4,456	2,010
Maize	8,701	2,314	2,181	617	493	2,277	2,764
Upland Cotton	12,414	15,324	13,125	7,607	12,965	16,455	12,982
Long Staple Cotton	361	274	312	425	812	1,590	629
Sugar Beets	330	645	749	288	60	150	370
Grapes		93	32	90	70	40	54

[a] San Carlos Irrigation Project annual crop reports 1968-1973.

Table 1-56. Partition of major crop acreages into different soil drainage classes, San Carlos Project—District Part.[a]

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa Hay	1,507	1,172	1,901
Barley	2,781	2,164	3,508
Safflower	294	229	371
Wheat	661	515	834
Maize	909	708	1,147
Upland Cotton	4,271	3,323	5,388
Long Staple Cotton	207	161	261
Sugar Beets	122	95	154
Grapes	18	14	22

[a] San Carlos Irrigation Project annual crop reports. Acreages are averages 1968-1973 cropping season.

Table 1-57. Acreages of major crops projected to include project land under irrigation after CAP water is introduced, San Carlos Project—District Part.[a]

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa	2,416	1,880	3,048
Barley	4,460	3,470	5,625
Safflower	470	370	595
Wheat	1,060	825	1,340
Maize	1,460	1,135	1,840
Upland Cotton	6,850	5,330	8,640
Long Staple Cotton	330	260	420
Sugar Beets	195	150	245
Grapes	30	20	35

[a] Acreages projected on the basis of 80,000 irrigated acres in the Project.

Table 1-58. Effective values of soil saturation extract conductivities (ECe in mmhos/cm) in three soil drainage classes, seven TDS levels, and five irrigation management treatments.[a]

TDS mg/l	Irrigations Per Year	Drainage Classification		
		Well	Moderate	Poor
860	16	0.3	1.8	4.1
	22	0.3	1.2	3.5
	29	0.3	1.0	3.2
	35	0.3	0.6	2.8
	Sprinkler	0.0	0.0	1.7
910	16	0.4	2.0	4.4
	22	0.4	1.4	3.8
	29	0.4	1.4	3.5
	35	0.4	0.7	3.1
	Sprinkler	0.0	0.0	2.2
950	16	0.6	2.2	4.7
	22	0.6	1.6	4.0
	29	0.6	1.3	3.7
	35	0.6	0.9	3.3
	Sprinkler	0.0	0.1	2.4
980	16	0.6	2.3	4.9
	22	0.6	1.6	4.2
	29	0.6	1.4	3.9
	35	0.6	0.9	3.4
	Sprinkler	0.0	0.1	2.6
1020	16	0.7	2.5	5.1
	22	0.7	1.9	4.4
	29	0.7	1.6	4.1
	35	0.7	1.1	3.6
	Sprinkler	0.0	0.3	2.8
1060	16	0.8	2.7	5.4
	22	0.8	1.9	4.7
	29	0.8	1.7	4.4
	35	0.8	1.2	3.8
	Sprinkler	0.0	0.4	3.1
1100	16	0.9	2.9	5.7
	22	0.9	2.1	4.9
	29	0.9	1.8	4.6
	35	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3

Table 1-59. Yield decrement to be expected for the major crops of the San Carlos Project due to the level of salinity in the soil solution as shown by the electrical conductivity of the saturation extract in millimhos per centimeter.[a]

Crop	0% ECe	10% ECe	25% ECe	50% ECe
Alfalfa	2	3	5	8
Barley	8	12	16	18
Safflower	5.3	8	11	14
Wheat	4.7	7	10	14
Maize				
Cotton	6.7	10	12	16
Sugar Beets	6.7	10	13	16
Grapes	2.7	4	No Data	8
Watermelon	2	No Data	No Data	No Data
Cantaloupes	2.3	3.5	No Data	No Data
Carrots	1	1.5	2.5	4
Lettuce	1.3	2	3	5

[a] From the California Committee of Consultants (1974).

Table 1-60. Yields of major crops in the San Carlos Irrigation Project—District Part.[a]

Crop	1968	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	4.59	4.62	4.14	2.97	3.91	5.18	4.24 ± 0.80 Ton
Barley	1.82	1.77	1.83	1.82	1.82	1.82	1.81 ± 0.03 Ton
Safflower		1.30	1.04	1.46	1.27	1.30	1.27 ± 0.19 Ton
Wheat	1.48	1.64	2.55	2.45	2.51	2.15	2.13 ± 0.49 Ton
Maize	1.89		1.81	1.80	1.39	1.75	1.73 ± 0.24 Ton
Upland Cotton	2.58	2.12	2.18	2.18	2.27	2.31	2.27 ± 0.17 Bale
Upland Cotton Seed	1.05	0.86	0.89	0.89	0.93	0.94	0.93 ± 0.07 Ton
Long Staple Cotton	1.75	1.35	1.03	1.16	1.62	2.05	1.49 ± 0.40 Bale
Long Staple Cotton Seed	1.11	0.86	2.56	0.74	1.02	1.28	1.26 ± 0.70 Ton
Sugar Beets	19.56	16.83	11.69	18.17	16.00	20.86	17.19 ± 3.38 Ton
Grapes				3.33	3.33	3.30	3.32 Ton

[a]San Carlos Irrigation Project annual crop reports.

Table 1-61. Crop yields on the San Carlos Project (District Part) projected on the basis of 80,000 irrigated acres, as influenced by irrigation method and salinity of the irrigation water.

Drainage Classification	Irrigations Per Year	San Carlos Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of San Carlos and C.A.P. Water, mg/l						
		910	858	906	945	983	1022	1060	1098
			Alfalfa Hay in 100 Tons						
Well 2,416	16	All Values 102.44							
	22								
	29								
	35								
	Sprinkler								
Moderate 1,880	16	79.71	79.71	79.71	78.91	77.32	75.72	74.13	72.54
	22								78.91
	29								
	35								
	Sprinkler								
Poor 3,048	16	103.26	105.98	103.26	99.51	98.22	95.64	92.41	89.18
	22	108.56	111.79	108.56	106.62	104.68	103.26	99.51	98.22
	29	111.79	114.38	111.79	109.85	107.92	105.98	103.26	100.81
	35	115.02	118.90	115.02	113.09	112.44	110.50	108.56	106.62
	Sprinkler	126.66	129.24	126.66	124.07	121.49	118.90	115.02	113.09
			Safflower in Tons						
Well 470 Acres	16	All Values 597							
	22								
	29								
	35								
	Sprinkler								
Moderate 370 Acres	16	All Values 470							
	22								
	29								
	35								
	Sprinkler								
Poor 595 Acres	16	756						752.2	744.7
	22							756.0	756.0
	29			All Other Values 756.0					
	35								
	Sprinkler								

Table 1-61. Continued.

Drainage Classification	Irrigations Per Year	San Carlos Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of San Carlos and C.A.P. Water, mg/l						
		910	858	906	945	983	1022	1060	1098
			Wheat in 100 Tons						
Well	16	All Values 22.58							
1,060	22								
Acres	29								
	35								
	Sprinkler								
Moderate	16	All Values 17.57							
825	22								
Acres	29								
	35								
	Sprinkler								
Poor	16	28.54	28.54	28.54	28.54	28.25	27.97	27.68	27.26
1,340	22	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54
Acres	29	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54
	35	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54
	Sprinkler	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54
			Maize in 100 Tons						
Well	16	All Values 25.26							
1,460	22								
Acres	29								
	35								
	Sprinkler								
Moderate	16	All Values 19.64							
1,135	22								
Acres	29								
	35								
	Sprinkler								
Poor	16	31.19	31.67	31.19	30.56	30.40	28.49	29.60	29.12
1,840	22	31.83	31.83	31.83	31.83	31.51	31.19	30.56	30.40
Acres	29	31.83	31.83	31.83	31.83	31.83	31.67	31.19	30.88
	35	31.83	31.83	31.83	31.83	31.83	31.83	31.83	31.83
	Sprinkler	31.83	31.83	31.83	31.83	31.83	31.83	31.83	31.83
			Grapes in Tons						
Well	16	All Values 99.60							
30	22								
Acres	29								
	35								
	Sprinkler								
Moderate	16	All Values 66.40							
20	22								
Acres	29								
	35								
	Sprinkler								
Poor	16	99.93	103.42	99.93	96.45	94.12	91.80	88.31	84.31
35	22	106.32	109.23	106.32	104.58	102.26	99.93	96.45	94.12
Acres	29	109.23	111.55	109.23	109.49	105.16	103.42	99.93	97.61
	35	112.71	115.33	112.71	110.97	109.81	108.07	106.32	104.58
	Sprinkler	116.20	116.20	116.20	116.20	116.20	115.33	112.71	110.97

San Carlos Indian Irrigation Project

Acreages of the major crops grown in the San Carlos Indian lands are shown in Table 1-62, assigned to soil drainage classes in Table 1-63, and projected to include the land to be brought under irrigation by the introduction of CAP water in Table 1-64. Crop yields are shown in Table 1-65, and the projected yields for those crops which would be affected by the blended water salinity are shown in Table 1-66. The projected yields for major crops on the San Carlos Project (both Indian part and District part) which would not be reduced by the expected levels of salinity in the blended water are shown in Table 1-67. Crop values are shown by marketable units in Table 1-68 and by the acre in Table 1-69.

Table 1-62. Acreages planted to major crops in the San Carlos Irrigation Project—Indian Part.[a]

Crop	1968	1969	1970	1971	1972	1973	Average
Alfalfa Hay	1,244	740	1,905	1,788	2,210	2,436	1,720
Barley	6,473	7,030	5,200	3,882	3,991	3,751	5,055
Safflower	320	815	30	555	606	281	435
Wheat	74	145	2,590	1,470	1,405	2,541	1,370
Maize	2,553	1,305	1,035	290	945	662	1,130
Upland Cotton	2,170	3,186	2,145	1,270	2,593	2,411	2,295
Long Staple Cotton	160	198	195	584	196	387	285
Watermelon	80	150	210	400	345	440	270

[a] San Carlos Irrigation Project annual crop reports.

Table 1-63. Partition of major crop acreages into different soil drainage classes, San Carlos Project—Indian Part.[a]

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa Hay	1,006	502	212
Barley	2,957	1,476	622
Safflower	254	127	54
Wheat	801	400	169
Maize	661	330	139
Upland Cotton	1,343	670	282
Long Staple Cotton	167	83	35
Watermelon	158	79	33

[a] San Carlos Irrigation Project annual crop reports. Acreages are averages of 1968-1973 cropping seasons.

Table 1-64. Acreages of major crops projected to include project land under irrigation after CAP water is introduced, San Carlos Project—Indian Part.[a]

Crop	Drainage Classification		
	Well	Moderate	Poor
Alfalfa Hay	1,615	805	340
Barley	4,740	2,365	995
Safflower	405	205	85
Wheat	1,285	640	270
Maize	1,060	530	220
Upland Cotton	2,150	1,075	455
Long Staple Cotton	265	135	55
Watermelons	250	125	50

[a] Acreages projected on the basis of 80,000 irrigated acres in the Project.

Table 1-65. Yields of major crops in the San Carlos Irrigation Project—Indian Part.[a]

Crop	1968	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	2.13	6.0	5.61	5.00	6.00	5.89	5.11 ± 1.58 Ton
Barley	1.47	1.49	1.60	1.78	1.56	1.91	1.64 ± 0.18 Ton
Safflower	0.64	1.04	1.00	1.09	1.25	0.94	0.99 ± 0.21 Ton
Wheat	1.88	1.89	2.20	1.92	2.01	2.16	2.01 ± 0.15 Ton
Maize	1.14	1.00	1.00	1.13	1.25	1.25	1.13 ± 0.12 Ton
Upland Cotton	2.41	1.74	1.81	2.0	2.41	2.37	2.12 ± 0.33 Bale
Upland Cotton Seed	0.94	0.84		0.82	0.96	0.91	0.89 ± 0.08 Ton
Long Staple Cotton	1.49	1.00	0.50	1.0	0.94	2.01	1.16 ± 0.55 Bale
Long Staple Cotton Seed	0.64	0.84		0.50	0.33	0.87	0.64 ± 0.28 Ton
Watermelons			12.00	10.00	10.00	9.00	10.25 ± 2.0 Ton

[a] San Carlos Irrigation Project annual crop reports.

Table 1-66. Crop yields on the San Carlos Project (Indian Part) projected on the basis of 80,000 irrigated acres, as influenced by irrigation method and salinity of the irrigation water.

Drainage Classification	Irrigations Per Year	San Carlos Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of San Carlos and C.A.P. Water, mg/l						
		910	858	906	945	983	1022	1060	1098
			Alfalfa Hay in 100 Tons						
Well 1,615 Acres	16	All Values 82.53							
	22								
	29								
	35								
	Sprinkler								
Moderate 805 Acres	16	41.14	41.14	41.14	40.32	39.91	39.08	38.26	37.44
	22	41.14	41.14	41.14	41.14	41.14	41.14	41.14	40.73
	29	41.14	41.14	41.14	41.14	41.14	41.14	41.14	41.14
	35	41.14	41.14	41.14	41.14	41.14	41.14	41.14	41.14
	Sprinkler	41.14	41.14	41.14	41.14	41.14	41.14	41.14	41.14
Poor 340 Acres	16	13.81	14.24	13.81	13.37	13.20	12.85	12.42	11.99
	22	14.59	15.03	14.59	14.33	14.07	13.81	13.37	13.20
	29	15.03	15.37	15.03	14.76	15.37	14.24	13.81	13.55
	35	15.46	15.98	15.46	15.20	15.11	14.85	14.59	14.33
	Sprinkler	17.02	17.37	17.02	16.68	16.33	15.98	15.46	15.20
			Wheat in 100 Tons						
Well 1,285 Acres	16	All Values 25.83							
	22								
	29								
	35								
	Sprinkler								
Moderate 640 Acres	16	All Values 12.86							
	22								
	29								
	35								
	Sprinkler								
Poor 270 Acres Acres	16	5.43	5.43	5.43	5.43	5.38	5.32	5.27	5.20
	22								5.38
	29			All other values 5.43					
	35								
	Sprinkler								
			Maize in 100 Tons						
Well 1,060 Acres	16	All Values 11.98							
	22								
	29								
	35								
	Sprinkler								
Moderate 530 Acres	16	All Values 5.99							
	22								
	29								
	35								
	Sprinkler								
Poor 220 Acres	16	2.44	2.48	2.44	2.40	2.38	2.35	2.32	2.28
	22	2.49	2.49	2.49	2.49	2.47	2.44	2.40	2.38
	29	2.49	2.49	2.49	2.49	2.49	2.48	2.44	2.42
	35	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49
	Sprinkler	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49

Table 1-66. Continued.

Drainage Classification	Irrigations Per Year	San Carlos Without C.A.P.	T.D.S. of C.A.P. Water, mg/l						
			775	900	1000	1100	1200	1300	1400
			T.D.S. of San Carlos and C.A.P. Water, mg/l						
		910	858	906	945	983	1022	1060	1098
		Watermelon in 100 Tons							
Well 250 Acres	16	All Values 25.63							
	22								
	29								
	35								
	Sprinkler								
Moderate 125 Acres	16	12.81	12.81	12.81	12.55	12.49	12.30	12.04	11.85
	22	12.81	12.81	12.81	12.81	12.81	12.81	12.81	12.68
	29	12.81	12.81	12.81	12.81	12.81	12.81	12.81	12.81
	35	12.81	12.81	12.81	12.81	12.81	12.81	12.81	12.81
	Sprinkler	12.81	12.81	12.81	12.81	12.81	12.81	12.81	12.81
Poor 50 Acres	16	4.10	4.23	4.10	4.00	3.90	3.82	3.69	3.57
	22	4.36	4.49	4.36	4.28	4.21	4.10	4.00	3.90
	29	4.49	4.62	4.49	4.41	4.33	4.23	4.10	4.03
	35	4.67	4.80	4.67	4.59	4.54	4.46	4.36	4.28
	Sprinkler	5.13	5.13	5.13	4.95	4.87	4.80	4.67	4.59

Table 1-67. Major crops on the San Carlos Project not affected by increases in salinity of the CAP water to 1400 mg/l. Projected on the basis of 80,000 acres.

Crop	Drainage Classification					
	Well		Moderate		Poor	
	Acres	Yield	Acres	Yield	Acres	Yield
			District Part			
Barley	4,460	8,073 Tons	3,470	6,281 Tons	5,625	10,181 Tons
Safflower	470	597 Tons	370	470 Tons	595	756 Tons
Sugar Beets	195	3,352 Tons	150	2,579 Tons	245	4,212 Tons
Upland Cotton	6,850	15,550 Bales	5,330	12,099 Bales	8,640	19,613 Bales
Upland Cotton Seed	6,850	6,371 Tons	5,330	4,957 Tons	8,640	8,035 Tons
Long Staple Cotton	330	492 Bales	260	387 Bales	420	626 Bales
Long Staple Cotton Seed	330	416 Tons	260	328 Tons	420	529 Tons
			Indian Part			
Barley	4,740	7,774 Tons	2,365	3,879 Tons	995	1,632 Tons
Safflower	405	401 Tons	205	203 Tons	85	84 Tons
Upland Cotton	2,150	4,558 Bales	1,075	2,279 Bales	455	965 Bales
Upland Cotton Seed	2,150	1,914 Tons	1,075	957 Tons	455	405 Tons
Long Staple Cotton	265	307 Bales	135	157 Bales	55	64 Bales
Long Staple Cotton Seed	265	170 Tons	135	86 Tons	55	35 Tons

Table 1-68. Crop values on the San Carlos Irrigation Project.[a]

Crop	Market Value Per Unit						
	1968	1969	1970	1971	1972	1973	
			District Part				
Alfalfa Hay	23.00	26.00	33.00	35.00	44.00	45.00	Ton
Barley	45.00	50.00	49.17	57.00	55.00	79.00	Ton
Safflower	80.00	85.00	85.00	105.00	105.00	160.00	Ton
Wheat	45.00	50.00	40.00	44.80	44.00	80.00	Ton
Maize	40.00	50.00	52.00	51.00	59.14	100.00	Ton
Upland Cotton	107.50	97.50	112.50	144.97	155.00	275.00	Bale
Upland Cotton Seed	52.50	40.00	60.00	60.00	50.00	110.00	Ton
Long Staple Cotton	205.00	215.00	220.10	225.00	210.00	650.00	Bale
Long Staple Cotton Seed	51.01	40.00	14.50	58.00	48.00	108.00	Ton
Sugar Beets	14.23	14.00	14.00	13.00	15.00	22.00	Ton
Grapes		199.00	202.11	200.00	500.00	200.00	Ton
			Indian Part				
Alfalfa Hay	22.00	22.65	32.00	30.00	44.00	45.00	Ton
Barley	44.00	51.25	55.00	56.25	56.25	68.00	Ton
Safflower	75.00	64.38	60.00	105.00	115.00	216.00	Ton
Wheat	45.00	41.67	52.00	55.00	55.00	80.00	Ton
Maize	42.00	47.20	52.00	45.00	45.00	100.00	Ton
Upland Cotton	155.00	155.00	234.15	230.00	230.00	275.00	Bale
Upland Cotton Seed	52.00	50.00		60.00	52.00	110.00	Ton
Long Staple Cotton	210.00	200.00	289.00	200.00	260.00	650.00	Bale
Long Staple Cotton Seed	52.00	50.00		10.00	50.00	110.00	Ton
Watermelons	60.00	35.00	50.00	55.00	60.00	60.00	Ton

[a] San Carlos Irrigation Project annual crop reports.

Table 1-69. Crop values on the San Carlos Irrigation Project.[a]

Crop	Market Value Per Unit						
	1968	1969	1970	1971	1972	1973	
			District Part				
Alfalfa Hay	105.57	120.16	136.70	103.95	172.04	233.24	Ton
Barley	81.76	88.54	89.63	103.58	100.22	143.62	Ton
Safflower	60.00	110.45	88.17	153.40	133.11	208.02	Ton
Wheat	66.53	82.11	101.80	109.98	110.41	171.94	Ton
Maize	75.51	76.74	94.30	91.58	81.71	175.00	Ton
Upland Cotton	277.38	206.23	244.87	316.12	351.76	635.06	Bale
Upland Cotton Seed	55.17	34.48	53.21	53.31	46.26	103.51	Ton
Long Staple Cotton	357.81	291.23	277.16	261.45	339.25	1,334.31	Bale
Long Staple Cotton Seed	56.53	34.40	37.12	42.77	49.24	138.64	Ton
Sugar Beets	278.39	235.70	163.70	236.21	240.00	459.06	Ton
Grapes		90.00	120.00	666.66	1,650.00	200.00	Ton
			Indian Part				
Alfalfa Hay	46.90	135.90	179.60	150.00	264.00	264.00	Ton
Barley	64.52	76.26	87.94	99.90	87.75	129.88	Ton
Safflower	47.81	66.98	60.00	114.45	143.75	202.93	Ton
Wheat	84.53	78.75	114.62	105.76	110.55	172.85	Ton
Maize	47.89	47.20	52.00	50.85	56.25	125.00	Ton
Upland Cotton	373.29	269.95	423.33	460.00	554.30	651.75	Bale
Upland Cotton Seed	48.88	42.00		49.20	49.92	99.73	Ton
Long Staple Cotton	312.38	200.00	145.24	200.00	244.40	1,303.36	Bale
Long Staple Cotton Seed	33.28	42.00		5.00	16.50	95.79	Ton
Watermelons	30.00	70.00	600.00	550.00	600.00	540.00	Ton

[a] San Carlos Irrigation Project annual crop reports.

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APPENDIX 2
AGRICULTURAL CONSEQUENCES IN CALIFORNIA

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IMPERIAL VALLEY, CALIFORNIA

The salient reservations of each of many possible approaches to predicting the agricultural consequences of increasing salinity have been thoroughly reviewed by Young, Franklin, and Nobe (1973). Their suggestion was that data be sought in the areas being studied to obtain a better estimate of the declination of crop yield as a function of increasing salinity. Without an on site comparison of the conductivities of soil and irrigation water, large discrepancies can enter the approximations. Bernstein (1962) states,

> In an ideally drained and irrigated soil, the electrical conductivity of the saturation extract could approximate half the value of the electrical conductivity of the irrigation water as a lower limit, because the saturation percentage of a soil is approximately twice the field capacity. At the United States Salinity Laboratory, this relationship generally obtains in artificially salinized plots irrigated throughout a season with water of a given salinity. Under commercial conditions, such ideally restricted salinity levels rarely occur. Even in excellent citrus orchards, the electrical conductivity of the applied water at one depth or another in the root zone seldom, if ever, reaches the restricted salinity levels (Chapman and Harding, 1956). Under less favorable conditions with poorer management, much higher ratios develop.

A number of things may contribute to the variation noted by Bernstein, but drainage is the key and is closely associated with soil texture. Extremely high-salinity irrigation water has been used by Cavazza (1968) in Pugtia and Lucania. A maximum tolerance of 8 percent is reported for tomatoes. This value is in excess of 20 mmho and much higher than utilized in the United States. The key to this ability to use high-salinity water is the sandy-textured soil which is well drained. In the same publication, Boyko (1968) reports on the desert garden of Eilat where 2,000 to 6,000 mg/l TDS water is being used on sandy soils for a host of plant species. Van Hoorn et al. (1968) reports excellent yields of wheat, maize, sorghum, alfalfa, cotton, beans, asparagus, tomatoes, and melons in Tunisia using water of 4-5 g/l on a well-drained soil. Durand (1956) established an irrigation water evaluation system which incorporates five soil textures. Doneen (1963) set up a system of potential salinity but set limits for each of three soil permeabilities. The chloride hazard as listed in the Israel Salinity Survey (1964) indicates different levels in different soil textures.

A criticism of the Soviet soil scientists by a technical U.S. study group (Bower et al. 1960) was that they

> ...determine total salinity by weighing the residue obtained upon evaporation of a filtered 1:5 or 1:10 soil water extract to dryness. The results are expressed as percentage of salt on a dry soil basis and soil texture or water retention characteristics are not taken into account in relating salt content to plant growth.
>
> American soil scientists recognize that plants growing on saline soils respond to the salt concentration of the soil solution, and that with a given salt content (expressed on a dry-soil basis) the concentration of the soil solution in the field moisture range is inversely related to fineness of texture or water retention capacity. For this reason, most American scientists employ for the determination of salinity an extract obtained at a water content related to the water retention characteristics of the soil, e.g., saturation extract.

The mean conductivities of the top 30 cm of sandy Indio soils, sandy Meloland, loamy Imperial stratified, and Imperial clay complex soils after 70 years of irrigation with the same Colorado River water was 2.4, 2.7, 5.0, and 6.2 mmho/cm. These observations support the development of this report around soil textural units.

Classification of Colorado River Water Between 900 and 1400 mg/l Total Dissolved Solids (TDS)

Published analysis of the ionic composition, conductivity, and TDS of the Colorado River and several drains leading away from agricultural areas where the river water has been used and drained out of the soil are available, State of California (1971). If one considers that the factors concentrating the drainage water are the same ones that will operate to concentrate the Colorado in the future, it is likely that the drainage salt contents are a reasonable approximation of the Colorado River salt content if it should reach the same TDS as that in the drain. With this in mind, Table 2-1 was developed showing log regressions of Ec electric conductivity (meq/l) of C1-, Ca+, HCO_3-, Mg^+, Na^+, and $SO_4^=$ as a function of TDS in mg/l of all water data from below Imperial Dam.

The classification of these projected water salinities would fall within the median salinity range presented by Thorn and Peterson (1955) of 750 to 2,250 micro mho/cm. In Durand's (1956) evaluation, all of the projected concentrations would be suitable for sandy soil and for very sensitive crops which can have soil saturation extracts up to 4 mmho. Loamy sands could take the water up to 1,600 mmho and loamy soil up to 1,000 mmho. Loamy clays and clays are already exceeded on the sensitive crops. For plants that could have soil saturation extracts up to 10 mmho, the entire range of projected soil solutions could be used on all textures except the clay which has a 1 mmho/cm limit. For crops that could tolerate soil saturation extracts greater than 10 mmho, only the clay soil would be limited to values below 2.0. With horticultural and forage crops, the saturation for clay soil is 1.8 mmho; for the field crops the clay limit is 1.6 mmho. This system does not incorporate an allowance for $SO_4^=$ predominance.

The Antipov-Karataev (1960) method places all of the projected water values well below the X_{10} critical limit of sodium hazard. The Wilcox (1958) system would place all of the projected waters over 1,000 mg/l in the 52 classification which is described as "medium-sodium water." This system may present a moderate sodium problem in fine-textured (clay) soils unless there is gypsum in the soil. Water of the S2 classification can be used only on coarse-textured (sandy) or organic soils that take waters well.

Rhodes (1972) pointed out the need to adjust the calculation of exchangeable sodium percentage (ESP) for ionic strength and further stressed that the ESP at the base of the root system should be considered at various leaching ratios. Table 2-2 presents the factors in this calculation. If one utilizes the limit of ESP promulgated by the California Committee of Consultants (i.e., 9) as a critical value at which severe permeability problems develop, a leaching ratio of 30 percent should be used until the TDS exceeds 1,100 mg/l after which 40 percent should be used.

However, McNeal et al. (1966) showed that swelling would be minor at the ESP 22 and 1400 mg/l concentration of this study. Quirk (1955) agrees. In his diagram separating stable permeability and decreasing permeability the highest ESP values at 10 percent leaching fall within the stable permeability area.

It is concluded that if the ion mixes are not changed from their potential values, permeability will not be greatly effected by sodium.

Bicarbonate Hazard

Eaton (1950) introduced the residual sodium carbonate (RSC)

$RSC = (CO_3^= \quad + HCO_3^-) - (Ca^{++} + Mg^{++})$ in meq/l.

Wilcox (1955) in his classification of RSC values indicates that values less than +1.25 should be safe. The values of RSC for the projected water are well below the 1.25 marginal value. This should not cause problems. It should be noted at this point that the chemical analysis of HCO_3^- in the published data were

Table 2-1. Conductivity in micro mho/cm and ion concentration in meq/l as a function of total dissolved solids in mg/l. Potential salinity and SAR are indicated.

	Cor Coef
$\ln Ec = 0.97572 \ln TDS + 0.5630$	0.987
$\ln Cl = 1.49470 \ln TDS - 8.77014$	0.984
$\ln Ca - 0.658814 \ln TDS - 2.90328$	0.997
$\ln HCO_3 = 0.23401 \ln TDS - 0.48040$	0.195
$\ln Mg = 1.01057 \ln TDS - 5.79548$	0.988
$\ln Na = 1.146846 \ln TDS - 5.90873$	0.992
$\ln SO_4 = 0.78180 \ln TDS - 3.31381$	0.972

TDS	EC	Na	Mg	Ca	SO_4	Cl	HCO_3	SAR	Potential Salinity
900	1339	6.64	2.94	4.85	7.42	4.04	3.04	3.36	7.5
1000	1484	7.49	3.27	5.19	8.05	4.73	3.11	3.46	8.8
1100	1629	8.35	3.60	5.53	8.68	5.46	3.18	3.90	9.8
1200	1773	9.23	3.93	5.86	9.29	6.22	3.25	4.17	10.9
1300	1917	10.12	4.26	6.17	9.89	7.01	3.31	4.43	12.0
1400	2061	11.02	4.60	6.48	10.48	7.83	3.37	4.68	13.1

Data from State of California. 1971. Hydrologic Data 1969. Southern California. Department of Water Resources Bulletin 139-69. V:424-426.

Table 2-2. Calculation of exchangeable sodium percentage in soils at the surface and at the base of the root zone with 10, 20, 30, and 40 percent leaching ratios. After Rhodes (1972).

TDS mg/l	$(pk_2 - pkc)$	p(Ca+Mg)	Palk $p(HCl_3)$	pHc
900	2.29	2.42	2.515	7.225
1000	2.325	2.38	2.505	7.21
1100	2.335	2.34	2.495	7.17
1200	2.345	2.31	2.485	7.14
1300	2.354	2.29	2.480	7.12
1400	2.362	2.25	2.470	7.08

$pHc = (pK_2 - pKc) + p(Ca+Mg) + palk$

$ESPs = SAR_{lw}\ 1 + (8.4 - pHc)$

TDS	SAR	ESP_3	ESP_{b10}	ESP_{b20}	ESP_{b30}	ESP_{b40}
900	3.36	7.31	15.06	9.94	7.53	6.07
1000	3.46	7.57	15.59	10.29	7.80	6.28
1100	3.90	8.70	17.92	11.83	8.96	7.22
1200	4.17	9.42	19.40	12.81	9.70	7.82
1300	4.43	10.10	20.81	13.74	10.40	8.38
1400	4.68	10.86	22.37	14.76	11.19	9.01

scattered and the regression equation had a correlation coefficient of only 0.19. However, if the most active concentrating mechansim of these waters is leaching through soils, it is highly probable that $CO_3^=$ may precipitate and remain in the soil while the more soluble salts leach back to the river tributaries. Salt balance studies conducted by the Imperial Irrigation District (1972) and Soil Conservation Service show that approximately 13 percent of the salts brought into the valley precipitate as calcium carbonates and sulfates. No problem is anticipated from the RSC of the projected waters since there will be ample Ca^{++} to precipitate all the carbonate and still be some available in solution.

Chloride Hazard

In Scholfield's (1935) classification the projected waters would exceed the moderate Cl^- level at 1,300 TDS. His five levels were 4, 7, 12, 20 meq/l. Fireman and Kraus (1965) divided their Cl^- classification into four sections separated at 2, 5, and 8 meq/l. The projected waters fall within the precautionary zone. The California Committee of Consultants has adopted a three-stage division of Cl^- concentrations divided at 4 and 10 meq/l. All of the projected values fall in the zone labeled increasing problems. Doneen's (1963) classification of potential salinity places all of the projected Colorado River water within safe limits for good permeability, 5-20 meq/l, and medium permeability 3-15 meq/l. The Cl^- value exceeds the critical value for low permeability soils at 1,300 mg/l TDS, i.e., 3-7 meq/l. The Israel salinity survey (1964) indicates that there would be no danger of using this water for citrus on sandy and loamy soils, but a medium risk in clay, the tolerance of citrus root stock being 10 meq/l Cl^-. It is believed that Cl^- may become a problem for semi-tolerant plants in the Imperial clay.

Germination

The first time of contact between irrigation water and plants is during the germination stage. At this time, interaction of humidity (see Hoffman and Rawlins, 1971) can alter the salt tolerance of salt-sensitive plants such as onion. The more salt-tolerant crops such as cotton are not affected, Hoffman and Phene (1971).

Magistad et al. (1943) found a significant difference in the tolerance of onion bulbs to salinity in the marine climate of Torrey Pines and the desert climate of Indio in California.

This author agrees with Young's (1973) statement that "salt tolerance studies should be carried out within an ecologically discrete area in order to have the greatest validity." Salt tolerance of several crops is being tested in the Imperial Valley at this time.

Wakhab (1961) studied the germination of maize, barley, gram, rice, and cotton at 0.1, 0.2, 0.3, and 0.4 percent NaCl placed on loam and sandy loam at varying percentages of the moisture-holding capacity. Maize showed 100 percent germination up to 0.3 percent NaCl and 75 percent moisture capacity (MC), barley at 0.4 percent NaCl and 60 percent (MC), rice 0.3 percent NaCl and 75 percent (MC), cotton - 6 varieties at 0.2 percent NaCl and three varieties at 0.1 percent NaCl and 60 percent (MC).

Kneeb (1959) collected soil samples from plots to grow plants in a sequence of increasing salinities. Barley and corn gave 100 percent germination at 1.6 percent salt when moistened to field capacity on petri dishes, wheat produced 100 percent germination at 0.9 percent salt. In the field 1.5 percent was the upper limit for germination of corn and barley, and the wheat about 0.85 percent. This far exceeds the values of the projected Colorado River water. Dashevskii (1957) in agreement with Bernstein and Hayward (1958) found that higher levels of soil moisture would permit sugar beets to germinate at higher salt levels. Sugar beets could tolerate 0.014 percent Cl and 14 percent moisture, but 0.044 percent at 22 percent moisture.

Lopez (1968) utilized water containing 150 meq/l NaCl solutions to produce lower concentrations by dilution. He found a reduction of 71 to 59 percent at 3.31 mmho/cm and 5.65 mmho/cm in the germination of durum wheat. Common wheat showed a germination of 87.1 at 5.65 mmho and 55.2 at 12.10 mmho. Barley showed 73.1 percent germ at 16.4 mmho/cm and none at 32 mmho. Tomatoes showed varietal differences of 52 percent and 64.8 percent germ at 6.58 mmho/cm. He placed durum wheat, alfalfa, tomato, broccoli, and endive in the little tolerance group requiring water of less than 4 mmho. Moderate tolerance groups included vetch, some tomato varieties, lettuce, and common wheat with tolerance of 4-12 mmho during germination. Barley was capable of germination between 12-18 mmho.

It has been demonstrated that sprinkler irrigation is effective in removing salinity from the soil surface and enhancing emergence of lettuce, cabbage, carrots, onions, sugar beets, alfalfa, radishes, cauliflower, broccoli, safflower, flax, cantaloupes, and watermelons in Imperial Valley (Robinson et al., 1966; 1967abc; 1968abc; 1969; 1970; 1972). In an ongoing experiment utilizing water of 1,350 mg/l, no significant difference was noted in germination of lettuce, cabbage, carrots, onions, sugar beets, and alfalfa as compared to the water with the present Colorado salinity 900 mg/l Because the use of sprinklers has become a standard practice on most of the vegetables in this study as well as with commercially grown sugar beets and alfalfa, it will be assumed that the practice will continue in these crops and that they will experience no failure in emergence. Sprinkler irrigation has also been utilized effectively on wheat, cotton, barley, and sorghum. However, the relatively high tolerance of these crops to salinity indicates that sprinklers will probably not be needed for germination of these crops on soils other than the Imperial clay.

Salt Tolerance of Crops

Cotton. Kovda (1947) found that cotton was stunted by 8.5 g/l NaCl water, that fiber lengths were reduced about 3 mm from the normal, and that the index of strength was reduced by 0.5 g. Stroginov (1962) pointed out the physiological differences of cotton grown in SO_4-Cl waters. Passerini and Galli (1927) found cotton to be tolerant of 3 g/l solution of Cl. Grillot (1954) indicated that cotton could tolerate 6-8 parts of NaCl per 1,000 of dry earth. Kovda (1973) stated,

> Differences among various crops are compared by determining the soil salinity level (measured as electrical conductivity of the saturation extract) at which crop yields are reduced by 50 percent from yields on non-saline soils under comparable growing conditions. Some investigators have used a 20 or 25 percent reduction or other criteria for making similar comparisons. In spite of the differences in methods of evaluating salt tolerances, there is a high degree of agreement among most lists.

He then produced Bernstein's 1964 table of tolerance. The crops which are being considered in this report will be evaluated from the data given in the California Committee of Consultants (1974), wherein the work of Bernstein has been modified.

Leaching as a Means of Salt Removal

Experiments by Bigger and Nielsen (1962), Wilson (1963), Willardson (1972) showed that intermittent leaching was more efficient than ponding in removing soil salt per unit of water applied. Talsma (1967) summed things as follows:

> Analysis of results shows that during the ponding stage desalinization proceeds more rapidly near the drains than midway between, while during the falling water stage desalinization is more even over the whole area. This is explained by the difference in surface rates across the area between drains during the two stages.
>
> Comparison of continuous ponding with alternate ponding and draining shows that in the latter case complete desalinization is achieved with considerably less leaching water. The leaching efficiency is not very high under continuous ponding.

Robinson and Luthin (1967) concluded that intermittent flooding was more efficient in terms of salt removed per unit of water applied, but took longer to leach a given soil area than did the continuous ponding. Unpublished data of Malek Kaddah, Soil Scientist at Imperial Valley Conservation Research Center, ARS, Brawley, showed that leaching could reduce surface salts from a range of 15 mmho/cm to a range of 3-4 mmho/cm and that within 2 years the soil was back to its original salt content.

Sprinklers can be used to good advantage for leaching. Wilson and Luthin (1963) noted that rainfall was more effective than ponding for leaching. Nielsen, Bigger and Luthin (1965) noted that sprinkling was more effective than ponding in salt removal. Collis-George and Laryea (1971) note that

> When unstable soil moisture potential is 0 or near 0, the structure collapses, greatly reducing leaching, and the movement of the wetting front and infiltration rate are small compared to a stable soil.
>
> The infiltration behavior of unsaturated soils with restricted supply rates which do not develop surface ponding is similar to that of structurally stable materials under the same restricted supply rate in that the structure is not destroyed.

Robinson et al. (1968) noted that bulk densities of Imperial clay soils remained 10 percent lighter under sprinkler irrigation than under flood irrigation. The seed bed granulation remained under the sprinklers but broke down during flooding. Where sprinklers are available for non-ponding rates of application, they will be advantageous.

Kovda (1973) presents a concept of leaching after each 20 irrigations with a 1,000 mg/l water. The leaching would drop the soil salinity to one-half its value, i.e., when soil which initially contained 0.2 percent salt was allowed to increase to 0.4 percent salt, a 1,000 mg/l irrigation water would then have a leaching phase to drop the water to 0.2 percent again.

Agricultural operations used in the Imperial Valley to eliminate salt buildup and their costs as of November 1974, are as follows:

Drain tile—plastic (most of it is plastic today)

Polyethylene has gone from 13 cents prior to the oil shortage to 29 cents per pound. They expect to pay 35 cents around January 1, 1975.

Installing the tile costs:
30.5 cents per foot on 3" plowed in at 5½ feet deep with a gravel envelope
48.0 cents per foot on 4" trench installation at 5½ feet with gravel envelope
$1.00 per foot on 8" trench installation

Most systems have tile on 100 foot spacings with 3- or 4-inch tile and one 1,320-foot 8-inch main collector drain. 14 x 1,320 = 18,480 feet of 3- or 4-inch and 1,320 feet of 8-inch pipe.

Land leveling

Two years ago this cost 18 cents per cubic yard. Now it costs 23 cents per cubic yard. One might base his analysis on some given volume of soil movement such as 8 acre feet on a 40 acre field. At 23 cents per cubic yard this would be $2,968 for the 40 acre field. Two years ago this would have been $2,323 per 40 acre field.

Slip plowing

This requires two D-8 tractors and a slip plow. Present cost is $65 per hour. The present coverage is from 1 to 2 acres per hour depending upon the soil conditions. This operation is declining in importance. One operator reports plowing of only one 30-acre block in 1974.

Ditch lining

The on-farm ditch lining costs about $9,500 for 1/2 mile of 26-28 inch ditch with 1½-inch concrete and 14-inch outlets. This is up from $6,000 three years ago. The cost of this ditch would increase with different size valves, but this is the most common type.

Sprinkler Irrigation for Leaching

Sprinklers are now being more extensively utilized for leaching. Fred Jenkins is presently utilizing a 7-inch sprinkler application of water on land that is to grow sugar beets. His first crop grown on the land is rye and later sugar beets. He is presently using this method on 2,000 acres. John Elmore has found that sprinkler leaching leaves the soil more permeable and does a more complete removal of salts. It is increasingly common for lettuce growers to pre-irrigate fields with sprinklers to move the salt down into the profile and out the drain tile. An estimate of this cost could be obtained from the rental charges. Forty acres with pump, an 8-inch main line, and 3-inch sprinkler line and head costs about $160 for 3 months or $240 all year. Labor and fuel would average $35 per acre. If he utilized the system six times in 3 months, all costs would run around $62/acre. Utilizing the system throughout the year would reduce the cost to around $45/acre.

The following figures demonstrate the reduction in acreage ponded for leaching purposes: in 1967, 9157 acres; 1968, 7851 acres; in 1969, 8560 acres; 1970, 1685 acres; 1971, 1777 acres; 1972, 1202 acres; 1973, 973 acres. On the established cultural areas it is now more common to include a pre-irrigation of 4 to 6 inches by sprinkler, flood, or furrow to leach salts ahead of planting. The forming of borders for long-term ponding is utilized only in particularly poorly drained areas, and even some of these areas are being sprinkled as noted by Jenkins.

Discussion

The general criticism of Young et al. (1973) was that the Bernstein (1964) work was conducted with Cl salts whereas the Colorado River contains a substantial quantity of $SO_4^=$ could be stated generally for most studies in the world, Koval'skaia (1958), Kreeb (1959), Dashevskii (1957), Osawa (1957), T. Sing et al. (1956), Cavazza (1968), Lopex (1968), Gilbot (1954), Wahkab (1961), Simonneau (1945). The Russian school is aware of the influence of $SO_4^=$ and separates their soil classification into Cl- and $SO_4^=$ predominant classes. Generally, however, the Russians have ignored the influence of soil texture limiting the utility of their work in this study. Furthermore, their methods of extraction of soil salts brings solid sulfates into solution. Kovda (1946) concedes this point and further points out that the discrepancy would be stronger in the less saline soils.

In view of the facts that data from other countries would have to be corrected for sulfate waters also, that there was close similarity between all classifications of plant tolerance to soil salinity, and that the degree of completion of the work on the crop spectrum was greater at the U.S. Salinity Lab, it was concluded that these data would be the most productive starting point.

Within the State of California a Committee of Consultants (1974) has modified Bernstein's work to set up a series of declination values. Bernstein (1962) suggests that plants growing on soil containing gypsum salts can tolerate approximately 2 mmho/cm greater saturation extracts than those growing in the chloride treated soils at the Salinity Lab. Similar findings are reported by Shoshin (1955) as cited by Stroganov (1962) and Doneen (1963). Declination yield curves were based upon the California Committee of Consultants' Report and interpreted with a 2 mmho/cm increase when comparing soil saturation extracts from projected values.

Procedure

The base point of the soil extract conductivities was determined from mean values of soil extracts taken from 33 locations twice yearly over a 10-year period on four soil classifications on the Imperial Valley Field Station. The 95 percent confidence intervals of these samples are presented in Table 2-3. A similar interval was determined for the irrigation water conductivity. The ratios of the mean soil saturation extracts to the mean conductivity of the irrigation water is shown in Table 2-4. The median of each ratio was utilized to project the soil salinity which developed with the current best practice on that soil, as defined in Guidelines Imperial County Crops Circular 104 (1973).

In view of the statement,

> At present our ability to predict changes in soil solution concentration during infiltration and drainage has not been ascertained. Theoretical and experimental analysis involving nonsteady flow conditions are both meager and incomplete. Nielsen (1972).

This study will assume that the ratio between the conductivity of soil saturation extracts and the conductivity of the irrigation water will remain constant.

Consultation with Robert Zimmerman, Soil Conservation Service, produced the acreages of the major soil classifications in the Imperial Valley. He also indicated the general distribution of crops on each soil class, Table 2-5.

Mean crop yields and acreage were obtained from 1965 to 1972 from the Annual Crop Reports, Agricultural Commissioner, Imperial County Courthouse. These are shown in Table 2-6. Utilizing the Ec regression as a function of TDS from Table 2-1 and the median ratios from Table 2-4, Table 2-7 was constructed indicating a projected median conductivity of a saturated soil extract at different TDN levels. The irrigation management influence was defined as a function of the zone from which water was extracted from the soil. When intervals were long enough to require 13.3 cm application (16 irrigations per year), the salinity of the second 30 cm was used as an effective level of salinity. Where 9.7 cm was applied (22 irrigations per year), a mean was taken between

Table 2-3. Ninety-five percent confidence intervals of conductivities of saturated soil extracts on four soil textural classes from two samples per year over 10 years on the Imperial Valley Field Station. mmho/cm.

Area No.	Drainage Classification	
	Top 30 cm	30-60 cm
	Well	
91	2.69 ± 0.60	2.49 ± 0.63
92	2.46 ± 0.33	2.60 ± 0.54
94	2.50 ± 0.34	3.54 ± 0.67
96	3.71 ± 1.03	1.84 ± 0.46
97	2.16 ± 0.41	2.24 ± 0.28
Average	2.69	2.54
	Moderate	
43	3.52 ± 0.45	4.85 ± 0.49
44	2.72 ± 0.56	3.47 ± 0.32
51	3.25 ± 0.36	4.79 ± 0.52
52	3.31 ± 0.54	5.15 ± 0.84
53	2.82 ± 0.35	3.30 ± 0.39
54	2.68 ± 0.36	3.09 ± 0.47
65	2.51 ± 0.26	4.26 ± 0.34
66	2.76 ± 0.39	4.35 ± 0.57
81	2.18 ± 0.22	2.86 ± 0.39
82	3.19 ± 0.57	5.27 ± 0.47
83	2.37 ± 0.27	3.45 ± 0.58
Average	2.84	4.07
	Poor	
21	6.07 ± 0.67	8.13 ± 1.17
22	5.25 ± 0.53	7.60 ± 0.53
31	5.54 ± 0.77	6.77 ± 0.54
32	3.89 ± 0.53	5.51 ± 0.72
41	4.36 ± 0.77	5.21 ± 0.69
42	5.91 ± 1.51	6.64 ± 1.40
61	4.10 ± 0.46	6.27 ± 0.44
62	3.19 ± 0.32	5.37 ± 0.64
63	2.94 ± 0.46	4.82 ± 0.83
64	5.39 ± 0.76	6.64 ± 0.71
Average	4.66	6.30
	Very Poor	
71	7.28 ± 0.73	8.72 ± 0.69
72	6.16 ± 0.75	7.99 ± 0.60
73	6.44 ± 0.59	8.03 ± 0.81
74	6.21 ± 1.11	7.09 ± 1.51
75	6.77 ± 0.60	9.18 ± 1.21
76	6.25 ± 0.68	8.17 ± 0.94
Average	6.51	8.19

Table 2-4. Ratios of mean conductivity of saturated soil extract—mean conductivity of irrigation water, 1.41 mmho/cm.

Drainage Classification							
Well		Moderate		Poor		Very Poor	
0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
1.5	1.3	1.5	2.0	2.1	3.4	4.4	5.0
1.7	1.6	1.7	2.2	2.3	3.8	4.4	5.7
1.8[a]	1.8[a]	1.8	2.3	2.7	3.9	4.4	5.7
1.9	1.8	1.9	2.4	2.9	4.4	4.6[a]	5.8[a]
2.6	2.5	2.0	2.5	3.7[a]	4.7[a]	4.8	6.2
		2.0[a]	3.0[a]	3.8	4.8	5.2	6.5
		2.3	3.4	3.9	5.4		
		2.3	3.4	4.3	5.8		
		2.3	3.7				
		2.5	3.7				
		3.4	5.1				

a = median values.

Table 2-5. Crop acreage distribution in Imperial County in 1,000's of acres.

Crop	Drainage Classification			
	Well	Moderate	Poor	Very Poor
Lettuce	12	12	12	
Carrots	2	2		
Onions	1	1		
Tomatoes	0.5	0.5	1.0	
Watermelons	1	1	1	
Cantaloupe	4	4	4	
Asparagus			4	
Sorghum	12	12	19	7
Wheat	3	3	23	20
Barley	3	3	23	20
Sugar Beets	1	1	31	30
Cotton		2	24	12
Alfalfa	20	46	80	12
Total	59.5	87.5	222.0	101.0

Table 2-6. Ninety-five percent confidence interval of yields of crops from 1965 to 1972. (Tons per acre except cotton in pounds per acre.)

Crop	1972	1971	1970	1969	1968	1967	1966	1965	95% Confidence Interval
Asparagus	1.5	1.4	1.3	1.6	1.8	1.7	1.6	1.6	1.57 ± 0.13
Cabbage	12.3	11.5	19.0	10.0	10.4	12.5	11.9	9.6	12.19 ± 2.41
Cantaloupe	6.0	5.7	5.8	5.0	5.9	6.2	7.0	5.4	5.88 ± 0.48
Carrots	11.0	13.6	9.3	12.0	14.0	15.8	15.9	20.3	13.99 ± 2.79
Lettuce	10.9	11.7	10.2	9.2	9.7	9.5	11.3	9.0	10.79 ± 0.82
Onions mkt	13.7	12.8	14.0	10.0	15.7	18.1	12.6	12.5	13.68 ± 2.0
Tomato	11.2	11.4	5.0	6.4	6.3	10.5	5.8	4.8	7.68 ± 2.32
Watermelon	8.3	9.0	8.5	7.4	5.9	10.9	8.3	8.8	8.39 ± 1.15
Barley	1.8	1.8	1.8	2.0	1.8	2.2	1.6	2.2	1.9 ± 0.17
Cotton, lb.	1325	665	798	968	1660	971	1224	1717	1166 ± 314
Alfalfa	6.4	7.0	6.0	6.8	6.5	6.1	6.4	6.4	6.45 ± 0.27
Sorghum	2.3	2.5	2.3	2.5	1.8	1.9	2.2	2.5	2.25 ± 0.22
Sugar Beet	26.8	26.0	24.1	18.0	21.0	20.6	17.9	22.2	21.96 ± 2.6
Wheat	2.3	2.4	2.3	2.5	1.6	2.0	2.0	2.0	2.14 ±

Table 2-7. Projected median conductivity of saturated soil extract at different TDS levels.

TDS	Ec mmho cm	Drainage Classification							
		Well		Moderate		Poor		Very Poor	
		Top	Sub	Top	Sub	Top	Sub	Top	Sub
900	1.34	2.4	2.4	2.7	4.0	5.0	6.3	6.2	7.8
1000	1.48	2.7	2.7	2.0	4.4	5.5	7.0	6.8	8.6
1100	1.63	2.9	2.9	3.3	4.9	6.0	7.7	7.5	9.5
1200	1.77	3.2	3.2	3.5	5.3	6.5	8.3	8.1	10.3
1300	1.92	3.5	3.5	3.8	5.8	7.1	9.0	8.8	11.1
1400	2.06	3.7	3.7	4.1	6.2	7.6	9.7	9.5	11.9

the top and second 30 cm levels. At 7.3 cm and 29 irrigations a weighted mean of 2 (Ec surface + 1 (Ec sub))/3 was taken. Where 35 irrigations of 6.1 cm were used, the EC of the topsoil only was used. These values were estimated on the basis of Henderson (1946) and Wadleigh (1948). An effective Ec was derived from the above calculations by subtracting 2 mmho to adjust for the presence of significant gypsum in both soil and water. The Ec in the sprinkler case was determined by subtracting 1 mmho from the top soil and 2 mmho from the subsoil of Table 2-7 and calculating in the same manner as the soils above: Robinson (1969ac), Robinson et al. (1968), Robinson and Worker (1969). These data were developed for the soils and irrigation salinity levels shown in Table 2-8.

Tables 2-9 through 2-20 were developed for each of the crops in Table 2-6 at acreages shown in Table 2-5. Entering the corresponding salinity value from Table 2-8 into the declination yield curve from the California Committee of Consultants (1974), a yield

Table 2-8. Effective values of soil saturation extract conductivities in four soils, six TDS levels, and five irrigation management levels.

TDS	Irrigations Number	Drainage Classification			
		Well	Moderate	Poor	Very Poor
900	16	0.4	2.0	4.3	5.8
	22	0.4	1.4	3.7	5.0
	29	0.4	1.1	3.4	4.7
	35	0.4	0.7	3.0	4.2
	Sprinkler	0.0	0.0	2.1	3.4
1000	16	0.7	2.4	5.0	6.6
	22	0.7	1.7	4.3	5.7
	29	0.7	1.5	4.0	5.4
	35	0.7	1.0	3.5	4.8
	Sprinkler	0.0	0.2	2.7	4.1
1100	16	0.9	2.9	5.7	7.5
	22	0.9	2.1	4.9	6.6
	29	0.9	1.8	4.6	6.2
	35	0.9	1.3	4.0	5.5
	Sprinkler	0.0	0.5	3.3	4.9
1200	16	1.2	3.3	6.3	8.3
	22	1.2	2.4	5.4	7.2
	29	1.2	2.1	5.1	6.8
	35	1.2	1.5	4.5	6.1
	Sprinkler	0.0	0.8	3.8	5.5
1300	16	1.5	3.8	7.0	9.1
	22	1.5	2.8	6.1	8.5
	29	1.5	2.5	5.7	7.6
	35	1.5	1.8	5.1	6.8
	Sprinkler	0.2	1.2	4.4	6.3
1400	16	1.7	4.2	7.7	11.9
	22	1.7	3.2	6.7	8.7
	29	1.7	2.8	6.3	8.3
	35	1.7	2.1	5.6	7.5
	Sprinkler	0.4	1.5	5.0	7.0

declination was obtained. This was multiplied by the average yield of Table 2-6 and then by the acreage of each of the soil groups.

The amount of water for the 22-29-35 annual irrigations was based upon 213 cm or 84 inches of water per year. For alfalfa this would occur as shown in Table 2-21. Other crops which are grown during only part of the year would use the schedules as indicated in Guidelines (Staff Imperial County Extension office, 1973). It is important to note that where double cropping is practiced, the total number of irrigations on both crops would be used to enter the table. The sprinkler applications would be at 0.1 inch per hour so that a 24-hour period would give the required 2.4 inches. This could be broken into two 12-hour periods where soil begins to puddle or to three 8-hour periods.

To reconcile the Guidelines and base yearly irrigations of 16 per year, use tomatoes, p. 57, for an example. The Guidelines calls for 10 irrigations per year. Table 2-21 shows 10 irrigations starting in January through July for the 16 per year column. These same months show 14, 18, 22 rounds of irrigation for the yearly frequencies of 22, 29, and 35. To get base yield data use the yields provided in Table 2-6 for California. These yields are based upon the reported data, whereas, the Guidelines yield is a general estimate.

The sprinkler system considered here is a permanent one which could be operated at will, and the cost of power would be a function of the total hours of use. Such a system could be obtained for $800 to $1,000 per acre and written off over 10 years. Maintenance is estimated at $50/acre/year.

Table 2-9. Projected yields of Imperial Valley alfalfa with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

		Alfalfa in 1,000 Tons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 20,000 Acres	16	All Values 149					
	22						
	29						
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 46,000 Acres	16	343	329	312	302	288	277
	22	343	343	339	329	315	305
	29	343	343	343	339	326	315
	35	343	343	343	343	343	339
	Sprinkler	343	343	343	343	343	343
Holtville-Imperial Stratified (Sandy and Clay Stratified) 80,000 Acres	16	477	447	406	382	352	316
	22	501	477	447	429	394	363
	29	518	494	465	441	411	382
	35	537	513	494	471	441	418
	Sprinkler	590	552	525	501	474	447
Imperial Complex (Clay) 12,000 Acres	16	61	55	49	–	–	–
	22	67	62	55	51	–	–
	29	69	64	58	54	48	–
	35	72	68	63	59	54	49
	Sprinkler	78	73	67	63	57	53

Table 2-10. Projected yields of Imperial Valley asparagus with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

		Asparagus, Tons in 1,000's					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Holtville-Imperial Stratified (Sandy & Clay Stratified) 4,000 Acres	16	5.92	5.68	5.40	5.00	4.64	3.56
	22	6.12	5.92	5.68	5.52	5.16	4.84
	29	6.12	6.04	5.80	5.64	5.40	5.00
	35	6.12	6.12	6.04	5.84	5.64	5.40
	Sprinkler	6.12	6.12	6.12	6.12	5.88	5.68

Table 2-11. ***Projected yields of Imperial Valley barley with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Barley, Tons in 1,000's

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l 900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 3,000 Acres	16	All Values 5.7					
	22						
	29						
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 3,000 Acres	16	All Values 5.7					
	22						
	29						
	35						
	Sprinkler						
Holtville-Imperial Stratified (Sandy and Clay Stratified) 23,000 Acres	16	All Values 43.7					
	22						
	29						
	35						
	Sprinkler						
Imperial Complex (Clay) 20,000 Acres	16	38.0	38.0	38.0	37.6	36.8	34.2
	22	38.0	38.0	38.0	38.0	37.2	36.8
	29	38.0	38.0	38.0	38.0	38.0	38.0
	35	38.0	38.0	38.0	38.0	38.0	38.0
	Sprinkler	38.0	38.0	38.0	38.0	38.0	38.0

Table 2-12. ***Projected yields of Imperial Valley cantaloupe with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Cantaloupe, Tons in 1000's

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l 900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 4,000 Acres	16	All Values 23.5					
	22						
	29						
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 4,000 Acres	16	23.5	23.3	23.3	21.6	20.5	19.8
	22	23.5	23.5	23.5	23.3	22.6	21.9
	29	23.5	23.5	23.5	23.5	23.3	22.6
	35	23.5	23.5	23.5	23.5	23.5	23.5
	Sprinkler	23.5	23.5	23.5	23.5	23.5	23.5
Holtville-Imperial Stratified (Sandy and Clay Stratified) 4,000 Acres	16	19.5	18.3	17.2	15.9	14.5	13.2
	22	20.7	19.5	18.6	17.6	16.5	15.1
	29	21.4	20.2	19.1	18.1	17.2	16.0
	35	22.1	21.2	20.2	19.3	18.3	17.4
	Sprinkler	23.5	22.8	21.6	20.5	19.3	18.6

Table 2-13. ***Projected yields of Imperial Valley carrots with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Carrot, Tons in 1,000's

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 2,000 Acres	16	28.0	28.0	28.0	27.1	25.7	24.9
	22	28.0	28.0	28.0	27.1	25.7	24.9
	29	28.0	28.0	28.0	27.1	25.7	24.9
	35	28.0	28.0	28.0	27.1	25.7	24.9
	Sprinkler	28.0	28.0	28.0	28.0	28.0	28.0
Meloland (Sandy Surface Heavy Subsoil) 2,000 Acres	16	24.1	22.9	20.1	17.9	15.1	12.9
	22	26.3	24.9	23.8	22.9	21.3	18.3
	29	27.7	25.7	24.6	23.8	22.4	21.3
	35	28.0	28.0	26.6	25.7	24.6	23.4
	Sprinkler	28.0	28.0	28.0	28.0	27.1	25.7

Table 2-14. ***Projected yields of Imperial Valley cotton with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Cotton, Tons in 1,000's

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Meloland (Sandy Surface Heavy Subsoil) 2,000 Acres	16	All Values 1.17					
	22						
	29						
	35						
	Sprinkler						
Holtville-Imperial Stratified (Sandy and Clay Stratified) 24,000 Acres	16	14.0	14.0	14.0	14.0	13.9	13.6
	22	14.0	14.0	14.0	14.0	14.0	14.0
	29	14.0	14.0	14.0	14.0	14.0	14.0
	35	14.0	14.0	14.0	14.0	14.0	14.0
	Sprinkler	14.0	14.0	14.0	14.0	14.0	14.0
Imperial Complex (Clay) 12,000 Acres	16	7.00	7.00	6.86	6.64	6.51	5.25
	22	7.00	7.00	7.00	6.93	6.58	6.58
	29	7.00	7.00	7.00	7.00	6.85	6.64
	35	7.00	7.00	7.00	7.00	7.00	6.85
	Sprinkler	7.00	7.00	7.00	7.00	7.00	6.93

Table 2-15. ***Projected yields of Imperial Valley lettuce with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Lettuce, Tons in 1,000's

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 12,000 Acres	16	130	130	130	130	126	122
	22	130	130	130	130	126	122
	29	130	130	130	130	126	122
	35	130	130	130	130	126	122
	Sprinkler	130	130	130	130	130	130
Meloland (Sandy Surface Heavy Subsoil) 12,000 Acres	16	117	109	100	92.3	83.2	78.0
	22	129	122	116	109	103	94.9
	29	130	126	120	116	108	103
	35	130	130	130	126	120	116
	Sprinkler	130	130	130	130	130	126
Holtville-Imperial Stratified (Sandy and Clay Stratified) 12,000 Acres	16	76.5	64.8	51.8	42.8	29.8	18.1
	22	86.5	76.5	67.4	57.0	45.4	33.7
	29	90.7	80.3	71.3	63.5	51.8	42.8
	35	97.2	89.4	80.4	72.6	63.5	53.1
	Sprinkler	115	104	92.0	82.9	75.2	64.8

Table 2-16. Projected yields of Imperial Valley onions with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Onions, Tons in 1,000's							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 1,000 Acres	16	13.7	13.7	13.7	13.7	13.4	13.0
	22	13.7	13.7	13.7	13.7	13.4	13.0
	29	13.7	13.7	13.7	13.7	13.4	13.0
	35	13.7	13.7	13.7	13.7	13.4	13.0
	Sprinkler	13.7	13.7	13.7	13.7	13.7	13.7
Meloland (Sandy Surface Heavy Subsoil) 1,000 Acres	16	12.4	11.9	11.2	10.6	8.3	6.9
	22	13.7	13.0	12.3	11.9	11.3	10.8
	29	13.7	13.4	12.8	12.3	11.7	11.3
	35	13.7	13.7	13.7	13.4	12.8	12.3
	Sprinkler	13.7	13.7	13.7	13.7	13.7	13.4

Table 2-17. Projected yields of Imperial Valley sorghum with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Sorghum in 1,000's Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 12,000 Acres	16	All Values 27					
	22						
	29						
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 12,000 Acres	16	All Values 27					
	22						
	29						
	35						
	Sprinkler						
Holtville-Imperial Stratified (Sandy & Clay Stratified) 19,000 Acres	16	42.4	40.7	39.3	38.0	36.3	35.0
	22	42.8	42.4	41.4	39.7	38.6	37.2
	29	42.8	42.8	41.4	40.7	39.3	38.0
	35	42.8	42.8	42.8	42.0	40.7	39.3
	Sprinkler	42.8	42.8	42.8	42.8	42.0	40.7
Imperial Complex (Clay) 7,000 Acres	16	14.4	13.7	13.1	12.5	12.0	8.1
	22	15.0	14.5	13.7	13.2	12.3	12.1
	29	15.3	14.6	14.0	13.6	12.9	12.5
	35	15.6	15.3	14.6	14.2	13.6	13.1
	Sprinkler	15.8	15.8	15.3	14.6	14.0	13.4

Table 2-18. Projected yields of Imperial Valley sugar beets with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Sugar Beets in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 1,000 Acres	16						
	22						
	29	All Values 22					
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 1,000 Acres	16						
	22						
	29	All Values 22					
	35						
	Sprinkler						
Holtville-Imperial Stratified (Sandy and Clay Stratified) 31,000 Acres	16	682	682	682	682	676	670
	22	682	682	682	682	682	682
	29	682	682	682	682	682	682
	35	682	682	682	682	682	682
	Sprinkler	682	682	682	682	682	682
Imperial Complex (Clay) 30,000 Acres	16	660	660	648	627	606	540
	22	660	660	660	654	633	615
	29	660	660	660	660	648	627
	35	660	660	660	660	660	648
	Sprinkler	660	660	660	660	660	654

Table 2-19. Projected yields of Imperial Valley tomatoes with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Tomatoes in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 500 Acres	16						
	22						
	29	All Values 3.84					
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 500 Acres	16	3.84	3.84	3.80	3.69	3.50	3.42
	22	3.84	3.84	3.84	3.84	3.80	3.71
	29	3.84	3.84	3.84	3.84	3.84	3.84
	35	3.84	3.84	3.84	3.84	3.84	3.84
	Sprinkler	3.84	3.84	3.84	3.84	3.84	3.84
Holtville-Imperial Stratified (Sandy and Clay Stratified) 1,000 Acres	16	6.76	6.53	6.14	5.84	5.22	4.22
	22	7.07	6.76	6.53	6.37	5.99	5.53
	29	7.30	6.91	6.68	6.45	6.14	5.84
	35	7.52	7.22	6.91	6.68	6.45	6.22
	Sprinkler	7.68	7.68	7.37	6.99	6.76	6.53

Table 2-20. ***Projected yields of Imperial Valley wheat with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

		Wheat, Tons in 1,000's					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Indio (Coarse Well Drained) 3,000 Acres	16						
	22						
	29		All Values 6.42				
	35						
	Sprinkler						
Meloland (Sandy Surface Heavy Subsoil) 3,000 Acres	16						
	22						
	29		All Values 6.42				
	35						
	Sprinkler						
Holtville-Imperial Stratified (Sandy and Clay Stratified) 23,000 Acres	16	49.2	48.7	46.8	45.8	44.3	42.8
	22	49.2	49.2	48.7	47.7	45.8	44.8
	29	49.2	49.2	49.2	48.2	46.7	45.8
	35	49.2	49.2	49.2	49.2	48.2	47.2
	Sprinkler	49.2	49.2	49.2	49.2	49.2	48.7
Imperial Complex (Clay) 20,000 Acres	16	40.7	39.4	37.7	36.0	34.2	27.0
	22	42.4	40.7	39.4	38.1	35.5	35.1
	29	42.8	41.5	39.8	38.9	37.7	36.0
	35	42.8	42.8	41.1	39.8	38.9	37.7
	Sprinkler	42.8	42.8	42.4	41.5	39.8	38.5

Table 2-21. ***Amount and number of irrigations for alfalfa per month to apply 84 inches per year at different frequencies.***

Inches of Water Per Irrigation	5.25	3.82	2.90	2.40	2.40
Irrigations Per Year	16	22	29	35	Sprinkler
Irrigations Per Month					
January	1	1	1	1	1
February	1	1	1	2	2
March	1	1	2	2	2
April	1	2	3	3	3
May	2	3	3	4	4
June	2	3	4	4	4
July	2	3	4	6	6
August	2	2	3	3	3
September	1	3	3	4	4
October	1	1	2	3	3
November	1	1	2	2	2
December	1	1	1	1	1

COACHELLA VALLEY

The average yields of the major agricultural crops of the Coachella Valley were obtained from Crop Production Reports prepared by the Coachella Valley County Water District. The 95 percent confidence interval of nine crops together with yields from 6 years are shown in Table 2-22. Halsey (1954) prepared a crop distribution by soil series report for this area. This same distribution was applied to the acreages of the crops for the year 1973. These acreages were then grouped according to the drainage characteristics of each of the soil series (Soil Conservation Service, USDA, Indio, unpublished soil survey). This is shown in Table 2-23.

In Table 2-8 of the report on Imperial Valley the Indio soil was equated to the well drained soil in this valley, Meloland was equated to the moderately well drained soil, the stratified to a poorly drained soil, and the Imperial complex to the very poorly drained soil. These data together with the declination data from the California Committee of Consultants (1974) were used to calculate Tables 2-24 through 2-32 showing the projected yields of the nine major crops in Coachella. Sample costs of production can be found in Agricultural Extension Riverside County Mime's (1) Thompson seedless grapes, Marsh grapefruit, Naval oranges, and lemons.

Table 2-22. Yield of major crops—All American Canal service area in Coachella Valley (tons/acre).

Crop	1968	1969	1970	1971	1972	1973	95% Confidence Interval
Alfalfa Hay	8.80	8.20	8.00	7.30	6.66	6.70	7.61 ± 0.86
Carrots	8.90	9.04	12.9	14.1	10.3	13.1	11.39 ± 2.25
Sweet Corn	4.60	3.68	3.95	2.35	3.57	4.83	3.83 ± 0.88
Green Onions	25.3	31.8	24.4	24.6	14.5	18.8	23.2 ± 5.9
Grapefruit	12.4	10.40	–	8.00	10.80	9.65	10.24 ± 1.82
Lemon and Lime	8.35	2.58	2.93	2.01	3.48	4.55	3.98 ± 2.30
Orange and Tangerine	3.00	4.99	2.31	4.56	4.20	5.40	4.07 ± 1.19
Date	4.55	5.16	3.32	4.63	4.84	3.80	4.38 ± 0.69
Grape	3.20	3.70	4.00	4.83	5.79	3.50	4.17 ± 0.97

Table 2-23. Partition of crop acreage on different soil drainage classes.

Crop	Drainage Classification			
	Well	Moderate	Poor	Very Poor
Alfalfa	2,580	580	290	150
Carrots	7,000			
Corn	3,500	500	900	100
Green Onions	320			
Grapefruit	6,700	300	700	
Lemon and Lime	1,740	80	180	
Oranges and Tangerines	6,480	300	680	
Date	3,060	240	140	
Grape	6,650	450	380	
Total	38,030	2,450	3,290	250

Table 2-24. ***Projected yields of alfalfa in Coachella Valley crops with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

Alfalfa in 1000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 2,580 Acres	16	All Values 19.6					
	22						
	29						
	35						
	Sprinkler						
Moderate 580 Acres	16	4.4	4.2	4.0	3.9	3.7	3.6
	22	4.4	4.4	4.3	4.2	4.0	3.9
	29	4.4	4.4	4.4	4.3	4.2	4.0
	35	4.4	4.4	4.4	4.4	4.4	4.3
	Sprinkler	4.4	4.4	4.4	4.4	4.4	4.4
Poor 290 Acres	16	1.8	1.7	1.5	1.4	1.3	1.2
	22	1.9	1.8	1.7	1.6	1.5	1.3
	29	1.9	1.8	1.7	1.7	1.5	1.4
	35	2.0	1.9	1.8	1.8	1.7	1.5
	Sprinkler	2.2	2.0	1.9	1.9	1.8	1.8
Very Poor 150 Acres	16	0.8	0.7	0.6	–	–	–
	22	0.9	0.8	0.7	0.7	–	–
	29	0.9	0.8	0.7	0.7	0.6	–
	35	0.9	0.9	0.8	0.8	0.7	0.6
	Sprinkler	1.0	0.9	0.9	0.8	0.7	0.7

Table 2-25. ***Projected yield of carrots in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on well drained soil.***

Carrot in 1,000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well Drained 7,000 Acres	16	All Values 79.7					
	22						
	29						
	35						
	Sprinkler						

Table 2-26. ***Projected yields of dates in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

Dates in 1,000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 3,060 Acres	16	All Values 13.4					
	22						
	29						
	35						
	Sprinkler						
Moderate 240 Acres	16	All Values 1.1					
	22						
	29						
	35						
	Sprinkler						
Poor 140 Acres	16	All Values 0.6					
	22						
	29						
	35						
	Sprinkler						

Table 2-27. ***Projected yields of grapes in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

		Grapes in 1,000 Tons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Good 6,650 Acres	16						
	22						
	29	All Values 27.7					
	35						
	Sprinkler						
Moderate 450 Acres	16	1.9	1.9	1.8	1.8	1.7	1.7
	22	1.9	1.9	1.9	1.9	1.9	1.8
	29	1.9	1.9	1.9	1.9	1.9	1.9
	35	1.9	1.9	1.9	1.9	1.9	1.9
	Sprinkler	1.9	1.9	1.9	1.9	1.9	1.9
Poor 380 Acres	16	1.4	1.3	1.2	1.1	1.0	0.8
	22	1.5	1.4	1.3	1.2	1.1	1.0
	29	1.5	1.4	1.3	1.3	1.2	1.1
	35	1.5	1.5	1.4	1.3	1.3	1.2
	Sprinkler	1.6	1.6	1.5	1.5	1.4	1.3

Table 2-28. ***Projected yield of grapefruit in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

		Grapefruit in 1,000 Tons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 6,700 Acres	16						
	22						
	29	All Values 68.6					
	35						
	Sprinkler						
Moderate 300 Acres	16	3.0	2.8	2.6	2.4	2.2	2.0
	22	3.0	3.0	2.9	2.8	2.6	2.5
	29	3.0	3.0	3.0	3.0	2.8	2.6
	35	3.0	3.0	3.0	3.0	3.0	3.0
	Sprinkler	3.0	3.0	3.0	3.0	3.0	3.0
Poor 700 Acres	16	4.5	3.6	–	–	–	–
	22	5.2	4.5	3.8	–	–	–
	29	5.4	4.8	4.2	3.6	–	–
	35	5.9	5.4	4.8	4.3	3.6	–
	Sprinkler	6.9	6.3	5.6	5.0	4.3	3.6

Table 2-29. ***Projected yield of lemon and lime in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

Lemon and Lime in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 1,740 Acres	16						
	22						
	29	All Values 6.9					
	35						
	Sprinkler						
Moderate 80 Acres	16	0.3	0.3	0.3	0.2	0.2	0.2
	22	0.3	0.3	0.3	0.3	0.3	0.3
	29	0.3	0.3	0.3	0.3	0.3	0.3
	35	0.3	0.3	0.3	0.3	0.3	0.3
	Sprinkler	0.3	0.3	0.3	0.3	0.3	0.3
Poor 180 Acres	16	0.4	0.4	–	–	–	–
	22	0.5	0.4	0.4	–	–	–
	29	0.5	0.5	0.4	0.4	–	–
	35	0.6	0.5	0.5	0.4	0.4	–
	Sprinkler	0.7	0.6	0.5	0.5	0.4	0.4

Table 2-30. ***Projected yields of onions in Coachella Valley with four levels of surface irrigation intensities and sprinkler irrigation on well drained soil.***

Onions in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 320 Acres	16	7.4	7.4	7.4	7.4	7.3	7.0
	22	7.4	7.4	7.4	7.4	7.3	7.0
	29	7.4	7.4	7.4	7.4	7.3	7.0
	35	7.4	7.4	7.4	7.4	7.3	7.0
	Sprinkler	7.4	7.4	7.4	7.4	7.4	7.4

Table 2-31. ***Projected yield of orange and tangerine in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

Orange and Tangerine in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 6,480 Acres	16						
	22						
	29	All Values 264					
	35						
	Sprinkler						
Moderate 300 Acres	16	1.2	1.1	1.0	1.0	0.9	0.8
	22	1.2	1.2	1.2	1.1	1.0	1.0
	29	1.2	1.2	1.2	1.2	1.1	1.0
	35	1.2	1.2	1.2	1.2	1.2	1.2
	Sprinkler	1.2	1.2	1.2	1.2	1.2	1.2
Poor 680 Acres	16	1.7	1.4	–	–	–	–
	22	2.0	1.7	1.5	–	–	–
	29	2.1	1.9	1.6	1.4	–	–
	35	2.3	2.1	1.9	1.7	1.4	–
	Sprinkler	2.7	2.4	2.2	1.9	1.7	1.4

Table 2-32. Projected yields of sweet corn in Coachella Valley with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

		Sweet Corn in 1,000 Tons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 3,500 Acres	16 22 29 35 Sprinkler	All Values 13.4					
Moderate 500 Acres	16	1.8	1.7	1.7	1.6	1.5	1.4
	22	1.9	1.9	1.8	1.8	1.7	1.6
	29	1.9	1.9	1.9	1.9	1.7	1.7
	35	1.9	1.9	1.9	1.9	1.9	1.9
	Sprinkler	1.9	1.9	1.9	1.9	1.9	1.9
Poor 900 Acres	16	2.4	2.1	1.8	–	–	–
	22	2.7	2.4	2.2	2.0	1.7	–
	29	2.8	2.6	2.3	2.1	1.8	1.7
	35	2.9	2.8	2.6	2.4	2.1	1.9
	Sprinkler	3.2	3.0	2.8	2.6	2.5	2.1

PALO VERDE VALLEY

The average yields of major agricultural crops in the Palo Verde Valley were obtained from Riverside County Agricultural Commissioner reports for the years 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, see Table 2-33. Acreages of crops were based upon the Palo Verde Irrigation District Crop Report for 1973. The location of specific crops on specific soil drainage classes was obtained from unpublished reports of the Soil Conservation Service. Personal observations of Mr. Charles Morris of the SCS, Mr. Lester Ede, University of California Agricultural Farm Advisor, and Mr. Merle Turley of the USBR were also helpful in locating crops on specific soil drainage classes.

The soils of the Palo Verde Valley, Kocher and Youngs (1926), Weir and Storie (1946, 1947), were placed in four drainage classes as in Imperial Valley and Coachella Valley Sections of this report. The partitioning of crop acreages on soil drainage classes is shown in Table 2-34. These data together with the declination data from the California Committee of Consultants (1974) were used to calculate Tables 2-35 through 2-44, the projected yields of crops in varying levels of surface irrigation and sprinkler irrigation. Costs of production can be approximated from the Imperial Valley and Coachella Valley reports on the same crops.

Table 2-33. Yield per acre of major crops in the service area of Palo Verde Irrigation District.

Crop	Year									95% Confidence Interval
	1964	1965	1966	1967	1968	1969	1970	1972	1973	
Grapefruit					990	800	728	1035	1092	929 ± 162 Cartons
Lemon					775	325	593	303	251	450 ± 230 Cartons
Lettuce	450	456	487	485	470	500	518	336	466	474 ± 45 Cartons
Cantaloupe	120	160	175	182	150	120	173	130	175	154 ± 18 Crates
Watermelon	9.0	10.0	10.0	10.0	8.5	9.0	12.0	9.5	10.0	9.8 ± 0.7 Tons
Onions, Dehy.	18.8	21.3	16.0	15.0	13.0	12.7	13.0	17.0	13.0	15.5 ± 2.1 Tons
Alfalfa	5.5	6.0	6.0	6.0	6.0	5.5	5.5	7.0	7.0	6.1 ± 0.4 Tons
Sorghum	1.50	1.50	1.75	1.50	1.50	1.50	1.50	1.50	1.80	1.69 ± 0.02 Tons
Cotton	3.00	3.00	2.00	1.75	2.75	2.36	1.45	2.00	1.75	2.23 ± 0.41 Bales
Cotton Seed	1.10	1.18	0.80	0.70	1.10	0.93	0.57	0.80	0.70	0.87 ± 0.16 Tons
Wheat	---	1.50	–	1.75	2.00	2.00	2.25	2.25	2.50	2.04 ± 0.27 Tons

Table 2-34. Partition of crop acreage on different soil drainage classes in Palo Verde Irrigation District.

Crop	Drainage Classification			
	Well	Moderate	Poor	Very Poor
Grapefruit	700	100		
Lemon	3,000	300		
Lettuce	3,000	2,000	2,000	
Cantaloupe	700	700		
Watermelon	700	600		
Onion, Dehy.	2,000	1,500		
Alfalfa	9,500	10,500	10,500	7,500
Sorghum	3,000	2,000	1,000	500
Cotton	500	4,000	4,000	5,400
Wheat	5,000	5,000	5,000	5,000
Total	28,100	26,700	22,500	18,400

Table 2-35. Projected yields of alfalfa in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation of four soil drainage classes.

Alfalfa in 1,000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 9,500 Acres	16						
	22						
	29		All Values 58.0				
	35						
	Sprinkler						
Moderate 10,500	16	64.1	64.1	58.3	56.4	53.8	51.7
	22	64.1	64.1	63.3	61.4	58.8	57.0
	29	64.1	64.1	64.1	63.3	60.9	58.8
	35	64.1	64.1	64.1	64.1	64.1	63.3
	Sprinkler	64.1	64.1	64.1	64.1	64.1	64.1
Poor 10,500 Acres	16	51.8	48.5	44.1	41.5	38.2	34.3
	22	54.4	51.8	48.5	46.6	42.8	39.4
	29	56.2	53.6	50.5	47.9	44.6	41.5
	35	58.3	55.7	53.6	51.9	47.9	45.4
	Sprinkler	64.1	59.9	57.0	54.4	51.5	48.5
Very Poor 7,500 Acres	16	35.8	32.3	28.7	–	–	–
	22	39.3	36.4	32.3	29.2	–	–
	29	40.5	37.5	34.0	31.7	28.2	–
	35	42.2	39.9	37.0	34.6	33.4	28.7
	Sprinkler	45.8	42.8	39.3	37.0	33.4	31.1

Table 2-36. Projected yields of cantaloupe in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on two soil drainage classes.

Cantaloupe in 1,000 Crates

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 700 Acres	16						
	22						
	29		All Values 108				
	35						
	Sprinkler						
Moderate 700 Acres	16	108	108	102	99	94	91
	22	108	108	108	107	104	100
	29	108	108	108	108	107	104
	35	108	108	108	108	108	108
	Sprinkler	108	108	108	108	108	108

Table 2-37. ***Projected yields of watermelon in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on two soil drainage classes.***

		Watermelon in 1,000 Tons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 700 Acres	16	All Values 6.86					
	22						
	29						
	35						
	Sprinkler						
Moderate 600 Acres	16	5.88	5.88	5.57	5.39	5.12	4.95
	22	5.88	5.88	5.88	5.83	5.66	5.44
	29	5.88	5.88	5.88	5.88	5.83	5.66
	35	5.88	5.88	5.88	5.88	5.88	5.88
	Sprinkler	5.88	5.88	5.88	5.88	5.88	5.88

Table 2-38. ***Projected yields of cotton in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.***

		Cotton in 1,000 Bales					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 500 Acres	16	All Values 1.12					
	22						
	29						
	35						
	Sprinkler						
Moderate 4,000 Acres	16	8.92	8.92	8.92	8.92	8.83	8.67
	22	8.92	8.92	8.92	8.92	8.92	8.92
	29	8.92	8.92	8.92	8.92	8.92	8.92
	35	8.92	8.92	8.92	8.92	8.92	8.92
	Sprinkler	8.92	8.92	8.92	8.92	8.92	8.92
Poor 4,000 Acres	16	8.92	8.92	8.74	8.46	8.30	6.69
	22	8.92	8.92	8.92	8.83	8.38	8.38
	29	8.92	8.92	8.92	8.92	8.73	8.46
	35	8.92	8.92	8.92	8.92	8.92	8.73
	Sprinkler	8.92	8.92	8.92	8.92	8.92	8.83
Very Poor 4,000 Acres	16	12.04	12.04	11.74	11.44	10.54	9.03
	22	12.04	12.04	12.04	11.80	11.32	11.26
	29	12.04	12.04	12.04	12.04	11.74	11.44
	35	12.04	12.04	12.04	12.04	12.04	11.74
	Sprinkler	12.04	12.04	12.04	12.04	12.04	11.92

Table 2-39. ***Projected yields of grapefruit in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on two soil drainage classes.***

		Grapefruit in 1,000 Cartons					
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 700 Acres	16	All Values 650					
	22						
	29						
	35						
	Sprinkler						
Moderate 110 Acres	16	98	93	86	81	71	66
	22	102	102	97	93	87	83
	29	102	102	102	97	92	87
	35	102	102	102	102	102	97
	Sprinkler	102	102	102	102	102	102

Table 2-40. ***Projected yields of lettuce in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on three soil drainage classes.***

Lettuce in 1,000 Cartons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 3,000 Acres	16	1422	1422	1422	1422	1378	1334
	22	1422	1422	1422	1422	1378	1334
	29	1422	1422	1422	1422	1378	1334
	35	1422	1422	1422	1422	1378	1334
	Sprinkler	1422	1422	1422	1422	1422	1422
Moderate 2,000 Acres	15	859	794	729	673	607	569
	22	940	890	846	794	751	692
	29	948	919	875	846	788	751
	35	948	948	948	919	875	846
	Sprinkler	948	948	948	948	948	919
Poor 2,000 Acres	16	557	472	378	312	217	132
	22	630	558	492	416	331	246
	29	661	586	520	463	378	312
	35	708	652	586	529	463	387
	Sprinkler	838	758	671	604	548	473

Table 2-41. ***Projected yields of lemon in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on two soil drainage classes.***

Lemon in 1,000 Cartons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 3,000 Acres	16	All Values 1350					
	22						
	29						
	35						
	Sprinkler						
Moderate 300 Acres	16	129	123	114	107	94	87
	22	135	135	128	123	115	109
	29	135	135	135	128	122	115
	35	135	135	135	135	135	128
	Sprinkler	135	135	135	135	135	135

Table 2-42. ***Projected yields of onions in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on two soil drainage classes.***

Onions (Dehydrator) in 1,000 Tons							
Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 2,000 Acres	16	31.0	31.0	31.0	31.0	30.6	29.3
	22	31.0	31.0	31.0	31.0	30.6	29.3
	29	31.0	31.0	31.0	31.0	30.6	29.3
	35	31.0	31.0	31.0	31.0	30.6	29.3
	Sprinkler	31.0	31.0	31.0	31.0	31.0	31.0
Moderate 1,500 Acres	16	20.9	20.0	18.8	18.0	14.0	11.5
	22	23.3	22.0	20.8	20.0	19.1	18.1
	29	23.3	22.7	21.6	22.0	19.8	19.1
	35	23.3	23.3	23.3	22.7	21.5	21.6
	Sprinkler	23.3	23.3	23.3	23.3	23.3	22.7

Table 2-43. Projected yields of sorghum in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Sorghum in 1,000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 3,000 Acres	16	All Values 4.77					
	22						
	29						
	35						
	Sprinkler						
Moderate 2,000 Acres	16	All Values 3.18					
	22						
	29						
	35						
	Sprinkler						
Poor 1,000 Acres	16	1.58	1.51	1.46	1.41	1.35	1.30
	22	1.59	1.58	1.54	1.47	1.43	1.38
	29	1.59	1.59	1.54	1.51	1.46	1.41
	35	1.59	1.59	1.59	1.56	1.51	1.46
	Sprinkler	1.59	1.59	1.59	1.59	1.56	1.51
Very Poor 500 Acres	16	0.72	0.69	0.66	0.63	0.60	0.41
	22	0.75	0.72	0.69	0.66	0.62	0.61
	29	0.77	0.73	0.70	0.69	0.65	0.63
	35	0.78	0.77	0.73	0.71	0.69	0.66
	Sprinkler	0.80	0.80	0.77	0.73	0.70	0.67

Table 2-44. Projected yields of wheat in Palo Verde Valley with four levels of surface irrigation intensity and sprinkler irrigation on four soil drainage classes.

Wheat in 1,000 Tons

Drainage Class	Number of Irrigations Per Year	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 5,000 Acres	16	All Values 10.20					
	22						
	29						
	35						
	Sprinkler						
Moderate 5,000 Acres	16	All Values 10.20					
	22						
	29						
	35						
	Sprinkler						
Poor 5,000 Acres	16	10.20	10.10	9.70	9.50	9.18	8.87
	22	10.20	10.20	10.10	9.89	9.50	9.29
	29	10.20	10.20	10.20	9.99	9.68	9.50
	35	10.20	10.20	10.20	10.20	9.99	9.79
	Sprinkler	10.20	10.20	10.20	10.20	10.20	10.10
Very Poor 5,000 Acres	16	9.70	9.39	8.98	8.58	8.15	6.43
	22	10.10	9.70	9.39	9.08	8.45	8.36
	29	10.20	9.89	9.49	9.27	8.98	8.58
	35	10.20	10.20	9.79	9.49	9.27	8.98
	Sprinkler	10.20	10.20	10.20	9.89	9.49	9.18

PACIFIC COAST AREAS

All Colorado River water used in the coastal areas is pumped through the Colorado aqueduct of the Metropolitan Water District of Southern California (MWD). The water is distributed to the 27 members of the MWD. These members further distribute water to smaller divisions within their boundaries. The San Diego County Water Authority, for example, is one of the 27 members of MWD and has 22 constitutent cities and districts within its boundaries, Burzell (1973), Monroe (1972).

In addition to the water from the MWD the 27 members have locally developed water which presently constitutes 63 percent of the water used in the MWD area (Monroe, 1972). The local water is pumped from subsurface aquifers, transported from outside the MWD area, and/or collected in reservoirs from surface or stream flow (Brown, 1974).

Rainfall within the coastal area varies from 5 to 20 inches in the lower elevations and from 20 to 70 inches in the higher elevations (Close et al., 1970). Most of the agricultural areas are within a 10- to 15-inch rainfall zone (Boroman, 1973).

Agricultural yield records do not segregate crop yields obtained from local water irrigation and from Colorado River water irrigation (Little, 1968-73). In some areas the locally produced water is used first and then Colorado River water is used. In other areas the local and Colorado River water are stored in the same reservoir (Brown, 1974).

In 1972 the MWD took first delivery of water from the state project. This source of water is scheduled to increase eventually to two million acre feet. Meanwhile, the Central Arizona Project will claim an entitlement to Colorado River water so that the MWD supply will be reduced to 550,000 ac ft. Of this amount 100,000 ac ft may be utilized in the production of power. The remaining water will be blended in varying degrees with local and state water (Clinton, 1973; Lauten, 1974). The pricing of water rates is set by the MWD. The agencies and subagencies add suitable increases in this water price to cover operation, maintenance, and repayment scheduling of bonds for the distribution systems. Typical costs of water to the farmer are shown in Table 2-45 for portions of the San Diego County Water Authority.

Use of Colorado River water for agriculture has remained around 150,000 acre feet per year (Monroe, 1972). The agencies using this water in large quantity are the San Diego County Water Authority, 73,117 ac ft in 1972; Eastern MWD, 29,620 ac ft; MWD of Orange County, 31,470 ac ft; Western MWD of Riverside County, 33,713 ac ft (Monroe, 1972). With the exception of the San Diego CWA aqueduct #1, these areas will have blended 50 percent state water available In the mid or late 1980s the blend will move to 75 percent state water. It should be noted at this point that in the 50 percent Colorado River water that the TDS could move to 1,230 mg/l and to 2,210 mg/l in the 25 percent Colorado River water when mixing with 250 mg/l state water without increasing the TDS in the blend beyond the present 740 mg/l of Colorado River water. The cost to the agricultural economy receiving the blended water will be the increased price since there will probably be no reduction in yield due to salinity increase above the present value.

Even though the increased price of blended water was politically derived by the MWD board of directors and may not reflect the true cost of obtaining the water, it still remains the actual cost increase to those farming. The surcharges for the blended 50 percent Colorado River water will be (Clinton, 1973):

1974-75	$5/ac ft	1978-79	$9
1975-76	$6	1979-80	$10
1976-77	$7	1980-2000	$10
1977-78	$8		

In the 75 percent state water blended the increased charge would be $15 per ac ft as presently planned, (Clinton, 1973).

The study of yield effects of increased salinity in the Pacific Coast area then narrows to the region

Table 2-45. Water cost to grower in dollars per acre foot.

San Diego County Water Authority[a]	
Helix Irrigation District	95.80
Fallbrook PUD	52.25
Olivenhain MWD	65.00
Oceanside, City of	65.00
Poway MWD	75.00
Ramona MWD	76.00
Rainbow MWD	56.50
Santa Fe Irrigation District	56.75
Valley Center MWD	71.69
Otay MWD	95.00

[a] Source—response to questionnaire.

served by the first San Diego aqueduct with a capacity of 190 cfs. The second San Diego aqueduct has pipeline 3 with a capacity of 250 cfs and pipeline 4 with a capacity of 380 cfs. The pipelines 3 and 4 will have blended state water available in 1975. As presently planned, pipelines 1 and 2 of the first aqueduct are to have Colorado River water exclusively until 1980-1985 (Montgomery, 1974). The four preferred filtration distribution studies suggested by SDCWA all indicate that pipelines 1 and 2 will receive water from Skinner plants which would be blended water during the second phase of construction 1980-1995, (Montgomery, 1974). Metropolitan Water District of Southern California indicates plans to supply blended water to pipelines 1 and 2 by 1987-88 which is the same time that the blend will go to 75 percent state water (Clinton, 1973).

The data developed in this study of yield decreases from increased salinity in the Colorado will apply only to unblended water. The assumption made is that the irrigation water is unsoftened Colorado River water.

Mean yields for the San Diego County area were obtained from the Agricultural Commissioner Reports 1968-73 (Little, 1968-73), and are shown in Tables 2-46 through 2-60. Table 2-46 showing the partitioning of acreages of crops into three permeability classes, was obtained from Bowman (1973) the soil series permeabilities and the Agricultural Commissioner's acreage report (Little, 1968-73). The very rapid, and rapid permeabilities were placed in the group labeled rapid. The moderately rapid and moderate were labeled moderate, and the moderately slow, slow, and very slow were labeled slow.

Table 2-48 presents the effective saturation extract values. The surface irrigation salinity was taken from the 35 irrigation per year line of Table 2-8. The rationale is that 10 to 15 inches of rain would have a diluting effect similar to additional irrigations. The sprinkler values were the same as previously used. The new trickler or drip method of irrigation seeing rapid expansion in this area (Valley Center MWD, 1973) appears to deliver water to root systems at the same concentration as the irrigation water. The effective salinity was reduced one mmho/cm below the irrigation water value because the $CaSO_4$ would have no harmful effect and rainfall would provide dilution and leaching (Hall, 1971). The first trials of trickler systems support this usage (Hall, 1971; Hall, 1973; Valley Center MWD, 1973).

The use of drip irrigation has produced advantages in water saving, labor saving, convenience in harvesting, and reduced weed control. The drip method is being adopted for these reasons and would proceed even though the water contained no salt. For this reason, it would not be appropriate to charge the \$200-\$300/acre/crop (Hall, 1973), to increasing salinity, particularly in the rapid and moderately drained soils. In the slowly drained soils a yield benefit is projected because of salinity reduction. Therefore, a portion of the cost of drip irrigation should be charged to the increasing salinity.

Avocado is seeing extensive development with drip irrigation (Valley Center MWD, 1973). The requirement of rapid permeability soils for this crop places it in areas where salinity will probably not be a problem even at 1,400 mg/l. The citrus and tomato plantings on rapid and moderately permeability soil show little yield reduction, but the slow permeability soil shows drastic reductions in yield. The drip or trickler irrigation would see great advantages here. It should be noted that a sprinkler system may be required to periodically leach out salt accumulations between plants (Hall, 1971). It should also be noted that this analysis assumes that the mean annual rainfall will continue. In drought years the number of sprinkler leachings may need to be increased.

Table 2-46. Yields of crops in the San Diego County Water Authority service area. Agricultural Commissioner reports.

Crop	Year						Mean
	1968	1969	1970	1971	1972	1973	
Avocados, Ton	1.7	3.2	1.7	3.0	1.5	3.5	2.43 ± 0.81
Citrus							
Grapefruit	10	12	21.0	7.8	12.9	17.4	13.5 ± 4.5
Lemon	15.4	10.6	16.5	20.0	16.2	24.0	17.7 ± 4.1
Lime	10.0	6.5	8.2	14.0	11.0	14.0	10.6 ± 2.8
Orange, Navel	7.3	11.0	8.8	6.2	6.7	7.2	7.87 ± 1.62
Orange, Valencia	5.9	7.4	6.6	8.8	10.3	7.0	7.57 ± 1.57
Tangerine	–	–	7.7	10.7	10.5	17.4	11.6 ± 4.4
Strawberry	17.0	15.0	17.2	19.0	21.0	21.0	18.4 ± 2.2
Potato	12.0	16.0	21.0	18.0	22.0	20.0	18.2 ± 3.4
Tomato							
Spring	20.1	25.4	24.1	20.5	27.8	36.8	25.8 ± 5.6
Fall	18.7	22.2	16.6	16.0	19.4	24.5	19.6 ± 3.0
Summer	–	–	–	13.0	33.6	36.0	27.5 ± 18.9

It is of interest that long-term citrus plantings irrigated with Colorado River water (740 mg/l) on a moderately slow permeability soil showed a 10 percent reduction in yield (Bingham et al., 1973). Table 22 shows an 18 percent yield reduction at 900 mg/l which is in general agreement.

Tables 2-49 to 2-60 were obtained as in the first three parts of this study using Tables 2-46 and 2-47 and the guidelines for interpretation of quality of water for irrigation (Committee of Consultants, 1974).

The future course of irrigated agriculture in the San Diego area is somewhat clouded. As can be seen in Tables 2-61 (Montgomery, 1974), San Diego CWA is projecting a 58 percent increase in agricultural demand for water. The Valley Center MWD (1973) projection in Table 2-62 is equally optimistic. However, this same study shows the total payment capacity per acre foot of water to be $85.39 for avocados and $78.93 for citrus. Two agencies Helix ID and Otay MWD are already charging more than this $95. The projected increase in charges for 75 percent

Table 2-47. Partition of crop acreage on different soil drainage classes, San Diego County.

Crop	Drainage Classification		
	Well	Moderate	Poor
Citrus			
Grapefruit	77	348	230
Lemon	373	1,670	1,115
Lime	38	172	115
Orange. Navel	135	606	404
Orange, Valencia	1,115	5,010	3,340
Tangerine	126	566	378
Potato	325	300	
Strawberry	635		
Tomato			
Spring	46	417	556
Summer	15	135	180
Fall	142	1,283	1,710
Avocado	6,027	7,232	
Total	9,054	12,739	8,028

Table 2-48. Effective values of soil saturation extract conductivities in three drainage classes, three management systems, and six TDS contents of water.

TDS mg/l	Irrigation Method	Drainage Classification		
		Well	Moderate	Poor
900	Surface	0.4	0.7	3.0
	Sprinkler	0.0	0.0	2.1
	Trickler	–	–	0.3
1000	Surface	0.7	1.0	3.5
	Sprinkler	0.0	0.2	2.7
	Trickler	–	–	0.5
1100	Surface	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3
	Trickler	–	0.6	0.6
1200	Surface	1.2	1.5	4.5
	Sprinkler	0.0	0.8	3.8
	Trickler	–	0.8	0.8
1300	Surface	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
	Trickler	–	0.9	0.9
1400	Surface	1.7	2.1	5.6
	Sprinkler	0.4	1.5	5.0
	Trickler	–	1.1	1.1

blended state water is $15. Another charge of $20/ac ft for filtered water (Montgomery, 1974), may be added towards the end of the 1980s. This moves the water price $45/ac ft beyond the avocado grower's ability to pay and $52 beyond the citrus grower.

As pointed out by John H. Lauten (1974), General Manager of MWD, pumping Colorado River water to the MWD area requires energy equivalent to three barrels of oil. The state water requires the equivalent of 5 barrels. Desalting Colorado River water requires 10 barrels per acre foot and desalting ocean water 33 barrels.

The future cost of obtaining water will reflect the cost of energy. In 1984, for example, on peak pumping of water through the east branch will be $77/acre foot and $45 through the west branch. The average of on and off peak pumping will be $38/acre foot as projected today for the year 2000 (Clinton, April 1973). Agriculture's share of this cost may lead to a reduction in farmed acreage and allow farming on only the most productive areas.

Since the submission of this report in August 1974, changes in the planned proportions of pumping state and Colorado River water reflect the cost of power. Approximately 330,000 acre feet of state water are planned as substitute for Colorado River water with a net saving of $10 million in power costs (Lauten, Sept. 1974).

Table 2-49. Projected yield of San Diego avocados using furrow, sprinkler, or trickler irrigation at six different TDS levels and two drainage classes.

		Avocados in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well (2) 6,027 Acres	Surface	14.6	14.6	14.6	14.6	14.2	13.8
	Sprinkler	14.6	14.6	14.6	14.6	14.6	14.6
	Trickler	14.6	14.6	14.6	14.6	14.6	14.6
Moderate (3) 7,232 Acres	Surface	17.6	17.6	17.6	17.0	16.3	15.6
	Sprinkler	17.6	17.6	17.6	17.6	17.6	17.0
	Trickler	17.6	17.6	17.6	17.6	17.6	17.6

Table 2-50. Projected yield of San Diego grapefruit using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.

		Grapefruit in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 77 Acres	Surface Sprinkler Trickler	All Values 1.04					
Moderate 348 Acres	Surface	4.69	4.69	4.69	4.69	4.69	4.46
	Sprinkler	4.69	4.69	4.69	4.69	4.69	4.69
	Trickler	4.69	4.69	4.69	4.69	4.69	4.69
Poor 230 Acres	Surface	2.55	2.30	2.04	1.74	1.55	--
	Sprinkler	2.94	2.70	2.41	2.17	1.86	1.50
	Trickler	3.10	3.10	3.10	3.10	3.10	3.10

Table 2-51. Projected yield of San Diego lemons using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.

		Lemon in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 373 Acres	Surface	All Values 6.60					
	Sprinkler						
	Trickler						
Moderate 1,670 Acres	Surface	29.5	29.5	29.5	29.5	29.5	28.1
	Sprinkler	29.5	29.5	29.5	29.5	29.5	29.5
	Trickler	29.5	29.5	29.5	29.5	29.5	29.5
Poor 1,115 Acres	Surface	16.2	14.6	12.9	11.1	9.9	–
	Sprinkler	18.7	17.2	15.3	13.8	11.8	9.5
	Trickler	19.7	19.7	19.7	19.7	19.7	19.7

Table 2-52. Projected yield of San Diego limes using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.

		Lime in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 38 Acres	Surface	All Values 0.40					
	Sprinkler						
	Trickler						
Moderate 172 Acres	Surface	1.82	1.82	1.82	1.82	1.82	1.73
	Sprinkler	1.82	1.82	1.82	1.82	1.82	1.82
	Trickler	1.82	1.82	1.82	1.82	1.82	1.82
Poor 115 Acres	Surface	1.00	0.90	0.80	0.68	0.61	–
	Sprinkler	1.16	1.06	0.95	0.85	0.73	0.59
	Trickler	1.22	1.22	1.22	1.22	1.22	1.22

Table 2-53. Projected yield of San Diego naval oranges using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.

		Naval Orange in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 135 Acres	Surface	All Values 1.06					
	Sprinkler						
	Trickler						
Moderate 606 Acres	Surface	4.77	4.77	4.77	4.77	4.77	4.55
	Sprinkler	4.77	4.77	4.77	4.77	4.77	4.77
	Trickler	4.77	4.77	4.77	4.77	4.77	4.77
Poor 404 Acres	Surface	2.62	2.35	2.09	1.78	1.59	–
	Sprinkler	3.02	2.77	2.47	2.23	1.91	1.54
	Trickler	3.17	3.17	3.17	3.17	3.17	3.17

Table 2-54. ***Projected yield of San Diego valencia oranges using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.***

Valencia Orange in 1,000 Tons							
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 1,115 Acres	Surface	All Values 8.44					
	Sprinkler						
	Trickler						
Moderate 5,010 Acres	Surface	37.92	37.92	37.92	37.92	37.92	36.06
	Sprinkler	37.92	37.92	37.92	37.92	37.92	37.92
	Trickler	37.92	37.92	37.92	37.92	37.92	37.92
Poor 3,340 Acres	Surface	20.80	18.76	16.64	14.19	12.64	–
	Sprinkler	23.98	22.02	19.65	17.70	15.17	12.23
	Trickler	25.28	25.28	25.28	25.28	25.28	25.28

Table 2-55. ***Projected yield of San Diego potatoes using furrow, sprinkler, or trickler irrigation at six different TDS levels and two drainage classes.***

Potatoes in 1,000 Tons							
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 325 Acres	Surface	All Values 5.92					
	Sprinkler						
	Trickler						
Moderate 300 Acres	Surface	5.46	5.46	5.46	5.46	5.40	5.19
	Sprinkler	5.46	5.46	5.46	5.46	5.46	5.46
	Trickler	5.46	5.46	5.46	5.46	5.46	5.46

Table 2-56. ***Projected yield of San Diego strawberries using furrow, sprinkler, or trickler irrigation at six different TDS levels.***

Strawberry in 1,000 Tons							
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 635 Acres	Surface	11.68	11.68	11.68	11.39	11.04	10.69
	Sprinkler	11.68	11.68	11.68	11.68	11.68	11.68
	Trickler	11.68	11.68	11.68	11.68	11.68	11.68

Table 2-57. ***Projected yield of San Diego tangerines using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.***

Tangerine in 1,000 Tons							
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 126 Acres	Surface	All Values 1.46					
	Sprinkler						
	Trickler						
Moderate 566 Acres	Surface	6.57	6.57	6.57	6.57	6.57	6.25
	Sprinkler	6.57	6.57	6.57	6.57	6.57	6.57
	Trickler	6.57	6.57	6.57	6.57	6.57	6.57
Poor 378 Acres	Surface	3.60	3.25	2.89	2.46	2.19	–
	Sprinkler	4.16	3.82	3.41	3.07	2.63	2.12
	Trickler	4.38	4.38	4.38	4.38	4.38	4.38

Table 2-58. ***Projected yield of San Diego summer tomatoes using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.***

		Summer Tomato in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 15 Acres	Surface						
	Sprinkler	All Values 0.42					
	Trickler						
Moderate 135 Acres	Surface						
	Sprinkler	All Values 3.70					
	Trickler						
Poor 180 Acres	Surface	4.84	4.66	4.46	4.31	4.15	3.98
	Sprinkler	4.95	4.95	4.74	4.53	4.36	4.18
	Trickler	4.95	4.95	4.95	4.95	4.95	4.95

Table 2-59. ***Projected yield of San Diego fall tomatoes using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.***

		Fall Tomato in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well 142 Acres	Surface						
	Sprinkler	All Values 2.78					
	Trickler						
Moderate 1,283	Surface						
	Sprinkler	All Values 25.14					
	Trickler						
Poor 1,710 Acres	Surface	32.78	31.64	30.24	29.77	28.36	26.96
	Sprinkler	33.52	33.52	32.11	30.71	29.54	28.36
	Trickler	33.52	33.52	33.52	33.52	33.52	33.52

Table 2-60. ***Projected yield of San Diego spring tomatoes using furrow, sprinkler, or trickler irrigation at six different TDS levels and three drainage classes.***

		Spring Tomato in 1,000 Tons					
Drainage Class	Irrigation Method	Total Dissolved Solids in Irrigation Water, mg/l					
		900	1000	1100	1200	1300	1400
Well (2) 46 Acres	Surface						
	Sprinkler	All Values 1.19					
	Trickler						
Moderate (3) 417 Acres	Surface						
	Sprinkler	All Values 10.8					
	Trickler						
Poor (4) 556 Acres	Surface	14.1	13.5	12.9	12.7	12.1	–
	Sprinkler	14.3	14.3	13.7	13.1	12.6	12.1
	Trickler	14.3	14.3	14.3	14.3	14.3	14.3

Table 2-61. ***Projected agricultural demand for water in acre feet per year.*** *(San Diego County Water Authority, Table C4.)*

	1975	1980	1985	1990	1995
Carlsbad MWD	4,000	4,000	4,000	4,000	4,000
De Luz Heights	1,010	1,200	1,480	1,800	2,200
Ese & Rincon del Diablo	9,000	9,000	9,000	8,500	8,500
Fallbrook PUD	9,000	9,000	9,000	9,000	9,000
Helix WD	2,035	2,190	2,340	2,500	2,650
Nat'l City & South Bay ID	850	850	850	850	850
Oceanside City	1,075	1,355	1,685	2,770	3,765
Olivenhain MWD	1,310	1,870	2,390	2,820	3,040
Otay MWD	5,400	5,400	5,400	5,400	5,400
Poway MWD	1,960	2,130	2,310	2,530	2,830
Rainbow MWD	18,290	20,200	23,650	28,160	31,250
Ramona MWD	1,270	1,610	2,140	2,580	3,250
Rio San Diego MWD	470	680	695	820	965
San Dieguito & Santa Fe	3,200	3,200	3,200	3,200	3,200
San Marcos CWD	970	1,350	1,710	2,055	2,060
Valley Center MWD	21,420	28,080	32,435	38,465	43,730
Vista ID	6,000	6,000	6,000	6,000	6,000
Yaima MWD	9,630	11,560	14,050	17,410	21,140
Total	96,890 (1)	109,675 (2)	122,335 (3)	138,860 (4)	153,830 (5)
Total in cfs	133	150	168	190	210

Table 2-62. ***Valley Center Municipal Water District, San Diego County, California.***

District Lands and Estimated Water Use

The Bureau of Reclamation has classified the lands to determine the number of acres suitable for crop production of various types. This classification has been used to estimate water demand by assigning expected crops to each land classification and then establishing a duty for each expected type of use. New avocado plantings have surpassed the new citrus plantings in recent years. Avocado trees require good air and ground drainage. Consequently, areas previously considered open land are being planted to avocado trees. In the District's 1967 report, avocado planting was estimated to ultimately be 2,600 acres. The revised and current estimate is approximately 11,100 acres (which is an increase of 8,500 acres[a]). Citrus planting has been reduced from our original report (17,600 acres to 9,100 acres). The following tabulation summarizes the results.

Ultimate Land Use and Projected Water Demand

Land Use		Water Demand	
Expected Use	Net Area Acres	Duty (AF/ac/yr)	Ultimate Avg.-Year Water Demand AF/yr
Citrus	9,100	2.35	21,385
Avocado	11,100	2.56	28,416
Miscellaneous	4,900	1.2	5,900
M and I	2,200	3.7	8,100
Totals	27,300	–	63,800

Ultimate Average Annual Water Requirement with System Efficiency of 90.0%

70,900

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[a] Land use as of January, 1973–Citrus (6,300 acres), avocados (4,500 acres).

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APPENDIX 3

ECONOMIC DAMAGES IN AGRICULTURE FROM SALINITY IN THE LOWER COLORADO BASIN

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U.S. Bureau of Reclamation

METHODOLOGY

Major impacts from salinity are primarily experienced in the lower Colorado River Basin states of Arizona and California. The objective of this study is to estimate direct economic damages to agriculture associated with specific alternative levels of salt concentration in receiving areas of the lower basin. In addition, a damage function corresponding to selected areas is to be derived for estimation purposes.

Area Identification

The first step of the analysis was to identify the areas that should be considered. This was based on the current agricultural acreages receiving, or expected to receive in the near future, water from the Colorado River. The relevant areas for analysis of salinity impacts on agriculture are: the Central Arizona Project service area, the Yuma area, and the Colorado River Indian Reservation—all in Arizona; the Imperial Valley Irrigation District, the Coachella Valley Irrigation District, the Palo Verde Irrigation District, and the San Diego Coastal Region—all in California. Data requirements for the Central Arizona Project made it necessary to divide this area into six subareas which included the following irrigation districts: Salt River Valley Water Users Association, Lands Supplemental to Salt River Project, Roosevelt Water Conservation District, Roosevelt Irrigation District, and the San Carlos Project (Indian and non-Indian). This was also the case in the Yuma area where three major subareas resulted: Gila (North Gila, South Gila, Yuma Mesa, Yuma Auxiliary), Yuma Valley (Yuma Valley, Bard Unit), and Wellton-Mohawk Division. Acreage estimates for the present analysis placed total cultivated land at about 1.25 million acres including slightly over 200,000 acres as available for double cropping.

Farm Level Alternatives

Irrigators faced with the problem of increased salinity in their irrigation water have, in essence, two options. They can accept the damages in the form of declining yields and ultimately reduced acreages, as water supply conditions dictate, to the point of zero economic returns and ultimately go out of production; or, they can exercise several management options which mitigate or dampen some of the major effects of rising salinity. However, attached to each mitigation scheme is an associated cost of implementation.

A number of salinity adaptation practices are presently known which can help to alleviate decreases in crop yield resulting from increasing water and soil salinity. Farmers in Arizona and California receiving Colorado River water have already been applying various management practices in order to minimize impacts from water containing high counts of total dissolved solids (TDS). Some of these practices are applied by individual farmers while others are implemented by entire water districts. For example, some districts have supported the efforts of farmers in installing tile drains under their lands which discharge into master drains usually constructed by the district. Irrigation districts have also installed and operated pumps to lower the groundwater level and thereby more efficiently drain lands. Most of the irrigated lands receiving Colorado River water in California and Arizona have man-made drainage facilities of some nature to carry away the volume of water required to keep the soil-water salinity content at acceptable concentrations.

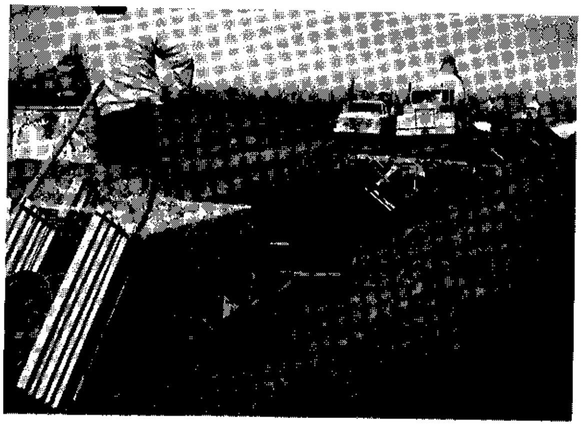
Other management measures are adopted by farmers, as necessary, to meet individual circumstances of coping with high-salinity water. For example, land surface is carefully leveled and releveled so as to insure more uniform application. Flood irrigation is an effective aid in percolating dissolved salts in the soil-water solution below the root zone and into the drainage facilities. Where land leveling is impractical, or where the crops are not receptive to being irrigated by flood or furrow irrigation, sprinklers are installed which also provide a high coefficient of uniformity. In both cases, irrigations must be scheduled at more frequent intervals using smaller quantities of water at each irrigation to maintain the downward movement of salts as total dissolved solids in the water reach higher levels of concentrations.

These management practices require substantial additional investment in farm operations. For example, expenditures of $200/acre to $600/acre for a sprinkler irrigation setup are not uncommon and $50/acre for land leveling is a minimum. In the case where farmers may not have access to the capital necessary for such practices, they may be forced to change to more salt-tolerant crops or discontinue operation altogether. Even though the choice to change to more salt-tolerant crops may result from a lack of capital, it is not a costless management practice. This is due in part to necessary changes in equipment and management techniques as well as lost revenue from the original crop.

In addition, there are other direct or variable expenses incurred by irrigators. As a means of illustration, there are costs of extra farm labor involved in a more precise irrigation regime, costs of additional water necessary to leach salts, added fertilizer costs resulting from increased water application, and other similar expenses. Generally stated: as the level of sophistication in farm management mitigation schemes increases, crop production costs generally increase accordingly. These increased costs attributed to salinity adaptation can be considered as economic detriments. Likewise, the decreased profits due to lower yields are also considered as economic detriments.

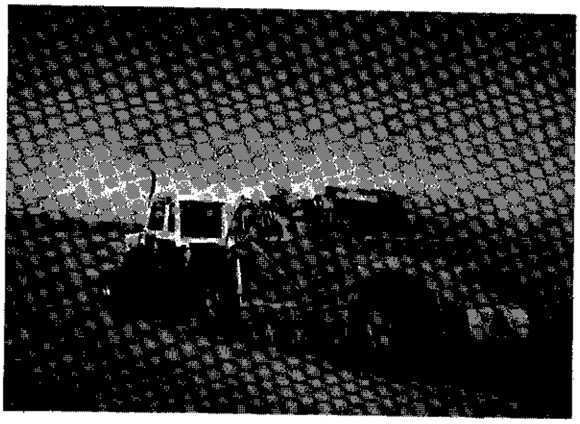
Indications are that with high salinity levels, farmers will most likely adopt feasible salinity adaptation practices rather than suffer yield losses or reduce acreages if sufficient capital is available. Management practices considered by this study which are currently or can be implemented by farmers to mitigate salinity impacts are briefly reviewed below:

1. As salinity and water costs increase, ditch lining is almost mandatory as a method of reducing seepage losses and alleviating soil salinization.



Concrete lining of a ditch in Imperial Valley, California.

2. Land leveling is necessary for uniform distribution of water and the prevention of salt buildup in high spots on a field.

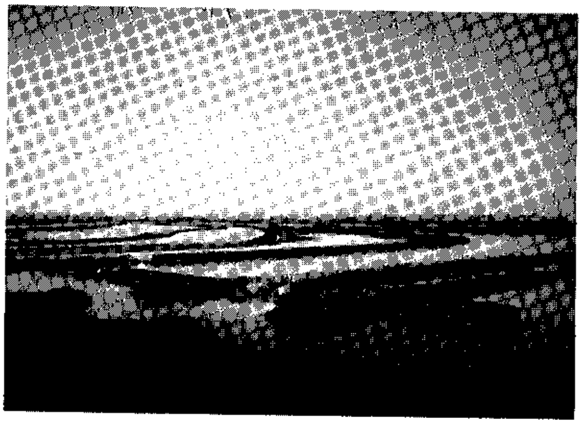


Land leveling in the Salt River Project, Arizona.

3. Moldboard and slip plowing to depths of 4 to 6 feet are practical and usually result in improved drainage efficiency and more uniform water penetration.

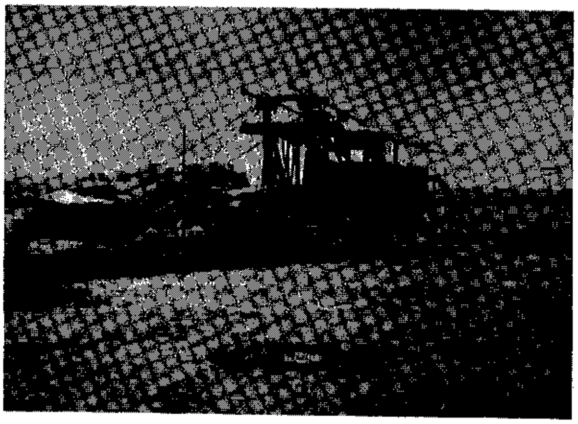
Slip plowing in Imperial Valley, California.

4. Salts generally accumulate more readily in the soil surface during the period of crop maturation when water is not being applied or in hills during conventional furrow irrigation. Leaching to move salts down and reduce soil salinity in the root zone is often necessary before planting the next crop.



A leaching irrigation in the Salt River Project, Arizona.

5. For leaching to be effective, a good drainage system must be provided. Tile drains most effectively increase the efficiency of water removal. Necessary drainage for maintaining a salt balance is also considered an economic detriment.



Deep tiling operation in Imperial Valley, California.

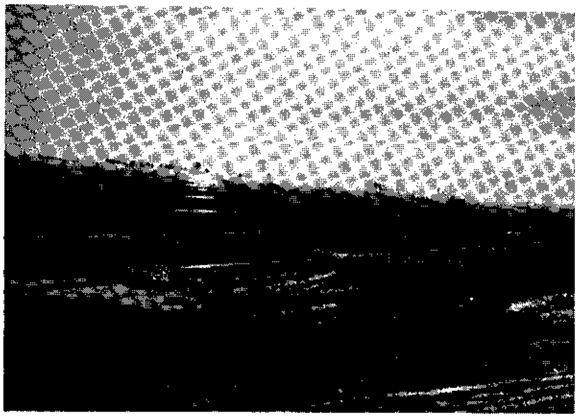
6. Special bedding practices such as double-row or sloping beds can achieve better salinity control by affecting the location of the salt buildup during the cropping period in relation to plant placement. A common practice in vegetable crops is to plant on the outer shoulders of the furrow. Instead of a single row in the center where salts tend to accumulate, two rows per mound are grown in the area of least salt concentration. Specially designed equipment is required which increases production costs.

Special bedding practice for lettuce in the Palo Verde Irrigation District, California.

7. A significant advantage of sprinkler irrigation over furrow or flood irrigation is the downward movement and slower buildup of salt in the surface layers of the soil. Sprinkler irrigation eliminates salt accumulation in conventional furrow irrigation beds and results in more efficient salt removal and lower root zone salinities than with flood irrigation.

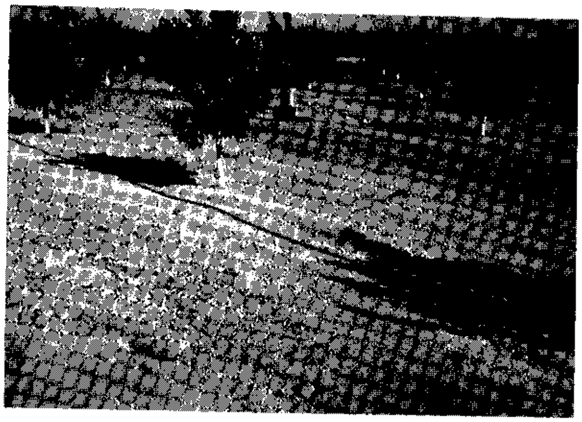
Two general methods of implementing sprinkler technology are common to the study area. The first is implemented to facilitate germination. Water is applied in this fashion until the plants break the surface of the ground. Advantages lie in the fact that less salt accumulates in the seed bed which would decrease germination probability and plant population. After the plants have completed the sprouting phase, furrow irrigation can resume with better success. This is especially true in the vegetable crops which tend to be rather salt sensitive.

Full sprinkler irrigation is the second method. Through the crop season this practice can more fully eliminate salt accumulation as explained above.



Sprinkler irrigation for germination, Imperial Valley, California.

8. Drip irrigation could be used for a number of crops, however, capital investment costs are substantial. Water with very high concentrations of TDS can be used on many crops with this system, but periodic leaching would still be necessary to remove salts accumulated from the lateral edges of the flow pattern.



Drip Irrigation installations, Wellton-Mohawk Irrigation District, Arizona.

9. Increased irrigation frequency with flood or furrow systems to maintain optimally low osmotic plus matrix stresses is an alternative to drip or sprinkler irrigation. This could be facilitated with moisture measuring devices such as tensiometers or through the use of an irrigation scheduling service.

A setup for irrigation timing efficiency, Salt River Project, Arizona.

Crop Selection

A large variety of crops are grown in the study area. They range from the very salt-tolerant group of grasses and to a lesser extent cotton and grains to the very salt-sensitive vegetable crops of tomatoes, lettuce, etc. Direct major regional economic impacts are closely related to the level of cultivation intensity of any particular crop. Highly salt-sensitive crops occupying insignificant acreages have small cumulative impacts on the total area. On the other hand, low-value crops on larger acreages also result in insignificant area impacts. Therefore, as a rule of thumb, crop selection was based on total value of production. Only those crops exceeding $1 million in total value of production for the 1974 crop year were chosen. In all cases relative to the selected project areas, these crops accounted for 85 percent and usually more of the total cropped acres. A list of the selected crops is given later on in this report where a separate analysis is presented for each study area.

Classification Procedures

As might be expected, many types of crops were selected by the model ranging from grains and cotton to vegetables and citrus. Crop sensitivity to changes in the levels of salinity were greatly dispersed also. This is due primarily to the relationship between soils, drainage, water quality and quantity, and crop variety. Therefore, these key variables had to be considered.

Project lands were classified according to soil texture and drainage characteristics. General classifications were formulated for the respective areas in the study and then yield functions were applied to each classification. Water quality intervals were established by setting the present level of salinity as the base and then analyzing the impacts occurring at 900, 1,000, 1,100, 1,200, 1,300, and 1,400 mg/l. The quantity and frequency of irrigation applications were based on the rates of 16, 22, 29, and 35 irrigations per year and adjusted for each crop depending on growing season, consumptive use of water, and normal number of applicable irrigtions.

The results of the above-mentioned interactions are evidenced in their effect on crop yield. Declining yields can be attributed to any one or all of these factors. In order to assess any single influence, isolation of its effects had to be achieved.

As a basic starting point, reference is made to work within the State of California where a committee of consultants (1974) has modified previous endeavors and established estimates for a series of expected declination values (Table 3-1). Yield declination curves were based upon these findings and adjusted to specific project areas by interpretation of soil saturation extracts as compared to those of the committee's report.

The base point of the saturated soil extract conductivities was determined from mean values of samples taken at various locations throughout the affected areas. A 95 percent confidence interval was set around these values. Similar intervals were established for electrical conductivities (EC) of irrigation water serving the various sites. Ratios of the mean soil saturation extract to the mean of the

Table 3-1. Expected yield decrement by crop per level of salinity in the soil solution as shown by the electrical conductivity of the saturation extract in millimhos per centimeter.

Crop	0% mmho/cm	10% mmho/cm	25% mmho/cm	50% mmho/cm	Maximum
Cotton	6.7	10.0	12.0	16.0	42
Alfalfa	2.0	3.0	5.0	8.0	28
Lettuce	1.3	2.0	3.0	5.0	18
Cantaloupes	2.3	3.5	ND[a]	ND	ND
Wheat	4.7	7.0	10.0	14.0	40
Sorghum	4.0	6.0	9.0	12.0	36
Bermuda Grass	8.7	13.0	16.0	18.0	44
Grapefruit	1.7	2.5	ND	5.0	16
Oranges and Tangerines	1.7	2.5	ND	5.0	16
Lemons and Limes	1.7	2.5	ND	5.0	16
Onions (Green and Dehydrated)	1.3	2.0	3.5	4.0	12
Carrots	1.0	1.5	2.5	4.0	12
Sweet Corn	1.7	2.5	4.0	6.0	20
Date	5.3	8.0	ND	16.0	48
Grape	2.7	4.0	ND	8.0	24
Avocados	1.3	2.0	ND	4.0	12
Strawberry	1.0	1.5	ND	3.0	10
Potato	1.7	2.5	4.0	6.0	20
Tomato (Spring, Fall, Summer)	2.7	4.0	6.5	8.0	22
Watermelon	2.0	ND	ND	ND	ND
Asparagus[b]	3.7	5.5	7.0	8.0	ND
Barley	8.0	12.0	16.0	18.0	44
Sugar Beets	6.7	10.0	13.0	16.0	42

[a] ND = No data.

[b] Spinach values.

Source: California Committee of Consultants (1974).

irrigation water conductivity were derived. These values were calculated for each soil classification at depths of 0 to 30 cm and 30 to 60 cm. The median value for each sample of observations was chosen to project the soil salinity buildup which develops under the best current cultural practice on that specific soil type and for measurements taken at the two soil depths. A major assumption which provided the link between incoming irrigation water and salt buildup in the soil is that the ratio between the EC of the soil saturation extracts and the EC of the irrigation water will remain constant.

Finally, if one considers that the factors concentrating the drainage water are the same ones that will operate to concentrate the Colorado River in the future, it is likely that the drainage salt contents are a reasonable approximation of the Colorado River salt content if it should reach the same TDS as that in the drain. With this in mind, Table 3-2 was developed showing log regressions of electric conductivity in micro mho/cm and ion concentration in meg/l as a function of TDS in parts per million. The EC of Cl^-, Ca^{+}, HCO_3^-, Mg^{+}, Na^{+}, and $SO_4^{=}$ were considered. Utilizing these regression results, Table 3-3 was constructed showing the median conductivity of soil saturation extracts at different TDS levels. Median values, denoted by an asterisk, were chosen as the basis for projecting extract levels.

As an example, Robinson (Appendix 2, Table 2-3) used soil samples taken from 33 locations twice yearly over a 10-year period to determine mean conductivities for four distinct soils with different internal drainage characteristics on the Imperial Valley Field Station. He then compared these conductivities with the mean conductivity of the irrigation water used during this period to establish ratios of soil saturation extract conductivity to irrigation water conductivity (Table 3-3).

Regression of EC as a function of total dissolved solids in Colorado River water as it progresses from 900 mg/l to 1,400 mg/l was determined from hydrologic data published by the State of California (Table 3-2). These regression values and the ratios described above were used to project the saturated soil extract conductivities to be expected for the possible combinations of irrigation water salinity with the various soil classifications as shown in Table 3-4. For an explanation of Table 3-4, take 1.34 EC for 900 mg/l water and multiply it by the ratio of 1.8 for Indio topsoil. The 2.4 found in the table opposite these two figures is the projected EC of the saturated soil solution.

In California, the Indio, Meloland, Holtville-Imperial stratified, and Imperial complex soils were equated to the four general classes: "well drained," "moderately drained," "poorly drained," and "very poorly drained." Arizona soils were classified under three general headings also based on internal drainage characteristics. There is very little soil in Arizona which could be equated to the Imperial complex. Consequently, this classification was not used in Arizona.

Table 3-2. Conductivity in micro mho/cm and ion concentrations in meq/l as a function of total dissolved solids in p/m. Potential salinity and SAR are indicated. (Appendix 2, Table 2-1.)

	Cor Coef R
$\ln EC = 0.97272 \ln TDS + 0.5630$	0.987
$\ln [Cl^-] = 1.49470 \ln TDS - 8.77014$	0.984
$\ln [Ca^+] = 0.658814 \ln TDS - 2.90328$	0.997
$\ln HCO_3 = 0.23401 \ln TDS - 0.48040$	0.195
$\ln Mg = 1.01057 \ln TDS - 5.79548$	0.988
$\ln Na = 1.146846 \ln TDS - 5.90873$	0.992
$\ln SO_4 = 0.78180 \ln TDS - 3.31381$	0.972

TDS	EC mmho/cm	Na meg/l	Mg meg/l	Ca meg/l	SO_4 meg/l	Cl meg/l	HCO_3 meg/l	SAR	Potential Salinity
900	1.339	6.64	2.94	4.85	7.42	4.04	3.04	3.36	7.5
1000	1.484	7.49	3.27	5.19	8.05	4.73	3.11	3.46	8.8
1100	1.629	8.35	3.60	5.53	8.68	5.46	3.18	3.90	9.8
1200	1.773	9.23	3.93	5.86	9.29	6.22	3.25	4.17	10.9
1300	1.917	10.12	4.26	6.17	9.89	7.01	3.31	4.43	12.0
1400	2.061	11.02	4.60	6.48	10.48	7.83	3.37	4.68	13.1

Source: Data from State of California, 1971, Hydrologic Data, 1969, Southern California, Department Water Resources Bul. 139-69, V:424-426.

Bernstein (1962) and others, as reviewed by Robinson (no date), suggest that plants growing on soils containing gypsum salts can tolerate approximately 2 mmhos/cm higher salinity than those growing on chloride-treated soils used by the Salinity Laboratory to establish the tolerances shown in Table 3-1. For this reason, 2 mmhos/cm were subtracted from the values shown in Table 3-4 to adjust for the presence of gypsum in both the soil and water.

"Guidelines to Production Costs and Practices for Imperial Valley" (1973) show an annual water requirement of 84 inches if the land is cropped continuously. Irrigations might be as frequent as six per month in mid-summer and as few as one per month in mid-winter. Actual water application to any one crop depends upon the season of growth and the irrigation management practice.

Table 3-3. Ratios of mean conductivity of saturated soil extract ÷ mean conductivity of irrigation water, 1.41 mmho/cm.

Indio		Meloland		Holtville Imperial Stratified		Imperial Complex	
0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
1.5	1.3	1.5	2.0	2.1	3.4	4.4	5.0
1.7	1.6	1.7	2.2	2.3	3.8	4.4	5.7
1.8[a]	1.8[a]	1.8	2.3	2.7	3.9	4.4	5.7
1.9	1.8	1.9	2.4	2.9	4.4	4.6[a]	5.8[a]
2.6	2.5	2.0	2.5	3.7[a]	4.7[a]	4.8	6.2
		2.0[a]	3.0[a]	3.8	4.8	5.2	6.5
		2.3	3.4	3.9	5.4		
		2.3	3.4	4.3	5.8		
		2.3	3.7				
		2.5	3.7				
		3.4	5.1				

[a] Median values.

Source: Appendix 2, Table 2-4.

Eighty-four inches of water per year is used as the basis for the irrigation management influence on soil salinity. For example, if irrigation is delayed long enough to require 5.25 inches of water to replace moisture used from the profile and to provide the necessary leaching fraction it will take only 16 irrigations per year to apply the 84 inches. If only 2.4 inches of water meet this requirement it will take 35 irrigations to apply the 84 inches. The frequency of irrigation has a definite influence upon root development and therefore upon the soil zone from which water is extracted.

On the basis of work by Henderson (1946) and Wadleigh (1948), the following formulae are used to account for the irrigation management influence: When only 16 irrigations per year are applied, subsoil salinity shown in Table 3-4 (-2 mmhos/cm) is used as the effective level. When 22 irrigations are applied the mean of the topsoil and subsoil salinities is taken as the effective level. When 29 irrigations are applied a weighted mean of (2(ECtopsoil) + 1(EC subsoil))/3 is taken as the effective level. Where 35 irrigations are applied the EC of the topsoil only is used. With sprinkler irrigation the water has to be applied more often and in smaller amounts. Therefore, the roots are nearer the surface. The effective EC for Sprinkler irrigation is determined by subtracting 3 mmhos/cm from the topsoil values in Table 3-4 and 4 mmhos/cm from the subsoil values before calculating a weighted mean with the formula above (Appendix 2, p. 90). The effective values of soil saturation extract conductivities thus derived for four soil drainage classes, six TDS levels, and five irrigation management practices are shown in Table 3-5.

An example will explain how extract values were obtained. Consider the effective soil saturation extract conductivity for 1,100 mg/l are 3.3 and 4.9, respectively. Referring to the procedure above for this situation, the value for the second 30 cm is taken

Table 3-4. Projected conductivities of saturated soil extract for four soils and six levels of irrigation water salinity (TDS).

Irrigation Water Salinity TDS (mg/l)	EC mmho/cm	Ratios of Soil Saturation Extract Conductivity to Irrigation Water Conductivity							
		Well Drained		Moderately Drained		Poorly Drained		Very Poorly Drained	
		Top	Sub	Top	Sub	Top	Sub	Top	Sub
		1.8	1.8	2.0	3.0	3.7	4.7	4.6	5.8
900	1.34	2.4	2.4	2.7	4.0	5.0	6.3	6.2	7.8
1000	1.48	2.7	2.7	3.0	4.4	5.5	7.0	6.8	8.6
1100	1.63	2.9	2.9	3.3	4.9	6.0	7.7	7.5	9.5
1200	1.77	3.2	3.2	3.5	5.3	6.5	8.3	8.1	10.3
1300	1.92	3.5	3.5	3.8	5.8	7.1	9.0	8.8	11.1
1400	2.06	3.7	3.7	4.1	6.2	7.6	9.7	9.5	11.9

Source: Unpublished report to Economics Section, Bureau of Reclamation, Denver, Colorado, from F. E. Robinson, Appendix 2, Table 2-7.

Table 3-5. Effective values of soil saturation extract conductivities in four soil drainage classes, six TDS levels, and in five irrigation management treatments.[a]

TDS (mg/l)	Irrigations Per Year	Drainage Classification			
		Well	Moderate	Poor	Very Poor
900	16	0.4	2.0	4.3	5.8
	22	0.4	1.4	3.7	5.0
	29	0.4	1.1	3.4	4.7
	35	0.4	0.7	3.0	4.2
	Sprinkler	0.0	0.0	2.1	3.4
1000	16	0.7	2.4	5.0	6.6
	22	0.7	1.7	4.3	5.7
	29	0.7	1.5	4.0	5.4
	35	0.7	1.0	3.5	4.8
	Sprinkler	0.0	0.2	2.7	4.1
1100	16	0.9	2.9	5.7	7.5
	22	0.9	2.1	4.9	6.6
	29	0.9	1.8	4.6	6.2
	35	0.9	1.3	4.0	5.5
	Sprinkler	0.0	0.5	3.3	4.9
1200	16	1.2	3.3	6.3	8.3
	22	1.2	2.4	5.4	7.2
	29	1.2	2.1	5.1	6.8
	35	1.2	1.5	4.5	6.1
	Sprinkler	0.0	0.8	3.8	5.5
1300	16	1.5	3.8	7.0	9.1
	22	1.5	2.8	6.1	8.5
	29	1.5	2.5	5.7	7.6
	35	1.5	1.8	5.1	6.8
	Sprinkler	0.2	1.2	4.4	6.3
1400	16	1.7	4.2	7.7	11.9
	22	1.7	3.2	6.7	8.7
	29	1.7	2.8	6.3	8.3
	35	1.7	2.1	5.6	7.5
	Sprinkler	0.4	1.5	5.0	7.0

[a] Adapted from Robinson, F. E., Appendix 2, Table 2-8.

and a numerical value of 2 is subtracted resulting in the tabular value of 2.9.

In a more complicated case, consider 1,100 mg/l, 29 irrigations per year, and moderately drained soil. The appropriate formula multiplies the value for the top 30 cm by 2, adds the value of the sub 30 cm, divides by 3, and adjusts the results of 3.8 by 2 (accounting for the presence of gypsum) for an answer of 1.8.

Interpolation of data from Table 3-1 and Table 3-5 generated a matrix for each crop comparable to the one displayed in Table 3-6 for lettuce. Average expected yield was used as the base number. In the case of Imperial Valley, this figure was averaged over 8 years (1965-1972) resulting in 10.8 tons/acre with a 95 percent confidence interval of 0.84. To calculate per acre expectations of yield for 1,100 mg/l, 29 irrigations, and moderate drainages refer first to Table 3-5 and locate the respective value of 1.8. In Table 3-1, 1.8 falls within the interval 1.3 to 2.0 in the row corresponding to lettuce. Interpolation of the predicted yield reduction percentage for the interval estimates a magnitude of about 7.1 percent. Therefore, 7.1 percent was subtracted from the base yield of 10.8 tons/acre resulting in an expectation of 10.0 tons/acre. Remaining values of the table were derived through the same process.

Yield Declination Curves

With these data, a matrix could be developed to show yield impacts due to changing salinity. This was accomplished by comparing localized tables of effective soil saturation values to Table 3-1 accounting for the adjustment factor applied to each study area. The resulting matrix contained yield per acre under three to four soil classes, five levels of irrigation application, and six levels of TDS. Empirical yields associated with each study area were used as a base figure. Damages were formulated by establishing normal expected yields (base yield figure) from these data and then fitting the declination function to each crop under each of the assumed alternatives.

Monetary values were attached to the estimated physical damages estimates through a crop budgeting procedure. Different points along the damage function indicate different yield levels. Translation of a lower or higher yield into dollar terms results in a corresponding change in profit. The following section explains how agricultural profits were calculated and implemented in the LP model.

Model Description

Methodology followed in this study essentially sought to assess the current situation or status or cultural practices in agriculture and relate them to the different alternatives available in the face of rising TDS. This was accomplished in terms of applying linear programming to each area in order to develop a regional agricultural model. The objective function was to maximize net returns to management over variable costs for each project area as a whole. A brief description of the model follows.

Activities Description

The activities were composed of crop budgets, double cropping alternatives, and management alternatives. Representative enterprise budgets were collected for each study area. Both secondary and primary sources were used in localizing these data. Regional prices for inputs and outputs were applied where sufficient data existed.

Empirical data were gathered to determine general cropping patterns common to each area. With the exception of the Coastal Region, all areas practiced, to various extents, several forms of double

Table 3-6. Projected yield of lettuce by four levels of surface irrigation intensity and one level of sprinkler irrigation intensity for three soil classes and six levels of TDS, Imperial Valley.

	Irrigations Per Year	TDS (mg/l)					
		900	1000	1100	1200	1300	1400
Indio	16	10.8	10.8	10.8	10.8	10.5	10.2
	22	10.8	10.8	10.8	10.8	10.5	10.2
	29	10.8	10.8	10.8	10.8	10.5	10.2
	35	10.8	10.8	10.8	10.8	10.5	10.2
	Sprinkler	10.8	10.8	10.8	10.8	10.8	10.8
Meloland	16	9.8	9.1	8.3	7.7	6.9	6.5
	22	10.8	10.2	9.7	9.1	8.6	7.9
	29	10.8	10.5	10.0	9.7	9.0	8.6
	35	10.8	10.8	10.8	10.5	10.0	9.7
	Sprinkler	10.8	10.8	10.8	10.8	10.8	10.5
Holtville Imperial	16	6.4	5.4	4.3	3.6	2.5	1.5
	22	7.2	6.4	5.6	4.8	3.8	2.8
	29	7.6	6.7	5.9	5.3	4.3	3.6
	35	8.1	7.5	6.7	6.1	5.3	4.4
	Sprinkler	9.6	8.8	7.7	6.9	6.3	5.4

cropping. Selection of feasible and common double cropping patterns followed. Matrix coefficients were established to represent corresponding changes in costs of production and yield as a result of these patterns. Rather than combine the resulting double cropping possibilities with single crop enterprise budgets to form separate combined activities, single processes comprising resources implemented solely by double cropping actions were selected. The LP model is allowed to select various combinations of crops, some leading and others following, in the rotation cycle. Some combinations allowed the same crop to be both the leading and following crop as indicated by local practices. The resulting crop linkages represented the optimum mix of single and double cropping possibilities.

The final section of activities dealt with a set of feasible management alternatives available to the farmer in order to mitigate salinity impacts to crop yields. Present and possible near future management alternatives were assessed for applicability to each respective area. Costs of exercising such options were constructed as pertained to their implementation and installation. Estimates of additional yields gained or maintained by such actions were compared to costs and resulting net benefits (returns) were thus derived. Again, the LP model was allowed to choose any combination of alternatives which represented the optimum mix under the conditions specified.

In order to illustrate the magnitude that the model could acquire, a theoretical example of the Imperial Valley is presented. Consider four classes of land, thirteen different crops, six management alternatives, five irrigation treatments, and eight double cropping possibilities. For each respective level of TDS there are 12,480 possible combinations. Fortunately, many activities could be eliminated or precluded before processing was initiated and therefore, considerable reduction in matrix size was obtained. The damage functions derived from this report are based on a minimum of six LP model runs for each study area corresponding to the TDS levels of 900, 1,000, 1,100, 1,200, 1,300, and 1,400 mg/l. In certain cases additional TDS levels were considered.

Rows Description

Row activities included both accounting and constraining equations. Subdivisions of the general categories of labor and capital constituted the majority of the accounting rows. The remainder were made up of transfer rows to account for double cropping and management alternatives.

Land, water, and physical crop production were considered as major constraining factors to the model. Empirical data were gathered concerning the cultivated acreages for both single and double cropping techniques. Statistical analysis produced estimates of land available in the various land classes under the two-land use alternatives (single and double cropping). Cultivation was not allowed to occur on lands in excess of these estimates. These limits represented the extent of agricultural lands available for use in each area.

Water was limited to the total supply available or historically diverted. Total supply available translates into the upper limit of water rights allocated to each specific site. Where no legal water right had been established, the amount of water historically diverted to the project minus credits for return flows was considered as a reliable supply figure. Total water available to agriculture was limited to these figures.

Finally, in order to simulate regional demand for the various agricultural commodities produced on any one project and to circumvent the necessity of a massive demand projection study, empirical production quantities were gathered for at least the past 10 years and used to estimate expected production for the period of this study. Estimation techniques depended on the nature of the data. They varied from use of a simple time series linear regression, where evident trends existed, to establishment of historic means surrounded by confidence intervals. Flexibility in the model was desired in order to represent variation in market demand. Therefore, where reliable statistical data were analyzed, the standard deviation from the mean was used as a proxy for market variations and consequently served as a production range. This value, when added to estimated production, was set as the upper limit of production; when subtracted, a lower limit was derived. The model was allowed to produce crops at any production level within this specified range. Where a low level of confidence was given by the empirical data, which indicated an absence of reliability, estimates of upper and lower parameters were based as much as possible on conditions deemed to be representative for the period of this study (1974 conditions).

Derivation of Monetary Losses

Execution of the LP model for conditions representing an estimation of the lowest mg/l concentration in each respective study area constituted the base run. Each successive TDS level necessitated changes in the model matrix resulting from movement along the damage function (yield declination function) with respect to the various crops. The solution results from these runs were matched to that of the base run for comparison. Salinity damages were calculated as the difference between the optimal solution of the base run and that of the solution derived for the highest level of TDS. Solutions for the intermediate TDS levels aided in constructing the proper shape of the resulting damage function.

Theoretically, *a priori* conditions suggest that crop yields react to increasing salinity as illustrated in Figure 3-1. As TDS rises, the function is assumed to decline at an increasing rate. The curve takes on a slightly different shape for each crop depending on its sensitivity at different TDS levels. When these functions are aggregated for a region, a general damage curve results similar to that in the figure.

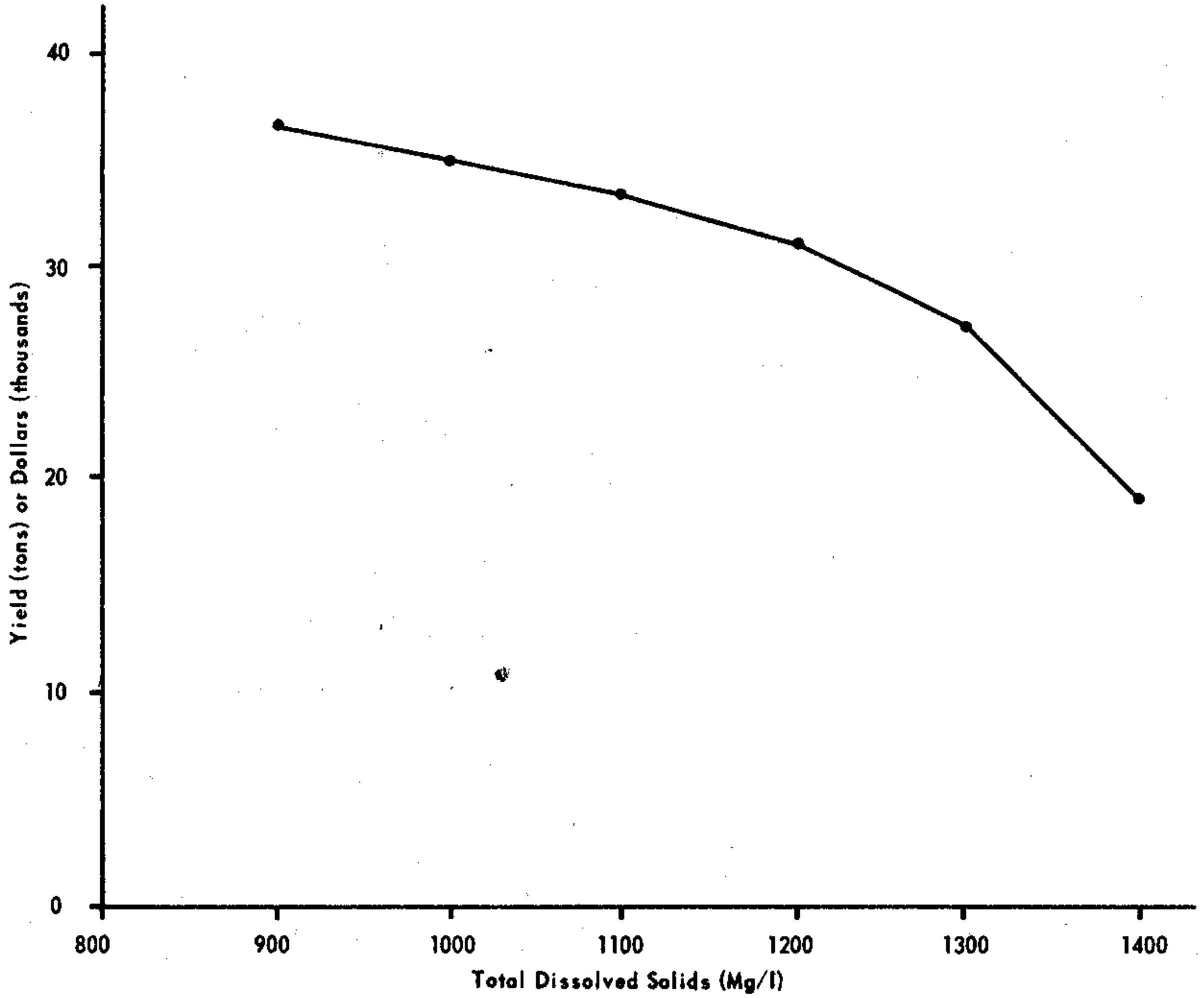


Figure 3-1. Hypothetical yield delineation curve.

Dollar values can replace yield on the vertical axis without altering the general shape of the function.

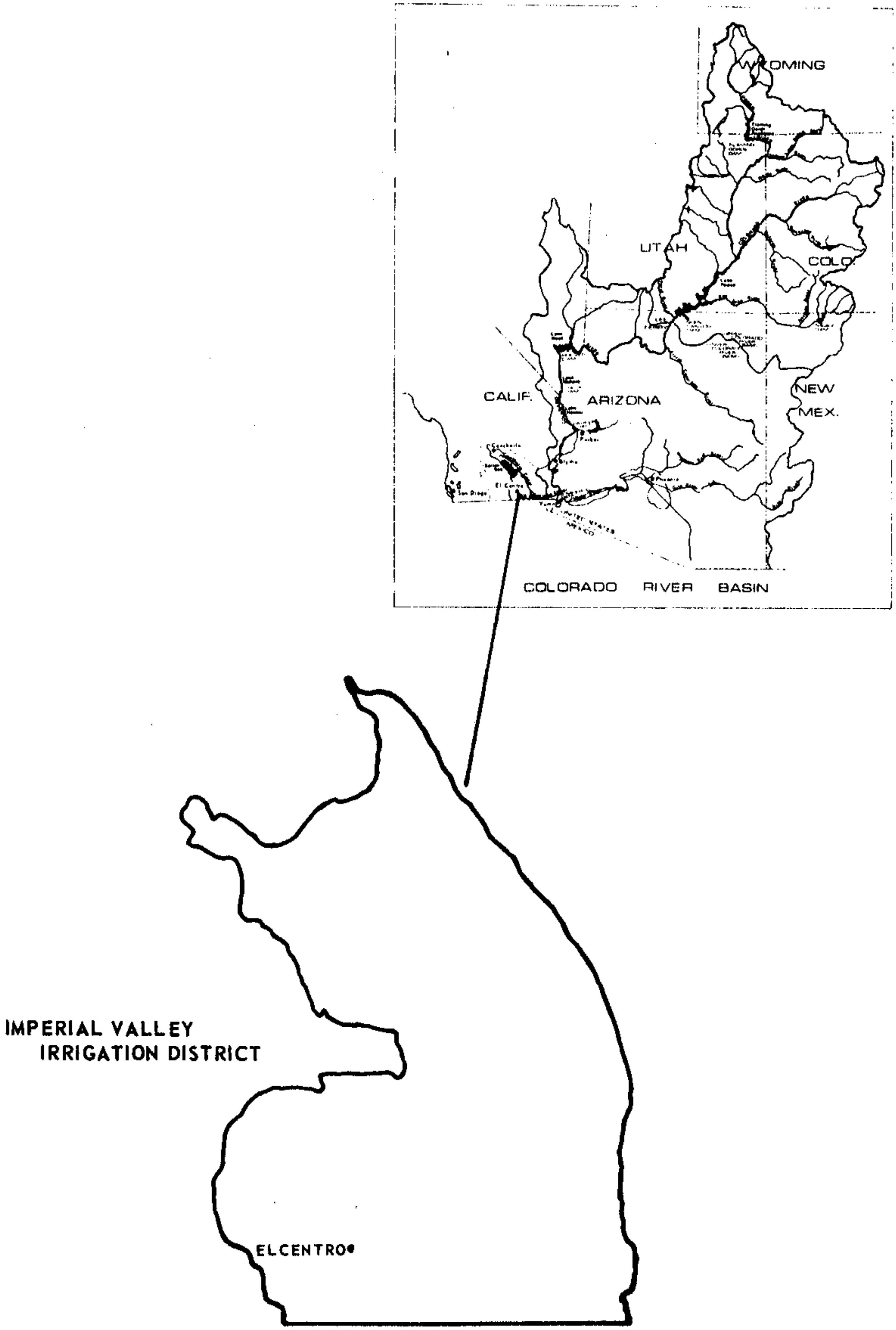
ANALYSIS OF IMPERIAL VALLEY IRRIGATION DISTRICT

Perhaps the greatest impact of increasing salinity in the Colorado River Basin has been in the area encompassed by the Imperial Valley Irrigation District (Map 3-1), which is located in the extreme southwestern portion of the United States. Imperial Valley water users are constantly exercising available alternatives to lessen impacts of salinity problems.

Large areas of heavy clay soils (Holtville-Imperial stratified and Imperial complex) are a major limiting factor in obtaining optimal agriculture productivity. Definite relationships exist between water, drainage, and soil characteristics which further compound the initial effects of poor quality irrigation water.

In accordance with the assumptions as explained in a previous section, the parameters necessary for model formulation were made specific to this area. For agricultural purposes, four aggregated land classes represented general soil characteristics encountered in the area. Descending from best to worst they were: Indio (coarse and well drained), Meloland (sand surface, heavy subsoil, moderately drained), Holtville-Imperial stratified (sandy and clay stratified, poorly drained), and Imperial complex (clay, very poorly drained). Table 3-7 shows the agricultural area used as land constraints in the model. Total acreage is partitioned into land classes associated with general drainage characteristics and in accordance with single or double cropping activities.

Crops exceeding $1 million in gross value of production in 1974, as selected for analysis by this study area are exhibited in Table 3-8, which also includes a list of possible double cropping combinations considered feasible in this area.



Map 3-1. Imperial Valley Irrigation District, California.

Table 3-7. Number of acres available for single and double cropping by land class, Imperial Irrigation District.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	48,872	15,583	64,455
Land 2 Moderately Drained)	71,577	22,822	94,399
Land 3 (Poorly Drained)	181,635	57,913	239,548
Land 4 (Very Poorly Drained)	82,736	26,380	109,116
Total	384,820	122,698	507,518

Management alternatives available to the model are important for the estimation of impacts to Imperial Valley agriculture. Practically all of the options named earlier are common practice except for drip irrigation. Consideration was given to partial sprinkler, tiling, leaching, full sprinkler, deep plowing, ditch lining, land leveling, special bedding, and different irrigation frequencies. Upon closer examination of the costs and returns for these options, it was obvious that deep plowing and ditch lining could be deleted because performance of these activities, per se, would not increase marginal yield enough to cover the costs involved.

Partial sprinkler, leaching, land leveling, deep plowing, ditch lining, and special bedding practices were included in much of the secondary data due to frequent use. Consequently, difficulties arose when attempts were made to identify the individual contribution of each. For example, when singled out and placed on the basis of marginal contributions to yield, the increased production was less than sufficient to cover additional costs; and therefore, it was decided that effective identification and isolation could not be accomplished. In order to avoid double counting, the assumption was made that the above options were practiced often enough so as to be considered the common cultural practice in the basin and thus were sufficiently accounted for in the secondary data sources. On the other hand, practices such as tiling, full sprinkler, and applying different irrigation frequencies were not commonly included in secondary data and, therefore, could be analyzed separately. These specific model activities were structured in order to represent net (marginal) additions to profit based on contributions to yield. Using the yield declination matrices developed for the different crops, measures of the impact of selecting or not selecting these options were enumerated. In the case of tiling, mesurements were calculated for each land class and irrigation frequency resulting in many combinations. Since approximately 75 percent of the land is presently tiled, model constraints were developed which allowed only the remaining 25 percent to be available for tiling under this option. Costs and returns were calculated and inserted into the model matrix.

Replacing surface irrigation with full sprinkler irrigation constituted another management decision in the model. The major trade offs lie in the advantages of better salinity control and increased germination as opposed to the disadvantages of higher costs and variance in crop quality. Full sprinkler application principally has the role of maintaining, rather than increasing, plant yield under conditions of increasing TDS in this particular case.

Different irrigation frequencies and applications were considered for both surface and sprinkler systems. The major cost was associated with manual labor. As the number of applications increased, so did the cost for irrigation labor due to the fact that "setup" time was assumed to be a constant amount regardless of the amount of water applied. A labor cost function was constructed to represent the inherent fixed costs to set up for water delivery along with associated

Table 3-8. Selected crops and double cropping possibilities, Imperial Irrigation District.

Crops	Double Cropping Possibilities[a]							
	Wheat	Barley	Lettuce	Cantaloupe	Onion	Tomato	Watermelon	Sorghum
Asparagus								
Cantaloupe	x	x	x	x	x		x	x
Carrots	x	x	x	x	x	x	x	x
Alfalfa								
Tomato	x	x	x	x	x	x	x	x
Watermelon	x	x	x		x			x
Barley								
Wheat								
Sugar Beets								
Lettuce	x	x	x	x	x		x	x
Onion (Mkt.)	x	x						x
Sorghum	x	x	x	x	x	x	x	x
Cotton			x					

[a]Crops under these columns are those crops assumed to lead in the double cropping rotation.

variable costs for additional time required depending on water volume applied. In essence, the function had a positive slope which decreased as amount of water applied increased as shown in Figure 3-2. Marginal units of water applied under the same setting were assigned a smaller cost as set time increased. As set time decreased, marginal costs were maintained at a higher rate. As shown in the figure, marginal cost changes occurred after the application of each acre-inch above 2 inches. Fixed costs were assumed to apply to the first 2 inches. Thus, the marginal factor costs of labor were computed for the various crops under differing irrigation regimes.

Construction of declination curves for the respective crops was based on empirical yield data and projected median conductivity of effective soil saturation extracts. Average yields were based on data presented in Table 3-9. Information in Table 3-4 was localized resulting in Table 3-10. The base average yields for each crop were compared to the parameters in Table 3-10, and declination values were extropolated from Table 3-1. This procedure resulted in a matrix of expected yield reductions for each crop under four soil conditions, six levels of TDS, and five irrigation management alternatives.

With the relevant parameters now having been defined for the Imperial Valley, the model was complete. Computer runs were made for the TDS levels of 900, 1000, 1100, 1200, 1300, and 1400 mg/l. At each of these levels model matrix coefficients had to be adjusted to reflect the yield changes that occurred over the corresponding range for the affect crops. The results indicated not only substantial differences between objective function values but also in cropping patterns, land use and value, water consumption, production levels, and the respective crops in terms of profitability. Table 3-11 displays the changes in cropping patterns and production over the 900-1400 mg/l TDS range. For more detail on specific technologies and double cropping patterns refer to sub-Appendix A.

Several distinct patterns developed in the number of acres cultivated and total amount produced. For example, the acreages of asparagus, alfalfa, and sugar beets periodically show an increase because the program has set minimum as well as maximum production levels, and in order for these crops to comply with model conditions they have to occupy an increasing amount of acres. To maintain a constant level of production, while at the same time experiencing decreased yields per acre, more area would be required.

High net returns per acre make cantaloupe and carrot production very profitable relative to other crops. The model brings these crops in at the upper bound. Here again, in order to maintain the upper

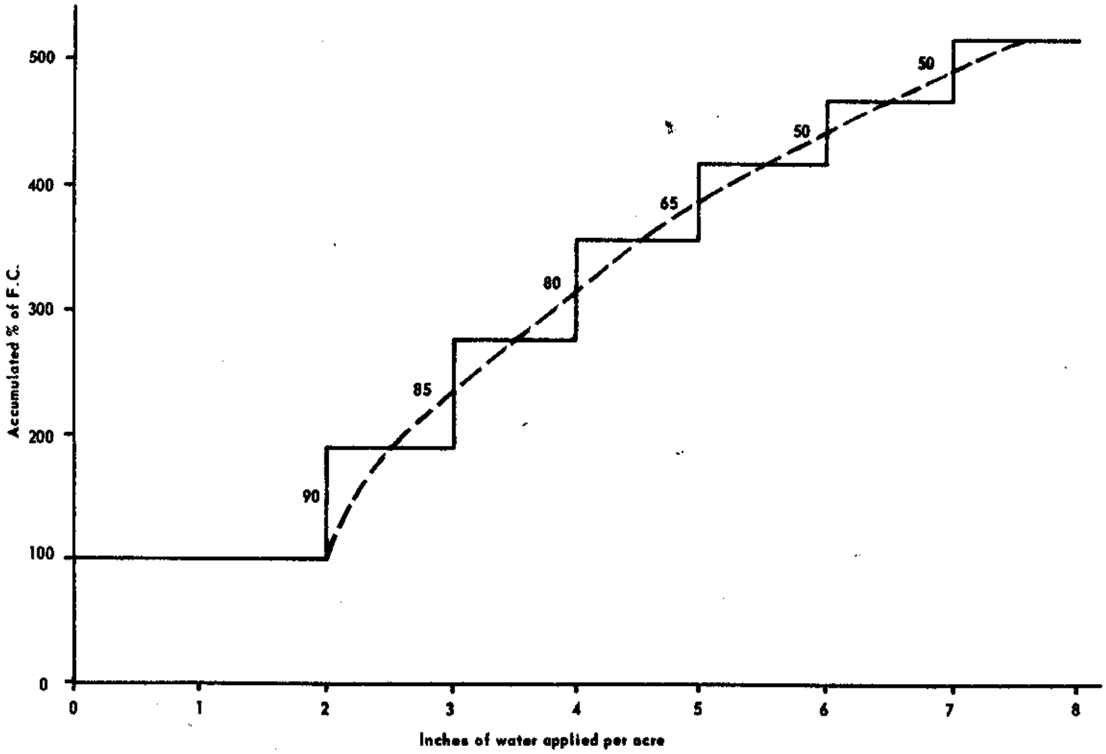


Figure 3-2. Marginal factor cost curve for irrigation labor.

Table 3-9. Yields of major crops in the Imperial Valley Irrigation District, 1965-1972, (tons/acre).

	1972	1971	1970	1969	1968	1967	1966	1965	95 Percent Confidence Interval
Asparagus	1.5	1.4	1.3	1.6	1.8	1.7	1.6	1.6	1.57 ± 0.13
Cantaloupe	6.0	5.7	5.8	5.0	5.9	6.2	7.0	5.4	5.88 ± 0.49
Carrots	11.0	13.6	9.3	12.0	14.0	15.8	15.9	20.3	13.99 ± 2.86
Lettuce	10.9	11.7	10.2	9.2	9.7	9.5	11.3	9.0	10.79 ± 0.84
Onions (Mkt.)	13.7	12.8	14.0	10.0	15.7	18.1	12.6	12.5	13.68 ± 2.01
Tomato	11.2	11.4	5.0	6.4	6.3	10.5	5.8	4.8	7.68 ± 2.38
Watermelon	8.3	9.0	8.5	7.4	5.9	10.9	8.3	8.8	8.39 ± 1.18
Barley	1.8	1.8	1.8	2.0	1.8	2.2	1.6	2.2	1.9 ± 0.18
Cotton	1325	665	798	968	1660	971	1224	1717	1166 ± 322[a]
Alfalfa	6.4	7.0	6.0	6.8	6.5	6.1	6.4	6.4	6.45 ± 0.28
Sorghum	2.3	2.5	2.3	2.5	1.8	1.9	2.2	2.5	2.25 ± 0.23
Sugar Beet	26.8	26.0	24.1	18.0	21.0	20.6	17.9	22.2	21.96 ± 2.81
Wheat	2.3	2.4	2.3	2.5	1.6	2.0	2.0	2.0	2.14 ± 0.24

[a] Pounds per acre.

Source: Office of Agricultural Commissioner, El Centro, California. (Appendix 2, Table 2-6.)

Table 3-10. Effective values of soil saturation extract conductivities in four soils, six TDS levels, and five irrigation management levels—Imperial Valley. (Appendix 2, Table 2-8.)

TDS (mg/l)	Irrigations Per Year	Drainage Classification			
		Well	Moderate	Poor	Very Poor
900	16	0.4	2.0	4.3	5.8
	22	0.4	1.4	3.7	5.0
	29	0.4	1.1	3.4	4.7
	35	0.4	0.7	3.0	4.2
	Sprinkler	0.0	0.0	2.1	3.4
1000	16	0.7	2.4	5.0	6.6
	22	0.7	1.7	4.3	5.7
	29	0.7	1.5	4.0	5.4
	35	0.7	1.0	3.5	4.8
	Sprinkler	0.0	0.2	2.7	4.1
1100	16	0.9	2.9	5.7	7.5
	22	0.9	2.1	4.9	6.6
	29	0.9	1.8	4.6	6.2
	35	0.9	1.3	4.0	5.5
	Sprinkler	0.0	0.5	3.3	4.9
1200	16	1.2	3.3	6.3	8.3
	22	1.2	2.4	5.4	7.2
	29	1.2	2.1	5.1	6.8
	35	1.2	1.5	4.5	6.1
	Sprinkler	0.0	0.8	3.8	5.5
1300	16	1.5	3.8	7.0	9.1
	22	1.5	2.8	6.1	8.5
	29	1.5	2.5	5.7	7.6
	35	1.5	1.8	5.1	6.8
	Sprinkler	0.2	1.2	4.4	6.3
1400	16	1.7	4.2	7.7	11.9
	22	1.7	3.2	6.7	8.7
	29	1.7	2.8	6.3	8.3
	35	1.7	2.1	5.6	7.5
	Sprinkler	0.4	1.5	5.0	7.0

Table 3-11. Cropping and production pattern changes, Imperial Irrigation District.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Asparagus	4,533	2,963	4,533	2,963	4,533	3,002	4,544	3,105	4,533	3,215	4,533	3,358
Cantaloupe	77,504	14,028	77,504	14,623	77,504	15,347	77,504	16,063	77,504	16,941	77,504	17,817
Carrots	67,254	4,804	67,254	4,804	67,254	4,804	67,254	4,963	67,254	5,234	67,254	5,402
Alfalfa	1,072,288	150,726	1,072,288	153,972	1,072,288	156,710	1,072,288	160,323	1,072,288	165,721	1,072,288	170,331
Tomatoes	19,018	2,529	19,018	2,634	19,018	2,752	19,018	2,847	19,018	2,949	19,018	2,476
Watermelon	29,846	3,046	29,846	3,046	29,846	3,046	29,846	3,046	29,846	3,046	29,846	3,046
Barley	52,606	27,687	52,606	27,687	52,606	27,687	52,606	27,687	52,606	27,687	52,606	27,687
Wheat	131,182	61,300	124,235	58,054	129,469	60,500	141,726	66,227	123,575	58,845	122,849	59,787
Sugar Beets	1,459,281	66,331	1,459,281	66,331	1,459,281	66,331	1,459,281	66,331	1,459,281	66,331	1,459,281	67,356
Lettuce	641,159	59,202	641,159	59,202	641,159	53,934	537,972	43,057	540,281	42,653	390,469	33,650
Onions (Dry)	81,752	5,967	81,752	5,967	81,752	5,967	81,752	5,967	81,752	6,101	81,752	4,192
Sorghum	91,101	67,736	89,548	67,036	86,886	66,254	86,886	66,745	86,886	67,633	86,886	69,810
Cotton[a]	100,182	41,199	100,182	41,199	101,182	41,184	100,182	41,157	100,182	41,163	100,182	41,157
Total		507,518		507,518		507,518		507,518		507,518		506,068
Fallow												1,450

[a] 480-pound bales.

limit of production under decreasing yields, more acres need to be farmed.

Several crops are highly resistent to salinity. The two least affected in the Imperial Valley are watermelon and barley. As noted on the table, production and acreage amounts remain constant over the entire TDS range. Watermelon is maintained at the upper level and barley at the lower.

Tomato production utilizes increasing quantities of land until the 1400 mg/l TDS level is reached. At this juncture, profits diminish to the point where a change in land class results. Up to this level, tomatoes are produced on class 3 land. However, yield decreases enough during the interval of 1300 to 1400 mg/l TDS that it becomes more profitable to shift production to classes 1 and 2. Consequently, since yield is higher on these two land classes, less acres are required to meet the upper production limit than required even at the 900 mg/l TDS level.

Throughout the range of the analysis wheat was selected by the model as the major "slack" activity. In relative terms to the other crops, wheat production was ranked about middle priority. The model satisfied production requirements of upper limit crops (cotton, tomatoes, onions, cantaloupe, carrots, watermelon, and partly lettuce) and then allocated resources to wheat. Since there were not enough resources to produce wheat at the upper limit and still comply with the lower limit conditions of lesser priority crops, production occurred between the two limits. Both production and producing acres varied as more resources were required due to the impacts of decreasing yields and increasing salinity to the other crops.

Perhaps the most interesting case is that of lettuce. This crop is quite sensitive to salinity and yet provides substantial returns to its growers which make higher risk levels more acceptable. For the first three periods production was maintained at the upper limit of 641,159 tons. Slight increases in land area were required as lettuce yields declined. Incidently, the model allocated the best and second best drained lands to lettuce production at the initial level of 900 mg/l TDS thus limiting possible reallocation to better land classes early in the range of analysis. The remaining alternatives were those dealing with management options. Such activities were not profitable until TDS reached the 1100 mg/l level. At this stage, both tiling and full sprinkler became more profitable than to accept less production. However, as salinity continued to rise, such alternatives could not add enough extra production to make it profitable enough to meet upper limit production. Therefore, even though these management options were exercised, yield could not be maintained and thus profits declined. This caused lettuce to become a slack activity at 1200 mg/l TDS and 1300 mg/l TDS and finally impacts were great enough that only the lower limit condition could be met at the 1400 mg/l TDS level. Acres harvested declined from 59,202 to 33,650 as crop substitution became more and more prevalent. Increasing salinity probably impacts lettuce more than any other crop in this area.

Another high value vegetable crop is onions. Salinity tolerance is somewhat stronger than that of lettuce. As indicated by the trend developed over the 900-1300 mg/l TDS interval, only insignificant changes in land area are required to maintain production at the upper limit. In fact, the land area is constant up to 1300 mg/l TDS where finally the variation of irrigation frequencies could no longer prevent decreased yields. Between 1300 and 1400 mg/l TDS yield is impacted enough to cause a shift in allocation of production from land classes 1 and 2 to only class 1. In addition, the trade off between declining yield and salinity mitigation is great enough that the model selects the management options of tiling and full sprinkler. Interactions of shifting land classes and applying salinity management mitigation alternatives raised yield to its highest level and thus less land was needed to satisfy the upper production limit.

Even though returns from sorghum production are relatively low, this crop is significantly important in double cropping rotations. Initially, sorghum was selected as a slack activity due to its tolerance of salinity and flexibility in possible double cropping combinations. However, as TDS rose, production declined until the lower limit was reached at 1100 mg/l TDS. From this level to the 1400 mg/l TDS level, increased acreages were needed just to meet the necessary conditions of the model. Only minimum impacts are felt as land area increased very slightly from 67,736 at the 900 mg/l TDS level to 69,810 at the 1400 mg/l TDS level with the greatest change occurring between 1300 mg/l and 1400 mg/l. The relative position of this crop is affected more by the declining yields of the other crops than by its own direct yield impacts due to its many double cropping combinations.

Cotton has been found to be tolerant of poor water quality as it could be grown on class 3 land and undergo very little reduction in yield. The trend of land used by cotton contains an interesting characteristic, in that, as salinity rises land area diminishes. With the exception of a slight increase at 1300 mg/l TDS, shifts in technology provide sufficient rises in yield between levels so as to require less land. The main reason is that the cotton yield function changes at a very moderate rate. When a trade off does occur (for example, a shift from an annual rate of 16 to 22 irrigations), the change is great enough to cause increased production per unit of land. This mainly happens in the double cropping pattern of fall lettuce followed by short season cotton. For a more indepth examination refer to sub-Appendix A.

As the LP model achieves an optimal solution it generates a value which is commonly known as a "shadow price." This represents the marginal value product (MVP) of each resource in short supply. The MVP is formulated through different relationships of the resources and constraints in the model. It should be viewed in relative terms to other inputs and not as an actual "going price" in the market place. Table 3-12 was constructed to show various relative values among land classes. Two general divisions of land classifications were selected depending upon drainage characteristics (Land 1-Land 4). In addition, time of planting was considered to determine land available for double cropping (Double Crop 1-Double Crop 4). Values for Land 1 and Land 2 classes increase as TDS increases. Indications are that as yields decline more rapidly on poorly drained soils, higher value is placed on the better drained soils. Support is given to this by observing that MVP for Land 3 and Land 4 decreases to the point where capital intensive measures such as installing tile drains and applying full sprinkler systems improve the drainage capabilities enough to slightly increase its value. Remaining MVP values are also shown for each set of assumptions considered in the analysis. (See sub-Appendix A.)

Empirical data were gathered from records of water deliveries received below drop No. 1 in the All American Canal System which is the conveyance structure from Imperial Dam to the district. Figures dated back to the year 1941. The year 1946 was selected as the starting period. A trend line was fitted through these 28 years of data to project a value for the 29th period (1974). This value was 2,838,558 ac ft of water. Since water rights are not clearly defined for certain irrigation districts in this area, the water constraint was set at this figure. Water consumption was not to exceed this value.

Total water consumption in acre feet is presented in Table 3-13. The most significant observation of these data is that as salinity rises, water use per acre also rises. To arrive at the number of acre feet applied per acre, the amount of water consumption generated by the model was simply divided by the corresponding number of acres farmed at the particular TDS level. In order to exhibit the insignificant amount of change, figures were carried out to three places. The range was comparatively small starting with 5.305 ac ft per acre at the 900 mg/l TDS level and finishing with 5.390 ac ft per acre at the 1400 mg/l TDS level. However, when the ratio of total net returns to total acre feet is taken into account, a definite pattern does develop which appears to be decreasing at an increasing rate.

Table 3-13. Ratio of amount of water used to land and profit all by level of TDS, Imperial Irrigation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	2,692,167	5.305	31.06
1000	2,703,775	5.327	30.22
1100	2,707,170	5.334	29.89
1200	2,707,551	5.335	29.29
1300	2,727,937	5.375	27.89
1400	2,727,818	5.390	25.49

An earlier explanation described the objective function of the model as total net returns above variable costs. Presented below in Table 3-14 are the actual values derived for each model run as they pertain to the 900-1400 mg/l TDS levels. Assuming that all factors are taken into account, these figures demonstrate that rises in TDS concentrations in irrigation water do have a pronounced effect upon farm profits. This fact is also evident in profits per acre.

Table 3-14. Total and per acre net profit by TDS level with and without management options, Imperial Irrigation District.

TDS (mg/l)	Profit (Dollars)	Without (Dollars)	Per Acre (Dollars)	Without (Dollars)
900	83,610,853		164.74	164.74
1000	81,704,414		160.99	160.99
1100	80,909,000	79,820,022	159.42	157.28
1200	79,316,828	77,091,963	156.28	151.90
1300	76,071,679	72,472,040	149.83	142.80
1400	69,527,177	66,810,464	136.99	131.64

A small distortion in the data prevents the function from being entirely smooth. Between 1000 mg/l and 1100 mg/l, the decrease is smaller than for any of the other intervals. Justification can be found

Table 3-12. Shadow prices of land per acre by class and level of TDS, Imperial Irrigation District.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	239	260	278	302	332	378
Land 2	239	258	275	298	328	367
Land 3	189	188	188	187	182	193
Land 4	189	188	186	184	181	183
Double Crop 1	154	133	114	122	50	–
Double Crop 2	142	121	150	184	180	62
Double Crop 3	50	50	75	72	66	44
Double Crop 4	48	46	63	59	51	38

by observing the role of management activities in the model. A threshold is reached at 1100 mg/l where the profit trade off between accepting accumulated dmanages or selecting specific mitigation options favors the latter. Therefore, profits and/or yields are maintained at a higher level than would have been the case if such options were nonexistent. However, after the initial contribution by management alternatives, the function proceeds to decline at an increasing rate. This can perhaps better be seen graphically where total net profit ($) is represented on the vertical axis and total dissolved solids (TDS) are represented on the horizontal axis (see Figure 3-3).

A major hypothesis of this study theorizes that farmers will follow the practice of accepting the lowest amount of profit loss. Under this rationale, we present only an analysis of the LP models containing the option of management alternatives because they have the possibility of contributing more to profit than to costs at higher TDS levels. However, for informational comparison, several tables also include values associated with models having no option of selecting management alternatives.

In reference to Table 3-14, we accumulate the marginal damages accruing over the range of TDS in question. The accumulated total is $14,083,676. Examination of these data resulted in trying many different types of functional fits. A few of the better ones were: exponential, power, logarithmic, and parabolic. In the exponential curve of the form $Y = be^{mx}$, where b is the value of Y when $x = 0$ (the Y-intercept), E is the constant 2.718281828, m is the slope or rate of growth of the curve, x is the independent variable, and Y is the dependent variable. Figure 3-4 shows the plotted data points along with the superimposed fit of the exponential curve. This function is very characteristic of this particular group of data as R^2 is equal to 0.99. Therefore, the function chosen that best represented the estimates of salinity damages for the Imperial Valley was the exponential curve.

Table 3-15 contains both the observed and estimated points plotted on Figure 3-4. Estimates of the damages occurring within the interval 800-1000 mg/l were derived by extending the curve downward. However, no estimates are taken for TDS values

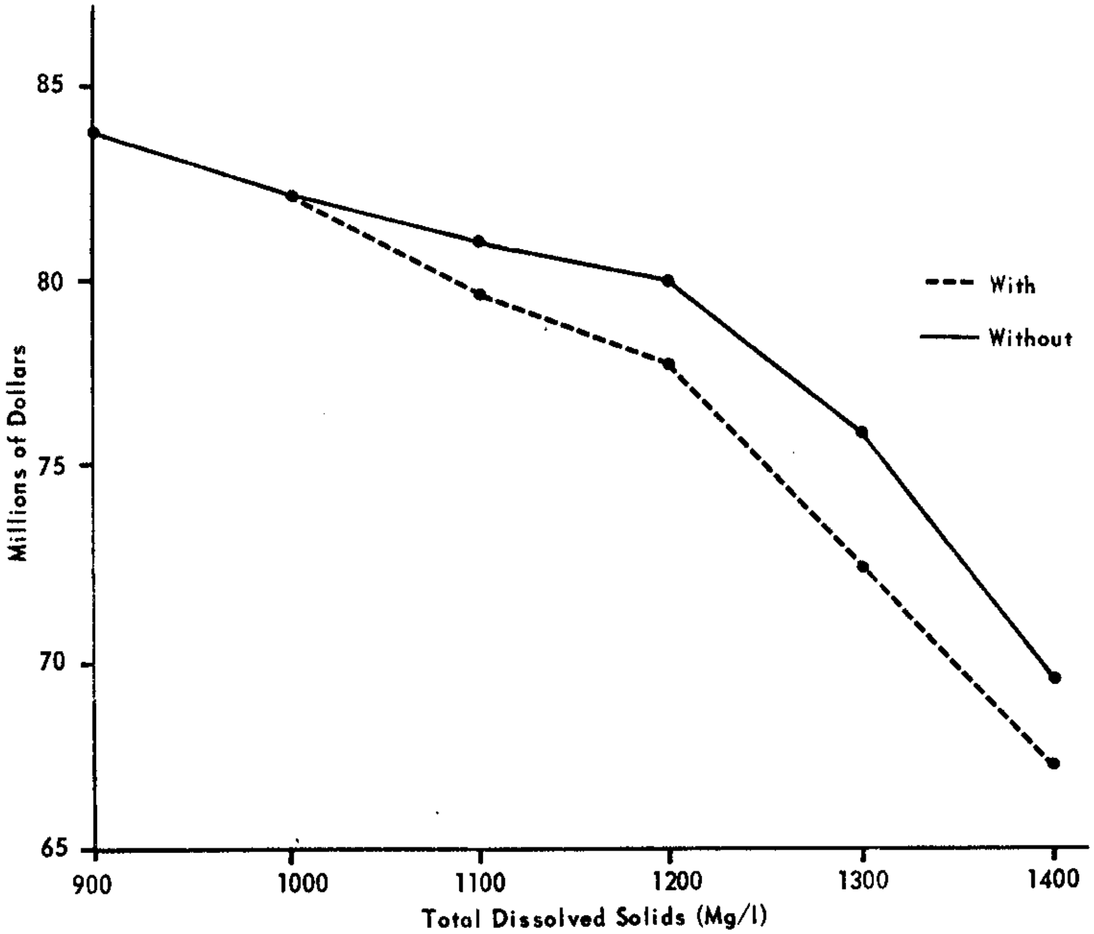


Figure 3-3. Total net profit by level of TDS, Imperial Valley.

Table 3-15. Accumulated damage totals of observed data and predicted values by level of TDS, Imperial Irrigation District.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
800	–	632,555
900	–	1,045,595
1000	1,906,439	1,728,336
1100	2,701,853	2,856,886
1200	4,294,025	4,722,346
1300	7,539,174	7,805,894
1400	14,083,676	12,902,904

greater than 1400 mg/l. Predictions beyond this level may or may not properly reflect actual occurrences because the nature of the exponential curve is that of a slope increasing at an increasing rate. Therefore, for purposes of estimation, confidence is placed in only those values derived at or below 1400 mg/l. Estimations above this point will not be considered until the analysis is amplified to include higher levels of TDS.

Under present assumptions the functional values, where b = 11,343 and m = 0.0050262, define the equation as follows: Y = (11,343) (2.718281828) 0.0050262x.

For summary purposes, Table 3-16 generalizes some of the more important statistics. Annual total damages is the difference between the objective function at 900 mg/l TDS and 1400 mg/l TDS. The total number of acres is divided into the damage figure to derive an annual estimate of per acre damages. This is also performed with milligrams per liter (defined the same as TDS). Annual damages per acre are then derived by dividing number of acres into damages per mg/l. This amounts to $0.0555 which is interpreted as the average annual damage in dollars incurred by each acre for each unit increment in mg/l. Care should be taken to recognize that such a constant value cannot be attached to each unit of TDS. Rather, the values

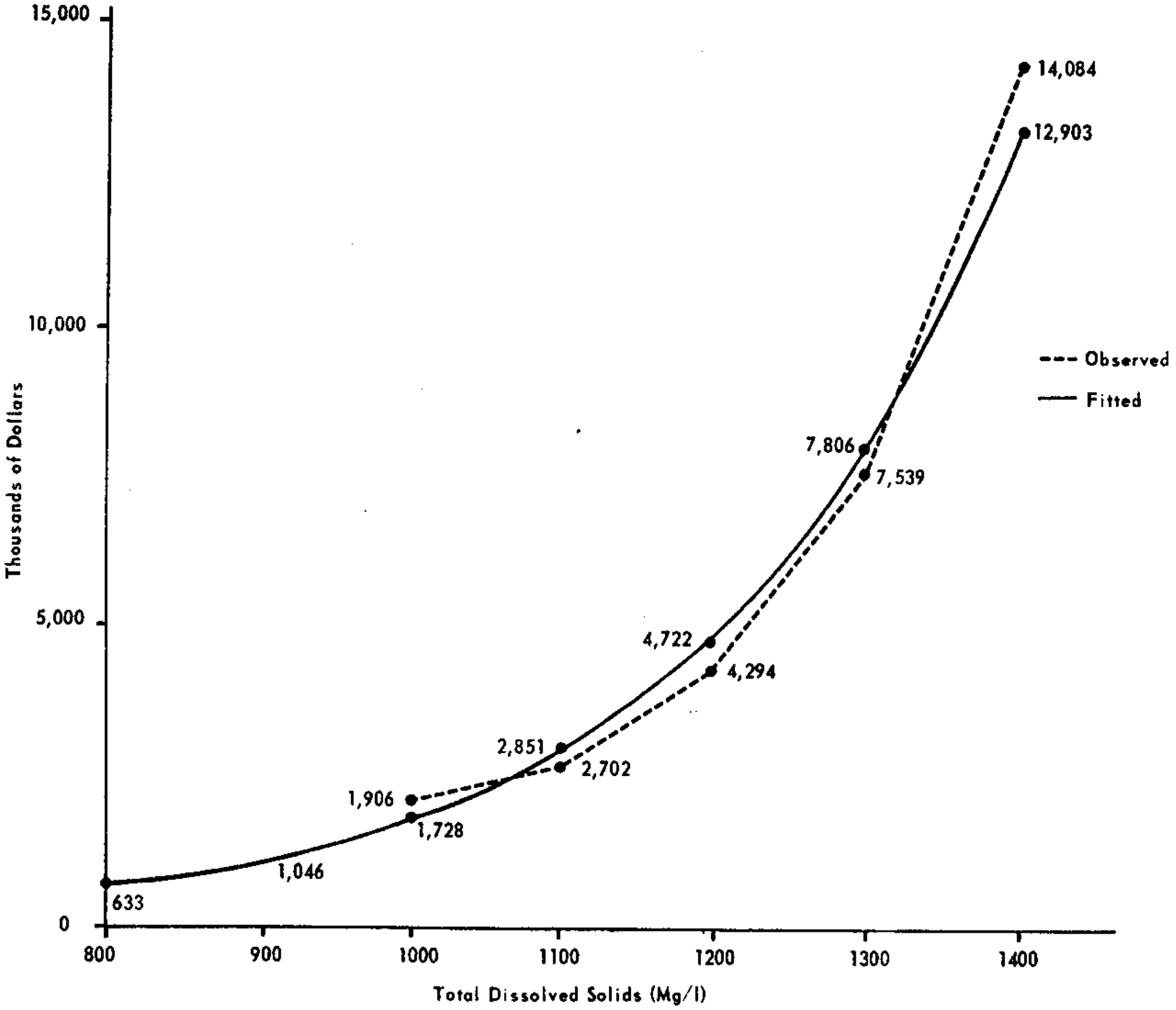


Figure 3-4. Observed data with fitted damage function, Imperial Valley Irrigation District.

Table 3-16. Summary statistics, Imperial Irrigation District.

		Without
Total Acres	507,518	507,518
Double Cropped (Acres)	122,698	122,698
Annual Total Damages ($)	14,083,676	16,800,389
Annual Per Acre Damages ($)	27.75	33.00
Annual Damages Per mg/l ($)	28,167	33,601
Annual Damages Per mg/l Per Acre ($)	0.0555	0.066

will be smaller as they approach 900 mg/l TDS and larger as they near the 1400 mg/l TDS level. This is only an average for the entire range in question.

COACHELLA VALLEY IRRIGATION DISTRICT

The Coachella Irrigation District also receives its water supply from the All American Canal system (see Map 3-2). As can be seen from the map, irrigated lands extend northward from the Salton Sea. Area soils as a whole, tend to be better drained with smaller acreage of land class 4 under cultivation than was the case in the Imperial Valley.

Lands were distributed among several soil classes as shown in Table 3-17. Since perennial crops such as citrus and dates are widespread throughout the district, double cropping occurs only on a limited amount of land. Carrots, onions, and sweet corn are the only crops considered in the rotation scheme. Furthermore, as shown in the table, double cropping activities are allocated solely to class 1 land due to the assumption that sweet corn can only lead in the rotation sequence followed by either carrots or onions which are assumed to be grown entirely on this land class. Table 3-18 contains a complete list of the crops selected for this area.

Average base yields have been calculated from the 6-year interval 1968 to 1973 (Table 3-19). Derivations of expected yield decreases due to rising salinity were developed for each crop. Localized estimates of effective saturation extract conductivities were considered the same as for Imperial Valley. Therefore, Tables 3-1 and 3-5 were compared and appropriate expected damage percentages were applied to the average yields thus resulting in expected damage functions.

Table 3-17. Number of acres available for single and double cropping by land class, Coachella Irrigation District.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	35,362	3,846	39,208
Land 2 (Moderately Drained)	2,292		2,292
Land 3 (Poorly Drained)	3,029		3,029
Land 4 (Very Poorly Drained)	245		245
Total	40,928	3,846	44,774

Table 3-18. Selected crops and double cropping possibilities, Coachella Irrigation District.

Crops	Double Cropping Possibilities[a]	
	Sweet Corn	Onions
Grapes		
Grapefruit		
Carrots	x	x
Alfalfa		
Dates		
Lemon and Lime		
Orange and Tangerine		
Onion (Mkt.)	x	x
Sweet Corn		

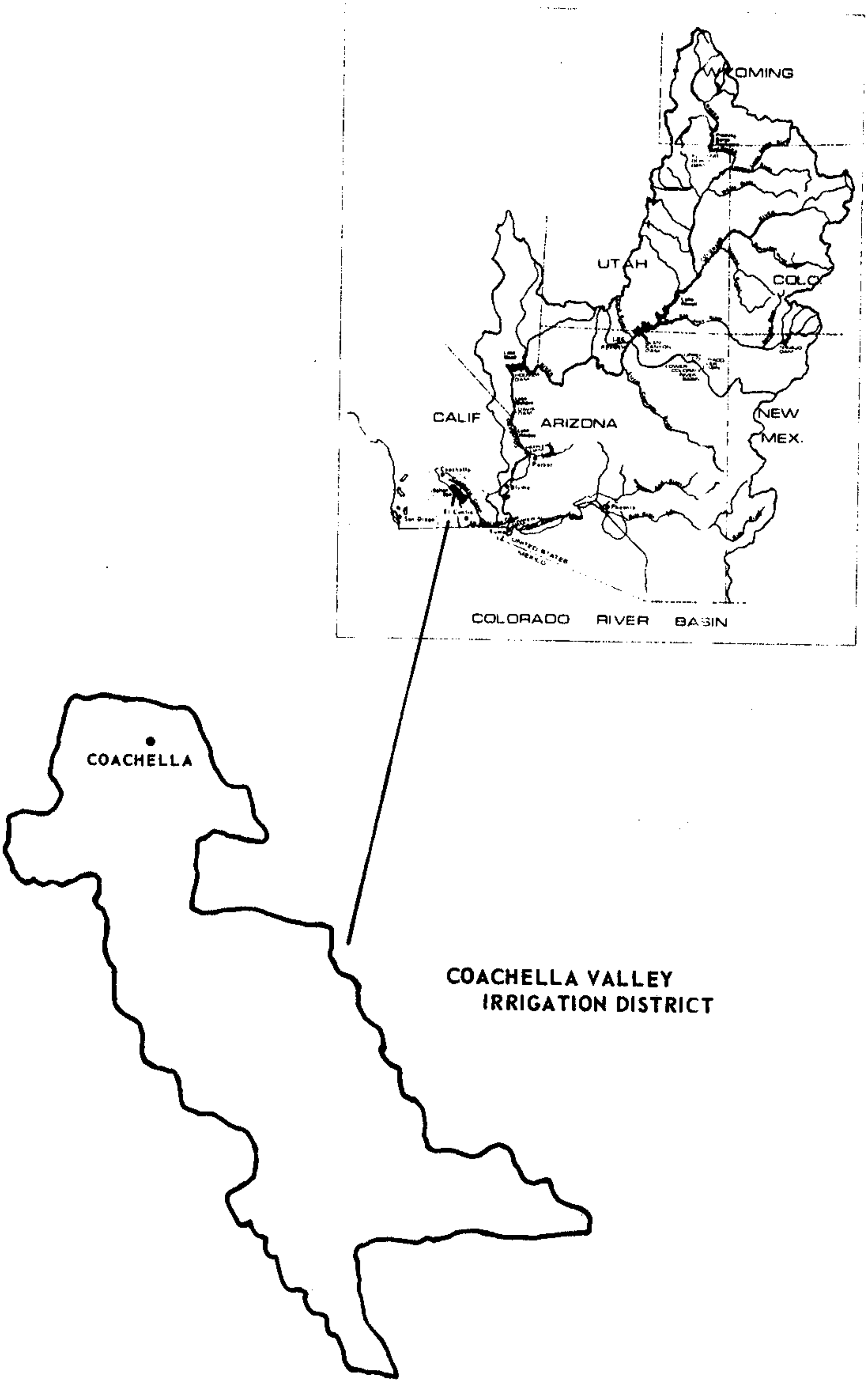
[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Variations in production and land use at the respective TDS levels are reflected in the model by selecting corresponding points on the declining yield functions. These points represent the expected decline in yield for a particular level of TDS, land classification, and irrigation management frequency. The changes are presented in Table 3-20. There is no observed change in production or land use with respect to grapes, grapefruit, carrots, dates, and lemons/limes.

The oranges/tangerines classification shows both a decrease in production and total land use (for detail concerning changes in land class consult sub-Appendix B). Activity occurs within the upper and lower production limits until 1400 mg/l TDS is reached where it drops to the lower limit. Sweet corn displays the same general trend with the exception being that production and land use remain constant up to the interval 1300-1400 mg/l TDS where both decline.

Onions are the only crop exhibiting a trend of constant production and increasing occupied land area. The magnitude of the latter is small, however, as only slight decreases in yield are detected. In this process, the model seeks to maintain production at the upper level and requires increased land area in order to do so.

A shift in technology is responsible for the up and down trend noticed in land use for alfalfa production. In comparison to the other crops, this activity has relatively low returns. The model sets production to the lower limit throughout the TDS interval. As yield per acre decreases, land area increases up to 1300 mg/l TDS. Between 1300 mg/l TDS and 1400 mg/l TDS, production is allocated entirely to land class 1



Map 3-2. Coachella Valley Irrigation District, California.

Table 3-19. Yields of major crops in the Coachella Irrigation District, 1968-1973 (tons/acres).

	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa Hay	8.80	8.20	8.00	7.30	6.66	6.70	7.61 ± 0.91
Carrots	8.90	9.04	12.9	14.1	10.3	13.1	11.39 ± 2.37
Sweet Corn	4.60	3.68	3.95	2.35	3.57	4.83	3.83 ± 0.93
Green Onions	25.3	31.8	24.4	24.6	14.5	18.8	23.2 ± 6.24
Grapefruit	12.4	10.40	–	8.00	10.80	9.65	10.24 ± 2.00
Lemon and Lime	8.35	2.58	2.93	2.01	3.48	4.55	3.98 ± 2.42
Orange and Tangerine	3.00	4.99	2.31	4.56	4.20	5.40	4.07 ± 1.25
Date	4.55	5.16	3.32	4.63	4.84	3.80	4.38 ± 0.72
Grape	3.20	3.70	4.00	4.83	5.79	3.50	4.17 ± 1.02

Source: Office of Agricultural Commissioner, Indio, California. (Appendix 2, Table 2-22.)

rather than among several classes as in the case to this point. Since this results in the overall yield being higher, less land area is needed.

Table 3-21 contains the shadow prices generated by the model. An overall observation is that as salinity increases, the value of better drained lands increases also while poorer drained lands decrease in value. The reader can compare specific values with sub-Appendix B for an indepth explanation.

The maximum amount of water available to the district was set at 485,400 ac ft. This figure is well above present diversions. Consumptive water use by the model is well below the maximum available as shown in Table 3-22. Agriculture requires approximately 260,000 ac ft annually in the 900 mg/l to 1300 mg/l range. Upon reaching 1400 mg/l, model water consumption drops suddenly. This is due to the decreased acreage of alfalfa which more than offsets water increases in the other crops.

Computer runs were made for the TDS levels of 900 mg/l, 1000 mg/l, 1100 mg/l, 1200 mg/l, 1300 mg/l, and 1400 mg/l. Resulting values of the objective function are presented in Table 3-23. Per acre damages appear to be much less than was the case in Imperial Valley due mainly to the fact that citrus and dates maintain yields remarkably well over the TDS interval of the study. These values are plotted in Figure 3-5. The resulting trend illustrates the small magnitude of damage as reflected in decreased profits.

Since interest lies in the accumulated damages, Table 3-24 was constructed in order that these values may be identified. A linear regression line best approximated the observed data. The predicted values are listed in the righthand portion of the table. The general equation form is $Y = mX + b$ where $Y =$ the dependent variable, $m =$ the slope of the straight line, $X =$ the independent variable, and $b =$ the value of Y when $X = 0$, commonly called the "Y-intercept." In this particular case, the values were as follows: $m = 81.8790$, $b = -80{,}353.4$, and $X =$ any level of TDS. The coefficient of determination has a value of 0.95.

Due to the nature of the data and the subsequent estimated function, a qualification should be made concerning the resulting predicted variables. In view of the fact that damages are minimal between 900 mg/l and 1000 mg/l, they are considered as nondectable within this interval. Therefore, interpretation of the negative Y-intercept of -6662 is ignored and effective damages begin when water quality reaches 1000 mg/l. A graphical representation is presented in Figure 3-6.

A summary is contained in Table 3-25 where some of the more important parameters indicate the overall extensiveness of impacts. Most significant perhaps is the $0.0016 value of annual damages per mg/l per acre. This is considerably less than the $0.0555 encountered in Imperial Valley.

PALO VERDE IRRIGATION DISTRICT

Located on the California side of the Colorado River, the Palo Verde Irrigation District encompasses around 100,000 acres of irrigated agricultural lands (Map 3-3). The area lands are divided into four classes as was the case in the first two regions. They were designated as well drained, moderately drained, poorly drained, and very poorly drained. Contained in Table 3-26 is a partitioning of the district's soils by land class which accounts for the total amount available for both single and double cropping activities in the model. Large percentages of the better drained soils are present in the district as contrasted to conditions in Imperial Valley. Almost 60 percent of the land is contained in Classes 1 and 2 versus only 19 percent for Imperial Valley. With regard to salinity control, this fact is much more favorable to mitigation schemes which result in higher benefit/cost ratios.

Consideration of management alternatives available to the district resulted in selection of the following: partial sprinkler, leaching, ditch lining, land leveling, special bedding, and irrigation frequencies. Close examination of the contribution (benefits/costs) of ditch lining revealed that economic justification could not be achieved on this fact alone. Undoubtedly, isolation of these impacts are confounded and cannot be effectively singled out as originating from any one source. However, the remaining alternatives are deemed to contribute significantly to salinity mitigation schemes. To obtain

Table 3-20. Cropping and production pattern changes, Coachella Irrigation District.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Grapes	50,255	12,052	50,255	12,052	50,255	12,052	50,255	12,052	50,255	12,052	50,255	12,052
Grapefruit	66,272	6,472	66,272	6,472	66,272	6,472	66,272	6,472	66,272	6,472	66,272	6,472
Carrots	88,756	7,792	88,756	7,792	88,756	7,792	88,756	7,792	88,756	7,792	88,756	7,792
Alfalfa	15,786	2,129	15,786	2,129	15,786	2,152	15,786	2,152	15,786	2,173	15,786	2,077
Dates	17,825	4,070	17,825	4,070	17,825	4,070	17,825	4,070	17,825	4,070	17,825	4,070
Lemons/Limes	3,546	893	3,546	893	3,546	893	3,546	893	3,546	893	3,546	893
Oranges/Tangerines	22,616	5,557	22,616	5,557	22,521	5,534	22,521	5,534	22,420	5,509	21,866	5,373
Onions (Green)	5,765	249	5,765	249	5,765	249	5,765	249	5,765	253	5,765	264
Sweet Corn	21,297	5,561	21,297	5,561	21,297	5,561	21,297	5,561	21,297	5,561	21,170	5,537
Total		44,775		44,775		44,775		44,775		44,775		44,530
Fallow												245

Table 3-21. Shadow prices of land by class and level of TDS, Coachella Irrigation District.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	168.2	168.2	168.2	168.2	168.2	179.1
Land 2	168.2	168.2	164.3	163.9	163.9	171.9
Land 3	168.2	168.2	164.3	163.9	163.9	171.9
Land 4	80.7	79.6	43.6	43.6	8.4	–
Double Crop 1	168.2	168.2	168.2	168.2	168.2	179.1

Table 3-22. Ratio of amounts of water used to land and profit all by level of TDS, Coachella Irrigation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	260,030	5.81	42.50
1000	260,030	5.81	42.49
1100	260,030	5.81	42.44
1200	260,030	5.81	42.44
1300	260,016	5.81	42.40
1400	258,328	5.77	42.36

Table 3-23. Total and per acre net profit by TDS level, Coachella Irrigation District.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	11,050,237	246.79
1000	11,049,960	246.79
1100	11,036,182	246.48
1200	11,035,707	246.47
1300	11,024,435	246.24
1400	11,014,394	245.99

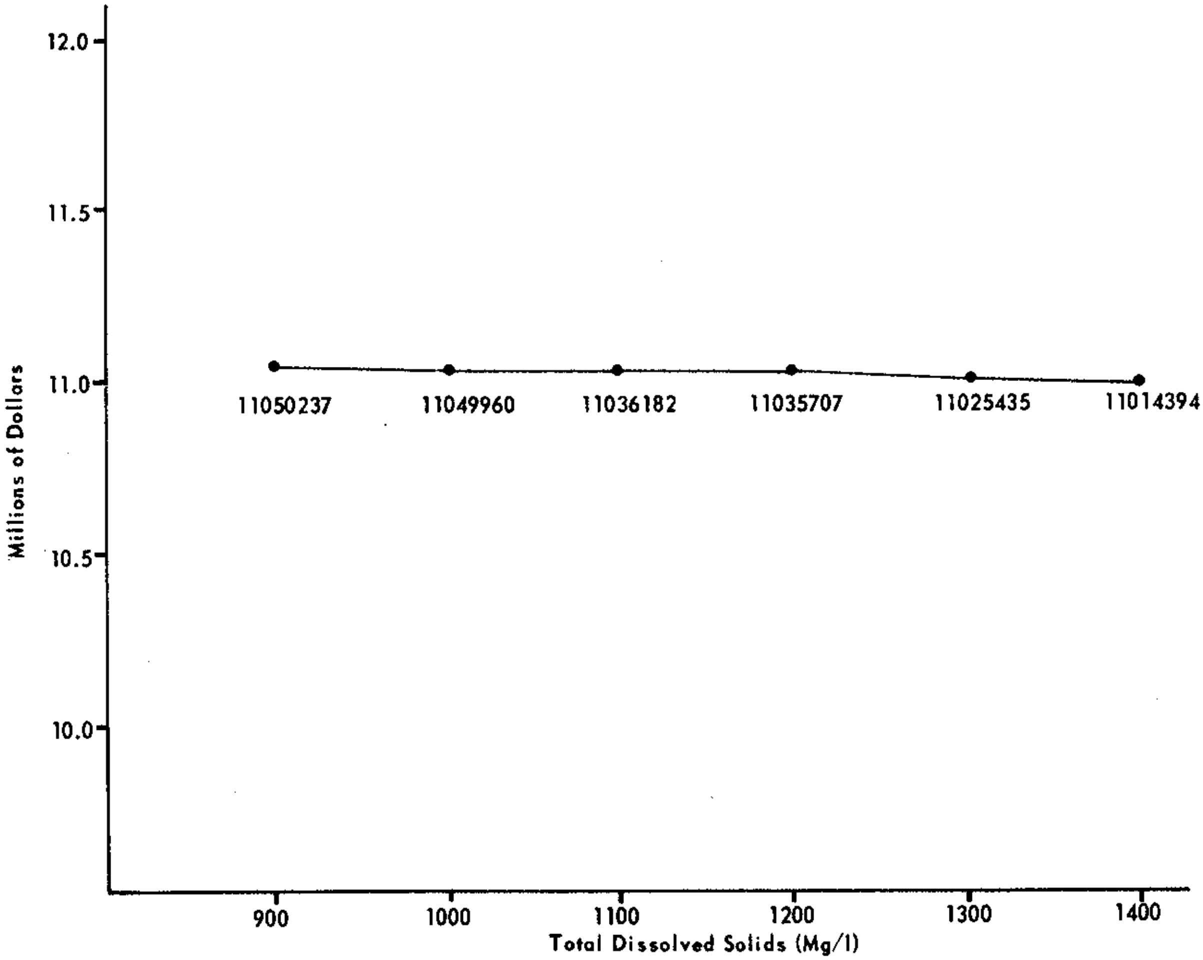


Figure 3-5. Total net profit by level of TDS, Coachella Valley Irrigation District.

Table 3-24. Accumulated damage totals of observed and predicted values by level of TDS, Coachella Irrigation District.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
900		(6,662)
1000	277	1,526
1100	14,055	9,714
1200	14,530	17,901
1300	24,802	26,089
1400	35,843	34,277

Table 3-25. Summary statistics, Coachella Irrigation District.

Total Acres	44,774
Double Cropped (Acres)	3,846
Annual Total Damages	$35,843
Annual Per Acre Damages	$ .80
Annual Damages Per mg/l	$ 71.69
Annual Damages Per mg/l Per Acre	$0.0016

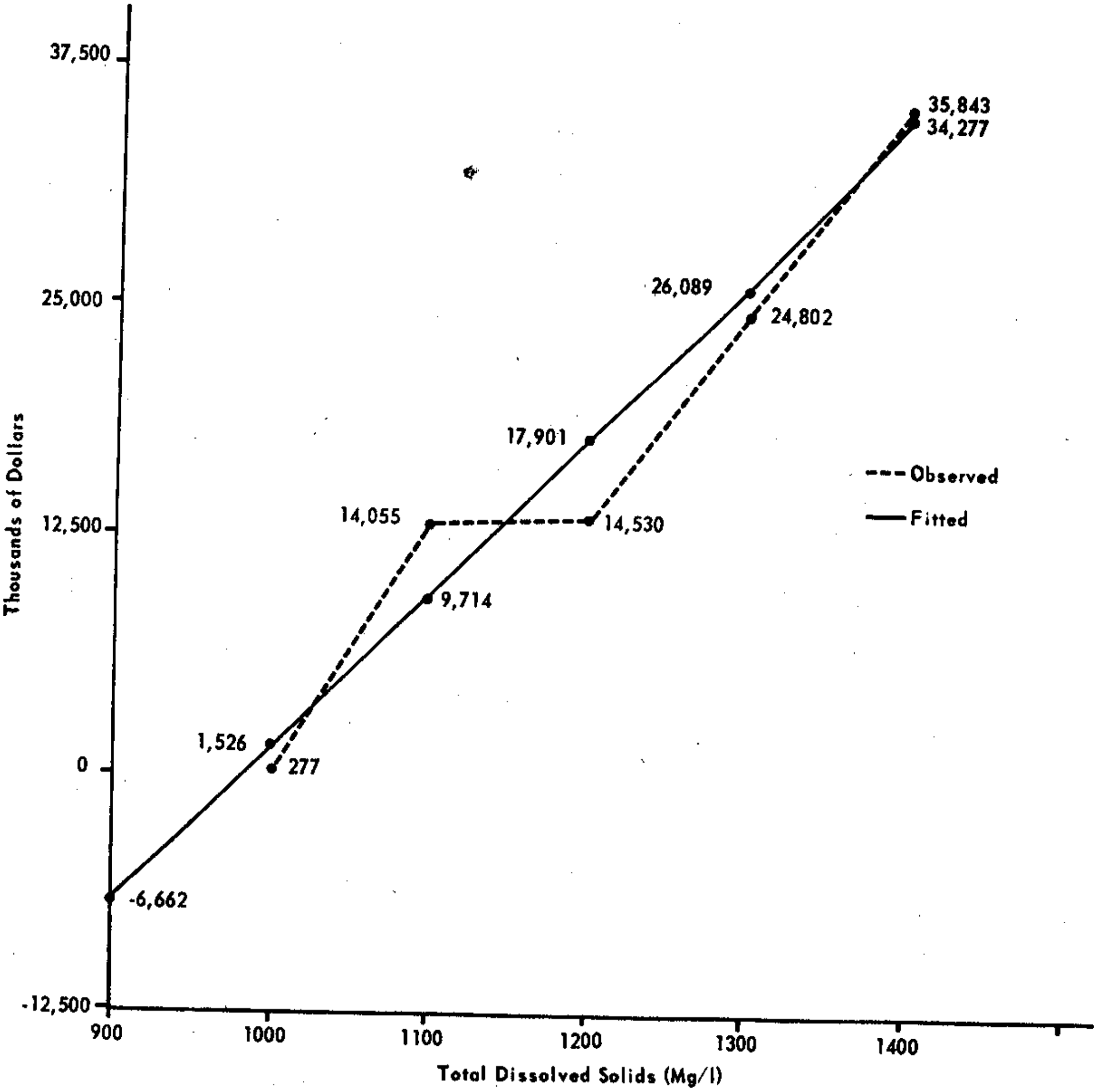
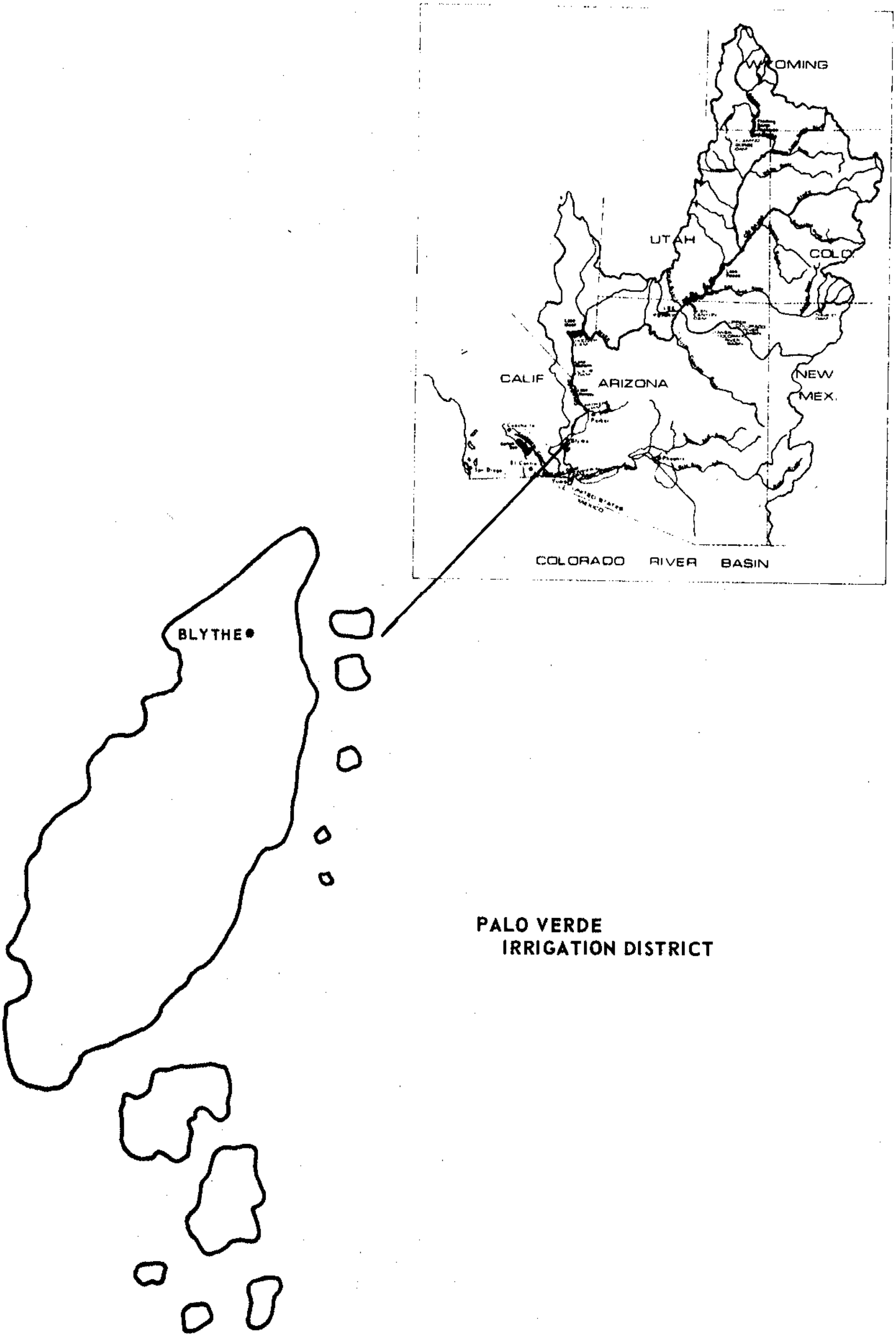


Figure 3-6. Observed data with fitted damage function, Coachella Valley Irrigation District.



Map 3-3. Palo Verde Irrigation District, California.

Table 3-26. Number of acres available for single and double cropping by land class, Palo Verde Irrigation District.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	24,360	3,625	27,985
Land 2 (Moderately Drained)	23,117	3,440	26,557
Land 3 (Poorly Drained)	19,472	2,898	22,370
Land 4 (Very Poorly Drained)	15,909	2,368	18,277
Total	82,858	12,331	95,189

a more detailed explanation of the relationship between these management options and the various crops, refer to sub-Appendix C.

A list of the crops exceeding $1 million in total gross value is presented in Table 3-27. Included also is a matrix which illustrates the possible combinations of double cropping assumed for the area.

Declination curves were estimated for respective crops by first establishing base yields as contained in Table 3-28, next, transforming projected conductivities (Table 3-4) to effective conductivities (Table 3-29), and finally, comparing effective values with Table 3-1 to obtain applicable damage estimations.

In Table 3-30, a presentation of cropping patterns and production levels resulting from model runs over the 900-1400 mg/l TDS range is shown. Grapefruit, lemons, cantaloupe, and watermelon show no variation in land use or production levels. Within this TDS interval, these crops are very insensitive to decreasing water quality.

Uniform trends are also found with respect to lettuce and onions. Upper levels of production are maintained throughout the range while, to maintain production at these upper levels as yields decline, more land area is required.

Alfalfa production functions as a slack activity up to the final TDS level (1400 mg/l). Production and land use decline throughout the range until the lower production limit is reached at 1400 mg/l. This is the reverse of what was happening to lettuce and onions.

Sorghum, cotton, and wheat show no evident trends. Sorghum has increased production from 900 mg/l TDS to 1000 mg/l TDS and then falls back to the original level as salinity increases. The aberration at 1000 mg/l occurs because of the fact that production of alfalfa and its subsequent land use declined sufficiently so that the economic trade off favored sorghum enough to allow increases in its production and land use. However, after reaching this point, production declines to the lower limit. Land increases are required just to meet the lower limit conditions of the model.

In the case of cotton, production is maintained at the upper level throughout the entire range of analysis. An interesting cycle, however, occurs in the use of land as the acreage remains the same for the 900 and 1000 mg/l TDS levels, increases at 1100 mg/l TDS, diminishes to the original level for the interval 1200 to 1300 mg/l TDS, and then rises again at the 1400 mg/l TDS level. This is due to the fact that cotton yield is maintained on class 3 and 4 lands (see sub-Appendix C) until 1100 mg/l TDS is reached. To maintain total production, land area is increased. Between 1100 and 1200 mg/l TDS, cotton production is shifted from land 4 to a combination of production from land 3 and double cropping behind lettuce on land 2. Since yield per acre is higher on these lands classes, less land is required. However, at 1400 mg/l TDS, the double cropping alternative is excluded because lettuce yields render the process nonoptimal. Consequently, since the upper production limit is maintained, more land area is required as production continues on Class 3 land.

Wheat production requires an increasing amount of land area to maintain upper level production as the TDS level rises. Upon reaching 1400 mg/l TDS, management practices can no longer maintain yield levels and therefore both production and required land area decrease.

Table 3-27. Selected crops and double cropping possibilities, Palo Verde Irrigation District.

Crops	Double Cropping Possibilities[a]					
	Wheat	Lettuce	Cantaloupe	Onion	Watermelon	Sorghum
Grapefruit						
Lemon						
Lettuce	x	x	x	x	x	x
Cantaloupe	x	x	x		x	x
Watermelon	x	x				x
Onion (Dry)						
Alfalfa						
Sorghum	x	x	x	x	x	x
Cotton		x				
Wheat						

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-28. Yields of major crops in the Palo Verde Irrigation District, 1964-1973 (tons/acre).

Crop	1964	1965	1966	1967	1968	1969	1970	1972	1973	95 Percent Confidence Interval
Grapefruit					14.85	12.00	10.92	15.53	16.38	13.94 ± 2.92
Lemon					13.56	5.69	10.38	5.30	4.39	7.88 ± 4.89
Lettuce	14.77	14.97	15.99	15.92	15.43	16.41	17.00	11.03	15.30	15.56 ± 1.32
Cantaloupe	4.99	6.65	7.27	7.56	6.23	4.99	7.19	5.40	7.27	6.4 ± 0.79
Watermelon	9.00	10.0	10.0	10.0	8.5	9.0	12.0	9.5	10.0	9.8 ± 0.77
Onions (Dehy.)	18.8	21.3	16.0	15.0	13.0	12.7	13.0	17.0	13.0	15.5 ± 2.34
Alfalfa	5.5	6.0	6.0	6.0	6.0	5.5	5.5	7.0	7.0	6.1 ± 0.45
Sorghum	1.50	1.50	1.75	1.75	1.50	1.50	1.50	1.50	1.80	1.59 ± 0.10
Cotton	3.00	3.00	2.00	1.75	2.75	2.36	1.45	2.00	1.75	2.23 ± 0.44[a]
Cotton Seed	1.10	1.18	0.80	0.70	1.10	0.93	0.57	0.80	0.70	0.87 ± 0.16
Wheat	–	1.50	–	1.75	2.00	2.00	2.25	2.25	2.50	2.04 ± 0.31

[a] 480-pound bales per acre.

Source: Office of Agricultural Commissioner, Blythe, California. (Appendix 2, Table 2-33.)

Table 3-29. Effective values of soil saturation extract conductivities in four soils, six TDS levels, and five irrigation management levels, Palo Verde Irrigation District. (Appendix 2, Table 2-8.).

TDS (mg/l)	Irrigation Number	Drainage Classification			
		Well	Moderate	Poor	Very Poor
900	16	0.4	2.0	4.3	5.8
	22	0.4	1.4	3.7	5.0
	29	0.4	1.1	3.4	4.7
	35	0.4	0.7	3.0	4.2
	Sprinkler	0.0	0.0	2.1	3.4
1000	16	0.7	2.4	5.0	6.6
	22	0.7	1.7	4.3	5.7
	29	0.7	1.5	4.0	5.4
	35	0.7	1.0	3.5	4.8
	Sprinkler	0.0	0.2	2.7	4.1
1100	16	0.9	2.9	5.7	7.5
	22	0.9	2.1	4.9	6.6
	29	0.9	1.8	4.6	6.2
	35	0.9	1.3	4.0	5.5
	Sprinkler	0.0	0.5	3.3	4.9
1200	16	1.2	3.3	6.3	8.3
	22	1.2	2.4	5.4	7.2
	29	1.2	2.1	5.1	6.8
	35	1.2	1.5	4.5	6.1
	Sprinkler	0.0	0.8	3.8	5.5
1300	16	1.5	3.8	7.0	9.1
	22	1.5	2.8	6.1	8.5
	29	1.5	2.5	5.7	7.6
	35	1.5	1.8	5.1	6.8
	Sprinkler	0.2	1.2	4.4	6.3
1400	16	1.7	4.2	7.7	11.9
	22	1.7	3.2	6.7	8.7
	29	1.7	2.8	6.3	8.3
	35	1.7	2.1	5.6	7.5
	Sprinkler	0.4	1.5	5.0	7.0

Table 3-30. Cropping and production pattern changes, Palo Verde Irrigation District.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Grapefruit	13,123	942	13,123	942	13,123	942	13,123	942	13,123	942	13,123	942
Lemons	28,369	3,600	28,369	3,600	28,369	3,600	28,369	3,600	28,369	3,600	28,369	3,600
Lettuce	62,538	3,770	62,538	3,770	62,538	3,770	62,538	3,774	62,538	3,903	62,538	4,039
Cantaloupe	8,571	1,339	8,571	1,339	8,571	1,339	8,571	1,339	8,571	1,339	8,571	1,339
Watermelon	10,809	1,103	10,809	1,103	10,809	1,103	10,809	1,103	10,809	1,103	10,809	1,103
Onions (Dry)	83,501	5,387	83,501	5,387	83,501	5,387	83,501	5,387	83,501	5,458	83,501	5,700
Alfalfa	216,510	35,472	214,494	35,106	213,030	34,866	208,433	34,113	203,410	33,291	199,958	32,911
Sorghum	10,469	8,168	11,004	8,535	10,469	8,317	10,469	8,431	10,469	8,549	10,469	8,695
Cotton[a]	30,323	13,598	30,323	13,598	30,323	13,962	30,323	13,598	30,323	13,598	30,323	13,910
Wheat	44,492	21,810	44,492	21,810	44,492	21,903	44,492	22,902	44,492	23,407	42,556	22,950
Total		95,189		95,189		95,189		95,189		95,189		95,189

[a] 480-pound bales.

In summary, impacts of salinity on the district's total use of land are minimal while slight decreases in production are noted in alfalfa and wheat. Though total land use remains constant, types of land use show significant changes over the range of the analysis.

Presented in Table 3-31 are the shadow prices generated by the model which correspond to the various land classes. The model shifts various crops among land classes according to relative value and available land in any one class. For instance, in the interval 900-1400 mg/l TDS, lands 2, 3, and 4 declined in relative value. This results from decreasing yields on these particular land classes, but, in addition, having as an alternative, production on a better land class. In this case, the model allocates production to technologies on yield maintaining land classes and places the more insensitive crops on poorer lands. Applying this to the table, observation indicates that the demand for land 1 is fairly constant up to 1400 mg/l TDS. However, the trend is quite different for the remaining land, Classes 2, 3, and 4. Value of demand for 2 starts out at $143.90, declines until it bottoms out at 1300 mg/l TDS, and then rises upon reaching 1400 mg/l. This can be explained by the fact that the model shifts the higher valued, more salt-resistant crops to poorer lands and replaces them with crops having less resistance to salt. Consequently, lower shadow prices result until the point is reached where the model can no longer shift crops. At this juncture no alternatives exist other than accepting lower yields. Since at this point less output per acre requires more area to maintain production, demand for the various land classes has to result in higher land values.

The above reasoning seems to apply only to the trend exhibited in land 2. However, application can be made to the remaining two classes. At 1100 mg/l TDS, economic trade offs are great enough to allow double cropping of lettuce followed by cotton. Though less cotton is produced per acre of double cropped land as opposed to single cropped cotton, overall returns increase which increases the value of lands 3 and 4 to a higher level. From this point on normal trends follow which first exhibit declining values, second, a bottoming out, and finally, increasing values. For greater detail, sub-Appendix C shows where demand trends can be followed for both the single and double cropped land classes.

Much difficulty was encountered in attempting to derive an effective water constraint. This was mainly due to the fact that diversion credit is given to the district for return flows. Since establishment of a concrete water figure was biased somewhat by data problems, the procedure utilized data prepared for the Second National Water Assessment. Consumptive use figures for the crops in question were taken from the Assessment and multiplied by the estimated land area occupied by each individual crop. These figures were summed to a total of 443,000 ac ft which represented the water constraint for the model.

Total water consumption values are presented in Table 3-32. Water use as a percent of the total amount available is about 94 percent to 96 percent. Perhaps overshadowing all other conclusions is the fact that as TDS increases, water consumption seems to decrease. This is in direct opposition to what has been stated earlier for Imperial Valley and in agreement with the trend existing in the Coachella Valley. Again, we find that the amount of water consumed by crops increasing in occupied land area which, in effect, displaces nonoptimal crops, is less than the amount given up by displaced crops. In this particular case, lettuce, onions, sorghum, and cotton actually increase in amounts of water used, while, at the same time, alfalfa and wheat decrease in land area thus decreasing consumption of water. The latter amount overshadows the former amount and thus is reflected in the total as a net decrease in water used. The ratio of net profit to acre feet of water indicates that water is more efficiently used if allocated in this manner. Applying less volume of water does not rule out the implementation of various management alternatives such as leaching, etc. Actually, water use per acre increases due to leaching in the district. However, reallocation of water among crops results in a lesser total amount required due as explained. The fact is, that as salinity increases, the amount of net returns realized per acre foot decreases at an increasing rate.

Optimal solutions were obtained for conditions in Palo Verde Irrigation District which were representative of TDS levels corresponding to the range of 900 to 1400 mg/l TDS. The values of the various objective

Table 3-31. Shadow prices of land by class and level of TDS, Palo Verde Irrigation District.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	143.9	143.9	143.9	143.9	143.9	176.3
Land 2	143.9	141.6	140.5	140.1	140.1	169.1
Land 3	106.1	102.3	137.3	123.9	134.0	157.3
Land 4	106.1	102.3	128.8	108.7	116.6	136.5
Double Crop 1	61.5	60.1	85.6	92.6	116.7	139.7
Double Crop 2	51.9	50.6	77.6	54.8	80.6	102.3
Double Crop 3	54.2	51.7	78.0	63.9	67.2	79.1
Double Crop 4	48.5	44.7	57.8	44.4	47.8	55.7

Table 3-32. Ratio of amount of water used to land and profit all by level of TDS, Palo Verde Irrigation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	425,018	4.465	45.87
1000	424,175	4.456	45.79
1100	423,787	4.452	45.32
1200	421,665	4.430	45.12
1300	419,299	4.405	44.72
1400	418,056	4.392	43.46

functions are presented in Table 3-33. Values appear to decline in greater increments as TDS rises (Figure 3-7). This is also evident with the ratio of net returns to total number of acres. Marginal values were derived from the differences between successive TDS levels beginning with 900 mg/l. Total derived damages for the TDS range in question are $1,326,909. These figures are presented in Table 3-34.

Table 3-33. Total and per acre net profit by TDS level, Palo Verde Irrigation District.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	19,497,011	204.82
1000	19,423,252	204.05
1100	19,204,357	201.75
1200	19,026,666	199.88
1300	18,752,243	197.00
1400	18,170,102	190.88

An exponential curve fit was chosen as more representative of the data in Table 3-34 than other curves applied to the same data. Estimated values for each corresponding observed value are also contained in the table. In addition, estimates were derived for the lower TDS levels of 700, 800, and 900 mg/l since salinity levels are lower at this point on the river. In the equation $Y = be^{mx}$ $b = 126.3069$, $e = 2.718281828$, $m = 0.006714$, and $x =$ any level of TDS within the range of analysis. Correlation was quite

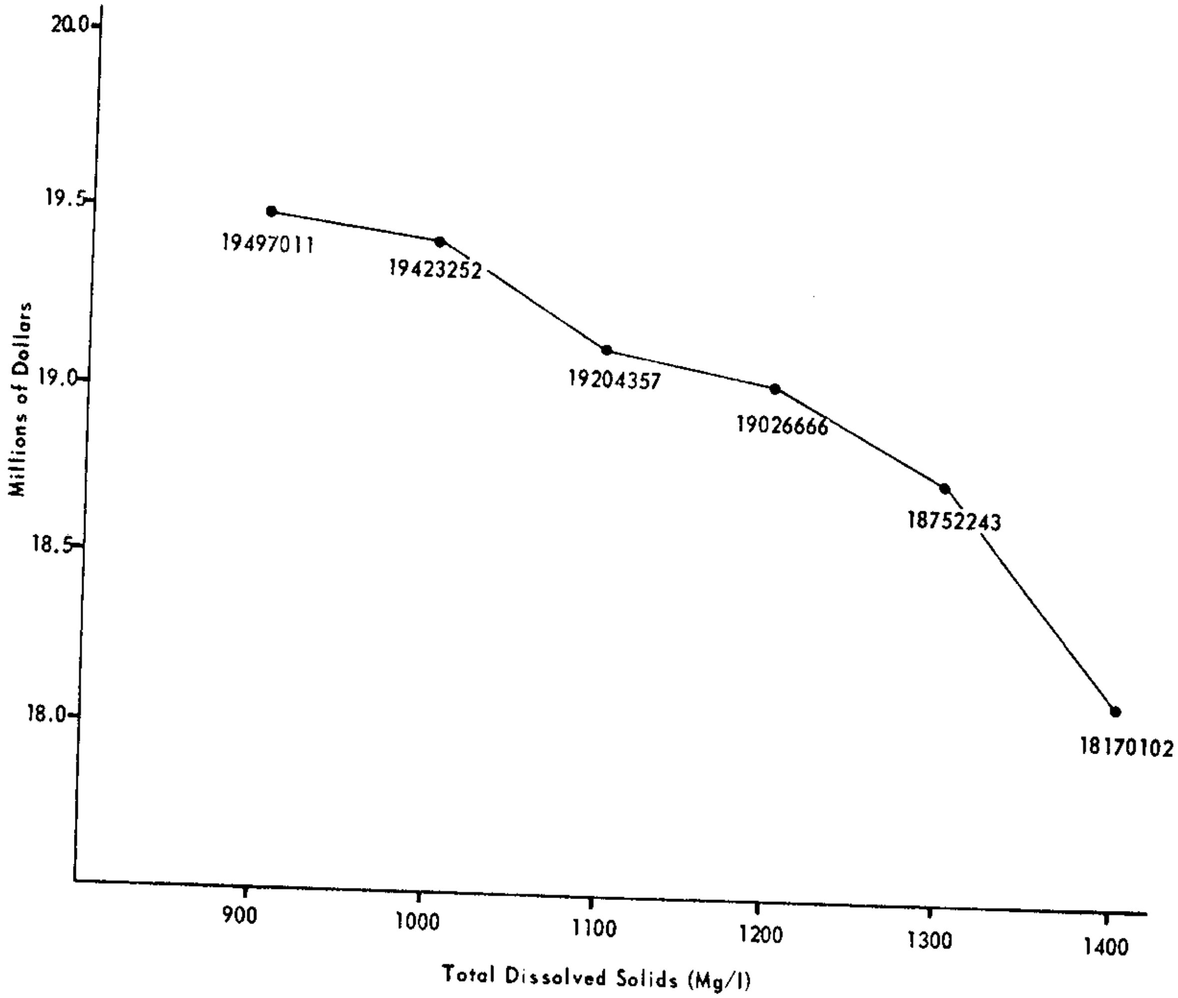


Figure 3-7. Total net profit by level of TDS, Palo Verde Irrigation District.

Table 3-34. Accumulated damage totals of observed data and predicted values by level of TDS, Palo Verde Irrigation District.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
700	–	13,881
800	–	27,165
900	–	53,159
1000	73,759	104,027
1100	292,654	203,572
1200	470,345	398,373
1300	744,768	779,581
1400	1,326,909	1,525,574

good as $R^2 = 0.94$. These values were used to derive Y corresponding to the different levels of TDS. Figure 3-8 illustrates the relationship between the values of the observed data and the predicted values. Within the TDS interval studied in this report, the function as represented above will be used to estimate monetary values of damages for the Palo Verde Irrigation District.

In summary, Table 3-35 lists some general indicators of expected damage. Total annual damages incurred are $1,326,909. Per acre damages derived from this figure are $13.94. For a one unit increase in TDS, annual damages are expected to increase $2,654. Finally, annual damages per mg/l per acre are

Table 3-35. Summary statistics, Palo Verde Irrigation District.

Total Acres	95,189
Double Cropped Acres	12,331
Annual Total Damages	$1,326,909
Annual Per Acre Damages	$ 13.94
Annual Damages Per mg/l	$ 2,654
Annual Damages Per mg/l Per Acre	$ 0.0279

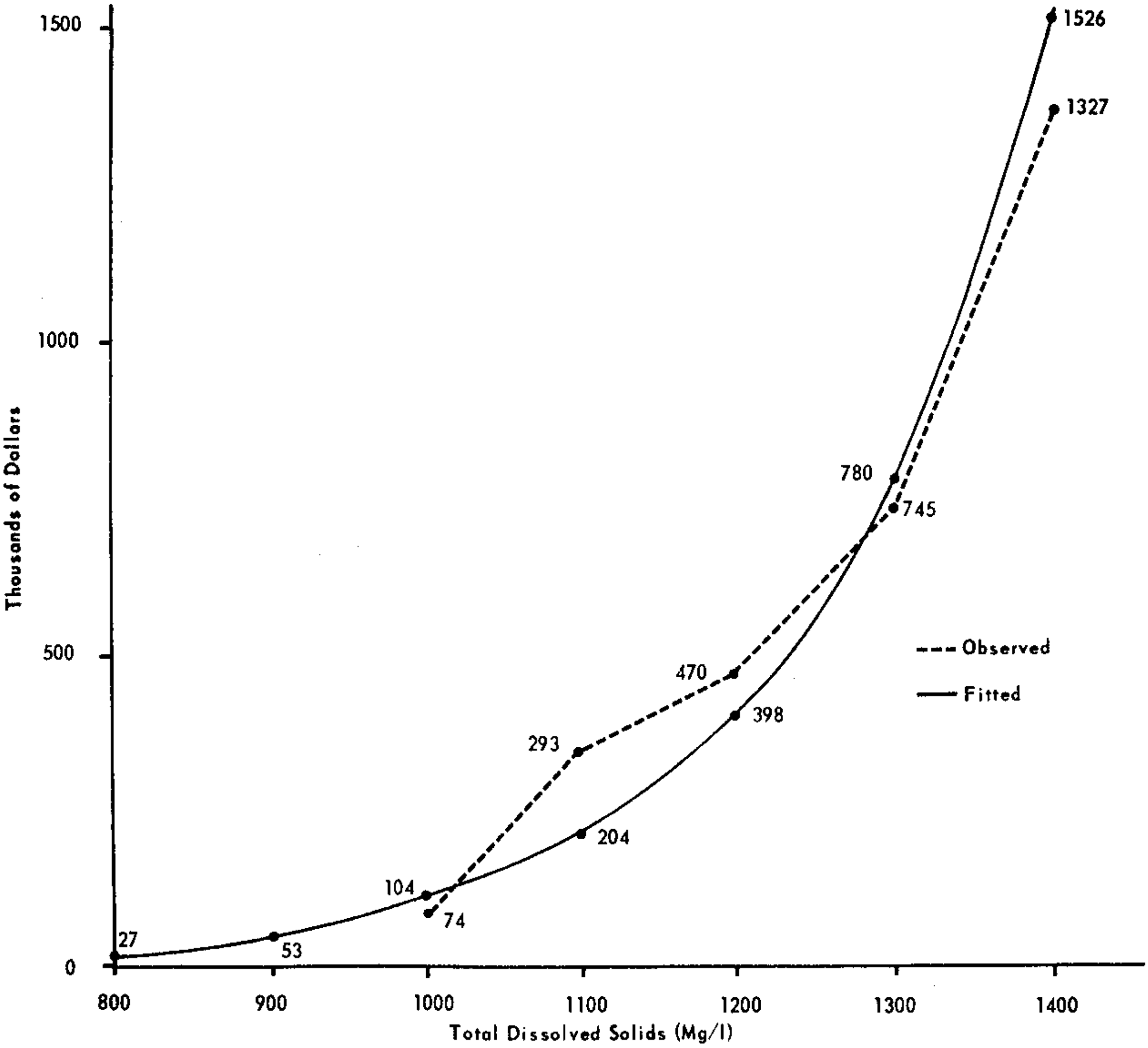


Figure 3-8. Observed data fitted damage function, Palo Verde Irrigation District.

estimated to be $0.0279 as an average value over the 500 mg/l range from 900 to 1400 mg/l.

COLORADO RIVER INDIAN RESERVATION

The Colorado River Indian Reservation is located up river from the Palo Verde District near Parker on the Arizona side of the Colorado River (see Map 3-4). Reclamation and development of arable lands is an ongoing process with the eventuality of cultivating around 105,000 acres at full development. However, for the period of this study, an estimated 63,000 acres were considered as in actual production. Lands were placed into three general classifications as presented in Table 3-36. Double cropping is gaining status in the area but still represents a small portion of total land use.

Table 3-36. Number of acres available for single and double cropping by land class, Colorado River Indian Reservation.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	32,226	3,158	37,384
Land 2 (Moderately Drained)	19,243	1,776	21,019
Land 3 (Poorly Drained)	9,279	856	10,135
Total	62,748	5,790	68,538

As development continues, the list of crops produced in this area will grow. At the present time, only a small number of crops are represented as shown by Table 3-37. The matrix of double cropping possibilities assumed for the area is also shown.

Table 3-38 shows the empirical data used in estimating average base yields. Damage estimates can be derived by a comparison of the effective soil saturation extract conductivity values in Table 3-39 to the declination percentages in Table 3-1 as has been the procedure in previous sections. Partial sprinkler, leaching, land leveling, special bedding, and irrigation frequencies were the management alternatives assumed to apply in the area. Special bedding and partial sprinkler mainly benefited speciality crops such as lettuce, cantaloupe, and onions, whereas leaching, land leveling, and irrigation frequencies significantly contributed to all crops in varying degrees. Full sprinkler irrigation and tiling were not selected by the model under any of the TDS assumptions due to availability of other more profitable alternatives.

In analyzing the various changes in land use and crop production found in Table 3-40, it is shown that the total amount of land remains constant. However, as salinity increases, different types and amounts of land use are selected by the model. As was evident in the previous areas, cotton emerges as having substantial tolerance to increasing levels of TDS. In this case, both amount of production and number of acres of intensive management practices need be applied in order to maintain yields as water quality deteriorates.

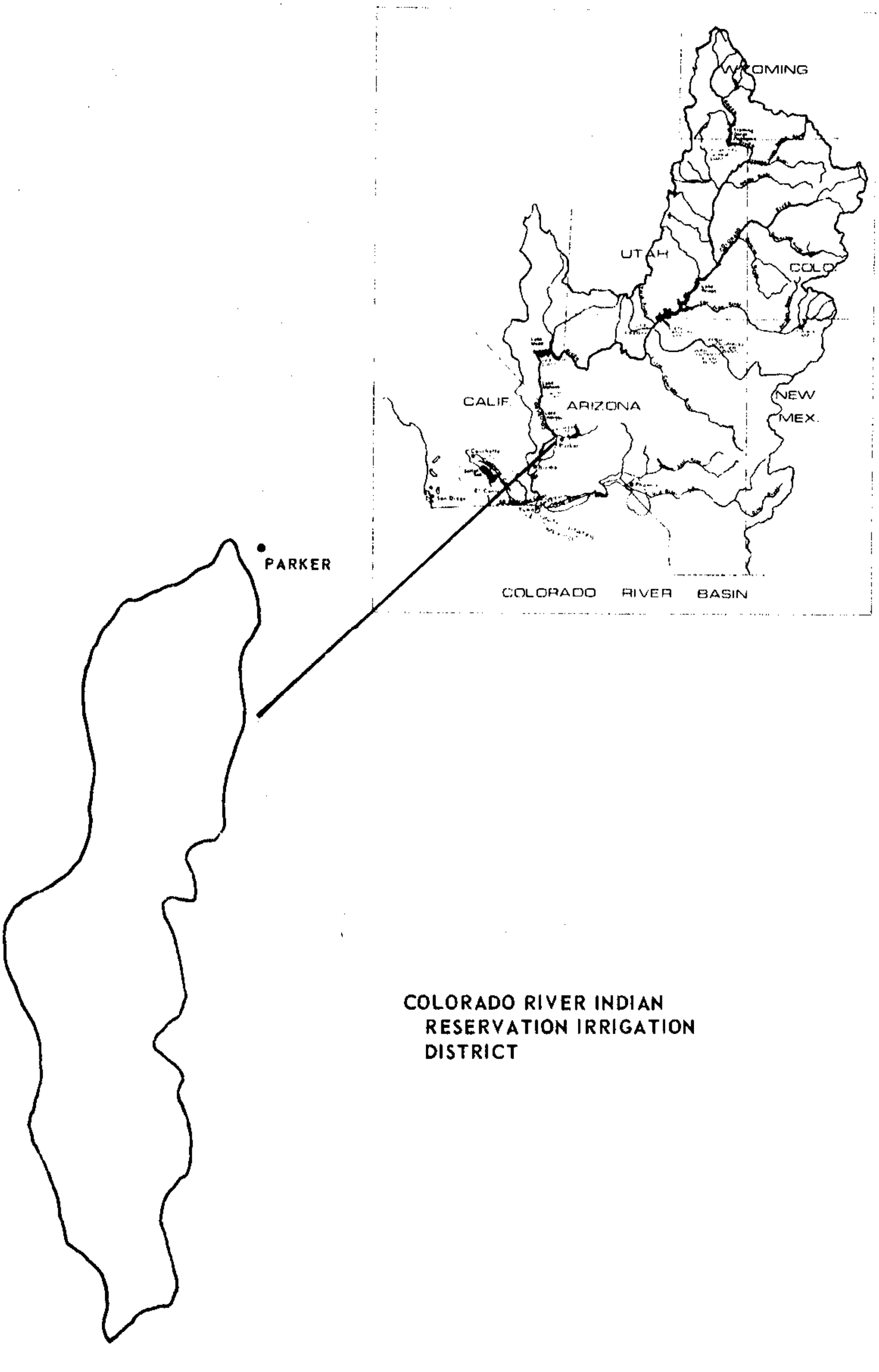
Production of alfalfa and wheat is impacted to a greater extent than cotton. With respect to both, land area and amount of production decline. Total production of sorghum, cantaloupe, lettuce, and onions is constant while land area increases in order to maintain these output levels as yield declines.

Management activities, mainly irrigation frequencies, are the cause of what appear to be irregular patterns of land use in the case of cantaloupe. Between 900 mg/l TDS and 1000 mg/l TDS, land area increases as production remains constant. However, from 1100 mg/l TDS to 1400 mg/l TDS, land use is utilized at a lesser amount than was required even at the 900 mg/l TDS level. Being that production remains constant throughout the entire range, one would expect land area to increase. This trend only occurs for two TDS levels, 900 and 1000 mg/l TDS. At these levels of TDS, cantaloupe is produced on class 2 and class 3 land with the majority placed on the latter. Upon reaching 1100 mg/l TDS, it becomes more profitable (also in

Table 3-37. Selected crops and double cropping possibilities, Colorado River Indian Reservation.

Crops	Double Cropping Possibilities[a]				
	Wheat	Cantaloupe	Lettuce	Onion	Sorghum
Alfalfa					
Cotton			x		
Wheat					
Sorghum	x	x	x	x	x
Cantaloupe	x	x	x		x
Lettuce	x	x	x	x	x
Onion					

[a] Crops under these columns are those assumed to lead in the double cropping rotation.



Map 3-4. Colorado River Indian Reservation Irrigation District, Arizona.

Table 3-38. Yields of major crops in the Colorado River Indian Reservation, 1969-1973 (tons/acre).

Crop	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa	8.00	8.00	8.00	8.25	8.50	8.15 ± 0.28
Cotton	2.75	2.25	2.25	2.75	3.00	2.60 ± 0.42[a]
Wheat	1.80	2.25	2.10	2.40	2.80	2.27 ± 0.46
Grain Sorghum	1.50	1.50	2.04	2.00	1.60	1.73 ± 0.34
Cantaloupe	8.75	8.75	10.50	8.75	12.25	9.80 ± 1.94
Lettuce	14.00	21.00	17.50	17.50	13.30	16.66 ± 3.86
Onions	15.00	18.00	11.50	12.00	8.30	12.96 ± 4.58

[a] 480-pound bales per acre.

Source: Annual irrigation crop report No. 55-13F. Branch of Land Operations, Bureau of Indian Affairs, USDI.

relation to the rest of crops) to move the entire production onto class 2 land. Since yield is higher for a larger portion of the amount produced, less land is needed. Variation in irrigation management occurs as TDS rises in order to maintain yield. At slightly higher costs for these more intensive operations, yields are held at the same level as is land area and production. The major changes are reflected in profit. A detailed illustration is contained in sub-Appendix D concerning land use and production patterns for cantaloupe as well as for the other crops.

Table 3-39. Effective values of soil saturation extract conductivities in three soil drainage classes, six TDS levels, and five irrigation management treatments, Colorado River Indian Reservation.

TDS (mg/l)	Irrigation Number	Drainage Classification		
		Well	Moderate	Poor
900	16	0.4	2.0	4.3
	22	0.4	1.4	3.7
	29	0.4	1.1	3.4
	35	0.4	0.7	3.0
	Sprinkler	0.0	0.0	2.1
1000	16	0.7	2.4	5.0
	22	0.7	1.7	3.0
	29	0.7	1.5	4.0
	35	0.7	1.0	3.5
	Sprinkler	0.0	0.2	2.7
1100	16	0.9	2.9	5.7
	22	0.9	2.1	4.9
	29	0.9	1.8	4.6
	35	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3
1200	16	1.2	3.3	6.3
	22	1.2	2.4	5.4
	29	1.2	2.1	5.1
	35	1.2	1.5	4.5
	Sprinkler	0.0	0.8	3.8
1300	16	1.5	3.8	7.0
	22	1.5	2.8	6.1
	29	1.5	2.5	5.7
	35	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
1400	16	1.7	4.2	7.7
	22	1.7	3.2	6.7
	29	1.7	2.8	6.3
	35	1.7	2.1	5.6
	Sprinkler	0.4	1.5	5.0

Source: Adapted from Robinson, F. E., Appendix 2, Table 2-8.

Shadow prices derived from the model are contained in Table 3-41. For the single cropped land classes, land values increase as we ascend the range. These lands are in greater demand as TDS rises. Little distinction develops among land classes until 1300 and 1400 mg/l TDS levels are obtained. At these levels, class 3 differs slightly from the other two classes which indicated that differences in soils can be partially made up for by specific management alternatives. More important though, is the fact that under the assumed conditions for this area as compared to areas such as Imperial Valley and Palo Verde, the "threshold of incurrence" of major damages is reached at higher levels of TDS.

Water diversions follow the same procedure as in Palo Verde, that is, credit is given for return flows. However, maximum net depletion was set at 485,400 ac ft. This figure is larger than the water constraint used for Palo Verde which has about 33 percent more area under cultivation. Though the figure is large for present circumstances, it has been established in anticipation of full development and therefore was used as the upper water constraint in the model.

Consumptive use of water totals contained in Table 3-42 is greatly influenced by alfalfa due to its relatively high consumption per acre. Significant decreases in alfalfa production and land use cause the total amount of water consumed for the area to decrease to 1300 mg/l TDS. When alfalfa acreage and production remain constant between 1300 and 1400 mg/l TDS, total water use rises due to increased demands by the other crops. At lower levels, such increased demands for water are overshadowed by the large decrease in demand from alfalfa.

Objective function results indicate that some economic losses are incurred over the 900 to 1400 mg/l TDS range. Table 3-43 illustrates that profits per acre appear to decline at an increasing rate. Total damages are estimated to be $378,000. Figure 3-9 portrays the

Table 3-40. Cropping and production pattern changes, Colorado River Indian Reservation.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	198,630	24,372	198,353	24,338	197,437	24,225	197,138	24,189	195,978	23,985	195,478	23,985
Cotton[a]	41,245	15,864	41,245	15,864	41,245	15,864	41,245	15,864	41,245	15,864	41,245	15,864
Wheat	33,794	14,887	33,794	14,887	33,794	14,887	33,794	14,887	33,794	14,876	33,080	14,607
Sorghum	8,091	4,677	8,091	4,677	8,091	4,875	8,091	4,895	8,091	4,919	8,091	4,944
Cantaloupe	10,830	1,157	10,830	1,191	10,830	1,105	10,830	1,105	10,830	1,105	10,830	1,105
Lettuce	105,693	6,344	105,693	6,344	105,693	6,344	105,693	6,361	105,693	6,539	105,693	6,758
Onions (Dry)	16,043	1,238	16,043	1,238	16,043	1,238	16,043	1,238	16,043	1,250	16,043	1,276
Total		68,539		68,539		68,539		68,539		68,539		68,539

[a] 480-pound bales.

Table 3-41. Shadow prices of land by class and level of TDS, Colorado River Indian Reservation.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	178.9	178.9	178.9	178.9	204.2	204.2
Land 2	178.9	178.9	178.9	178.9	204.2	204.2
Land 3	178.9	178.9	178.9	178.9	202.8	201.9
Double Crop 1	178.9	178.9	178.9	178.9	204.2	204.2
Double Crop 2	172.5	171.7	171.7	155.1	165.2	153.7
Double Crop 3	142.8	125.0	113.6	107.3	119.0	99.7

Table 3-42. Ratio of amount of water used to land and profit all by level of TDS, Colorado River Indian Reservation.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	369,061	5.384	46.25
1000	368,906	5.382	46.21
1100	368,590	5.378	46.23
1200	368,493	5.376	46.19
1300	368,030	5.370	45.86
1400	368,348	5.374	45.30

Table 3-43. Total and per acre net profit by TDS level, Colorado River Indian Reservation.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	17,066,111	249.00
1000	17,048,435	248.74
1100	17,038,692	248.60
1200	17,021,259	248.34
1300	16,877,843	246.25
1400	16,687,877	243.48

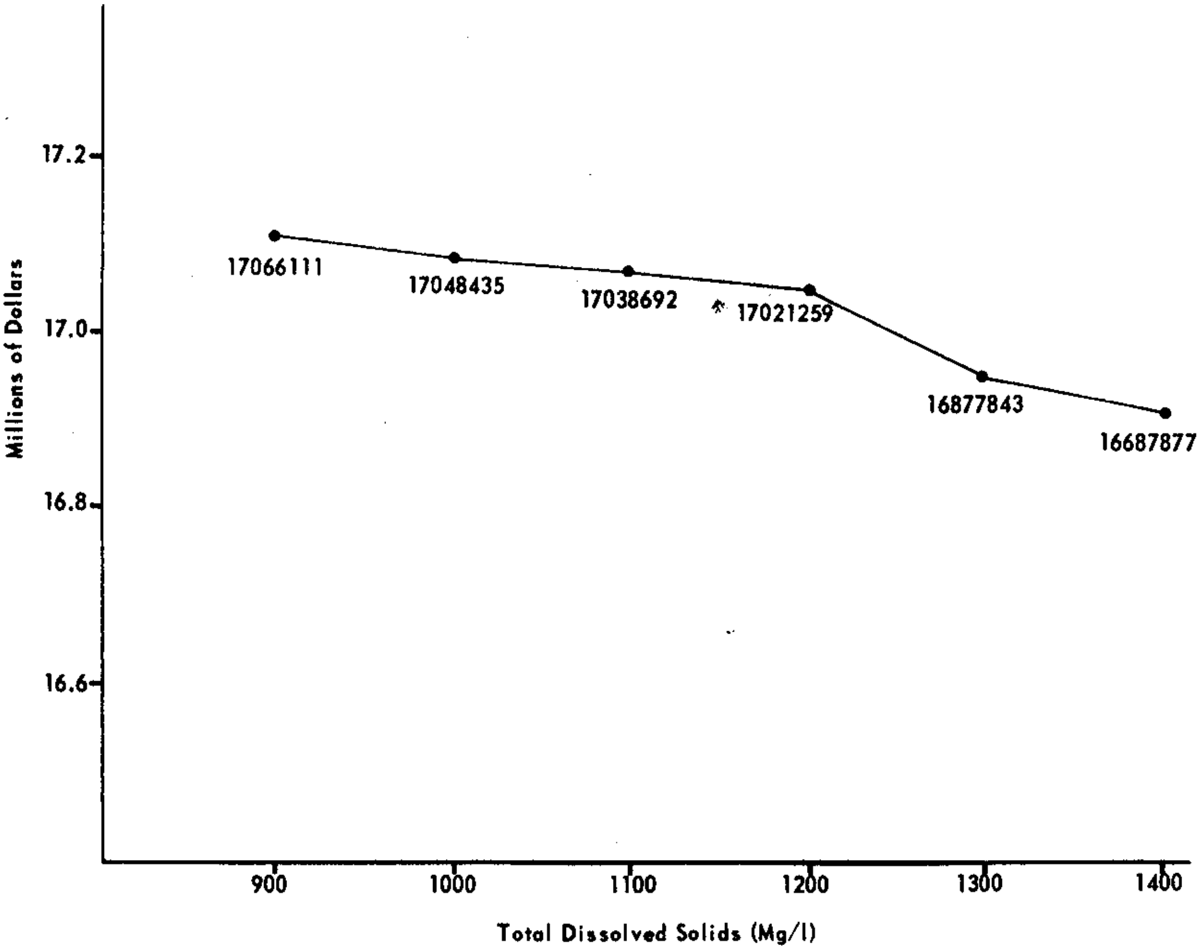


Figure 3-9. Total net profit by level of TDS, Colorado River Indian Reservation.

shape of the net profit function for the various TDS levels.

Differences between objective functions were derived and placed in Table 3-44. In addition, predicted values are presented which pertain to the exponential function $Y = be^{mx}$, where $b = 4.3750$, $e = 2,718281828$, $m = 0.008053$, and $x =$ any TDS level. These two sets of data are plotted (Figure 3-10) in order to better observe how well the estimated function fits the observed data points. The fit is good with $R^2 = 0.95$. This function will be used in estimation of economic impacts resulting from rising salinity.

Table 3-44. Accumulated damage totals of observed data and predicted values by level of TDS, Colorado River Indian Reservation.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
800	–	2,748
900	–	6,148
1000	17,676	13,755
1100	27,419	30,775
1200	44,852	68,857
1300	188,268	154,063
1400	378,234	344,704

In summary, the model employs 68,538 acres of cropland with 5,790 acres of that total considered available for purposes of doubling cropping. Per annum total damages to the district as a whole as derived by the model are $378,234. Annual per acre damages are $5.52. An average of $756.50 is incurred for each milligram per liter (mg/l) within the range of 900 mg/l to 1400 mg/l. Finally, annual damages per mg/l per acre are set at $0.011 which represents an average for the range in question. These data are summarized in Table 3-45.

Table 3-45. Summary statistics, Colorado River Indian Reservation.

Total Acres	68,538
Double Cropped Acres	5,790
Annual Total Damages	$378,234
Annual Per Acre Damages	$ 5.52
Annual Damages Per mg/l	$ 756.50
Annual Damages Per mg/l Per Acre	$ 0.0110

CALIFORNIA COASTAL REGION

The Colorado River Aqueduct delivers water to agricultural lands near the California coast. Many producing areas receive water from this source. In attempting to account for agricultural use of Colorado River water, emphasis is focused on the area between Los Angeles and San Diego (Map 3-5).

All Colorado River water used in the coastal areas is pumped through the Colorado Aqueduct of the Metropolitan Water District of Southern California (MWD). The water is distributed to the 27 members of the MWD. These members further distribute water to smaller divisions within their boundaries. The San Diego County Water Authority, for example, is one of the 27 members of MWD and has 22 constituent cities and districts within its boundary (Burzell, 1973; Monroe, 1972).

In addition to the water from the MWD, the 27 members have locally developed water which presently constitutes 63 percent of the water used in the MWD area (Monroe, 1972). The local water is pumped from subsurface aquifiers, transported from outside the MWD area, and/or collected in reservoirs from surface or stream flow (Brown, 1974).

Rainfall within the coastal area varies from 5 to 20 inches in the lower elevations and from 20 to 70 inches in the higher elevations (Close et al., 1970). Most of the agricultural areas are within a 10 to 15 inch rainfall zone (Bowman, 1973).

Agricultural yield records do not segregate crop yields as to whether they were irrigated with local water or with Colorado River water (Little, 1973). In some areas the locally produced water is used first and then Colorado River water is used. In other areas, the local and Colorado River water are stored in the same reservoir (Brown, 1974).

In 1972, the MWD took first delivery of water from the California State Project. This source of water is scheduled to increase eventually to 2 million ac ft annually. In the meanwhile, the Central Arizona Project will claim an entitlement to Colorado River water so that the MWD supply will be reduced to 550,000 ac ft per year. Of this amount, 100,000 ac ft may be utilized in the production of power. The remaining water will be blended in varying degrees with local and state water (Clinton, 1973; Lauten, no date).

Use of Colorado River water for agriculture has remained around 150,000 ac ft per year (Monroe, 1972). The agencies using this water in large quantity are the San Diego County Water Authority, 73,117 ac ft; Western MWD of Riverside County, 33,713 ac ft; Eastern MWD, 29,620 ac ft; and MWD of Orange County, 31,470 ac ft (Monroe, 1972). With the exception of the San Diego County Water Authority Aqueduct No. 1, these areas will have 50 percent blended state water available. In the mid or late 1980s, the blend will move to 75 percent state water. With 50 percent Colorado River water the TDS could move to 1,230 mg/l when mixing with 250 mg/l state water without increasing the TDS in the blend beyond the present 740 mg/l. In a 25 percent Colorado River water blend, TDS could achieve 2,210 mg/l without altering the content of the resulting mix. The cost to the agricultural economy receiving the blended water will be the increased price since there will probably be no reduction in yield due to salinity increase above the present value.

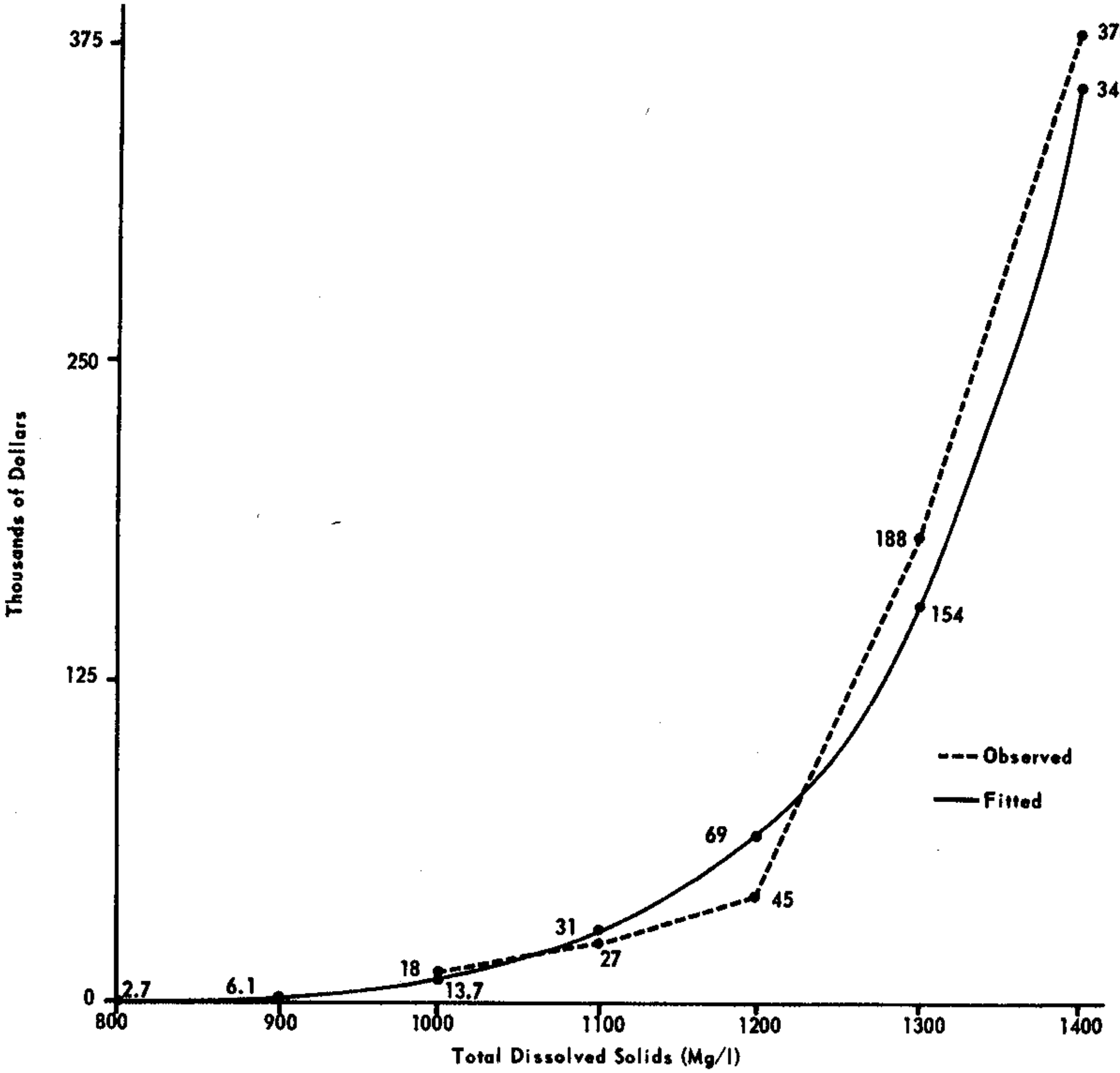


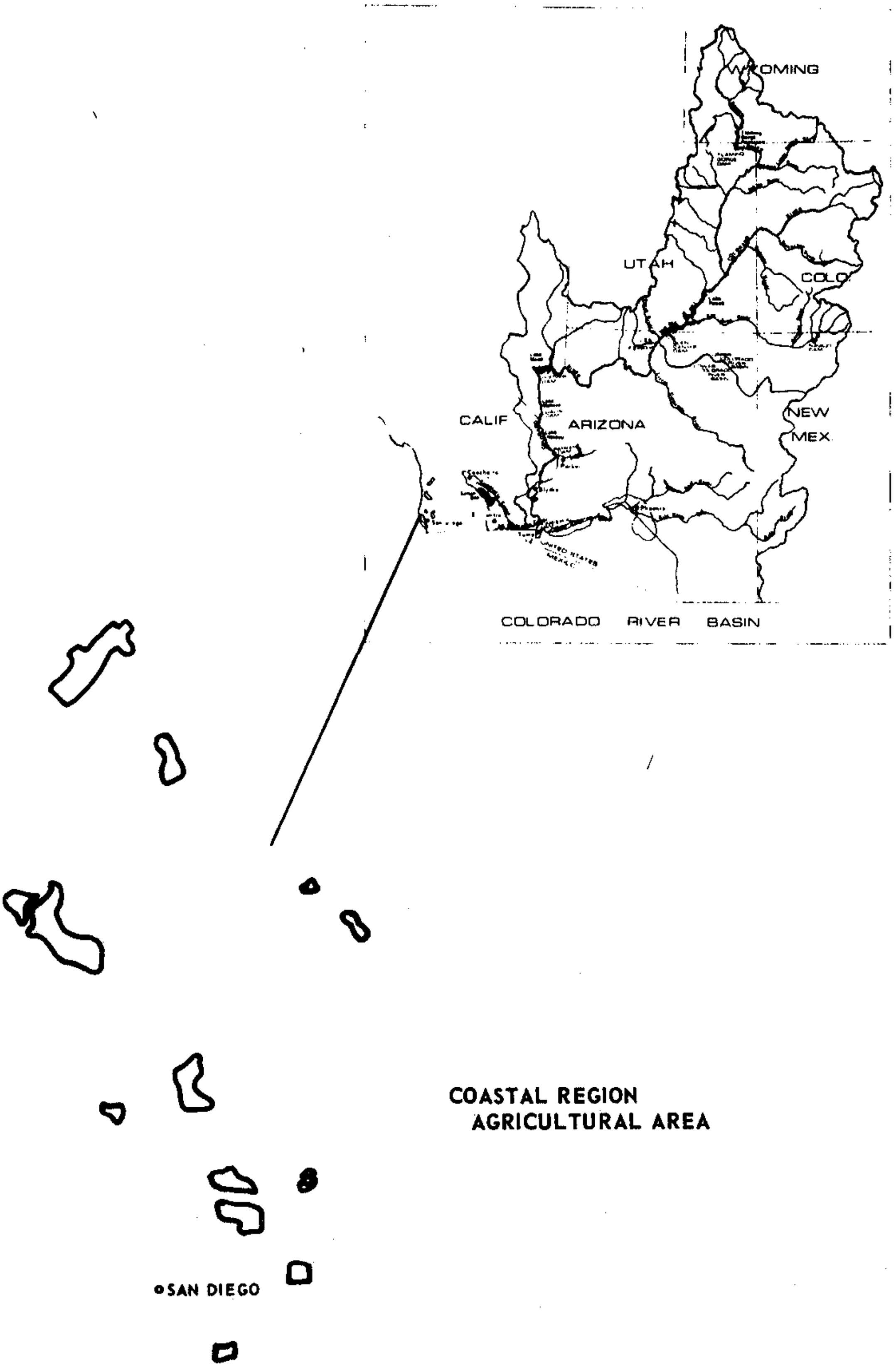
Figure 3-10. Observed data with fitted damage function, Colorado River Indian Reservation.

Determination of yield effects of increased salinity in the coastal area then narrows to the region served by the first San Diego Aqueduct with a capacity of 190 ft^3/s. The second San Diego Aqueduct has pipeline No. 3 with a capacity of 250 ft^3/s and pipeline No. 4 with a capacity of 380 ft^3/s. Pipelines No. 3 and 4 will have blended state water available in 1975. As presently planned, pipelines No. 1 and 2 of the first aqueduct are to have Colorado River water exclusively until 1980-1985 (Montgomery, 1974). Metropolitan Water District of Southern California indicates plans to supply blended water to pipelines No. 1 and 2 by 1987-1988 which is the same time that the blend will go to 75 percent state water (Clinton, 1973).

Date developed in this study of yield declination will apply only to unblended water. The assumption made is that the irrigation water is unsoftened Colorado River water.

Some 35,000 acres are included in the analysis as shown in Table 3-46. No double cropping alternatives were established due to the perennial nature of many crops. However, several specialty crops such as tomatoes and strawberries do have double cropping possibilities. Nevertheless, estimations of this type of land use are varied and overall, the number of acres is small; therefore the model considers only single cropped land classes.

A list of selected crops is presented in Table 3-47 along with empirical yield data. Mean yields for the San Diego County area were obtained from the Agricultural Commissioner Reports 1968-1973 (Little, 1973). Comparison of effective values of soil saturation



Map 3-5. California Coastal Region.

Table 3-46. Number of acres available for single and double cropping by land class, California Coastal Region.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	9,054	–	9,054
Land 2 (Moderately Drained)	17,739	–	17,739
Land 3 (Poorly Drained)	8,028	–	8,028
Total	34,821		34,821

Table 3-48. Effective values of soil saturation extract conductivities in three drainage classifications, three management systems, and six TDS contents of water. (Appendix 2, Table 2-48.)

TDS (mg/l)	Irrigation Method	Drainage Classification		
		Well	Moderately	Poor
900	Surface	0.4	0.7	3.0
	Sprinkler	0.0	0.0	2.1
	Trickler	–	–	0.3
1000	Surface	0.7	1.0	3.5
	Sprinkler	0.0	0.2	2.7
	Trickler	–	–	0.5
1100	Surface	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3
	Trickler	–	0.6	0.6
1200	Surface	1.2	1.5	4.5
	Sprinkler	0.0	0.8	3.8
	Trickler	–	0.8	0.8
1300	Surface	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
	Trickler	–	0.9	0.9
1400	Surface	1.7	2.1	5.6
	Sprinkler	0.4	1.5	5.0
	Trickler	–	1.1	1.1

extract conductivities in Table 3-48 to declination intervals in Table 3-1 resulted in percentage estimations of yield decreases. This process was used to formulate a yield declination curve for each crop.

Several new terms also appear in Table 3-48. Surface irrigation salinity is taken from the 35 irrigation per year assumption explained earlier in the report. The rationale was that 10 to 15 inches of rain would have a diluting effect similar to additional irrigations. Sprinkler values are the same as previously used. Production and land use are practically unchanged over the 900 to 1400 mg/l range (Table 3-49). The only major change occurs between 900 mg/l and 1000 mg/l where avocado production and land use both increase slightly. The new trickle or drip method of irrigation experiencing rapid expansion in this area (Valley Center Municipal Water District, 1973) appears to deliver water to root systems at the same concentration as the irrigation water. Effective salinity is reduced 1 mmho/cm below the irrigation water value because the $CaSO_4$ would have no harmful effect and rainfall would provide dilution and leaching (Hall, 1971). The first trials of trickle systems support this usage (Valley Center Municipal Water District, 1973; Hall, 1971; 1973). At the same time, land area occupied by spring tomatoes is decreased by 5 acres while production remains constant. Shifting tomato production from class 3 land to class 2 land due to a yield decrease on the former, results in having a higher initial yield thus requiring less acreage. The five additional acres, released by spring tomatoes are allocated to avocados which account for rises in both production and land area.

Even though total production amounts and land use are relatively constant, the model still varies its crop allocation among the respective land classes and technologies. Sub-Appendix E should be consulted for more information on this adjustment process.

Table 3-47. Yields of major crops in the California Coastal Region, 1968-1973 (tons/acre).

Crop	Year						Mean
	1968	1969	1970	1971	1972	1973	
Avacadoes	1.7	3.2	1.7	3.0	1.5	3.5	2.43 ± 0.94
Citrus							
Grapefruit	10.0	12.0	21.0	7.8	12.9	17.4	13.5 ± 5.12
Lemon	15.4	10.6	16.5	20.0	16.2	24.0	17.7 ± 4.75
Lime	10.0	6.5	8.2	14.0	11.0	14.0	10.6 ± 3.19
Orange, Navel	7.3	11.0	8.8	6.2	6.7	7.2	7.87 ± 1.85
Orange, Valencia	5.9	7.4	6.6	8.8	10.3	7.0	7.67 ± 1.69
Tangerine	-	–	7.7	10.7	10.5	17.4	11.6 ± 6.55
Strawberry	17.0	15.0	17.2	19.0	21.0	21.0	18.4 ± 2.52
Potato	12.0	16.0	21.0	18.0	22.0	20.0	18.2 ± 3.89
Tomato							
Spring	20.1	25.4	24.1	20.5	27.8	36.8	25.8 ± 6.45
Fall	18.7	22.2	16.6	16.0	19.4	24.5	19.6 ± 3.44
Summer	–	–	–	13.0	33.6	36.0	27.5 ±31.41

Source: Office of Agricultural Commissioner, San Diego, California. (Appendix 2, Table 2-46.)

Table 3-49. Cropping and production pattern changes, California Coastal Region.

Crops	Total Dissolved Solids (mg/l) 900 Production (Tons)	900 Land Use (Acres)	1000 Production (Tons)	1000 Land Use (Acres)	1100 Production (Tons)	1100 Land Use (Acres)	1200 Production (Tons)	1200 Land Use (Acres)	1300 Production (Tons)	1300 Land Use (Acres)	1400 Production (Tons)	1400 Land Use (Acres)
Avocado	40,635	14,554	40,648	14,559	40,648	14,559	40,648	14,559	40,648	14,559	40,648	14.559
Summer Tomato	10,862	395	10,862	395	10,862	395	10,862	395	10,862	395	10,862	395
Fall Tomato	83,667	4,269	83,667	4,269	83,667	4.269	83,667	4,269	83,667	4,269	83,667	4,269
Spring Tomato	39,613	1,540	39,613	1,535	39,613	1,535	39,613	1,535	39,613	1,535	39,613	1,535
Lemon	38,265	2,162	38,265	2,162	38,265	2,162	38,265	2,162	38,265	2,162	38,265	2,162
Lime	2,978	281	2,978	281	2,978	281	2,978	281	2,978	281	2,978	281
Navel Orange	7,020	892	7,020	892	7,020	892	7,020	892	7,020	892	7,020	892
Valencia Orange	63,036	7,860	63,036	7,860	63,036	7,860	63,036	7,860	63,036	7,860	63,036	7,860
Tangerine	10,040	866	10,040	866	10,040	866	10,040	866	10,040	866	10,040	866
Grapefruit	6,150	456	6,150	456	6,150	456	6,150	456	6,150	456	6,150	456
Potato	13,867	762	13,867	762	13,867	762	13,867	762	13,867	762	13,867	762
Strawberries	14,452	785	14,452	785	14,452	785	14,452	785	14,452	785	14,452	785
Total		34,821		34,821		34,821		34,821		34,821		34,821

Table 3-50 contains the shadow prices generated for each land class by the model. Upon reaching 1400 mg/l, the values of land classes 2 and 3 decline. Elsewhere, no change can be detected from the initial values established at 900 mg/l. The water quality range of 900-1400 mg/l appears to be too confining for development of a conclusive trend for this parameter.

Based on average diversions, the total amount of water available to the area for agricultural use is 150,000 ac ft. This is the amount of unblended Colorado River water distributed by pipelines No. 1 and 2 of the San Diego County Water Authority Aqueduct No. 1. Total water consumption decreases by less than 1000 ac ft over the entire interval as indicated by Table 3-51. Specific notice should be taken of the values derived for the net profit/total water consumption ratio.

At 1200, 1300, and 1400 mg/l profits are larger than the initial value per acre foot consumed. Within the 1100-1200 mg/l interval the model shifts strawberry production from furrow irrigation to full sprinkler due to yield damages suffered by the former technology. Slightly more than an acre foot of water is required for furrow irrigation than required by sprinkler irrigation resulting in an overall decrease of some 920 ac ft. Since net profits are approximately 1 percent lower while water consumption is over 25 percent less, efficiency per net dollar of profit increases. Up to 1200 mg/l furrow irrigation is more profitable in dollar terms but less efficient in water use. Net profit is the overriding factor in the model and therefore receives top consideration in allocation decisions. Under alternative sets of assumptions where, for example, water supply is restricted so that emphasis is placed on efficient use, different consumption figures would result. However, total profits to the area as a whole would be decreased. Model assessment of current conditions estimate that about 86 percent of total water available to agriculture is put to efficient, productive use.

Table 3-52 contains the resulting objective function values for the different TDS levels. Decreases are incurred in three distinct steps with major damages occurring between 1300-1400 mg/l. The magnitude of the respective decreases can be viewed in Figure 3-4, as the results are plotted over the interval in question.

Table 3-51. Ratio of amount of water used to land and profit all by level of TDS, California Coastal Region.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	129,312	3.714	175.93
1000	129,302	3.713	175.91
1100	129,302	3.713	175.91
1200	128,383	3.687	177.13
1300	128,383	3.687	177.13
1400	128,383	3.687	176.66

Table 3-52. Total and per acre net profit by TDS level, California Coastal Region.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	22,749,771	653.33
1000	22,746,025	653.23
1100	22,746,025	653.23
1200	22,740,158	653.06
1300	22,740,158	653.06
1400	22,680,497	651.35

Table 3-53. Accumulated damage totals of observed data and predicted values by level of TDS, California Coastal Region.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
900	–	813
1000	3,746	3,159
1100	3,746	5,506
1200	9,613	7,853
1300	9,613	10,200
1400	69,274	69,274

Estimation of a representative damage function proved to be more difficult than for other areas due to the nature of the data. As can be seen in Table 3-53, damage increments emerge in three separate stages. Because of the large difference between 1300 and 1400 mg/l, low correlation coefficients were encountered when attempting to fit one of the more common functions to the data. It was therefore elected to combine information derived from two separate linear regression equations in order to more accurately assimulate the situation.

Table 3-50. Shadow prices of land by class and level of TDS, California Coastal Region.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	556.6	556.6	556.6	556.6	556.6	556.6
Land 2	556.6	556.6	556.6	556.6	556.6	548.1
Land 3	548.1	548.1	548.1	548.1	548.1	539.7

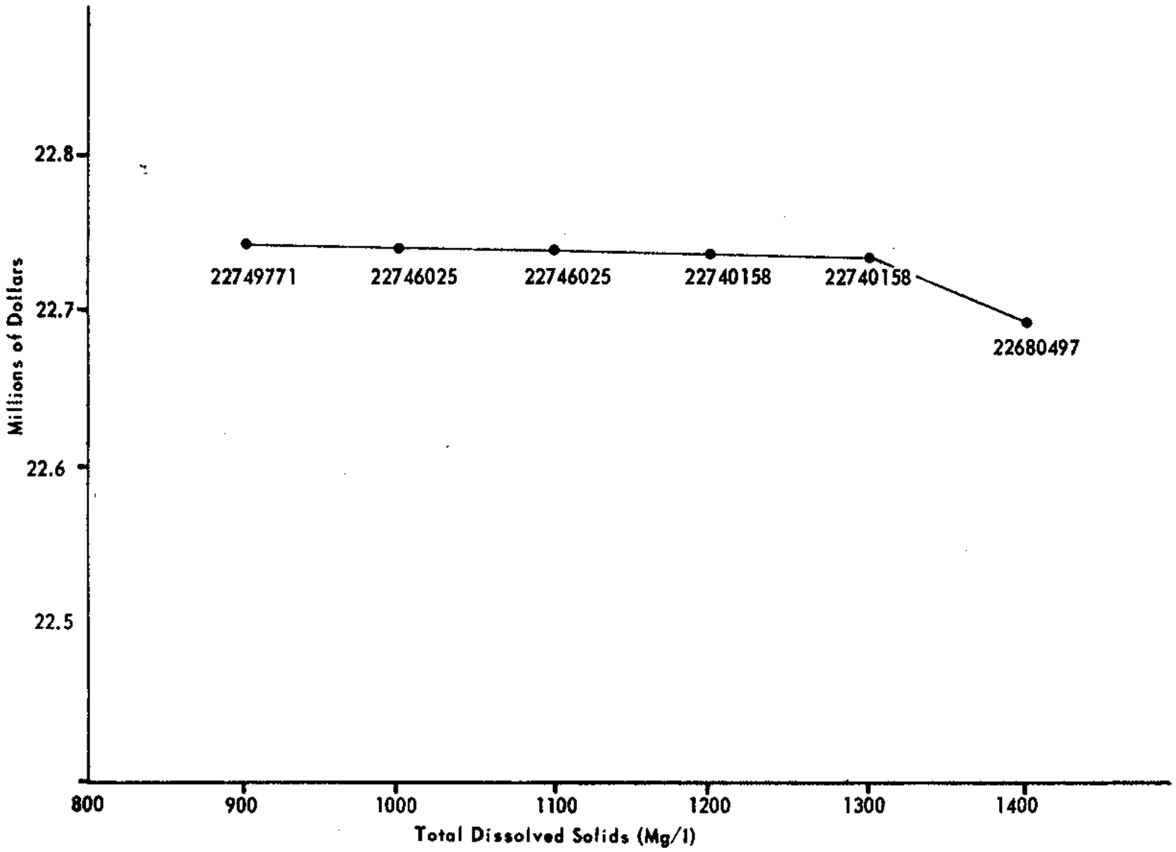


Figure 3-11. Total net profit by level of TDS, California Coastal Region.

The first equation is estimated from the observed data points corresponding to 1000, 1100, 1200, and 1300 mg/l, respectively. A general form of the equation is Y = mX + b, where Y = the dependent variable, m = slope of the straight line, b = the value of Y when X=? ("Y-intercept"), and X = any value of TDS between 900 and 1400 mg/l. Pertinent values derived from the data were, m = 23.4680 and b = -20,308.70.

The second equation derived by using the predicted value for 1300 mg/l of $10,200 and fitting a line from that point to the observed point for 1400 mg/l. Equational values resulted in having m = 590.74 and b = -757,762. A graphical view of how these two equations are used to estimate damage values over the appropriate TDS interval is contained in Figure 3-12.

Summarizing the impacts for this area we find that annual total damages sum to $69,274 (Table 3-54). Annual per acre damages are $1.99 and annual damages per mg/l are $138.55. Results indicate that for a one unit increment in TDS, additional costs incurred per average acre in the area will be $0.00398. This is not a large figure when compared to other study regions, however, trickle irrigation is a rapidly expanding technology and therefore diminishes a certain amount of damages which would otherwise be incurred.

Table 3-54. Summary statistics, California Coastal Region.

Total Acres	34,821
Double Cropped Acres	0
Annual Total Damages	$ 69,274
Annual Per Acre Damages	$ 1.99
Annual Damages Per mg/l	$ 138.55
Annual Damages Per mg/l Per Acre	$0.00398

WELLTON-MOHAWK IRRIGATION DISTRICT

Sitauted in southwestern Arizona, the Wellton-Mohawk Irrigation District receives water from the Colorado River by way of Imperial Dam (Map 3-6). Estimates place the cultivated land area at about 68,000 acres. For purposes of the model, Table 3-55 places the total number of acres into three classes and two potential uses (single or double cropping).

Table 3-56 lists the crops selected for consideration by the model. The selection was based on crops having $1 million or more in terms of gross value of production (1974). In addition, possible double cropping combinations are also presented.

In Table 3-57, the average base yields used for this area are shown. Citrus production is not extensive

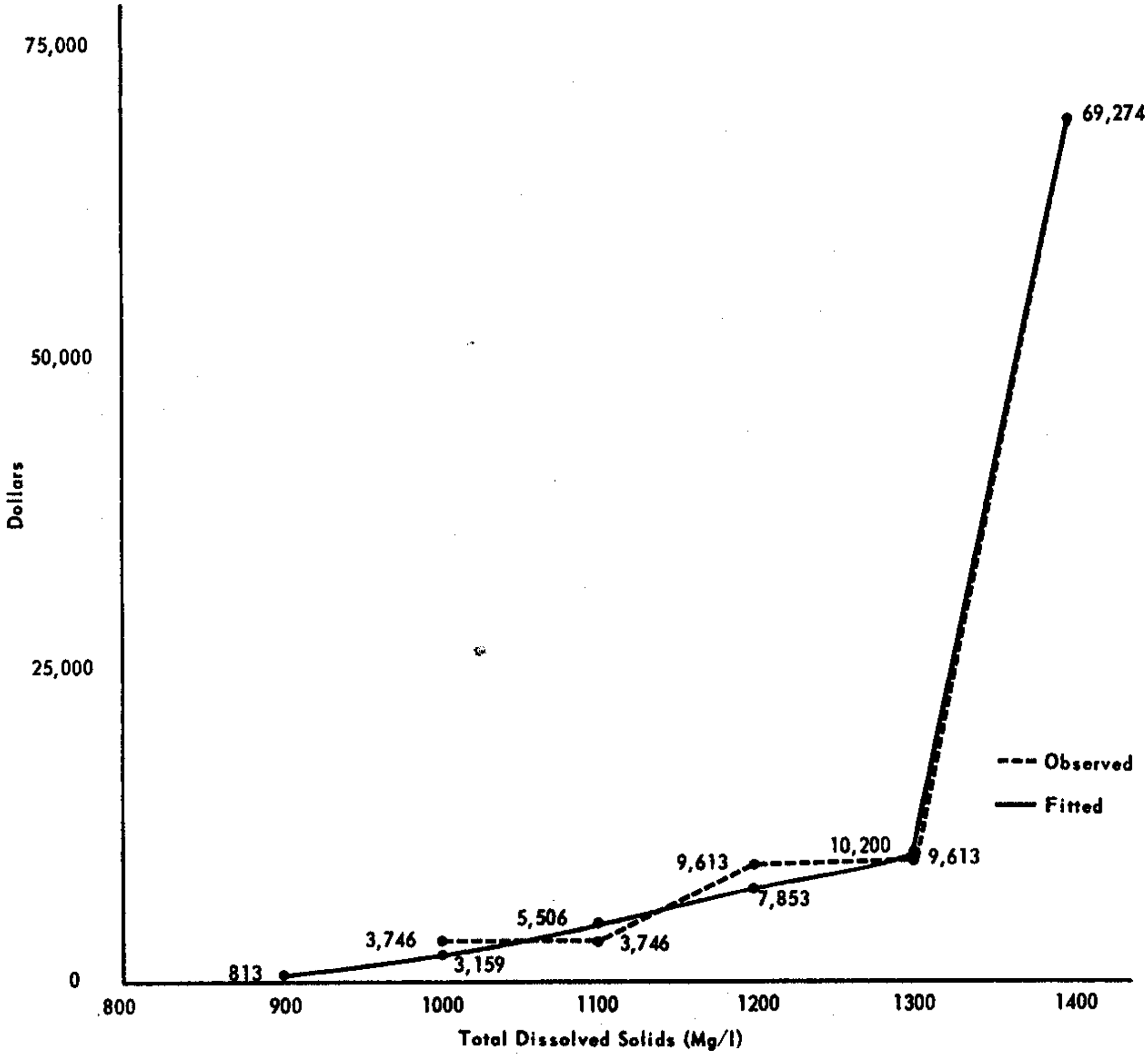


Figure 3-12. Observed data with fitted damage function, California Coastal Region.

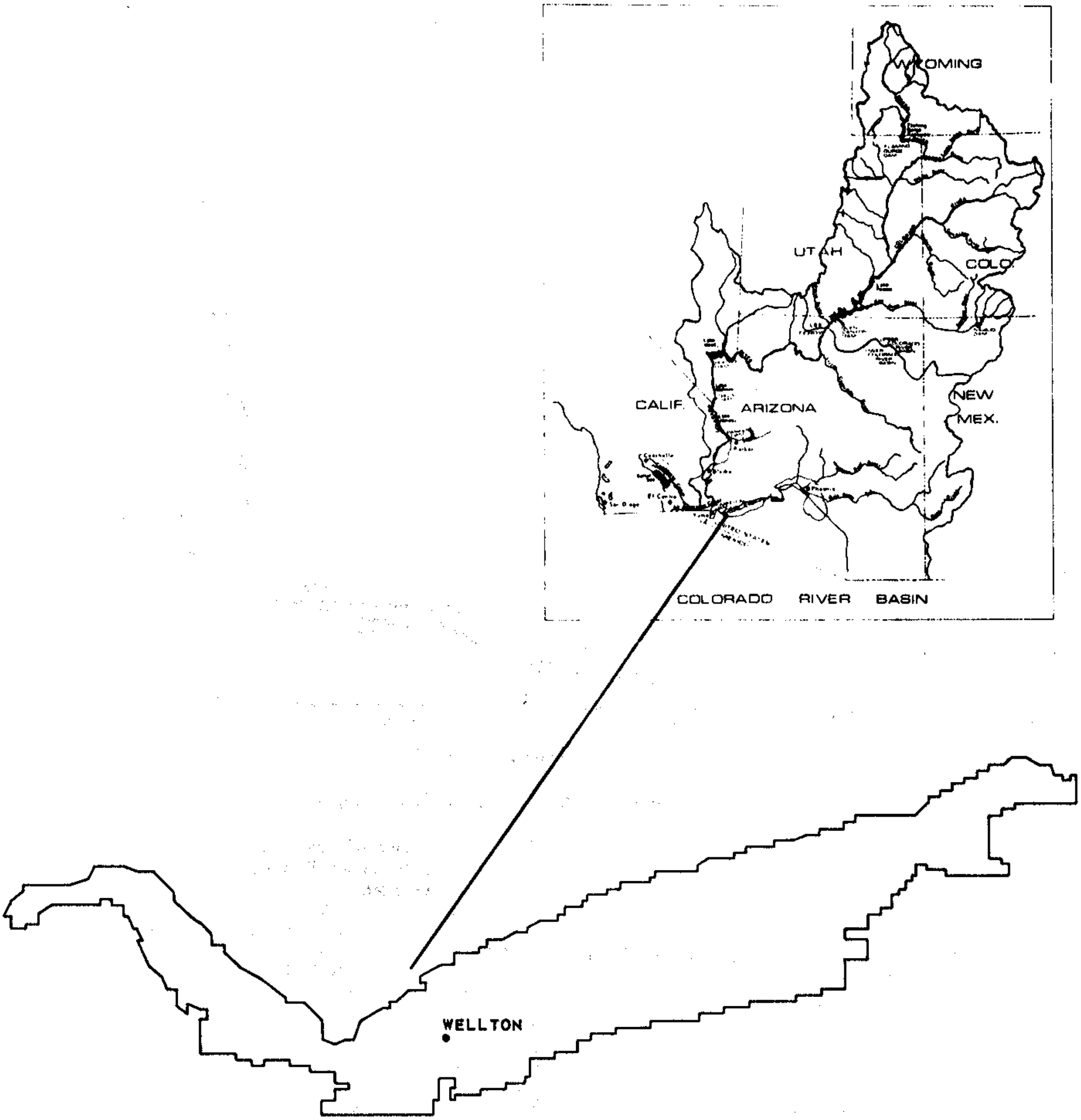
Table 3-55. Number of acres available for single and double cropping by land class, Wellton-Mohawk Irrigation District.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	41,562	8,218	49,780
Land 2 (Moderately Drained)	6,052	1,196	7,248
Land 3 (Poorly Drained)	9,477	1,874	11,351
Total	57,091	11,288	68,379

Table 3-56. Selected crops and double cropping possibilities, Wellton-Mohawk Irrigation District.

Crops	Double Cropping Possibilities[a]			
	Wheat	Cantaloupe	Lettuce	Sorghum
Cotton			x	
Alfalfa	x	x	x	x
Lettuce				
Cantaloupe	x	x	x	x
Wheat				
Sorghum	x	x	x	x
Grass Seed				
Grapefruit				
Oranges/ Tangerines				
Lemons				

[a] Crops under these columns are those assumed to lead in the double cropping rotation.



Map 3-6. Wellton-Mohawk Irrigation District.

Table 3-57. Yields of major crops in the Wellton-Mohawk Irrigation District, 1966-1973 (*tons/acre*).

	1966	1967	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Cotton	1.96	1.40	1.97	2.34	2.01	2.06	2.26	2.19	2.02 ±0.24[a]
Alfalfa	5.50	5.80	6.00	6.30	6.40	6.50	6.80	7.70	6.38 ±0.56
Lettuce	6.69	6.86	6.30	6.65	6.09	7.79	7.21	11.19	7.35 ±1.37
Cantaloupe	6.61	6.23	7.87	7.07	8.44	9.29	9.04	3.34	7.24 ±1.61
Wheat	1.68	1.95	2.10	2.07	2.13	2.37	2.46	2.46	2.15 ±0.23
Sorghum	1.79	1.65	1.90	1.82	1.85	1.90	2.04	1.93	1.86 ±0.10
Grass Seed	7.30	7.10	8.10	6.60	6.70	6.60	7.40	8.60	7.30 ±0.61
Grapefruit	0.25	8.12[b]	9.38[b]	7.50[b]	2.40	0.25	0.75	0.95	8.33 ±2.38
Oranges/Tangerines	1.58	2.47	1.43	3.67	0.67	8.36[b]	12.9[b]	5.85	10.63 ±28.84
Lemons	–	–	–	0.83	0.81	2.32	5.43[b]	2.14	5.43[b]

[a] 480-pound bales per acre.

[b] Yields considered to be representative mature trees.

Source: U.S. Bureau of Reclamation, Water and Land Resources Accomplishments, 1966-1973.

and therefore continuous annual data were scarce. Asterisks denote data years considered to be representative of mature trees. In an attempt to isolate average expected yields from erratic yields of immature trees, yield numbers were selected as those most likely to occur. Calculations were then based on these representative yields.

Declination curves for the respective crops are predicted by comparing the average base yields in Table 3-57 to Tables 3-39 and 3-1.

Management alternatives selected by the model as profitable options were leaching, land leveling, special bedding, and irrigation frequencies. Other alternatives available but not chosen by the model were full sprinkler, partial sprinkler, and tiling.

Total physical production and number of acres allocated by the model to each of the respective crops are contained in Table 3-58. Without exception, due to alternatives such as management, three district trends develop. The first is a case where production and land use are constant throughout the TDS range including crops of cotton, cantaloupe, grass seed, grapefruit, oranges/tangerines, and lemons.

Next, in the face of decreasing yields, land area occupied by lettuce, wheat, and sorghum increases in order to maintain a constant level of production. Finally, both the number of acres and the amount of production decrease as TDS increases in the case of alfalfa. For detailed information concerning various management alternatives considered by the model under each set of assumed conditions refer to sub-Appendix F. Such information provides the reasons why total land is held constant but total production and net profits decline throughout the range of analysis for this study.

The shadow prices corresponding to the various land classes (Table 3-59) indicate that there is little if any variation in the respective MVP's as salinity rises.

Maximum depletion of water for the district was set at 300,000 ac ft. This amount represents the total available water to the model under any possible combination of circumstances expected to be encountered.

As was the case in Palo Verde, total water consumption decreases over the range. This is due to the predominance of alfalfa production over changes occurring in the other crops (Table 3-60). Minor increases in water consumption by lettuce, wheat, and sorghum are cancelled out by the large decrease in water consumption in alfalfa due to production and land use being placed at lower levels by the model.

Most important, perhaps, is that net profit is smaller at each successive TDS level. These data are presented in Table 3-61 and a graphical representation is shown in Figure 3-13.

Construction of Table 3-62 is based on the accumulated differences among the objective functions (net profit). In fitting an exponential function to these data points, predicted values are derived. In the function $Y = be^{mx}$, $b = .128423$, $e = 2.718281828$, $m = .010184$, and x = level of TDS. Correlation is good as R^2 is 0.97. The contents of Table 3-62 are presented in Figure 3-14. Dramatic increases in damages are predicted for TDS levels beyond 1200 mg/l.

Table 3-63 summarizes total district acres, annual damages per acre, and per milligram per liter, and finally an average annual damage per milligram per liter per acre.

GILA AREA

Adjacent to the Wellton-Mohawk Project is the Gila area which also receives Colorado River water by way of Imperial Dam (Map 3-7). The land area is relatively small as can be seen from Table 3-64. Very little double cropping takes place due to the large

Table 3-58. Cropping and production pattern changes, Wellton-Mohawk Irrigation District.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Cotton[a]	22,484	11,131	22,484	11,131	22,484	11,131	22,484	11,131	22,484	11,131	22,484	11,131
Alfalfa	112,310	17,603	112,310	17,603	111,924	17,543	111,667	17,503	110,292	17,287	108,912	17,071
Lettuce	39,133	5,324	39,133	5,324	39,133	5,324	39,133	5,324	39,133	5,489	39,133	5,631
Cantaloupe	21,769	3,007	21,769	3,007	21,769	3,007	21,769	3,007	21,769	3,007	21,769	3,007
Wheat	22,535	10,481	22,535	10,481	22,535	10,481	22,535	10,481	22,535	10,516	22,535	10,560
Sorghum	17,005	9,937	17,005	9,937	17,005	9,998	17,005	10,038	17,005	10,054	17,005	10,085
Grass Seed	55,747	7,637	55,747	7,637	55,747	7,637	55,747	7,637	55,747	7,637	55,747	7,637
Grapefruit	334	27	334	27	334	27	334	27	334	27	334	27
Oranges/Tangerines	25,608	3,013	25,608	3,013	25,608	3,013	25,608	3,013	25,608	3,013	25,608	3,013
Lemons	2,630	219	2,630	219	2,630	219	2,630	219	2,630	219	2,630	219
Total		68,379		68,379		68,379		68,379		68,379		68,379

[a] 480-pound bales.

Table 3-59. Shadow prices of land by class and level of TDS, Wellton-Mohawk Irrigation District.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	81.7	81.7	81.7	81.7	81.7	81.7
Land 2	81.7	81.7	81.7	81.7	81.7	81.7
Land 3	81.7	81.7	81.7	81.7	81.7	81.7
Double Crop 1	37.0	37.8	37.8	38.3	38.5	37.8
Double Crop 2	37.0	37.0	37.0	37.0	37.0	36.3
Double Crop 3	35.8	34.4	28.6	24.9	16.4	7.0

Table 3-60. Ratio of amount of water used to land and profit all by level of TDS, Wellton-Mohawk Irrigation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	292,537	4.278	39.01
1000	285,306	4.172	39.99
1100	285,028	4.168	39.99
1200	284,843	4.166	39.99
1300	283,737	4.149	39.88
1400	282,642	4.133	39.79

Table 3-61. Total and per acre net profit by TDS level, Wellton-Mohawk Irrigation District.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	11,411,576	166.89
1000	11,408,871	166.85
1100	11,398,008	166.69
1200	11,390,995	166.59
1300	11,315,540	165.48
1400	11,246,177	164.47

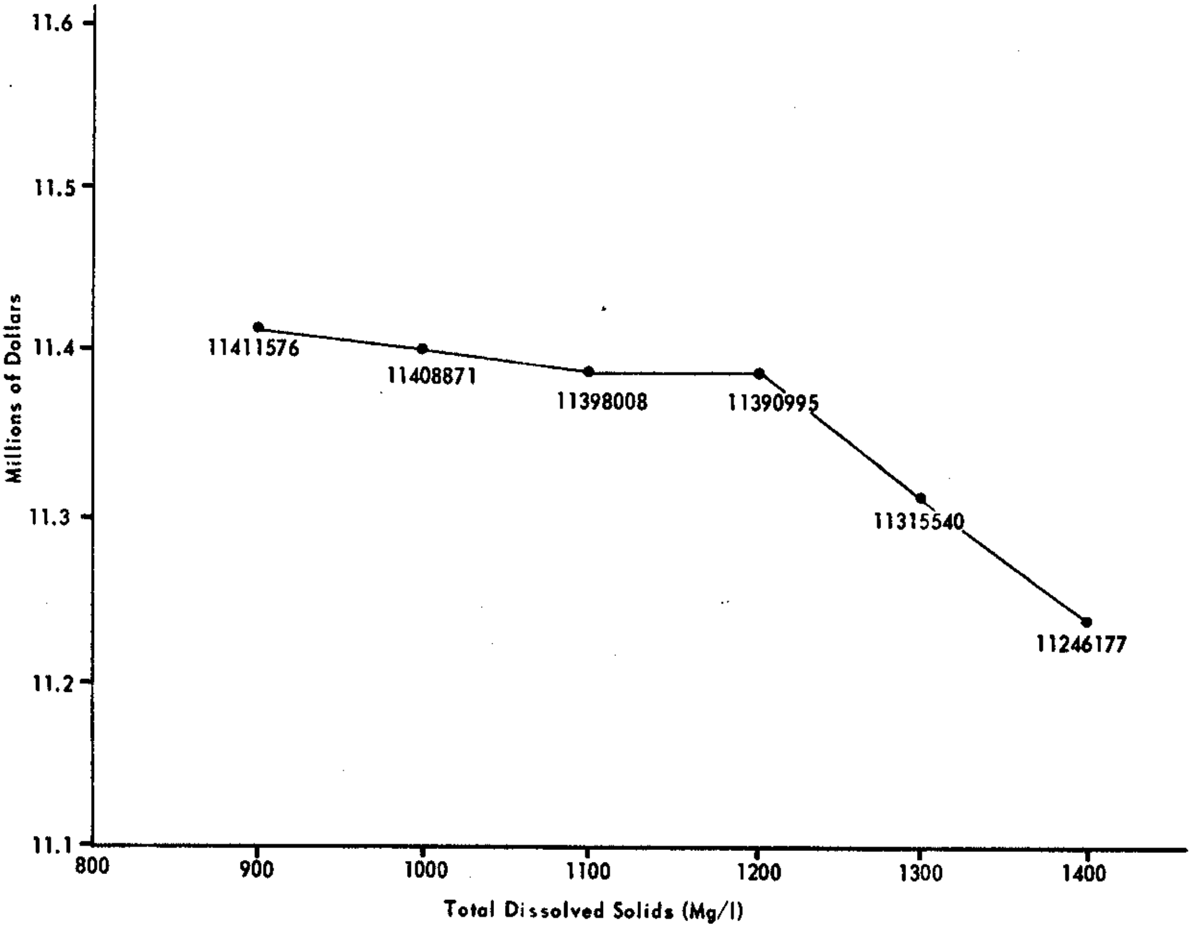


Figure 3-13. Total net profit by level of TDS, Wellton-Mohawk Irrigation District.

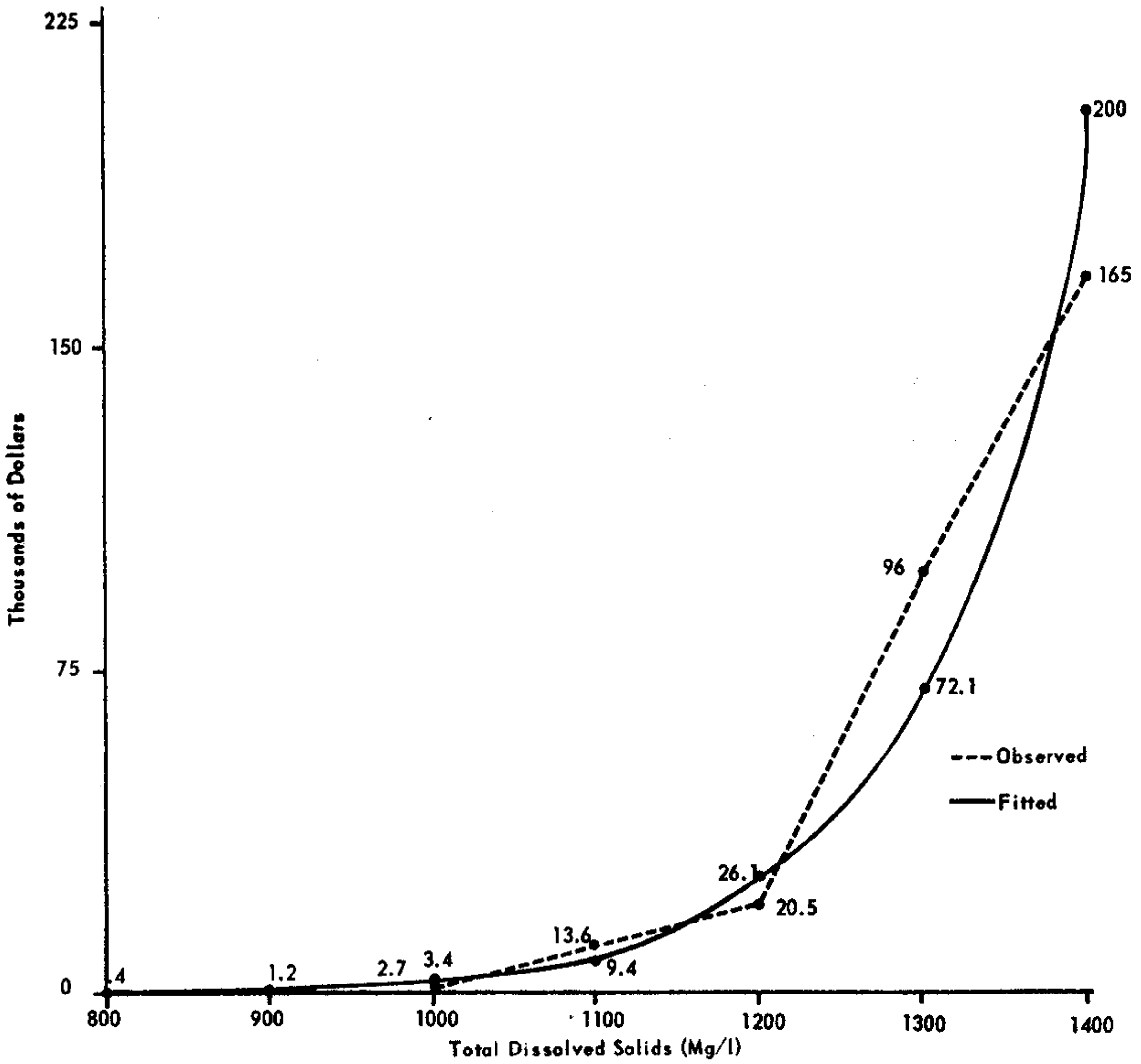


Figure 3-14. Observed data with fitted damage function, Wellton-Mohawk Irrigation District.

Table 3-62. Accumulated damage totals of observed data and predicted values by level of TDS, Wellton-Mohawk Irrigation District.

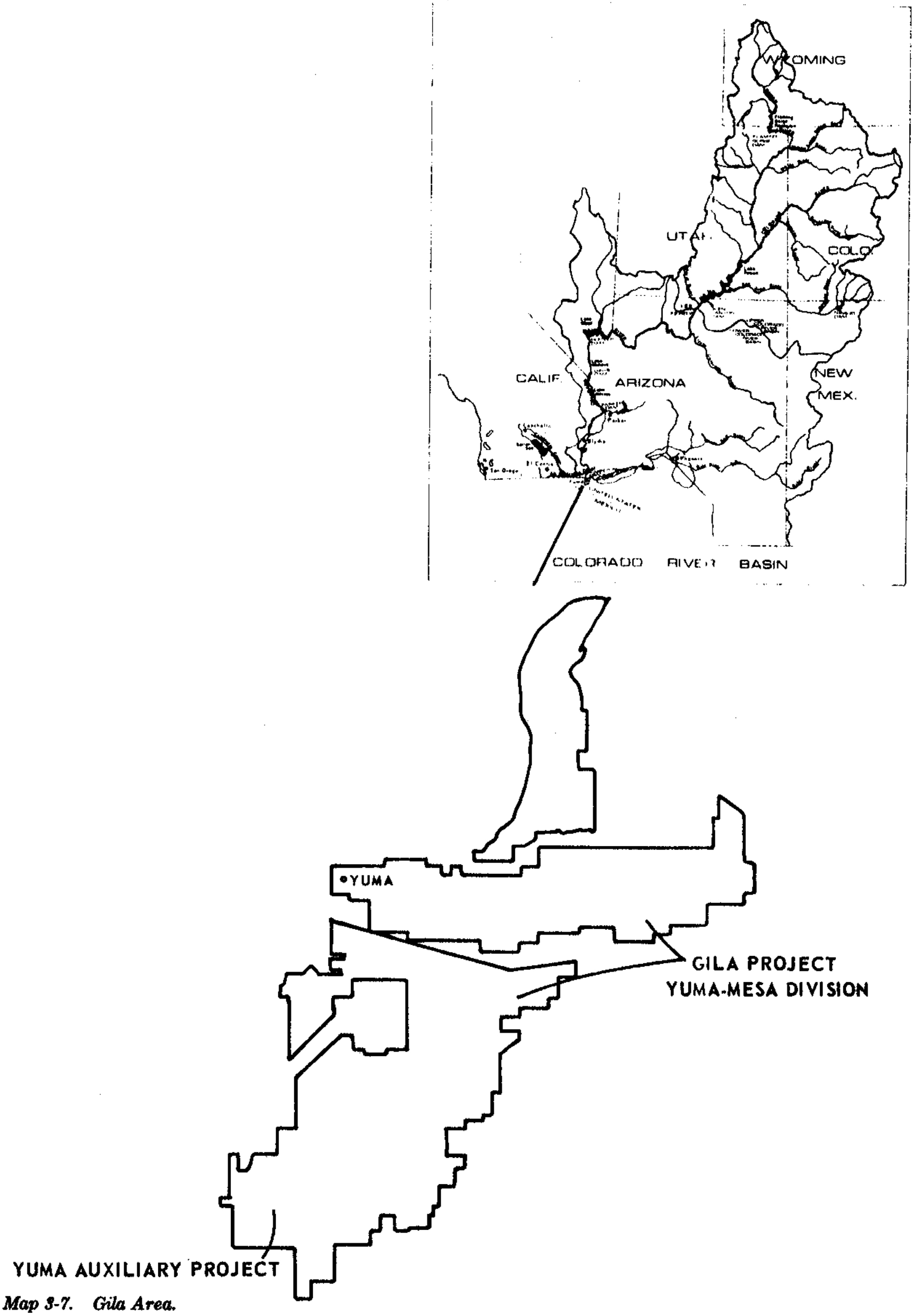
TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
800	–	443
900	–	1,228
1000	2,705	3,399
1100	13,568	9,409
1200	20,581	26,051
1300	96,036	72,125
1400	165,399	199,689

amount of acreages devoted to citrus. However, several types of specialty crops are grown such as lettuce and cantaloupe. A list of selected crops is presented in Table 3-65 along with a matrix of assumed double cropping possibilities which account for the small acreages involved in this process.

Since several distinct subareas were included under this heading weighted averages were taken to derive an overall average base yield for the area as a whole. Table 3-66 presents the weighted averages

Table 3-63. Summary statistics, Wellton-Mohawk Irrigation District.

Total Acres	68,379
Double Cropped Acres	11,285
Annual Total Damages	$165,339
Annual Per Acre Damages	$ 2.42
Annual Damages Per mg/l	$ 330.68
Annual Damages Per mg/l Per Acre	$ 0.0048



Map 3-7. Gila Area.

Table 3-64. Number of acres available for single and double cropping by land class, Gila area.

	Single Cropping (Acres)	Double Cropping (Acres)	Total (Acres)
Land 1 (Well Drained)	22,476	491	22,967
Land 2 (Moderately Drained)	3,273	72	3,354
Land 3 (Poorly Drained)	5,125	112	5,237
Total	30,874	675	31,549

Table 3-65. Selected crops and double cropping possibilities, Gila area.

Crops	Double Cropping Possibilities[a]			
	Wheat	Cantaloupe	Lettuce	Sorghum
Cotton			x	
Alfalfa				
Lettuce	x	x	x	x
Cantaloupe	x	x	x	x
Wheat				
Sorghum	x	x	x	x
Grass Seed				
Grapefruit				
Oranges and Tangerines				
Lemon				

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-66. Yields of major crops in the Gila area, 1966-1973 (tons/acre).

	1966	1967	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Cotton	3.01	1.63	3.30	3.23	2.49	2.73	2.56	2.43	2.67 ± 0.54[a]
Alfalfa	5.39	6.29	5.83	7.95	7.91	6.29	6.67	7.45	6.72 ± 0.96
Lettuce	9.03	13.93	9.62	8.80	7.07	10.52	7.68	10.16	9.60 ± 2.10
Cantaloupe	7.64	6.35	7.09	6.18	6.97	5.56	8.27	10.80	7.36 ± 1.63
Wheat	1.58	2.04	2.42	2.45	2.14	2.52	2.54	2.71	2.30 ± 0.36
Sorghum	2.16	1.83	2.23	1.92	2.42	3.12	N/A	1.69	2.19 ± 0.48
Grass Seed	9.80	7.80	11.00	8.84	5.00	9.50	10.30	7.20	8.68 ± 1.94
Grapefruit	19.03	12.36	14.78	16.97	16.35	14.52	16.96	11.28	15.28 ± 2.57
Oranges/Tangerines	4.25	9.03	8.36	11.11	8.99	7.77	8.72	12.45	8.84 ± 2.41
Lemons	10.54	15.20	20.08	15.96	19.41	11.24	9.07	12.63	14.27 ± 4.08

[a] 480-pound bales per acre.

Source: U.S. Bureau of Reclamation, Water and Land Resources Accomplishments, 1966-1973.

corresponding to the time period 1966-1973 and the resulting average base yields used in the model. Tables 3-39 and 3-1 were used to estimate potential decreased yields due to increasing salinity. Functions were constructed from these data for each of the respective crops in the area.

The model selected the following management alternatives: leaching, land leveling, special bedding, and irrigation frequencies. Implementation methods of these options as applied to the area are of the same nature as explained earlier (Imperial Valley section). Full sprinkler and partial sprinkler activities were not selected. In addition, tiling was also excluded as an indication of somewhat improved soil drainage characteristics as compared to soils in Imperial Valley, for example.

Quantity of production and amount of land occupied under the various assumed salinity levels are shown in Table 3-67. Several patterns develop which merit explanation. First of all, the citrus crops of grapefruit, oranges/tangerines, and lemons along with grass seed and cotton indicate that minimal effects are incurred as TDS rises. That is, production levels and amount of land used are constant throughout the range.

Alfalfa, wheat, and sorghum maintain production levels but more land is needed to do so. Impacts, however, are not major until 1300 mg/l TDS is reached. Upon reaching this level, increases in land area are noted.

Cantaloupe production remains constant throughout the range of analysis. Land area increases slightly until 1300 mg/l TDS where it decreases to 1489 acres and maintains this level through 1400 mg/l TDS. Production is allocated to class 1 lands and double cropped on class 2 and 3 lands up to 1300 mg/l TDS. Under this allocation, increasing amounts of land are required to sustain a constant level production. At 1300 mg/l TDS, the allocation mix changed and production is assigned to class 2 only. Since a larger percentage of production is assigned to this class, less total land is needed to meet production levels at 1300 and 1400 mg/l TDS.

Lettuce is the slack activity. As TDS increases, overall land area for the other crops increases also.

Table 3-67. Cropping and production pattern changes, Gila area.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Cotton[a]	4,889	1,831	4,889	1,831	4,889	1,831	4,889	1,831	4,889	1,831	4,889	1,831
Alfalfa	36,302	5,402	36,302	5,402	36,302	5,402	36,302	5,402	36,302	5,402	36,302	5,408
Lettuce	19,366	2,017	19,355	2,017	19,312	2,012	19,270	2,007	18,368	1,973	17,647	1,946
Cantaloupe	10,961	1,499	10,961	1,499	10,961	1,504	10,961	1,509	10,961	1,489	10,961	1,489
Wheat	3,334	1,449	3,334	1,449	3,334	1,449	3,334	1,449	3,334	1,472	3,334	1,490
Sorghum	2,008	917	2,008	917	2,008	917	2,008	917	2,008	949	2,008	952
Grass Seed	19,500	2,247	19,500	2,247	19,500	2,247	19,500	2,247	19,500	2,247	19,500	2,247
Grapefruit	21,522	1,409	21,522	1,409	21,522	1,409	21,522	1,409	21,522	1,409	21,522	1,409
Oranges/Tangerines	73,788	8,347	73,788	8,347	73,788	8,347	73,788	8,347	73,788	8,347	73,788	8,347
Lemons	91,765	6,431	91,765	6,431	91,765	6,431	91,765	6,431	91,765	6,431	91,765	6,431
Total		31,549		31,549		31,549		31,549		31,549		31,549

[a] 480-pound bales.

Since slack exists only in lettuce production, both total production and amount of land used decrease to accommodate the requirements of the remaining crops. Hence, both production and land decrease throughout the 900 to 1400 mg/l TDS range (see sub-Appendix G for more information).

Table 3-68 presents a list of the shadow prices generated by the model for each land class. Without exception, all classes show a trend of decreasing value over the range in question. Production restrictions placed on the model require at least a certain amount of production for the crops in question. In this particular situation, assumed conditions of available resources are such that the model produces every crop at the lower production level except lettuce which is slack. Attainment of higher levels are constrained by lack of sufficient land area. Therefore, given the fact that lettuce production contains the only available flexibility, demand for the various classes of land has peaked and is decreasing from the initial computer run. With limited flexibility as prescribed by the area conditions, land values decrease as net returns per acre decrease causing the above mentioned trend. In previous areas, at least one or more crops were produced at upper production limits. Inflexibility in the model comes from the lack of alternatives to shift acreages and production levels among several different crops. In all cases, however, shadow prices are only relative values and should be viewed in that manner.

Total available water for agricultural purposes is considered to be 400,500 ac ft. The model water demands cannot exceed this figure. Model results indicate that water availability is not a constraining factor as considerable capacity exists betweeen amount demanded and amount available.

Information relating to total amount of water used, acre feet per acre applied, and the ratio of water used to net profit is presented in Table 3-69. Total amount used varies slightly as an increase is noted at 1200, 1300, and 1400 mg/l TDS. However, the total magnitude of change is only 191 ac ft. Still, a trend is developing where amount of water used increases as salinity rises. In this case, alfalfa does not dominate or offset the demands of the other crops and the ratio of water used to net profit decreases at an increasing rate as expected. Anticipated trends also exist for data presented in Table 3-70. Stated more specifically, net profit declines as salinity increases and net profit per acre also decreases. The total net profit figures for each level of TDS are plotted in Figure 3-15.

Table 3-69. Ratio of amount of water used to land and profit all by level of TDS, Gila area.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	162,263	5.143	44.83
1000	162,263	5.143	44.81
1100	162,263	5.143	44.78
1200	162,278	5.144	44.75
1300	162,470	5.150	44.26
1400	162,454	5.149	43.89

Table 3-70. Total and per acre net profit by TDS level, Gila area.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	7,274,676	230.58
1000	7,270,947	230.47
1100	7,266,752	230.33
1200	7,262,480	230.20
1300	7,190,687	227.92
1400	7,130,585	226.02

Differences between each respective level of TDS and the succeeding level are derived and accumulated. Table 3-71 is constructed using these data. Fitting an exponential function to these data points resulted in an R^2 of 0.95. Predicted values calculated from this function are also included in the table. With respect to the derived function of the order $Y = be^{mx}$, $b = .194497$, $e = 2.718281828$, $m = 0.009669$, and $x =$ any level of TDS. Both the observed data points and the predicted values are plotted in Figure 3-16. Estimation of primary monetary damages for the TDS range considered in this report will be calculated from this type of function.

Summarizing some of the general indicators of damage losses for the Gila area, total damages were found to be $144,091, annual per acre damges to be $4.57, annual damages per mg/l to be $288.18, and annual damages per mg/l per acre to be $0.00913 (see

Table 3-68. Shadow prices of land by class and level of TDS, Gila area.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	541.3	541.3	541.3	541.3	515.3	493.7
Land 2	541.3	540.4	539.9	539.7	513.7	484.8
Land 3	541.3	539.5	538.6	538.3	499.1	460.8
Double Crop 1	541.3	541.3	541.3	541.3	515.3	493.7
Double Crop 2	541.3	540.4	539.9	539.7	513.7	484.8
Double Crop 3	470.0	461.2	430.0	399.5	341.9	306.4

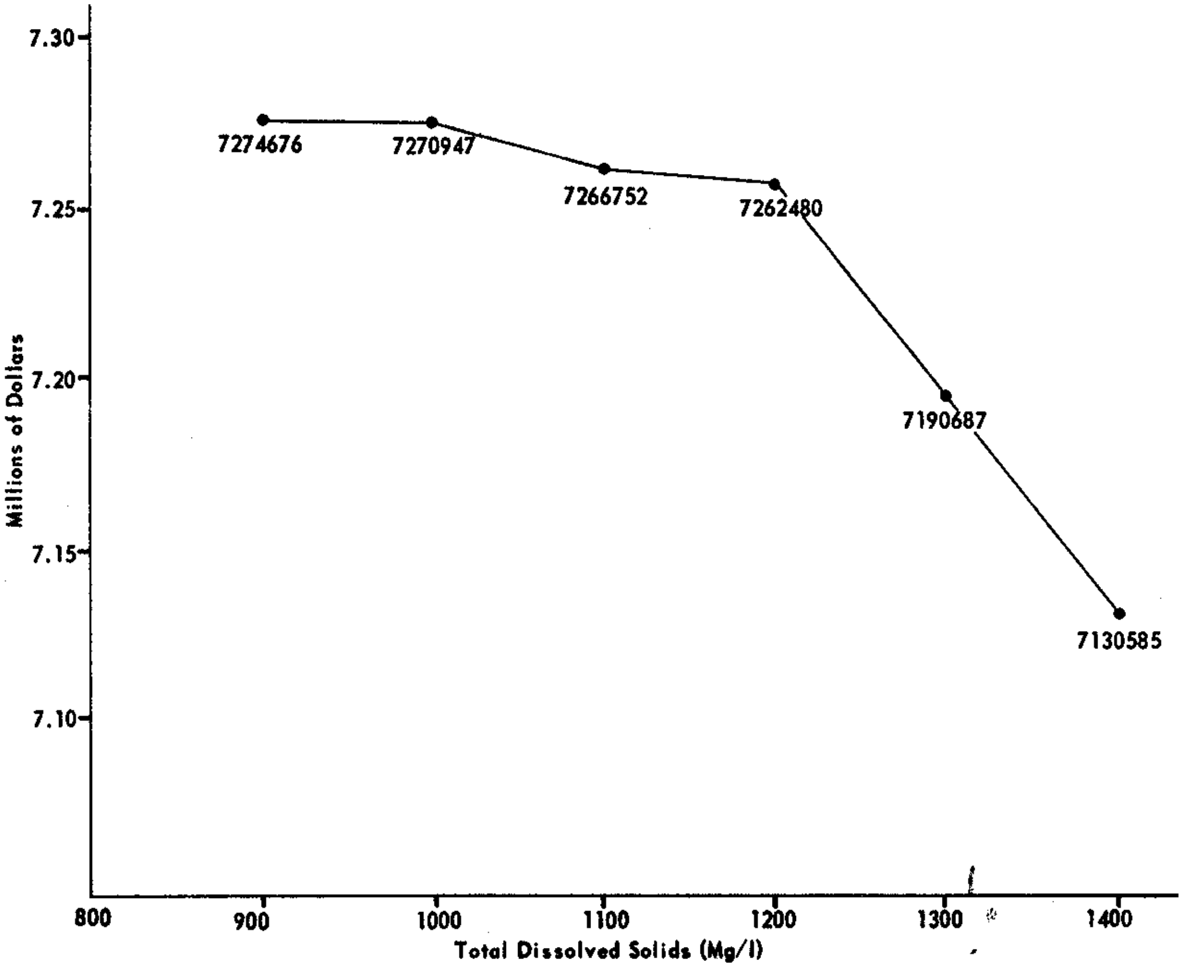


Figure 3-15. Total net profit by level of TDS, Gila area.

Table 3-71. Accumulated damage totals of observed data and predicted values by level of TDS, Gila area.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
800	–	445
900	–	1,170
1000	3,729	3,076
1100	7,927	8,091
1200	12,196	21,278
1300	83,989	55,958
1400	144,091	147,162

Table 3-72). The latter figure represents an average expected loss per acre to agriculture for each milligram per liter increase observed in the Colorado River at this diversion point.

Table 3-72. Summary statistics, Gila area.

Total Acres	31,549
Double Cropped Acres	675
Annual Total Damages	$144,091
Annual Per Acre Damages	$ 4.57
Annual Damages Per mg/l	$ 288.18
Annual Damages Per mg/l Per Acre	$0.00913

YUMA VALLEY AREA

In addition to several previous areas mentioned, Imperial Dam also diverts water for the Yuma Valley area (Map 3-8). Irrigation occurs on approximately 57,900 acres which are classified in respective classes by Table 3-73. Double cropping is practiced to a greater extent in this area than occurred in the Gila area. Still, only about 10 percent of the irrigated acres are used in this way. Table 3-74 shows the various combinations of couble cropping rotations assumed to be feasible.

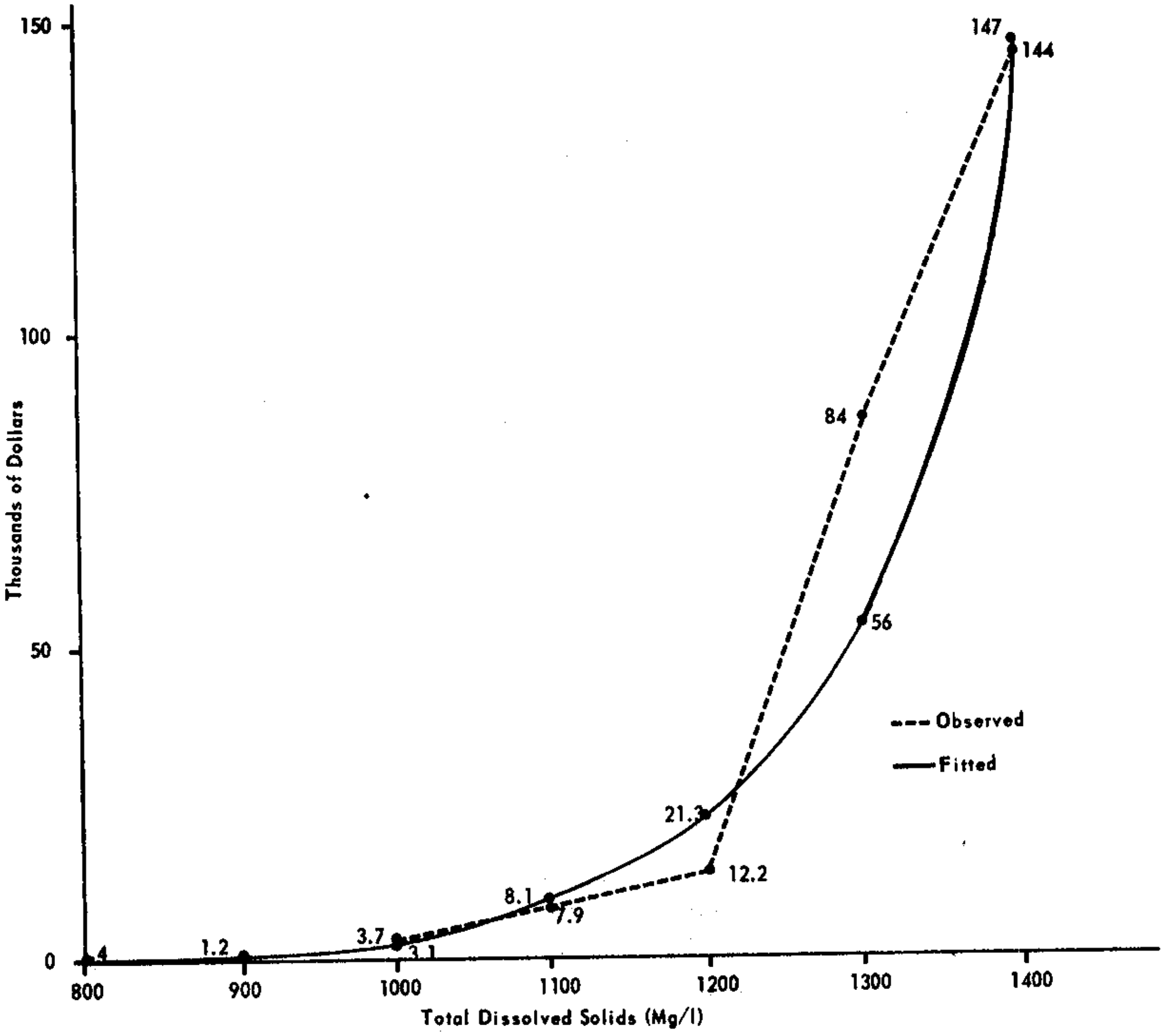


Figure 3-16. Observed data with fitted function, Gila area.

Table 3-73. Number of acres available for single and double cropping by land class, Yuma Valley area.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	38,297	3,908	42,205
Land 2 (Moderately Drained)	5,576	569	6,145
Land 3 (Poorly Drained)	8,732	891	9,623
Total	56,605	5,368	57,973

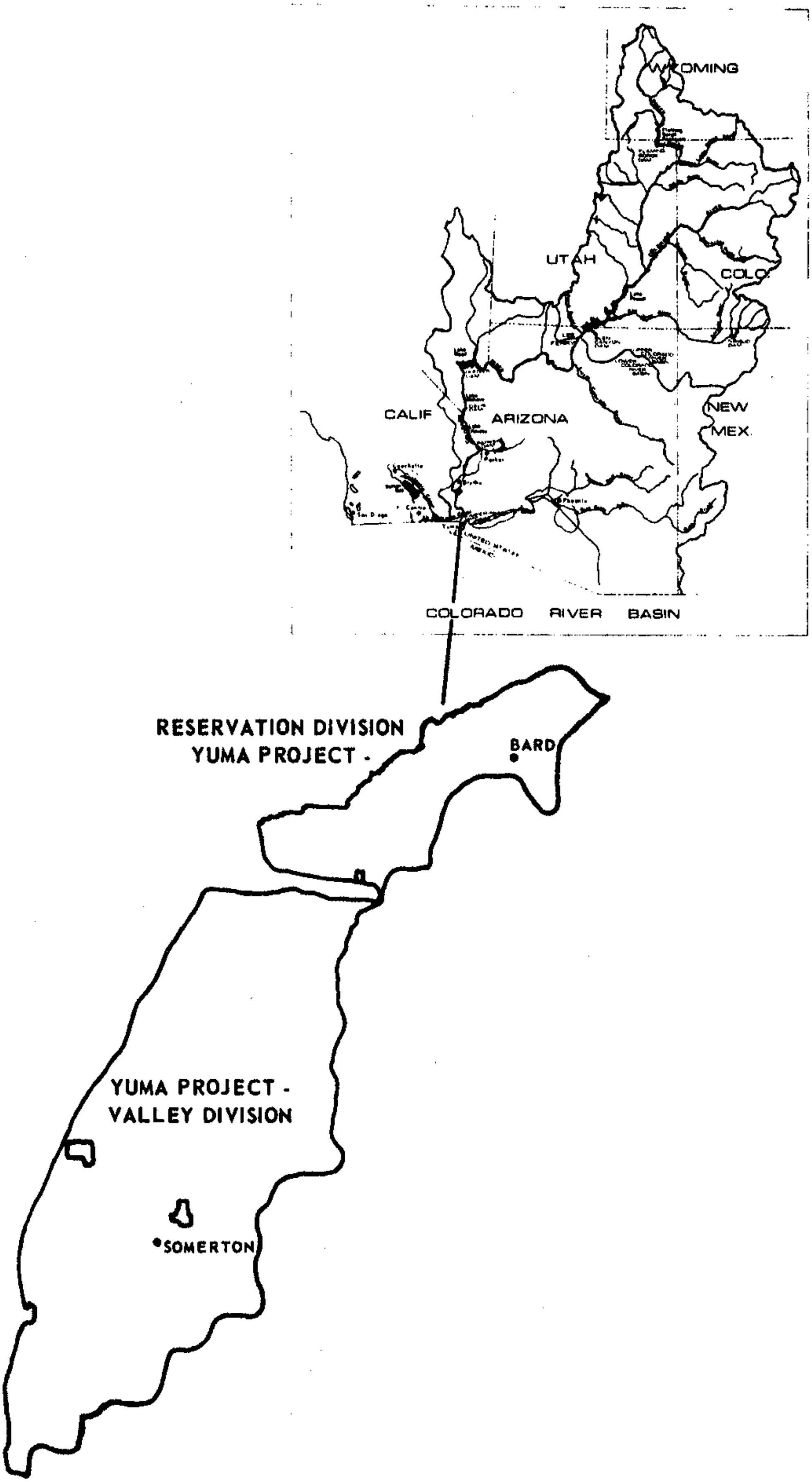
Average base yields for the Yuma Valley area are contained in Table 3-75. Crop damage functions were estimated by comparing effective values of soil saturation extract conductivities for the three soil types (Table 3-39) to the declination percentages in Table 3-1.

Table 3-74. Selected crops and double cropping possibilities, Yuma Valley area.

Crops	Double Cropping Possibilities[a]			
	Wheat	Cantaloupe	Lettuce	Sorghum
Cotton			x	
Alfalfa				
Lettuce	x	x	x	x
Cantaloupe	x	x	x	x
Wheat				
Sorghum	x	x	x	x
Grass Seed				
Grapefruit				
Oranges/Tangerines				
Lemons				

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Leaching, land leveling, special bedding, and irrigation frequencies were selected by the model as



Map 3-8. Yuma Valley area.

Table 3-75. Yields of major crops in the Yuma Valley area, 1966-1973 (tons/acre).

	1966	1967	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Cotton	3.32	2.11	3.12	2.49	1.90	2.16	2.09	2.31	2.44 ± 0.43[a]
Alfalfa	6.00	6.30	5.90	6.80	6.30	6.90	7.30	7.70	6.65 ± 0.53
Lettuce	12.67	12.64	7.11	7.63	12.53	9.00	11.04	10.81	10.43 ± 1.89
Cantaloupe	5.32	4.75	4.94	5 70	5.70	8.50	8.10	6.40	6.18 ± 1.18
Wheat	1.62	2.04	2.10	2.01	2.13	1.83	2.19	2.49	2.05 ± 0.21
Sorghum	1.71	2.46	1.51	1.26	2.10	1.76	2.13	2.18	1.89 ± 0.33
Grass Seed	9.00	7.30	8.20	6.50	4.80	5.80	5.90	7.80	6.91 ± 1.18
Grapefruit	10.26[b]	16.88[b]	4.72	7.22[b]	11.91[b]	4.94	3.66	2.70	11.57 ± 6.43
Oranges/Tangerines	7.87	6.67	N/A	11.51	10.64	6.84	5.78	6.31	7.95 ± 2.07
Lemons	—	—	—	10.66	12.83	6.11	5.57	5.26	8.90 ± 4.27

[a] 480-pound bales per acre.

[b] Yields considered to be representative of mature trees.

Source: U.S. Bureau of Reclamation, Water and Land Resources Accomplishments, 1966-1973.

being profitable management alternatives. Partial sprinkler, full sprinkler, and tiling were not selected.

Changes in the amounts of production and land use are shown in Table 3-76. Alfalfa, grapefruit, and lemons are the crops which have both a constant level of production and a constant amount of acres used.

Lettuce, wheat, and sorghum have constant levels of production throughout the TDS range. But as yields decline, more land is required when the TDS level increases. The most significant increase occurs in lettuce at the 1300 and 1400 mg/l TDS levels.

An interesting trend develops in the case of cotton, grass seed, and oranges/tangerines. Both production and land area decline. In the initial run, cotton and oranges/tangerines are produced at the upper level while grass seed is a slack activity (produced neither at the upper level nor the lower level but somewhere in between). Grass seed production and occupied land area decline until 1300 mg/l TDS is reached. At this level, grass seed has declined to the lower level of the model and so oranges/tangerines decrease in production and land area. However, at 1400 mg/l TDS, the lower limit is reached for oranges/tangerines and cotton incurs a loss in production and land area. Redistribution of these crops occurs due to declining yields of the remaining crops and consequently, more land of better drainage characteristics is required in order to meet their production needs according to the model.

Cantaloupe demonstrates the same kind of allocation pattern as in the previous analysis of the Gila area. In maintaining a constant level of production throughout the TDS range, first, land area increases and then it decreases. For 900 to 1200 mg/l TDS, increased land area is required to maintain a constant level of production. At 1300 mg/l TDS, relative economic trade offs between cantaloupe and the other crops cause more cantaloupe production to be allocated to better land classes. Previously, production was placed on class 1, 2, and 3 lands. Now the model assigned production to class 1 and 2 lands reaching 1400 mg/l TDS, the model places most of the production on class 1 land. Since a larger share of total production is produced on higher yielding land at 1300 and 1400 mg/l TDS, less land is required, and thus a constant production level can be maintained with lower land use. For more details concerning the interactions of the different crops at the various levels of TDS refer to sub-Appendix H.

Table 3-77 contains the shadow prices of the various land classes. In all land classes, the trend is toward higher relative values. Evidently demand for the various land classes increased throughout the range causing the values to increase. A significant jump occurs between 1300 and 1400 mg/l TDS where, for example, the value of class 1 land increases from $190 to $323. Similar jumps occur in the remaining land classes. Double cropped land classes behave somewhat differently and the reader is referred to sub-Appendix H for a more detailed explanation.

The total water constraint established in the model was 270,900 ac ft. This amount is the total available for agricultural purposes. In Table 3-78, total water consumption appears to be declining in a normal trend until at 1300 and 1400 mg/l TDS sharp decreases are detected. This is explained by examining the trade offs occurring in cotton, grass seed, and oranges/tangerines. At 1300 mg/l TDS, both land area and production declined for the latter two crops. Since these crops consume water almost year around, large amounts are required as compared to a crop with a shorter season. Due to the fact that less water is needed for these two crops because of less production and smaller occupied land area, overall total consumption of water also declines. The same reasoning is applied at the 1400 mg/l TDS level, but instead of grass seed declining, cotton is the crop which undergoes a loss in production and land area. Along with cotton, oranges/tangerines also decline which precipitates another sharp decrease in the demand for water.

Net profit as estimated by the model objective function coresponding to the different TDS levels, are

Table 3-76. Cropping and production pattern changes, Yuma Valley area.

Crops	Total Dissolved Solids (mg/l)											
	900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Cotton[a]	32,138	13,171	32,138	13,171	32,138	13,171	32,138	13,171	32,138	13,171	31,709	12,995
Alfalfa	75,771	11,394	75,771	11,394	75,771	11,394	75,771	11,394	75,771	11,394	75,771	11,394
Lettuce	98,457	9,440	98,457	9,440	98,457	9,440	98,457	9,440	98,457	9,729	98,457	9,985
Cantaloupe	28,337	4,639	28,337	4,703	28,337	4,711	28,337	4,746	28,337	4,585	28,337	4,585
Wheat	19,377	9,452	19,377	9,452	19,377	9,452	19,377	9,452	19,377	9,470	19,377	9,487
Sorghum	8,380	4,434	8,380	4,434	8,380	4,434	8,380	4,434	8,380	4,717	8,380	4,740
Grass Seed	23,564	3,410	23,116	3,346	23,064	3,338	22,827	3,303	20,652	2,989	20,652	2,989
Grapefruit	2,244	194	2,244	194	2,244	194	2,244	194	2,244	194	2,244	194
Oranges/Tangerines	8,133	1,023	8,133	1,023	8,133	1,023	8,133	1,023	7,221	908	6,253	787
Lemons	9,792	816	9,792	816	9,792	816	9,792	816	9,792	816	9,792	816
Total		57,973		57,973		57,973		57,973		57,973		57,973

[a] 480-pound bales.

Table 3-77. Shadow prices of land by class and level of TDS, Yuma Valley area.

	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	171.5	171.5	171.5	171.5	190.4	323.2
Land 2	171.5	171.5	171.5	171.5	190.4	323.2
Land 3	171.5	171.5	171.5	171.5	189.6	322.5
Double Crop 1	171.5	171.5	171.5	171.5	190.4	323.2
Double Crop 2	171.5	170.6	170.6	170.6	188.9	321.8
Double Crop 3	145.1	113.9	110.2	93.8	93.3	162.4

Table 3-78. Ratio of amount of water used to land and profit all by level of TDS, Yuma Valley area.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
900	223,658	3.858	65.16
1000	223,535	3.856	65.07
1100	223,521	3.856	65.06
1200	223,456	3.854	65.01
1300	222,483	3.838	64.57
1400	221,504	3.821	64.10

Table 3-80. Accumulated damage totals of observed data and predicted values by level of TDS, Yuma Valley area.

TDS (mg/l)	Observed (Dollars)	Predicted (Dollars)
800	–	4,737
900	–	9,595
1000	28,253	19,434
1100	31,622	39,366
1200	46,152	79,738
1300	208,241	161,515
1400	375,417	327,160

Table 3-81. Summary statistics, Yuma Valley area.

Total Acres	57,973
Double Cropped Acres	5,368
Annual Total Damages	$375,417
Annual Per Acre Damages	$ 6.48
Annual Damages Per mg/l	$ 750.83
Annual Damages Per mg/l Per Acre	$0.01295

presented in Table 3-79. The overall decrease in profits for the interval 900 to 1400 mg/l TDS is of the magnitude of $375,000. Objective function values are plotted in Figure 3-17 which illustrates a trend of declining values in net profits. Table 3-80 accumulates the differences between the objective functions for the various TDS levels. In Figure 3-18, a function of the order $Y = be^{mx}$ is fitted to these points where $b = 16.7145$, $e = 2.718281828$, $m = 0.007059$, and $x =$ any level of TDS. This function was used to derive the predicted values also contained in Table 3-80. As can be noted from the table, a larger amount of variation is present as R^2 was equal to 0.90. However, the functional fit is sufficient to estimate further monetary damages incurred by farmers in this area as the amount of TDS increases.

Table 3-81 summarizes some of the model findings. Annual total damages are expected to be $375,417. Average annual per acre damages are estimated to be $6.48. For an increment of 1 mg/l TDS, incurred losses are placed at $750.83. Analization of the two latter estimates, predicts that a cost of $0.01295 per mg/l per acre will be incurred for a 1 mg/l TDS increase at the diversion point to the area.

Table 3-79. Total and per acre net profit by TDS level, Yuma Valley area.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
900	14,573,704	251.39
1000	14,545,451	250.90
1100	14,542,082	250.84
1200	14,527,552	250.59
1300	14,365,462	247.80
1400	14,198,286	244.91

CENTRAL ARIZONA PROJECT SERVICE AREA

The Bureau of Reclamation awarded the first construction contract of the Central Arizona Project in April of 1973. Groundbreaking ceremonies were held on the shores of Lake Havasu on May 6, 1973, and it is anticipated that water will be flowing through the Granite Reef Aqueduct by 1987. In view of this fact, the Arizona Water Commission has less than 5 more years to complete the task of allocating Central Arizona Project water to the many potential users. They have "expressions of interest" from approximately one hundred sources. These include between 16 and 20 old, established irrigation and drainage districts; newly formed districts; utility companies; mining companies; water companies; municipalities; military posts; ranches; individuals; and others. It is obvious that any sort of equitable distribution will be extremely difficult.

In the course of negotiations which finally resulted in authorization of the Central Arizona

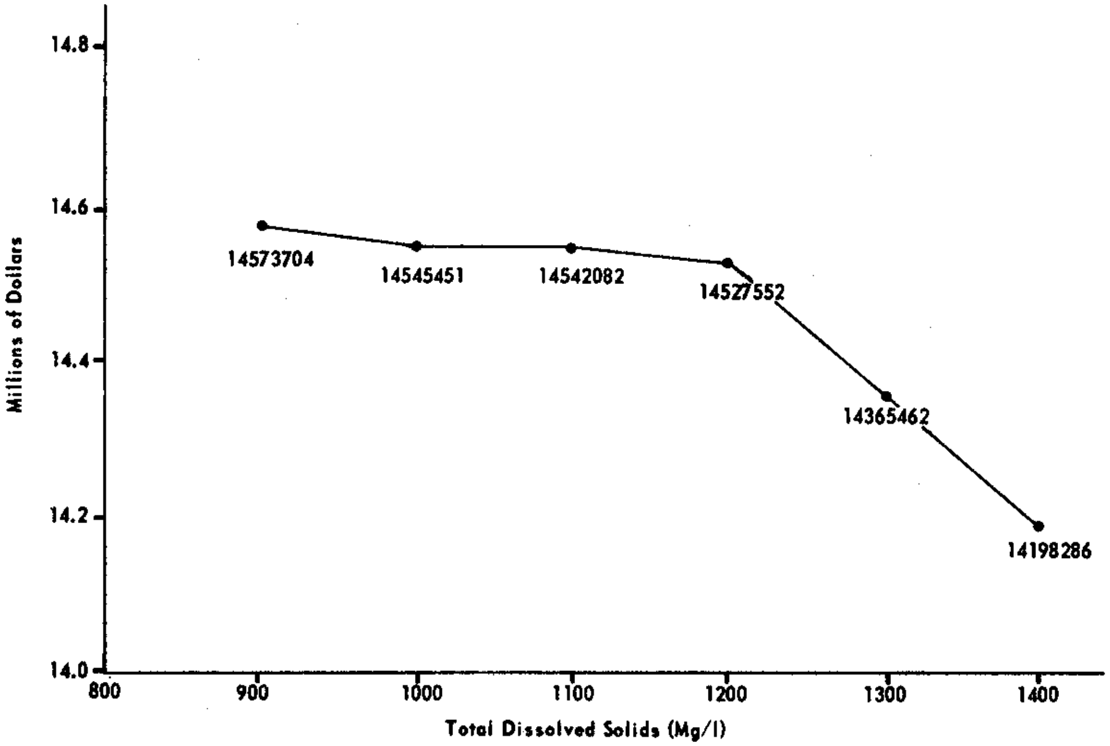


Figure 3-17. Total net profit by level of TDS, Yuma Valley area.

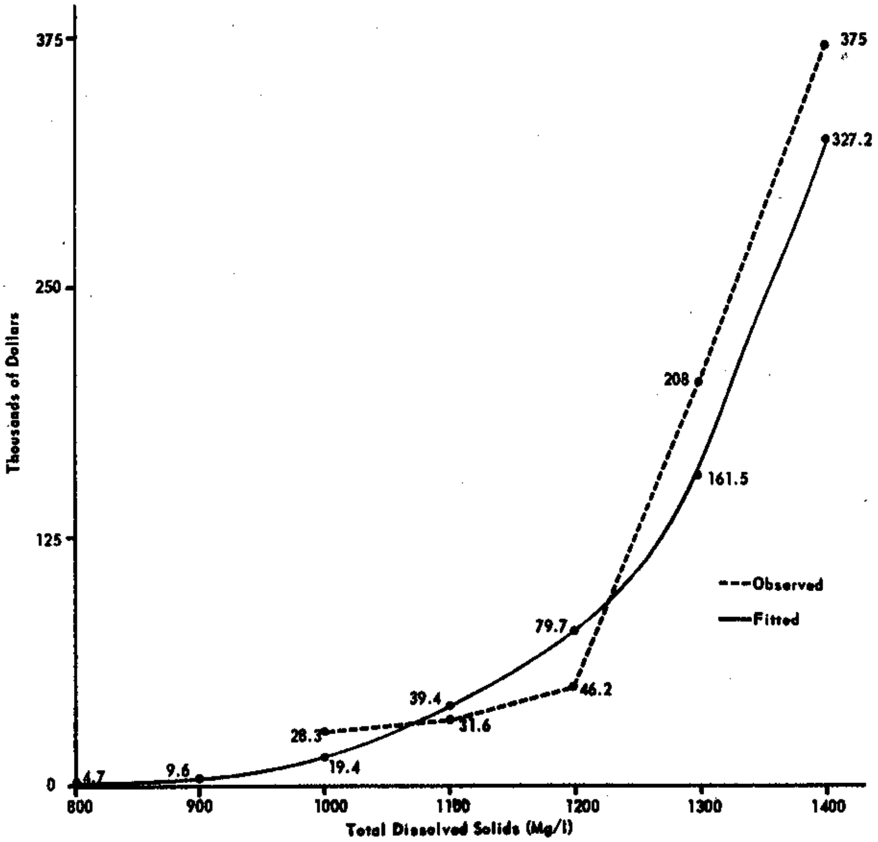


Figure 3-18. Observed data with fitted damage function, Yuma Valley area.

Project, the Department of the Interior assured Congress that there would be a water supply adequate to deliver an annual average of 1,200,000 ac ft to the potential Central Arizona Project service area during the 50-year project cost repayment period. However, in any year in which there should be too little water available to deliver the minimum allotments to California, Nevada, and Arizona, it is agreed that the shortage will be borne first by the Central Arizona Project. By the same token, Central Arizona Project will share in any surplus above these minimums.[1]

The Arizona Water Commission estimates that by the year 2000 municipal and industrial users will take at least 400,000 ac ft, leaving approximately 800,000 for agriculture. This will fall far short of meeting present requests. One large irrigation district alone has asked for more than 500,000 ac ft of Central Arizona Project water. Thus, it is clear that if only the established irrigation districts are considered in the allocation of water, few can expect to receive as much as half of what they have asked for. Exceptions might be such districts as the Salt River and San Carlos projects. These projects have surface water supplies, storage facilities, and distribution systems in operation that could be greatly enhanced by allotments of Central Arizona Project water. Conversely, it is doubtful if comparable areas which depend entirely upon groundwater could sustain the capital investment necessary to construct distribution systems.

Since agricultural lands are dispersed over a rather large area, it was decided to divide the potential Central Arizona Project service area into several subgroups or areas as outlined in a previous section. In recapitulation, these areas were: Salt River Project, Lands Supplemental to Salt River Project, Roosevelt Water Conservation District, Roosevelt Irrigation District, San Carlos Project (Non-Indian), and San Carlos Project (Indian). In addition, due to the fact that many possible allocations of Central Arizona Project water still exist, certain assumptions had to be made concerning representative conditions of each respective area. Delineation of the circumscribed areas, Central Arizona Project impacts on present agricultural water supplies, and model results corresponding to the respective subareas follow.

Salt River Project

The Salt River Project irrigation system serves approximately 261,246 acres of land in the Salt River Valley of Central Arizona (Map 3-9). It supplies full service to the Salt River Valley Water Users Association (238,264 acres), supplemental service to special contractors (22,982 acres), and 5.6 percent of the surface water diverted at Granite Reef Dam to the Roosevelt Water Conservation District (Arizona Water Commission files; Annual Crop Production Reports, Roosevelt Water Conservation District and Salt River Project).

In 1973 the acreage under full supplemental irrigation (not including Roosevelt Water Conservation District) consisted of 101,370 acres of urban and suburban residential, commercial, and industrial lands; 9,414 acres of farmsteads, roads, ditches, and drains; and 150,462 acres of cultivated cropland. Of the cropland 136,385 acres were irrigated (Annual Crop Production Reports, Salt River Project).

In general, the Salt River Project includes: 1) the Verde River with its two reservoirs above Horseshoe Dam and Bartlett Dam; 2) the Salt River and its reservoirs above Stewart Mountain Dam, Mormon Flat Dam, Horse Mesa Dam; 3) Granite Reef Diversion Dam at the confluence of the Verde and Salt Rivers; 4) the distribution system which includes the Arizona Canal, Grand Canal, Tempe Canal, Western Canal, Consolidated Canal, Eastern Canal, and their laterals; and 5) drainage and pumping works with 252 active wells.

Electrical power is also generated from the Salt River Project with the releases or flows from the dams on the Salt and Verde Rivers. These hydroelectric plants are not necessarily a part of this report except as they affect the quality of water which reaches the farms and cities. This effect may not be of great importance because of the relatively low salt content of the combined rivers. However, water quality varies between the rivers and with the amount of natural flow. Operation of the power generating plants helps determine which water source is released or stored at any given time and, therefore, is a factor to consider. This will be especially true if Orme Dam is built and different proportions of Salt River Project and Central Arizona Project waters are stored there at different times of the year.

There are other possibilities that could affect the quality of water that might be delivered to the Salt River Project as well as to other contractors for Central Arizona Project water: 1. Orme Dam may or may not be built. This would affect the water quality for any user below this point in the Central Arizona Project system. 2. The Salt River Project may have to make exchanges with other Central Arizona Project water contractors. The amount of Salt River Project water involved would affect the mixture of Central Arizona Project and Salt River Project waters. 3. The quantities of water allocations to the Indians. 4. The allocation between various contractors for Central Arizona Project water and their diversion point locations. For the purposes of this report, the following assumptions are made: 1) continued surface water supply based on a 10-year average; 2) possible Central Arizona Project allocations; 3) groundwater pumpage to maintain the minimum balance required to meet Salt River Project obligations; and 4) uniform mixing of all water sources.

Water quality stations for which records are published on the surface water of the project are downstream from Bartlett Dam on the Verde River and the Stewart Mountain Dam on the Salt River. The 9-year average flow (1964-1972) of the Verde River

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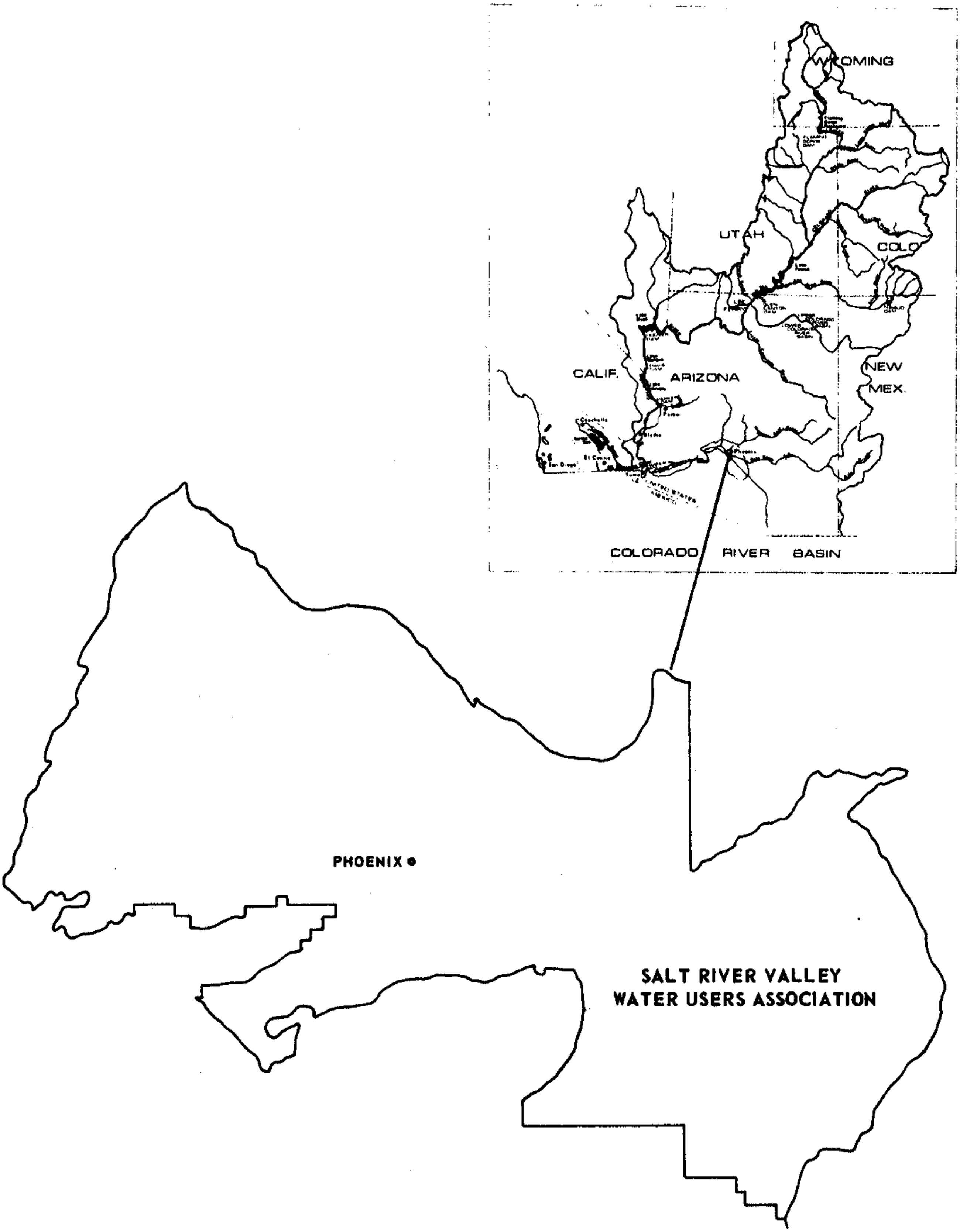
[1] Lower Basin allotments: California, 4,400,000 acre feet; Nevada, 300,000 acre feet; Arizona, 2,800,000 acre feet.



Map 3-9. Salt River Valley Water Users Association.

was 372,000 ac ft with a weighted average of 288 mg/l TDS, while that of the Salt River was 533,000 ac ft with 591 mg/l TDS (Arizona Water Commission Files; Water Resources Data for Arizona; Hubbard, personal interview). The project is presently pumping 252 wells. Over the 10-year period ending in 1970 they pumped an average of 400,000 ac ft per year while the depth to water in selected wells dropped an average of 13 feet per year (Arizona Water Commission files). In 1970 the U.S. Geological Survey estimated that a safe groundwater yield for the Salt River Project area is 300,000 ac ft per year, including that pumped by others within the Salt River Project boundaries.

It is estimated that by 1980 Salt River Project obligations will be 766,000 ac ft for agriculture, 190,000 for municipal and industrial, and 239,000 (20 percent) transportation and storage losses. With a continued supply of 850,000 acre feet of surface water and curtailed pumping of 200,000 acre feet, minimum balance to meet this obligation would be 150,000 acre feet of Central Arizona Project water.

The salinity in the active wells ranges from around 300 to 2,897 mg/l TDS with an average of 980 mg/l (Hubbard, personal interview). Since Central Arizona Project water is supposed to replace groundwater on a one to one basis, the highest salt content wells could be eliminated to bring this average down to somewhere near the present 775 mg/l of the Colorado River at Parker Dam. However, for the purposes of this report, an average groundwater quality of 980 mg/l TDS is used.

If we assume a continued supply of 850,000 ac ft of surface water and curtailed pumping of 275,000 ac ft, an allotment of 75,000 ac ft of Central Arizona Project water would meet the minimum balance needed to fill Salt River Project obligations. The project water before addition of Central Arizona Project water would then have an average salinity of around 600 mg/l TDS which would be increased only slightly by the addition of Central Arizona Project water and its present level, and only another 40 mg/l when the Central Arizona Project reaches 1400 mg/l (Table 3-82). If the Salt River Project were allotted the 150,000 ac ft of Central Arizona Project water they have requested, the salinity of the blend would be slightly lower initially and only 26 mg/l higher when Central Arizona Project water reaches 1400 mg/l (Table 3-83). This is because of the trade off of groundwater for Central Arizona Project water. Since this is the case, crop declinations are figured on the basis of the higher allotment.

The soils of the general area served by the Salt River Project irrigation system are assigned to drainage groups in Table 3-84. This breakdown was made from a general soils map of Maricopa County and Salt River Indian Reservation prepared by the U.S. Soil Conservation Service (General Soil Map, Maricopa County, Arizona). The proportions of different soils classes as shown here are used for both the Salt River Valley Water Users Association and areas of supplemental irrigation service. Of the total 165,942 acres assumed for the model, 134,225 acres are allocated to single cropping purposes while 31,717 acres are assigned to double cropping possibilities.

The crops selected for the Salt River Project are listed in Table 3-85. In addition, the table also shows the rotation sequence of double cropping alternatives. Wheat, barley, sorghum, lettuce, and to lesser extent onions, are the dominant crops in the double cropping rotation for this area.

Table 3-86 contains the data used to derive base yield figures for the area. These data were then compared to the effective values of soil saturation extract conductivities for the three drainage classes as

Table 3-82. Effects of increasing salinity of Central Arizona Project water when it is blended into the Salt River Project water (assuming an allotment of 75,000 ac ft of Central Arizona Project water).

850,000 ac ft Salt and Verde Rivers Water[a] TDS (mg/l)	275,000 ac ft Groundwater TDS (mg/l)	1,125,000 ac ft Salt River Project Water TDS (mg/l)	75,000 ac ft Central Arizona Project Water TDS (mg/l)	1,200,000 ac ft Blended Central Arizona Project and Salt River Project TDS (mg/l)
467[b]	980[c]	592	775[d]	604
467	980	592	900	612
467	980	592	1000	618
467	980	592	1100	624
467	980	592	1200	630
467	980	592	1300	637
467	980	592	1400	643

[a] Nine-year average flow (1964-1972) of 905,000 acre feet less 5.6 percent to the Roosevelt Water Conservation District, leaves 854,000 acre feet surface water.

[b] The 9-year average flow of the Verde River below Bartlett Dam was 372,000 acre feet with an average of 288 mg/l TDS, while that of the Salt River below Stewart Mountain Dam was 533,000 acre feet with an average of 591 mg/l TDS.

[c] Average salinity of active Salt River Project wells. Figure supplied by the Salt River Project Office. TDS of individual wells ranges from 200 to 3000 mg/l. Volumetric average varies according to which wells are being pumped.

[d] Present salinity of Colorado River water of the Central Arizona Project diversion point above Parker Dam.

Table 3-83. Effects of increasing salinity of Central Arizona Project water when it is blended into the Salt River Project water (assuming an allotment of the 150,000 ac ft requested).

850,000 ac ft Salt and Verde Rivers Water TDS (mg/l)	200,000 ac ft Groundwater TDS (mg/l)	1,050,000 ac ft Salt River Project Water TDS (mg/l)	150,000 ac ft Central Arizona Project Water TDS (mg/l)	1,200,000 ac ft Blended Central Arizona Project and Salt River Project TDS (mg/l)
467	980	565	775	591
467	980	565	900	607
467	980	565	1000	619
467	980	565	1100	632
467	980	565	1200	644
467	980	565	1300	657
467	980	565	1400	669

Table 3-84. Number of acres available for single and double cropping by land class, Salt River Project.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	73,815	17,441	91,256
Land 2 (Moderately Drained)	48,325	11,417	59,742
Land 3 (Poorly Drained)	12,085	2,859	14,944
Total	134,225	31,717	165,942

Table 3-85. Selected crops and double cropping possibilities, Salt River Project.

Crops	Double Cropping Possibilities[a]			
	Wheat	Barley	Lettuce	Sorghum
Alfalfa				
Cotton			x	
Barley				
Wheat				
Sorghum	x	x	x	x
Lettuce	x	x	x	x
Onion			x	x
Grapefruit				
Oranges/Tangerines				
Sugar Beets				
Carrots				

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-86. Yields of major crops in the Salt River Project, 1964-1973 (tons/acre).

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa	5.40	5.30	5.90	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.86 ± 0.19
Upland Cotton	2.25	2.30	1.50	1.75	2.50	2.25	2.00	2.25	2.43	2.55	2.18 ± 0.24[a]
Upland Cotton Seed	1.00	1.00	0.60	0.80	1.00	1.00	1.00	1.00	1.10	1.10	0.96 ± 0.11
Barley	2.04	1.92	1.80	1.99	1.97	1.70	1.99	2.04	2.14	2.21	1.98 ± 0.11
Wheat							2.25	2.55	2.70	2.82	2.58 ± 0.39
Sorghum	1.85	2.13	2.13	2.38	2.24	2.18	2.24	1.82	2.18	2.35	2.15 ± 0.13
Carrots	13.00	13.00	13.00	13.50	13.50	13.50	10.50	12.00	13.00	10.00	12.50 ± 0.91
Lettuce	10.45	11.85	13.15	10.00	9.45	10.25	10.23	12.80	11.83	13.13	11.31 ± 1.00
Onions (Dry)	15.00	15.00	15.00	15.00	15.00	18.75	18.00	18.75	22.50	22.50	17.55 ± 2.20
Grapefruit	10.15	7.95	9.60	6.15	18.00	12.40	22.00	10.45	9.90	10.80	11.74 ± 3.40
Oranges/Tangerines				6.85	5.90	10.05	13.75	6.70	8.40	10.30	8.85 ± 2.54
Sugar Beets				18.00	20.00	19.00	15.00	21.40	22.50	23.00	19.80 ± 2.80

[a] 480-pound bales per acre.

Source: Yields taken from annual crop reports of the Salt River Project, full and supplemental irrigation service.

computed for the expected levels of salinity after Central Arizona Project water is blended into the Salt River Project system (Table 3-87). As in previous study areas, these values were used in conjunction with Table 3-1 to construct yield declination curves for the respective crops.

Results from the model indicate that little change can be expected to occur in land use and production over the TDS interval in question. It can be observed in Table 3-88 that production and number of acres for each of the selected crops are constant over the TDS range from 775 to 1400 mg/l for Colorado River water. It was also observed that the shadow prices corresponding to the different classes of land were also constant. Since these values are relative, little additional information could be gained from a table as presented in previous sections and, consequently, one was not constructed for this district.

Table 3-89 contains the estimated amount of water used in the district as a whole and on a per acre basis. The resulting quality of blended water ranges between 591 and 669 mg/l. Water within this quality range has negligible effects on agriculture in this area as is evidenced in Table 3-90. The objective function shows no change at any TDS level within the defined range and, therefore, no damages are assumed to accrue to agriculture as a result of irrigating with water from the Colorado River. In view of this, no damage function has been constructed. The summary statistics contained in Table 3-91 illustrate that a monetary figure of damages is placed at zero for purposes of the present study.

Lands Supplemental to Salt River Project

Several small districts pump groundwater and contract for supplemental irrigation from the Salt

Table 3-87. Effective values of soil saturation extract conductivities (ECe x 10^3) in three soil drainage classes, four TDS levels, and five irrigation treatments, Salt River Project.

TDS (mg/l)	Irrigation Number	Drainage Classification Well	Moderate	Poor
500	16	0	0.3	1.5
	22	0	0	1.2
	29	0	0	1.0
	35	0	0	0.8
	Sprinkler	0	0	0
600	16	0	0.7	2.2
	22	0	0.3	1.8
	29	0	0.1	1.6
	35	0	0	1.3
	Sprinkler	0	0	0.3
700	16	0	1.4	3.3
	22	0	0.8	2.7
	29	0	0.6	2.5
	35	0	0.2	2.1
	Sprinkler	0	0	1.2
800	16	0.1	1.5	3.5
	22	0.1	1.0	3.0
	29	0.1	0.8	2.8
	35	0.1	0.4	2.4
	Sprinkler	0	0	1.4

Table 3-89. Ratio of amount of water used to land and profit all by level of TDS, Salt River Project.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
565	810,115	4.882	32.90
900	810,115	4.882	32.90
1100	810,115	4.882	32.90
1400	810,115	4.882	32.90

Table 3-88. Cropping and production pattern changes, Salt River Project.

Crops	Total Dissolved Solids (mg/l) 565 Production (Tons)	565 Land Use (Acres)	900 Production (Tons)	900 Land Use (Acres)	1100 Production (Tons)	1100 Land Use (Acres)	1400 Production (Tons)	1400 Land Use (Acres)
Alfalfa	275,149	46,954	275,149	46,954	275,149	46,954	275,149	46,954
Cotton[a]	67,763	31,084	67,763	31,084	67,763	31,084	67,763	31,084
Barley	32,150	16,237	32,150	16,237	32,150	16,237	32,150	16,237
Wheat	73,119	28,341	73,119	28,341	73,119	28,341	73,119	28,341
Sorghum	40,601	30,393	40,601	30,393	40,601	30,393	40,601	30,393
Lettuce	14,976	1,324	14,976	1,324	14,976	1,324	14,976	1,324
Onion	12,139	692	12,139	692	12,139	692	12,139	692
Grapefruit	23,360	1,990	23,360	1,990	23,360	1,990	23,360	1,990
Oranges/Tangerines	35,288	3,987	35,288	3,987	35,288	3,987	35,288	3,987
Sugar Beets	79,417	4,011	79,417	4,011	79,417	4,011	79,417	4,011
Carrots	11,618	929	11,618	929	11,618	929	11,618	929
Total		165,942		165,942		165,942		165,942

[a] 480-pound bales.

Table 3-90. Total and per acre net profit by TDS level, Salt River Project.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
565	26,649,599	160.60
900	26,649,599	160.60
1100	26,649,599	160.60
1400	26,649,599	160.60

Table 3-91. Summary statistics, Salt River Project.

Total Acres	165,942
Double Cropped Acres	31,717
Annual Total Damages	$ 0
Annual Per Acre Damages	$ 0
Annual Damages Per mg/l	$ 0
Annual Damages Per mg/l Per Acre	$ 0

River Project. Under the Salt River supplemental subgroup heading are a number of small districts representing varius acreages which are: Gila Crossing District, Maricopa Garden Falls District, Peninsular Ditch Company, Salt River Indian Reservation, and St. Johns Irrigation District (Map 3-10). The respective acreages were totaled and partitioned by drainage class in Table 3-92.

Table 3-92. Number of acres available for single and double cropping by land class, lands supplemental to Salt River Project.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	10,160	4,627	14,787
Land 2 (Moderately Drained)	6,300	2,676	8,976
Land 3 (Poorly Drained)	1,980	616	2,596
Total	18,440	7,919	26,359

A list of the crops chosen for the model is shown in Table 3-93 along with the matrix of double cropping possibilities. As can be seen, lettuce and sorghum are very important in that they provide the most double cropping alternatives.

Determination of base yields was made utilizing data information from the Salt River Project (Table 3-86). These base figures were used to establish crop yield declination curves under differing levels of water quality in accordance with the procedure in previous study areas. The model results demonstrated that little change can be expected in crop production and land use. Table 3-94 displays the optimal production and acreage amounts as estimated by the model.

Since no significant change is observed over the TDS range considered applicable to this area, no attempt is made to estimate a damage function. In spite of this, Table 3-95 presenting water use, Table 3-96 containing the dollar values of the objective functions, and Table 3-97 summarizing statistics applicable to the area are presented as supplementary information.

Table 3-93. Selected crops and double cropping possibilities, lands supplemental to Salt River Project.

Crops	Double Cropping Possibilities[a]			
	Wheat	Barley	Lettuce	Sorghum
Alfalfa				
Cotton			x	x
Barley				
Wheat				
Sorghum	x	x	x	x
Lettuce	x	x	x	x
Onion			x	x
Sugar Beets				

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Roosevelt Water Conservation District

The Roosevelt Water Conservation District (RWCD) is on the east side of and adjacent to the Salt River Valley Water Users Association District (Map 3-11). It has a total irrigable area of 39,415 acres. In 1973 this acreage consisted of 116 acres of urban and suburban residential, commercial, and industrial lands; 1,211 acres of farmsteads, roads, ditches, and drains; and 34,703 acres of cultivated cropland, of which 28,188 acres were irrigated (Annual Crop Production Reports, Roosevelt Water Conservation District).

The water supply consists of 5.6 percent of the surface water diverted at Granite Reef Dam by the Salt River Project (SRP) and 55 active wells. Well water is pumped directly into the distribution system which consists of 141 miles of concrete lined canals and laterals (McClanahan, personal interview). The average surface water supply from SRP has been approximately 50,000 ac ft per year[2], and the average pumpage has been approximately 100,000 acre feet per year (Arizona Water Commission files). If we assume an allotment of 50,000 ac ft of Central Arizona Project (CAP) water (RWCD request was 75,000 ac ft), they would still have to continue pumping 50,000 ac ft to meet their needs.

No specific data on the salinity of the wells being pumped are available, however, an estimate can be made by averaging the published analyses made on wells within the district area (Table 3-98) (Babcock, 1973). Increasing salinity of CAP water has the possibility of several different impacts to RWCD

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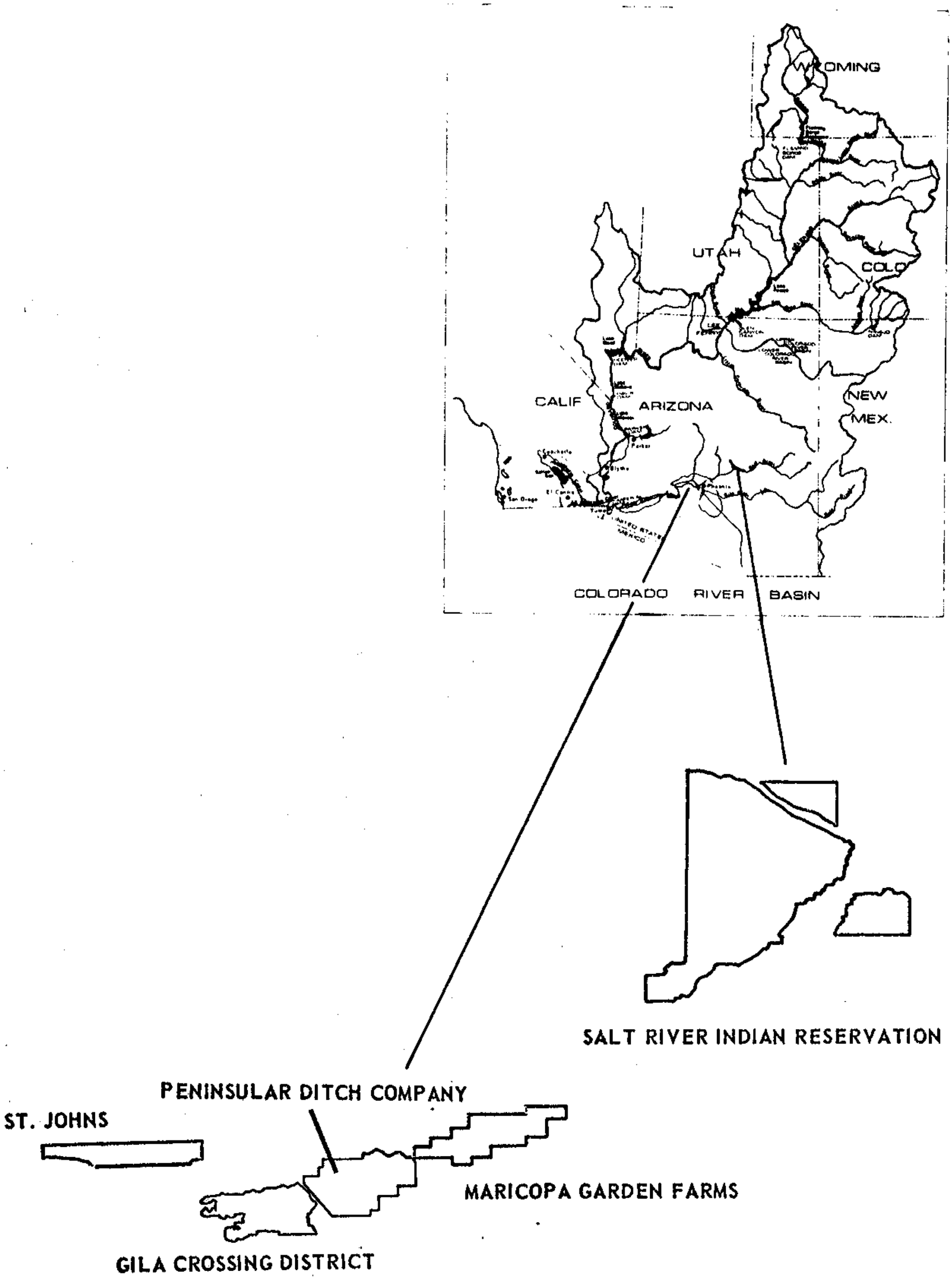
[2] 5.6 percent of 900,000 ac ft (9-year average flow of the Salt and Verde Rivers).



Map 3-10. Lands supplemental to Salt River project.

Table 3-94. Cropping and production pattern changes, lands supplemental to Salt River Project.

Crops	Total Dissolved Solids (mg/l)							
	565		900		1100		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	13,500	2,304	13,500	2,304	13,500	2,304	13,500	2,304
Cotton[a]	13,750	6,307	13,750	6,307	13,750	6,307	13,750	6,307
Barley	3,850	1,944	3,850	1,944	3,850	1,944	3,850	1,944
Wheat	7,777	3,014	7,777	3,014	7,777	3,014	7,777	3,014
Sorghum	9,256	4,535	9,256	4,535	9,256	4,535	9,256	4,535
Lettuce	55,000	4,863	55,000	4,863	55,000	4,863	55,000	4,863
Onion	7,916	451	7,916	451	7,916	451	7,916	451
Sugar Beets	18,000	909	18,000	909	18,000	909	18,000	909
Total		24,327		24,327		24,327		24,327
D. C. Fallow		2,032		2,032		2,032		2,032

[a] 480-pound bales.

Table 3-95. Ratio of amount of water used to land and profit all by level of TDS, lands supplemental to Salt River Project.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
565	110,000	4.520	45.30
900	110,000	4.520	45.30
1100	110,000	4.520	45.30
1400	110,000	4.520	45.30

Table 3-96. Total and per acre net profit by TDS level, lands supplemental to Salt River Project.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
565	4,982,678	204.81
900	4,982,678	204.81
1100	4,982,678	204.81
1400	4,982,678	204.81

Table 3-97. Summary statistics, lands supplemental to Salt River Project.

Total Acres	26,359
Double Cropped Acres	7,919
Annual Total Damages	$ 0
Annual Per Acre Damages	$ 0
Annual Damages per mg/l	$ 0
Annual Damages Per mg/l Per Acre	$ 0

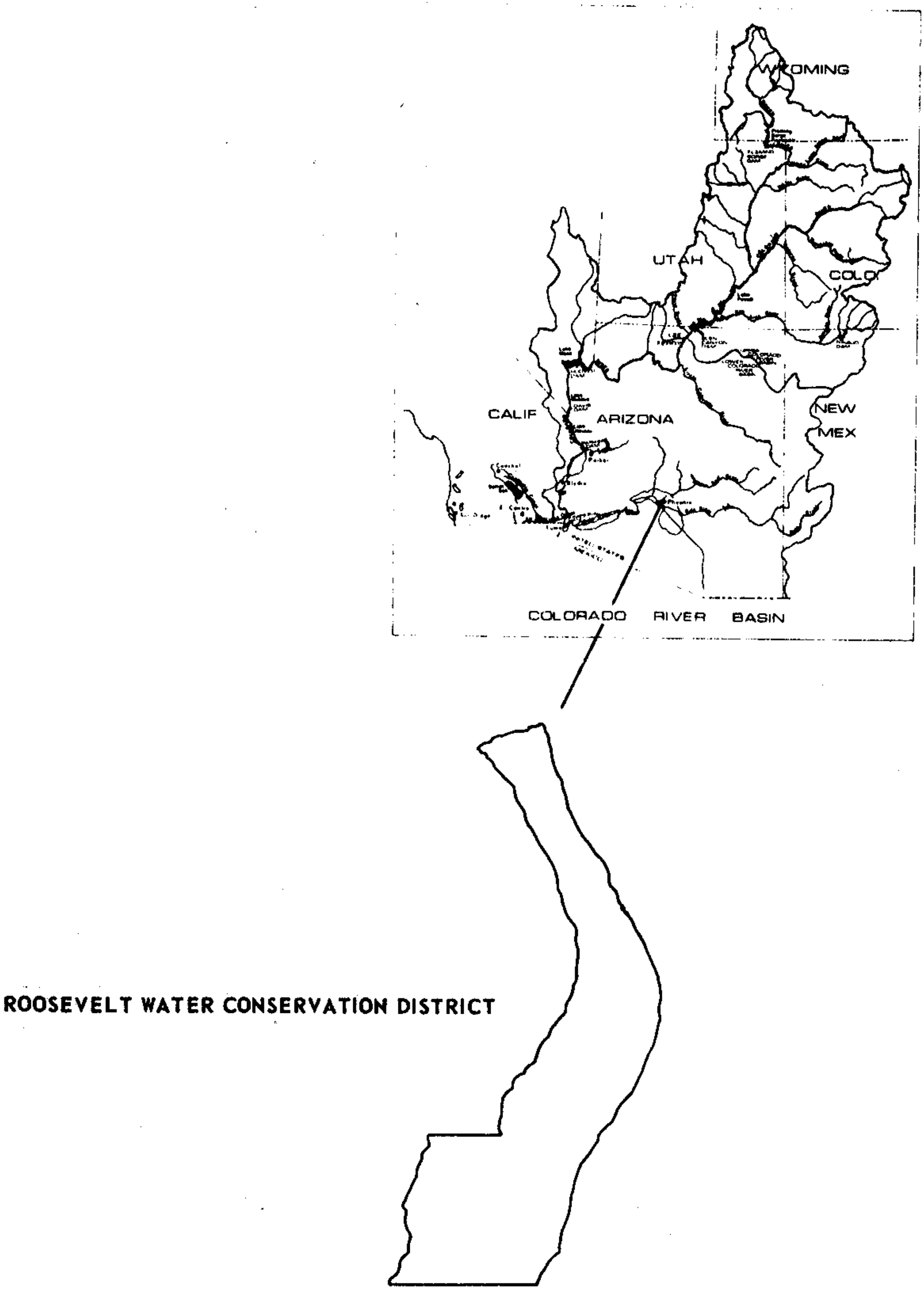
Table 3-98. Water quality of selected wells in the Roosevelt Water Conservation District.

Twp	Range	Section	Sample Date	EC x 10^3	TDS	SAR	Water Class
1 N	6 E	4	1966	1.2	780	4.7	C3-S1
		4	1960	1.2	835	4.9	C3-S1
		15	1963	1.7	931	4.1	C3-S1
		17	1959	1.5	740	5.5	C3-S2
		22	1961	1.1	639	8.6	C3-S2
		26	1959	1.1	734	8.5	C3-S2
		26	1959	1.2	655	9.4	C3-S2
		34	1967	0.8	520	4.7	C3-S1
1 S	6 E	10	1961	1.7	931	2.8	C3-S1
		13	1956	1.2	850	1.3	C3-S1
		21	1959	1.3	641	2.8	C3-S1
2 S	6 E	2	1950	1.0	681	1.6	C3-S1
		2	1950	1.4	993	1.5	C3-S1
		9	1950	1.4	977	1.9	C3-S1
		28	1951	0.9	638	2.5	C3-S2
		32	1957	0.8	693	7.0	C3-S2
Average				1.2	765	4.5	C3-S1

Source: Smith, H. V., G. E. Draper, and W. H. Fuller, "The Quality of Arizona Irrigation Waters," University of Arizona Experiment Station, Report 223, 1964.

water quality depending upon how it is delivered to the district. If the CAP water is mixed with the SRP surface water above Granite Reef Dam (or Orme Dam) the dilution will be very beneficial to RWCD, as shown in Table 3-99. However, if the CAP water is delivered directly to the RWCD system, the resulting blend will be significantly higher in TDS as shown in Table 3-100.

The soils of the RWCD are assigned to drainage groups in Table 3-101 where approximately 36,000 total acres are considered as the estimated cropland



Map 3-11. Roosevelt Water Conservation District.

Table 3-99. ***Effects of increasing salinity of Central Arizona Project water when it is blended with Salt River Project surface water before being delivered to the Roosevelt Water Conservation District (assuming an allotment of 200,000 ac ft, 150,000 Salt River Project, and 50,000 Roosevelt Water Conservation District, delivered above Granite Reef Dam).***

900,000 ac ft Salt and Verde Rivers Water TDS (mg/l)	200,000 ac ft Central Arizona Project Water TDS (mg/l)	100,000 ac ft Blended Salt River Project and Central Arizona Project Water TDS (mg/l)	50,000 ac ft Roosevelt Water Conservation District Groundwater TDS (mg/l)	150,000 ac ft Blended Central Arizona Project, Salt River Project, and Roosevelt Water Conservation District Groundwater TDS (mg/l)
470	775	522	765	603
470	900	548	765	620
470	1000	566	765	632
470	1100	585	765	645
470	1200	603	765	657
470	1300	621	765	669
470	1400	639	765	681

Table 3-100. ***Effects of increasing salinity of Central Arizona Project water when it is blended into the Roosevelt Water Conservation District Water (assuming an allotment of 50,000 ac ft of Central Arizona Project Water) delivered directly to the Roosevelt Water Conservation District System.***

50,000 ac-ft Salt and Verde Rivers Water[a] TDS (mg/l)	50,000 ac-ft Groundwater TDS (mg/l)	100,000 ac-ft Roosevelt Water Conservation District Water TDS (mg/l)	50,000 ac-ft Central Arizona Project Water TDS (mg/l)	150,000 ac-ft Blended Central Arizona Project, and Roosevelt Water Conservation District Water TDS (mg/l)
470	765	620	775[a]	672
470	765	620	900	713
470	765	620	1000	747
470	765	620	1100	780
470	765	620	1200	813
470	765	620	1300	847
470	765	620	1400	880

[a] Present salinity of the Colorado River water at the Central Arizona Project diversion point above Parker Dam.

Table 3-101. ***Number of acres available for single and double cropping by land class, Roosevelt Water Conservation District.***

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	10,630	2,574	13,204
Land 2 (Moderately Drained)	12,610	2,680	15,290
Land 3 (Poorly Drained)	6,365	1,337	7,702
Total	29,605	6,591	36,196

area. Some 6,600 acres or about 18 percent of the total are allocated for double cropping purposes. A double cropping matrix is presented in Table 3-102 along with a list of the selected crops.

Base yields were derived from data contained in Table 3-103 from which declination curves were formed. Once again the model results indicate that no measurable change in land use and production patterns should be expected within the TDS ranges defined for this study and, therefore, a damage function was not constructed for this area. Tables 3-104, 3-105, 3-106, and 3-107 are presented in order to illustrate the magnitudes assumed by the different factors such as the respective crop production and land use, water use, and estimated value of net returns to the area both as a whole and on a per acre basis.

Roosevelt Irrigation District

The Roosevelt Irrigation District (RID) is in western Salt River Valley and includes an area approximately 20 miles long and 3 miles wide along the north side of the old Gila River channel between the Agua Fria and Hassayampa Rivers (Map 3-12). The total irrigable area is 38,152 acres. In 1973 this

Table 3-102. Selected crops and double cropping possibilities, Roosevelt Water Conservation District.

Crops	Double Cropping Possibilities[a]				
	Wheat	Barley	Lettuce	Sorghum	Watermelon
Alfalfa					
Cotton			x		
Barley					
Wheat					
Sorghum	x	x	x	x	x
Lettuce	x	x	x	x	x
Watermelon	x	x	x		
Grapefruit					
Oranges/Tangerines					
Sugar Beets					

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-103. Yields of major crops in the Roosevelt Water Conservation District, 1968-1973, (tons/acre).[a]

	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa	6.00	6.00	6.00	6.00	6.00	6.00	6.00 ± 0
Barley	1.97	1.70	1.99	2.04	2.14	2.16	2.00 ± 0.17
Wheat	1.86	1.86	2.25	2.55	2.70	2.76	2.33 ± 0.42
Sorghum	1.92	2.18	2.24	1.82	1.71	2.16	2.01 ± 0.23
All Cotton	2.23	2.17	1.92	2.14	2.01	1.96	2.07 ± 0.13[b]
All Cotton Seed	0.90	0.95	0.97	0.95	0.85	0.88	0.92 ± 0.05
Carrots	13.50	13.50	9.00	12.00	6.50	13.00	11.25 ± 3.02
Lettuce	4.72	10.25	10.23	12.83	7.75	13.50	9.88 ± 3.42
Watermelon	14.00	14.00	8.50	12.00	13.00	10.00	11.92 ± 2.36
Sugar Beets	20.00	19.00	15.00	21.40	22.50	23.00	20.15 ± 3.08
Grapefruit	18.00	12.40	22.00	10.45	18.75	10.80	15.40 ± 5.06
Lemons/Limes			19.25	10.90	19.25	15.30	16.18 ± 6.33
Oranges/Tangerines	5.93	10.05	13.75	6.70	12.35	10.30	9.85 ± 3.22

[a] Yields prior to 1972 from Salt River Project crop reports.

[b] 480-pound bales per acre.

Source: Annual Crop Production Reports, Roosevelt Water Conservation District.

was broken down into 2,250 acres of farmsteads, roads, ditches, and drains; 660 acres of urban and suburban residential, commercial, and industrial; and 31,663 acres irrigated for harvest or pasture (Guidelines to Production Costs and Practices).

Irrigation water is pumped entirely into a concrete-lined distribution system (Arizona Water Commission files). The estimated pumpage is 160,000 ac ft per year within 106 active wells. Part of the water comes from wells within the western boundaries of the Salt River Valley Water Users Association and part from wells within the RID boundaries. In addition, a portion is also obtained from wells along the Agua Fria River to the east of the old river bed. Nearly all are high in salt content as is shown by published analyses of a few selected wells (Table 3-108). Water samples taken directly from the main canals have run around 1,300 mg/l TDS (McLouth, personal interview). If this figure is too low, as might be indicated by Table 3-99, the replacement of RID groundwater by Central Arizona Project (CAP) water could eliminate the worst wells and help bring the water from the remaining wells down to somewhere near this estimate.

The soils of the RID are predominantly well drained. This has made it possible to use the present water supply which has a relatively high salt content. Whatever the amount of CAP water allotted it will serve to improve the district's water quality by dilution, at least until the CAP water reaches 1300 mg/l TDS. Since the RID has requested 75,000 ac ft, it may not be too far off to assume an allotment of 40,000-50,000 ac ft. If they are allotted 40,000 ac ft, they will still have to pump 120,000 ac ft of groundwater to meet their commitments.

Table 3-109 shows the effect of increasing salinity in the CAP water on the resulting blend. If the district is allotted 50,000 ac ft and pump 110,000, the blend will be only slightly lower in TDS with the present

Table 3-104. Cropping and production pattern changes, Roosevelt Water Conservation District.

Crops	Total Dissolved Solids (mg/l)															
	620		775		900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	49,500	8,250	49,500	8,250	49,500	8,250	49,500	8,250	49,500	8,250	49,500	8,250	49,500	8,250	49,500	8,250
Cotton[a]	27,311	13,194	27,311	13,194	27,311	13,194	27,311	13,194	27,311	13,194	27,311	13,194	27,311	13,194	27,311	13,194
Barley	5,138	2,569	5,138	2,569	5,138	2,569	5,138	2,569	5,138	2,569	5,138	2,569	5,138	2,569	5,138	2,569
Wheat	3,208	1,377	3,208	1,377	3,208	1,377	3,208	1,377	3,208	1,377	3,208	1,377	3,208	1,377	3,208	1,377
Sorghum	3,556	2,859	3,556	2,859	3,556	2,859	3,556	2,859	3,556	2,859	3,556	2,859	3,556	2,859	3,556	2,859
Lettuce	2,750	278	2,750	278	2,750	278	2,750	278	2,750	278	2,750	278	2,750	278	2,750	278
Watermelon	7,275	610	7,275	610	7,275	610	7,275	610	7,275	610	7,275	610	7,275	610	7,275	610
Grapefruit	22,000	1,429	22,000	1,429	22,000	1,429	22,000	1,429	22,000	1,429	22,000	1,429	22,000	1,429	22,000	1,429
Oranges/Tangerines	23,151	2,351	23,151	2,351	23,151	2,351	23,151	2,351	23,151	2,351	23,151	2,351	23,151	2,351	23,151	2,351
Sugar Beets	6,360	316	6,360	316	6,360	316	6,360	316	6,360	316	6,360	316	6,360	316	6,360	316
Total		33,233		33,233		33,233		33,233		33,233		33,233		33,233		33,233
D. C. Fallow		2,963		2,963		2,963		2,963		2,963		2,963		2,963		2,963

[a] 480-pound bales.

Table 3-105. Ratio of amount of water used to land and profit all by level of TDS, Roosevelt Water Conservation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
620	150,000	4.514	35.00
775	150,000	4.514	35.00
900	150,000	4.514	35.00
1000	150,000	4.514	35.00
1100	150,000	4.514	35.00
1200	150,000	4.514	35.00
1300	150,000	4.514	35.00
1400	150,000	4.514	35.00

Table 3-106. Total and per acre net profit by TDS level, Roosevelt Water Conservation District.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
620	5,249,952	157.97
775	5,249,952	157.97
900	5,249,952	157.97
1000	5,249,952	157.97
1100	5,249,952	157.97
1200	5,249,952	157.97
1300	5,249,952	157.97
1400	5,249,952	157.97

Table 3-107. Summary statistics, Roosevelt Water Conservation District.

Total Acres	36,196
Double Cropped Acres	6,591
Annual Total Damages	$ 0
Annual Per Acre Damages	$ 0
Annual Damages Per mg/l	$ 0
Annual Damages per mg/l Per Acre	$ 0

Table 3-108. Water quality of selected wells which serve the Roosevelt Irrigation District.

Twp	Range	Section	Sample Date	EC x 10^3	TDS	SAR	Water Class
1 N	1 E	1	1963	1.7	1019	2.6	C3-S1
1 N	2 E	7	1963	2.0	1258	4.3	C3-S2
		9	1963	2.5	1524	6.9	C4-S2
2 N	1 E	4	1963	0.9	539	1.2	C3-S1
1 N	1 W	7	1960	2.0	1223	4.7	C3-S1
		10	1959	1.4	850	1.3	C3-S1
1 N	2 W	8	1963	2.6	1554	2.7	C4-S1
		13	1963	5.5	4581		
		15	1963	3.0	2081	5.6	C4-S2
		20	1963	4.9	3694	7.7	C4-S2
1 N	3 W	13	1963	6.3	4570		
		19	1963	7.2	4933		
		27	1963	5.5	4358		
		28	1963	6.2	4824		
		31	1963	5.5	4324		
1 N	4 W	20	1963	2.4	1563	9.6	C4-S1
		27	1963	7.0	4985		
		30	1963	4.7	3981		
		33	1963	6.4	5469		
		36	1963	5.5	4324		
2 N	1 W	25	1963	0.6	407	3.0	C2-S1
		26	1963	0.6	337	3.6	C2-S1
Average				3.8	2836		

Source: Smith, H. V., G. E. Draper, and W. H. Fuller, "The Quality of Arizona Irrigation Waters," University of Arizona Experiment Station, Report 223, 1964.

Table 3-109. Effects of increasing salinity of Central Arizona Project water when it is blended into the Roosevelt Irrigation District Water (assuming an allocation of 40,000 ac ft of Central Arizona Project water).

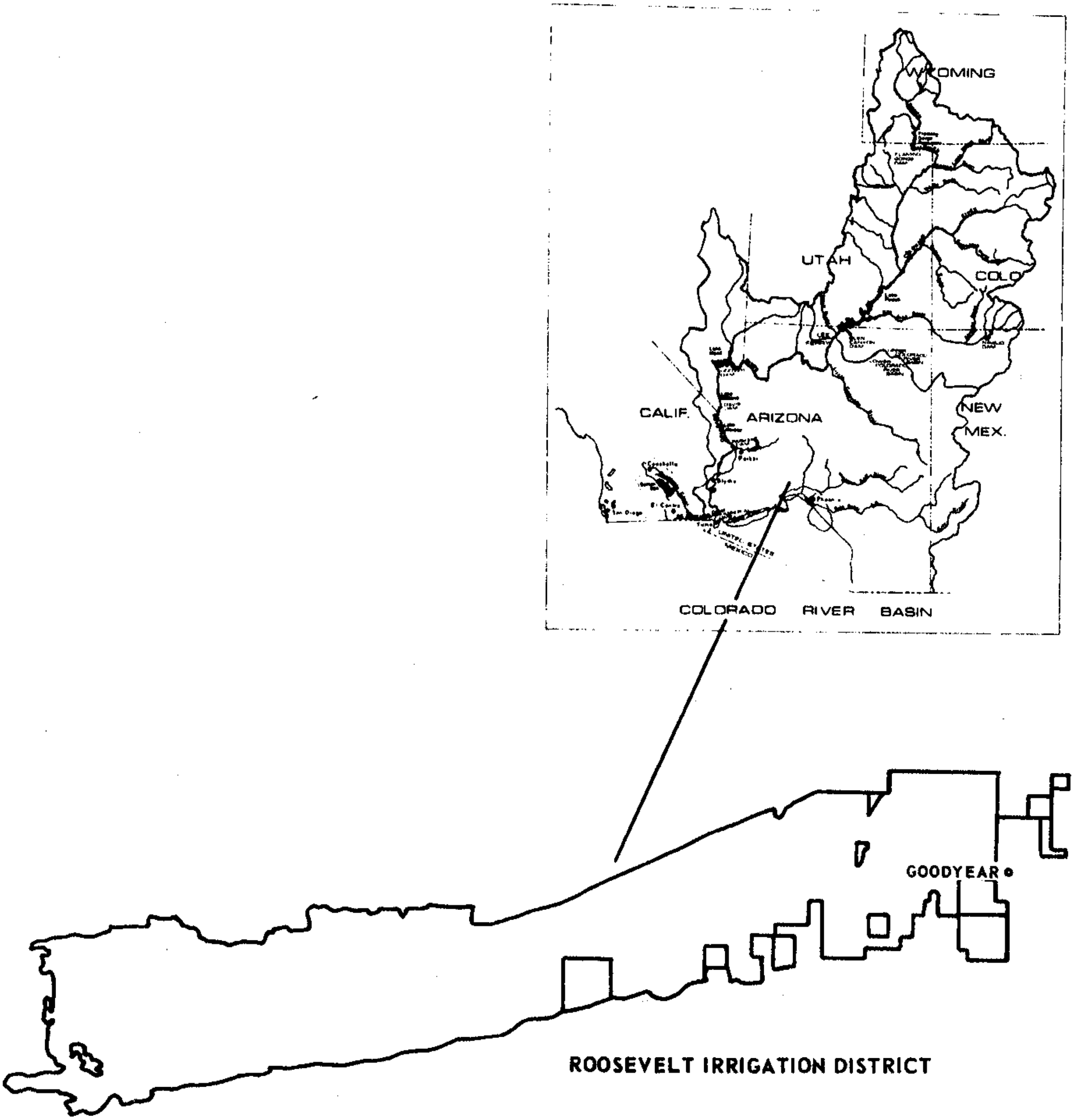
120,000 ac ft Roosevelt Irrigation District Groundwater TDS (mg/l)	40,000 ac ft Central Arizona Project Water TDS (mg/l)	160,000 ac ft Blended Water TDS (mg/l)
1300	775	1169
1300	900	1200
1300	1000	1225
1300	1100	1250
1300	1200	1275
1300	1300	1300
1300	1400	1325

level of Colorado River water at the diversion point and approximately the same when the Colorado reaches 1400 mg/l (1136, 1175, 1206, 1237, 1269, 1300, and 1331, respectively). Therefore, possible crop declinations are computed on the basis of a 40,000 ac ft allotment of CAP water.

About 31,000 acres are considered for this study area. Most of the acreage has been classified as belonging to land class 1. Table 3-110 shows how the lands were classified along with the amount of acreage considered available for double cropping. The crops chosen for RID are contained in Table 3-111.

Yields of the major crops were collected from district records. Base yield figures were computed from the numbers obtained (Table 3-112). These numbers were used in conjuction with Table 3-113 and compared to Table 3-1 in order to derive a salinity declination function for each of the respective crops.

Model runs were then made for each applicable level of TDS from the resulting blend of water after the CAP supply is introduced into the area. The results are shown in Table 3-114. A minor change is noted in the amount of acreage allocated to alfalfa, lettuce, and pasture. As salinity increases, both the production and occupied land area of alfalfa decrease. This occurs in order to release additional area in order to maintain the production levels of lettuce and pasture. Overall, these changes are very small and, as will be observed below, are insignificant.



Map 3-12. Roosevelt Irrigation District.

Table 3-110. Number of acres available for single and double cropping by land class, Roosevelt Irrigation District.

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	28,168	784	28,952
Land 2 (Moderately Drained)	2,130	55	2,185
Land 3 (Poorly Drained)	231	–	231
Total	30,529	839	31,368

There is a small change in the shadow price of land class 3 as demonstrated in Table 3-115. The remaining values, however, remain constant over the TDS interval in question and indicate that salinity has minimal effect on changes in demand for the different land classes.

Table 3-116 displays the total amount of water required in the model, number of acre feet used per acre, and the ratio of total water used to estimate net profit for each level of TDS. The change in water use over the interval 775-1400 mg/l is so small that it is assumed no difference exists. The same can also be deduced concerning changes in the objective function. In Table 3-117, seven objective functions vaues are presented which correspond to the respective levels of TDS. The total change over the interval (775-1400 mg/l) is only $5,409. It appears that significant agricultural damages will not be encountered within the specific TDS range especially in view of the fact that present water quality in the RID is about 1300 mg/l. Additions of Colorado River water below this level would improve water quality and benefit its users. However, when Colorado River water surpasses 1300 mg/l, damages are expected to increment quite rapidly. In light of the above discussion and the relatively small amount of estimated damages, it is assumed that the benefits accruing to the Colorado River supply up to 1300 mg/l are offset by expected damages from 1300 to 1400 mg/l. Figure 3-19 contains

Table 3-111. Selected crops and double cropping possibilities, Roosevelt Irrigation District.

Crops	Double Cropping Possibilities[a]				
	Wheat	Barley	Lettuce	Sorghum	Silage
Alfalfa					
Cotton			x	x	x
Barley					
Wheat					
Sorghum	x	x	x	x	x
Lettuce	x	x	x	x	x
Alfalfa Seed					
Silage	x	x	x	x	x
Pasture					
Sugar Beets					

[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-112. Yields of major crops in the Roosevelt Irrigation District, 1969-1973 (tons/acre).

	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa Hay	6.00	6.00	6.00	6.00	6.00	6.00 ± 0
Ensilage (Sorghum or Corn)	35.00	22.00	28.00	20.00	25.00	26.00 ± 7.29
Barley	1.70	1.99	2.11	2.14	2.26	2.04 ± 0.26
Wheat	1.86	2.25	2.55	2.70	3.24	2.52 ± 0.64
Upland Cotton	2.25	2.0	2.20	2.40	2.40	2.25 ± 0.21[a]
Upland Cotton Seed	1.00	1.00	1.00	1.00	1.10	1.02 ± 0.06
Sugar Beets	19.00	15.00	23.10	22.50	22.50	20.42 ± 4.27
Irrigated Pasture	6.30	6.00	6.10	6.00	6.10	6.10 ± 0.17[b]
Lettuce	10.28	10.25	13.20	11.25	N/A	11.24 ± 2.20
Sorghum	2.18	2.24	1.82	1.65	2.35	2.05 ± 0.37
Alfalfa Seed	2.0	2.0	1.0			1.67 ± 1.06[c]

[a] 480-pound bales per acre.

[b] Animal unit months.

[c] Hundred weight.

Source: Data from Roosevelt Irrigation District Crop Reports.

Table 3-113. Effective values of soil saturation extract conductivities for levels of salinity to be expected in the blended water of the Roosevelt Irrigation District as the salinity of Central Arizona Project water increases to 1400 mg/l (based on an allotment of 40,000 ac ft of Central Arizona Project water).

TDS of Roosevelt Irrigation District-Central Arizona Project Blend	Irrigation Number	Drainage Classification		
		Well	Moderate	Poor
1169	16	1.1	3.2	6.1
	22	1.1	2.3	5.2
	29	1.1	2.0	4.9
	35	1.1	1.4	4.3
	Sprinkler	0.0	0.7	3.6
1200	16	1.2	3.3	6.3
	22	1.2	2.4	5.4
	29	1.2	2.1	5.1
	35	1.2	1.5	4.5
	Sprinkler	0.0	0.8	3.8
1225	16	1.3	3.4	6.5
	22	1.3	2.5	5.6
	29	1.3	2.2	5.3
	35	1.3	1.6	4.7
	Sprinkler	0.1	0.9	4.0
1250	16	1.4	3.6	6.7
	22	1.4	2.6	5.8
	29	1.4	2.3	5.4
	35	1.4	1.7	4.8
	Sprinkler	0.1	1.0	4.1
1275	16	1.4	3.7	6.8
	22	1.4	2.7	5.9
	29	1.4	2.4	5.6
	35	1.4	1.7	5.0
	Sprinkler	0.2	1.1	4.3
1300	16	1.5	3.8	7.0
	22	1.5	2.8	6.1
	29	1.5	2.5	5.7
	35	1.5	1.8	5.1
	Sprinkler	0.2	1.2	4.4
1325	16	1.6	3.9	7.2
	22	1.6	2.9	6.3
	29	1.6	2.6	5.9
	35	1.6	1.9	5.2
	Sprinkler	0.3	1.3	4.6

the observed data and the corresponding fitted damage function. In the functional notation of $Y = be^{mx}$ as defined earlier, $b = 0.7983$, $e = 2.718281828$, $m = 0.6537$, and x = any level of TDS within the confines of the appropriate interval. The fitted curve has an R^2 of 0.91.

A summary of the findings for the RID is presented in Table 3-118. Even though annual total damages are listed as $5,409, the net contribution from this District is considered zero due to the TDS level of present water supplies of the RID as compared to present and projected salinity levels of Colorado River water in the CAP system.

SAN CARLOS PROJECT

The San Carlos Project is located in the lower Santa Cruz River Basin, between Florence and Casa Grande, Arizona, and includes 100,000 acres of Indian and non-Indian land. All project facilities are operated jointly. They include: 1) Coolridge Dam and San Carlos Reservoir with a capacity of 948,584 ac ft at spillway level; 2) Ashurst-Hayden Diversion Dam on the mainstream of the Gila River 10 miles east of Florence; 3) Picacho Reservoir with a capacity of 18,000 ac ft used to store and regulate the delivery of water; 4) Florence-Casa Grande Canal, Pima Lateral, and sublaterals which serve both Indian and non-Indian lands; and 5) drainage and pumping works with 110 producing wells.

Over the last 5 years the water supply has consisted of approximately 70 percent surface water and 30 percent groundwater. The surface water comes from the natural flow of the Gila River and releases from the San Carlos Reservoir, plus the erratic flows of the San Pedro River. The groundwater is pumped into the system from wells scattered throughout the project area. During the last 20 years, pumping for both project and nonproject lands has resulted in a progressive lowering of the water table at an average rate of 8 feet per year to its present level of approximately 236 feet (Babcock, 1973).

Since 1934 the project has pumped an average of 89,000 ac ft per year, but for the last 10 years the average has been approximately 75,000 ac ft per year (Records of the San Carlos Irrigation Project). However, the rapidly lowering water table indicates that this rate of pumping cannot be maintained. In addition, yearly diversions of surface water from the river at the Ashurst-Hayden Dam have averaged 190,000 ac ft and are a reasonable expectation for the future.

There has been no decision on how much CAP water the project will receive. They have requested 240,000 ac ft which would enable the district to irrigate the entire 100,000 acres of land with a minimum of 4.0 ac ft per acre after allowing for losses, which are expected to be minimized by lining all canals and laterals. For the purposes of this study, it seems reasonable to assume an allotment of no more than 150,000 ac ft to the San Carlos Project. Water sources for the project would then be 150,000 ac ft, Colorado River water, 190,000 ac ft Gila River water, and possibly 50,000 ac ft of groundwater.

The salinity of the Gila River ranges from 510 mg/l to around 1000 mg/l "mean annual" TDS (Water Resources Data for Arizona), or an average 775 mg/l. Salinity of the groundwater ranges from around 500 mg/l TDS for the best wells to a high of 3,957 mg/l. Records on 64 wells are summarized in Table 3-119. The average of these 64 wells is 1510 mg/l TDS. If we assume 50,000 ac ft of groundwater with 1500 mg/l

Table 3-114. Cropping and production pattern changes, Roosevelt Irrigation District.

Crops	Total Dissolved Solids (mg/l)													
	775		900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	42,180	7,030	42,173	7,029	42,159	7,027	42,144	7,024	42,130	7,022	42,108	7,018	42,091	7,015
Cotton[a]	15,604	6,935	15,604	6,935	15,604	6,935	15,604	6,934	15,604	6,934	15,604	6,934	15,604	6,904
Barley	7,027	3,445	7,027	3,445	7,027	3,445	7,027	3,445	7,027	3,445	7,027	3,445	7,027	3,445
Wheat	5,585	2,216	5,585	2,216	5,585	2,216	5,585	2,216	5,585	2,216	5,585	2,216	5,585	2,216
Sorghum	644	314	644	314	644	314	644	314	644	314	644	314	644	314
Lettuce	1,918	171	1,918	171	1,918	171	1,918	173	1,918	171	1,918	176	1,918	179
Alfalfa Seed	217	2,571	217	2,571	217	2,571	217	2,571	217	2,571	217	2,571	217	2,571
Silage	24,314	935	24,314	935	24,314	935	24,314	935	24,314	935	24,314	935	24,314	935
Pasture	41,421	6,814	41,421	6,815	41,421	6,817	41,421	6,817	41,421	6,820	41,421	6,821	41,421	6,821
Sugar Beets	19,138	937	19,138	937	19,138	937	19,138	937	19,138	937	19,138	937	19,138	937
Total		31,368		31,368		31,368		31,368		31,368		31,368		31,368

[a] 480-pound bales.

Table 3-115. Shadow prices of land by class and level of TDS, Roosevelt Irrigation District.

	775 mg/l (Dollars)	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	88	88	88	88	88	88	88
Land 2	88	88	88	88	88	88	88
Land 3	70	69	68	68	66	65	65
Double Cropped 1	88	88	88	88	88	88	88
Double Cropped 2	88	88	88	88	88	88	88

Table 3-116. Ratio of amount of water used to land and profit all by level of TDS, Roosevelt Irrigation District.

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
775	153,030	4.879	24.96
900	153,028	4.878	24.96
1000	153,023	4.878	24.95
1100	153,017	4.878	24.95
1200	153,013	4.878	24.94
1300	153,005	4.878	24.93
1400	152,998	4.878	24.93

Table 3-117. Total and per acre net profit by TDS level, Roosevelt Irrigation District.

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
775	3,819,047	121.75
900	3,818,861	121.74
1000	3,818,493	121.73
1100	3,817,075	121.69
1200	3,816,704	121.68
1300	3,815,144	121.63
1400	3,813,638	121.58

Table 3-118. Summary statistics, Roosevelt Irigation District.

Total Acres	31,368
Double Cropped Acres	839
Annual Total Damages	$ 5,409
Annual Per Acre Damages	$ 0.1724
Annual Damage Per mg/l	$ 8.654
Annual Damage Per mg/l Per Acre	$0.00028

TDS and 190,000 ac ft of surface water with 755 mg/l TDS the projected water would have an average salinity of around 910 mg/l TDS before addition of Colorado River water. This can be expected to remain fairly constant except for the possibly small effect of changes in groundwater salinity due to continued lowering of the water table. However, groundwater quality has little effect due to the proportion involved. As the CAP water increases in salinity, the proportionate increase in the project water would be as shown in Table 3-120.

The canals and laterals of the project are unlined and losses in the system are estimated to be 30 percent or more (San Carlos Project). This means that the 50,000 acres presently being irrigated are receiving less than 4 ac ft of water per acre. If the losses can be cut to 15 percent by lining the canals and laterals, approximately 330,000 ac ft would be available to irrigate 80,000 acres with a minimum of 4 ac ft per year. Apparently, any crop yield declination due to increasing salinity of the CAP water would be more than offset by the additional acres irrigated. However, since this study is concerned with crop declination due to increasing salinity of CAP water, projections to the year 2000 will be based upon the acreage to be irrigated after the CAP water is brought into the project (80,000 acres assumed).

Acreages of the different soil types or series were estimated from a general soil map of Pinal County prepared in March 1971 by the USDA Soil Conservation Service (Adams, 1972).

Yields and acreages of the major crops in the San Carlos Project were obtained from the annual crop reports published by the project. Since these reports are broken down into "District Part" and "Indian Part," the salinity impact analysis is also treated separately.

San Carlos Irrigation Project, Non-Indian

Approximately 55,000 acres are included in the non-Indian part of the San Carlos Project (Map 3-13). Table 3-121 partitions this acreage by land class and use. Presently, only small amounts of land are assumed to be used in a double cropping rotation. About 70 percent of the total project area under cultivation is contained in the non-Indian classification.

Alfalfa, cotton, and grains are the major crops in the area with smaller acreages going to sugar beet production. A list of crops selected for the present analysis are shown in Table 3-122. Limited double cropping possibilities exist with maize (sorghum) being the most important.

Average yields were derived from empirical data presented in Table 3-123. A 95 percent confidence interval was set around the averages as an aid in establishing base yield figures. Once a base yield had been established, Table 3-124 along with Table 3-1

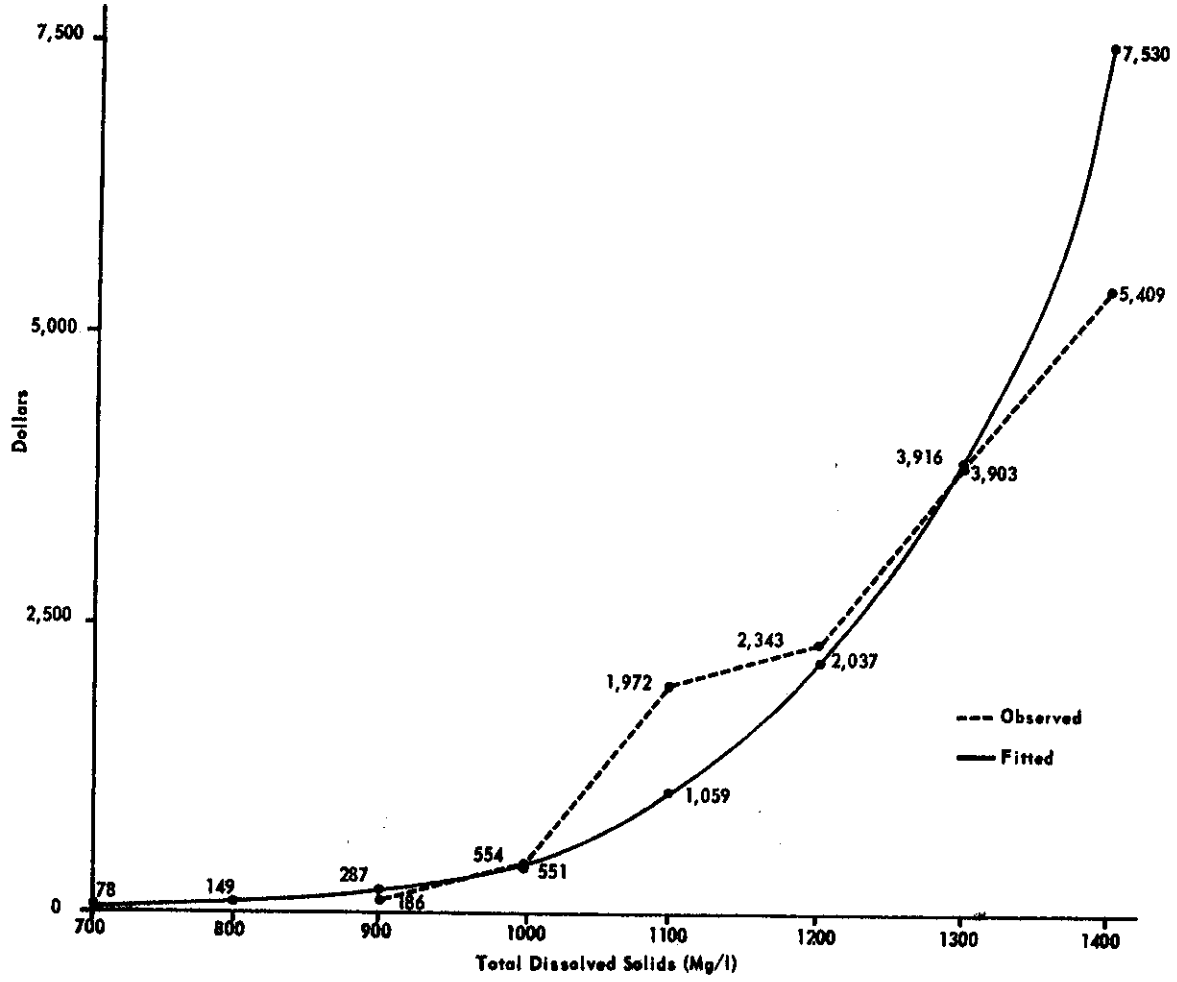


Figure 3-19. Observed data with fitted damage function, Roosevelt Irrigation District.

were employed to estimate yield declination functions for each crop selected in this area. Table 3-124 is based on the resulting TDS water mix as explained above which is unique to this project.

Consequent to the resulting irrigation water mix, the interval was widened to include the 775 mg/l conditions. Allocation of production and land to the various crops is presented in Table 3-125. These aggregated totals remained at the same levels over the entire TDS interval under study. However, sub-Appendix M should be consulted for a detailed analysis of model allocations to respective land classes and technologies.

The following two tables (Tables 3-126 and 3-127) contain constant amounts. For example, Table 3-126 shows 233,816 ac ft of water consumed out of a possible 240,000 ac ft available. No change is observed between 775 and 1400 mg/l. Likewise, in Table 3-127, the objective function estimated net profit to be $8,332, 477 for the whole area and $158.72 per acre. These amounts were also constant over the interval in question. Subsequently, no differences were detected and no portion of potential damages to this area were considered attributable to increasing salinity. Table 3-128 illustrates these conclusions as represented by the zero amounts opposite the lower four categories.

San Carlos Irrigation Project, Indian

Additional land is projected to be brought under irrigation by introduction of Central Arizona Project (CAP) water to the Indian part of the San Carlos Project (Map 3-14). Table 3-129 indicates that approximately 21,170 acres will be under irrigation. Lands are assigned to specific drainage classes as well as their feasible possibilities in relation to double cropping.

Most of the same crops were selected in the Indian part as were chosen to be major in the non-Indian part (Table 3-130). One addition is that of watermelon. The matrix of double cropping possibilities is slightly larger than in the previous area, however, land area available for this activity is much less.

Table 3-119. Groundwater quality, San Carlos Irrigation Project.

Sample Date	Well No.	Twp South	Range East	Section	Quadrant	EC x 10^3	TDS	SAR	Water Class
3-11-67	2	4	10	29	DAA	1.5	975		
8-1963	6	4	11	7	A	1.6	1176		
8-1963	9	4	9	28	CCA	2.2	1682		
8-1963	10	4	9	28	DAD	2.0	1441		
8-1963	12	4	10	16	ACC	1.1	767	4.0	C3-S1
1972	13	5	8	1	CBB	3.2	2103	4.56	C3-S1
1972	15	5	7	1	DDD	2.35	1600		
8-1963	17	5	9	30	CBB	1.0	661		
2- 3-67	23	5	8	23	CBB	2.5	1667		
8-1963	25	5	9	20	DAD	0.8	559		
1972	27	5	7	17	BBB	1.8	1174	3.96	C3-S1
1972	30	5	8	17	DDA	1.8	1175	3.59	C3-S1
1972	31	5	8	17	AAB	2.1	1386	3.15	C3-S1
1972	32B	5	8	18	BBB	1.6	1014	5.38	C3-S1
1972	33	5	8	2	AAB	2.5	1459	3.82	C3-S1
1972	34	5	7	1	AAC	2.5	1712	4.25	C3-S1
1972	35	4	7	36	DCD	2.5	1797	3.59	C3-S1
1972	36	4	7	35	DAD	1.6	1014	4.18	C3-S1
1972	37	4	7	34	DAB	1.95	1125	2.69	C3-S1
1972	39	4	7	36	CAC	1.5	923	6.39	C3-S2
1972	41	5	7	9	ADA	0.74	499		
1972	43B	4	6	4	AAA	1.4	893	8.74	C3-S2
1972	44	4	6	7	CCA	2.0	1439	3.44	C3-S1
1972	45	4	6	18	AAC	1.9	1244	4.92	C3-S1
1972	46	4	6	24	AAB	2.0	1355	4.05	C3-S1
1972	47	4	6	23	AAB	1.45	912	5.48	C3-S1
1972	48	4	6	3	BBC	2.1	1388	6.0	C3-S1
1972	49	4	5	12	AAA	2.4	1723	3.03	C3-S1
1972	50	5	8	10	CCA	1.6	1034	5.30	C3-S2
1972	51	4	5	10	AAA	2.4	1732	2.65	C3-S1
1972	52	5	7	22	BAC	4.0	2880	4.27	C4-S2
1972	55	4	6	8	DDD	1.95	1266	5.40	C3-S1
1972	56	4	6	7	AAD	1.95	1337	4.94	C3-S1
1972	58	4	5	15	BDA	4.5	3811	7.91	C4-S2
1972	59	3	5	29	BCA	1.75	1153	4.09	C3-S1
1972	60	3	5	31	CBA	1.6	1049	4.36	C3-S1
1972	62	3	5	30	CCC	2.2	1421	4.48	C3-S1
1972	64	4	6	21	BBB	3.2	2309	6.37	C4-S2
1972	65	3	6	19	DDD	1.6	1014	8.21	C3-S1
1972	67	3	6	31	DDA	1.6	924	4.28	C3-S1
1972	69	3	5	24	CBA	3.0	2079	5.79	C4-S3
1972	70	5	7	22	DDA	1.95	1337	4.94	C3-S1
1972	71	5	7	15	CCB	5.0	3624	4.55	C4-S2
1972	72	5	7	9	ADB	3.5	2480	4.67	C4-S2
1963	81	6	8	28	DBB	0.9	615	4.20	C3-S1
1972	86	4	7	28	DAA	1.3	735	14.63	C3-S3
1967	89	5	9	14	CBB	2.5	1667	5.94	C3-S2
1967	90	7	6	1	CCC	1.0	707	3.26	C3-S1
1972	94	3	5	4	ADA	2.3	1387	5.26	C3-S1
1972	95	3	5	4	BCB	5.6	3957	10.10	C4-S3
1972	98A	5	7	12	CCB	4.0	2974	4.47	C4-S2
1972	98B	5	7	22	AAA	3.4	2507	5.49	C4-S2
1963	102	6	6	34	CCB	2.8	1893		
1967	107	6	5	23	CDA	2.4	1739		
1972	109	4	5	10	DCC	4.0	3160	9.23	C4-S2
1972	110	5	9	12	BBC	1.0	736		
1972	120	5	8	5	CBA	2.1	1444	4.84	C3-S1
1972	121	4	5	3	CCC	3.1	2455	3.58	C4-S1
1972	123	4	4	1	CCC	1.5	934	4.36	C3-S1
1972	125	4	5	6	CCB	1.8	1176	4.96	C3-S1
1972	130	5	8	5	CBA	2.4	1533	3.89	C3-S1
1972	131	3	3	34	BBC	1.5	947	4.23	C3-S1
1972	132	5	8	5	BAB	1.5	849	2.07	C3-S1
1972	134	4	6	15	BAC	1.4	927	3.51	C3-S1
				Average		2.19	1510		

Source: Water analyses of producing wells made in 1972 by the University of Arizona.

Table 3-120. ***Effects of increasing salinity of Central Arizona Project water when it is blended into the San Carlos Project System.***

190,000 ac-ft Gila River Water TDS (mg/l)	50,000 ac-ft Groundwater TDS (mg/l)	240,000 ac-ft San Carlos Water TDS (mg/l)	150,000 ac-ft Central Arizona Project Water TDS (mg/l)	390,000 ac-ft Blended Water TDS (mg/l)
755	1500	910	775[a]	858
755	1500	910	900	906
755	1500	910	1000	945
755	1500	910	1100	983
755	1500	910	1200	1022
755	1500	910	1300	1060
755	1500	910	1400	1098

[a] Present salinity of Colorado River water of the Central Arizona Project diversion point above Parker Dam.

Table 3-121. ***Number of acres available for single and double cropping by land class, San Carlos Project (Non-Indian).***

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	17,271	986	18,257
Land 2 (Moderately Drained)	13,440	769	14,209
Land 3 (Poorly Drained)	21,788	1,245	23,033
Total	52,499	3,000	55,499

Table 3-122. ***Selected crops and double cropping possibilities, San Carlos Project (Non-Indian).***

Crops	Double Cropping Possibilities[a]			
	Wheat	Barley	Maize	Safflower
Alfalfa				
Barley				
Safflower				
Wheat				
Maize	x	x	x	x
Cotton			x	
Pima				
Sugar Beets				
Grapes				

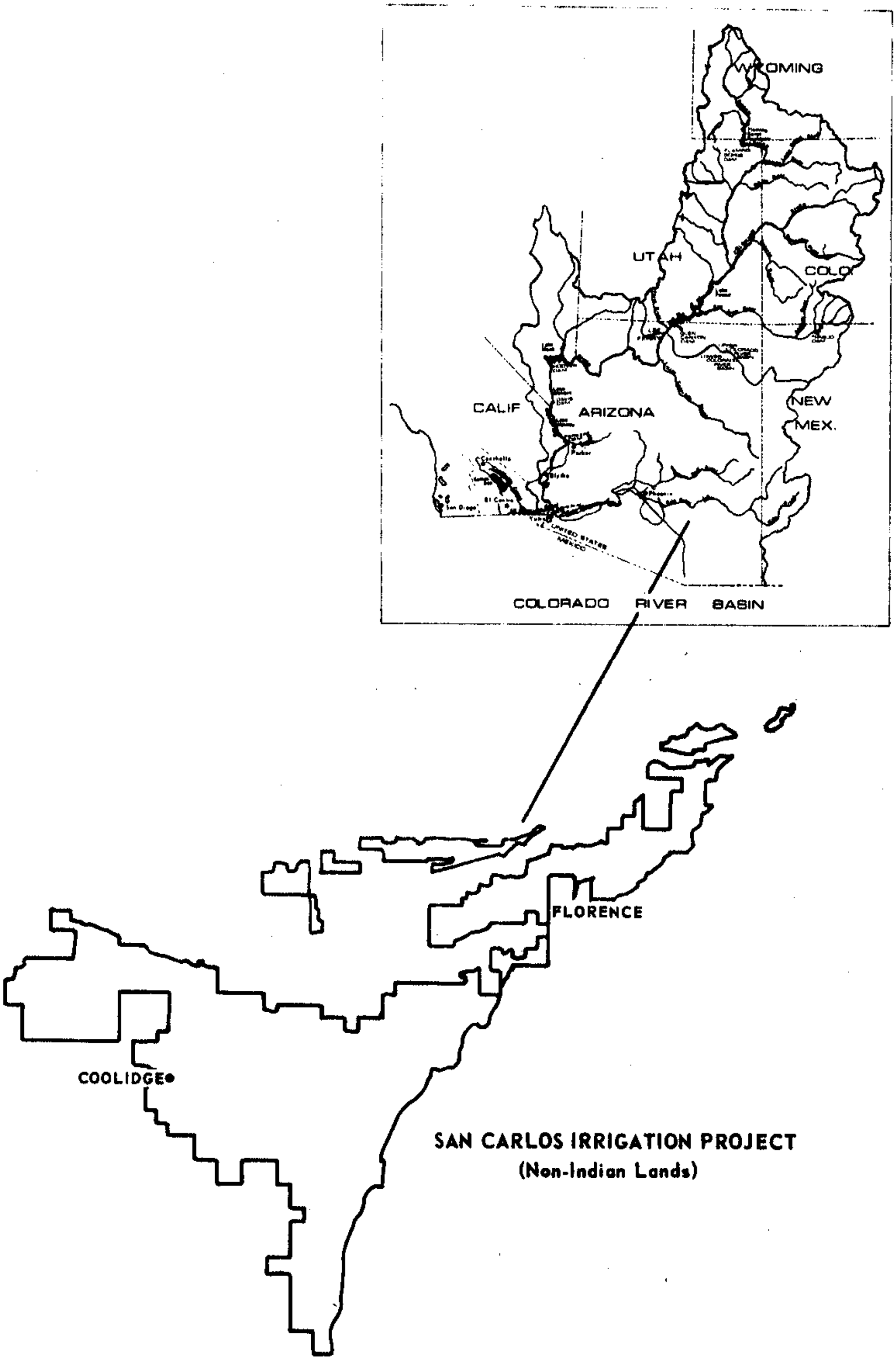
[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-123. ***Yields of major crops in the San Carlos Irrigation Project (Non-Indian), 1968-1973 (tons/acre).***

	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa Hay	4.59	4.62	4.14	2.97	3.91	5.18	4.24 ± 0.80
Barley	1.82	1.77	1.83	1.82	1.82	1.82	1.81 ± 0.03
Safflower		1.30	1.04	1.46	1.27	1.30	1.27 ± 0.19
Wheat	1.48	1.64	2.55	2.45	2.51	2.15	2.13 ± 0.49
Maize	1.89		1.81	1.80	1.39	1.75	1.73 ± 0.24
Upland Cotton	2.58	2.12	2.18	2.18	2.27	2.31	2.27 ± 0.17[a]
Upland Cotton Seed	1.05	0.86	0.89	0.89	0.93	0.94	0.93 ± 0.07
Long Staple Cotton	1.75	1.35	1.03	1.16	1.62	2.05	1.49 ± 0.04[a]
Long Staple Cotton Seed	1.11	0.86	2.56	0.74	1.02	1.28	1.26 ± 0.70
Sugar Beets	19.56	16.83	11.69	18.17	16.00	20.86	17.19 ± 3.38
Grapes				3.33	3.33	3.30	3.32

[a] 480-pound bales per acre.

Source: San Carlos Irrigation Project annual crop reports.



Map 3-13. San Carlos Irrigation Project (Non-Indian Lands).

Table 3-124. Effective values of soil saturation extract conductivities (ECe in mmhos/cm) in three soil drainage classes, seven TDS levels, and five irrigation management treatments.

TDS (mg/l)	Irrigation Number	Drainage Classification		
		Well	Moderate	Poor
860	16	0.3	1.8	4.1
	22	0.3	1.2	3.5
	29	0.3	1.0	3.2
	35	0.3	0.6	2.8
	Sprinkler	0.0	0.0	1.7
910	16	0.4	2.0	4.4
	22	0.4	1.4	3.8
	29	0.4	1.4	3.5
	35	0.4	0.7	3.1
	Sprinkler	0.0	0.0	2.2
950	16	0.6	2.2	4.7
	22	0.6	1.6	4.0
	29	0.6	1.3	3.7
	35	0.6	0.9	3.3
	Sprinkler	0.0	0.1	2.4
980	16	0.6	2.3	4.9
	22	0.6	1.6	4.2
	29	0.6	1.4	3.9
	35	0.6	0.9	3.4
	Sprinkler	0.0	0.1	2.6
1020	16	0.7	2.5	5.1
	22	0.7	1.9	4.4
	29	0.7	1.6	4.1
	35	0.7	1.1	3.6
	Sprinkler	0.0	0.3	2.8
1060	16	0.8	2.7	5.4
	22	0.8	1.9	4.7
	29	0.8	1.7	4.4
	35	0.8	1.2	3.8
	Sprinkler	0.0	0.4	3.1
1100	16	0.9	2.9	5.7
	22	0.9	2.1	4.9
	29	0.9	1.8	4.6
	35	0.9	1.3	4.0
	Sprinkler	0.0	0.5	3.3

Base yields were derived from historical data presented in Table 3-131. These figures were used to establish yield declination functions according to the procedure described in preceding areas.

Once again, a computer run was made to assimulate conditions of 775 mg/l as well as for the higher mg/l situations. Table 3-132 shows the results. A slight variation is noted in production and land use of barley and maize but this movement is so small that it can be safely assumed that these figures are constant. Sub-Appendix N provides additional information concerning allocation variations in technologies and land classes which adequately explain the occurrence in the table.

The relative marginal value products of the various land classes are presented in Table 3-133. No trends are evident except for land class 3 under the double cropping alternative. The values decline as TDS rises indicating that crops grown under these conditions suffer decreases in yield due to unfavorable economic trade offs for available yield maintaining technologies.

An estimated 90,000 ac ft of water will be available to irrigators upon delivery of CAP water under the assumptions outlined earlier. This amount would provide a little more than 4 ac ft per acre of cropland. Table 3-134 shows the amount of water allocated for agricultural purposes. Almost 100 percent of the total available supply is used.

It appears that within the TDS interval of 775 to 1400 mg/l additional increments of water will not be required in the face of rising salinity in order to maintain yields. In Table 3-135, net profits do decline over the interval in question, however, the magnitude is only a total of $224 which cannot be effectively attributed to any single source. Model biases or errors could well account for such a small amount of damage. Consequently, within the limits of the TDS interval for the present study, it was considered that increasing salinity contributed no appreciable amounts to costs in agriculture. Moreover, sizable damages are not anticipated to be incurred until TDS levels above 1400 mg/l are encountered. Therefore, as was the case in the non-Indian portion of the district, a damage function was not constructed for this area and losses due to salinity are considered as not to be measurable within the confines of the analysis.

The summary statistics in Table 3-136 indicate just how small of an effect on net profits would be realized if a damage function had been construed. Annual damages per mg/l per acre of $0.0000167 represent a cost of only $0.36 to the whole area of 21,170 acres for a 1 mg/l increase in the salinity content of the irrigation water. Even a rise of 10 mg/l would be very insignificant as far as increasing costs to agriculture are concerned. Quite appropriately then, it is assumed that damages due to poor quality water within the TDS interval considered in the present study are virtually nonexistent in this area.

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Table 3-125. Cropping and production pattern changes, San Carlos Project (Non-Indian).

Crops	Total Dissolved Solids (mg/l)													
	775		900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	25,139	5,929	25,139	5,929	25,139	5,929	25,139	5,929	25,139	5,929	25,139	5,929	25,139	5,929
Barley	25,331	13,995	25,331	13,995	25,331	13,995	25,331	13,995	25,331	13,995	25,331	13,995	25,331	13,995
Safflower	2,003	1,577	2,003	1,577	2,003	1,577	2,003	1,577	2,003	1,577	2,003	1,577	2,003	1,577
Wheat	7,569	3,554	7,569	3,554	7,569	3,554	7,569	3,554	7,569	3,554	7,569	3,554	7,569	3,554
Maize	8,443	4,880	8,443	4,880	8,443	4,880	8,443	4,880	8,443	4,880	8,443	4,880	8,443	4,880
Cotton	47,262	20,820	47,262	20,820	47,262	20,820	47,262	20,820	47,262	20,820	47,262	20,820	47,262	20,820
Pima	1,505	1,010	1,505	1,010	1,505	1,010	1,505	1,010	1,505	1,010	1,505	1,010	1,505	1,010
Sugar Beets	11,142	648	11,142	648	11,142	648	11,142	648	11,142	648	11,142	648	11,142	648
Grapes	283	85	283	85	283	85	283	85	283	85	283	85	283	85
Total		52,499		52,499		52,499		52,499		52,499		52,499		52,499
D. C. Fallow		3,000		3,000		3,000		3,000		3,000		3,000		3,000

Table 3-126. Ratio of amount of water used to land and profit all by level of TDS, San Carlos Project (Non-Indian).

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
775	233,816	4.454	35.64
900	233,816	4.454	35.64
1000	233,816	4.454	35.64
1100	233,816	4.454	35.64
1200	233,816	4.454	35.64
1300	233,816	4.454	35.64
1400	233,816	4.454	35.64

Table 3-127. Total and per acre net profit by TDS level, San Carlos Project (Non-Indian).

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
775	8,332,477	158.72
900	8,332,477	158.72
1000	8,332.477	158.72
1100	8,332,477	158.72
1200	8,332,477	158.72
1300	8,332,477	158.72
1400	8,332,477	158.72

Table 3-128. Summary statistics, San Carlos Project (Non-Indian).

Total Acres	55,499
Double Cropped Acres	3,000
Annual Total Damages	$ 0
Annual Per Acre Damages	$ 0
Annual Damages Per mg/l	$ 0
Annual Damages Per mg/l Per Acre	$ 0

Table 3-129. Number of acres available for single and double cropping by land class, San Carlos Project (Indian).

	Single Cropped (Acres)	Double Cropped (Acres)	Total (Acres)
Land 1 (Well Drained)	11,770	614	12,384
Land 2 (Moderately Drained)	5,880	307	6,187
Land 3 (Poorly Drained)	2,470	129	2,599
Total	20,120	1,050	21,170

Table 3-130. Selected crops and double cropping possibilities, San Carlos Project (Indian).

Crops	Double Cropping Possibilities[a]				
	Wheat	Barley	Maize	Safflower	Watermelon
Alfalfa					
Barley					
Safflower					
Wheat					
Maize	x	x	x	x	x
Cotton			x		
Pima					
Watermelon	x	x			

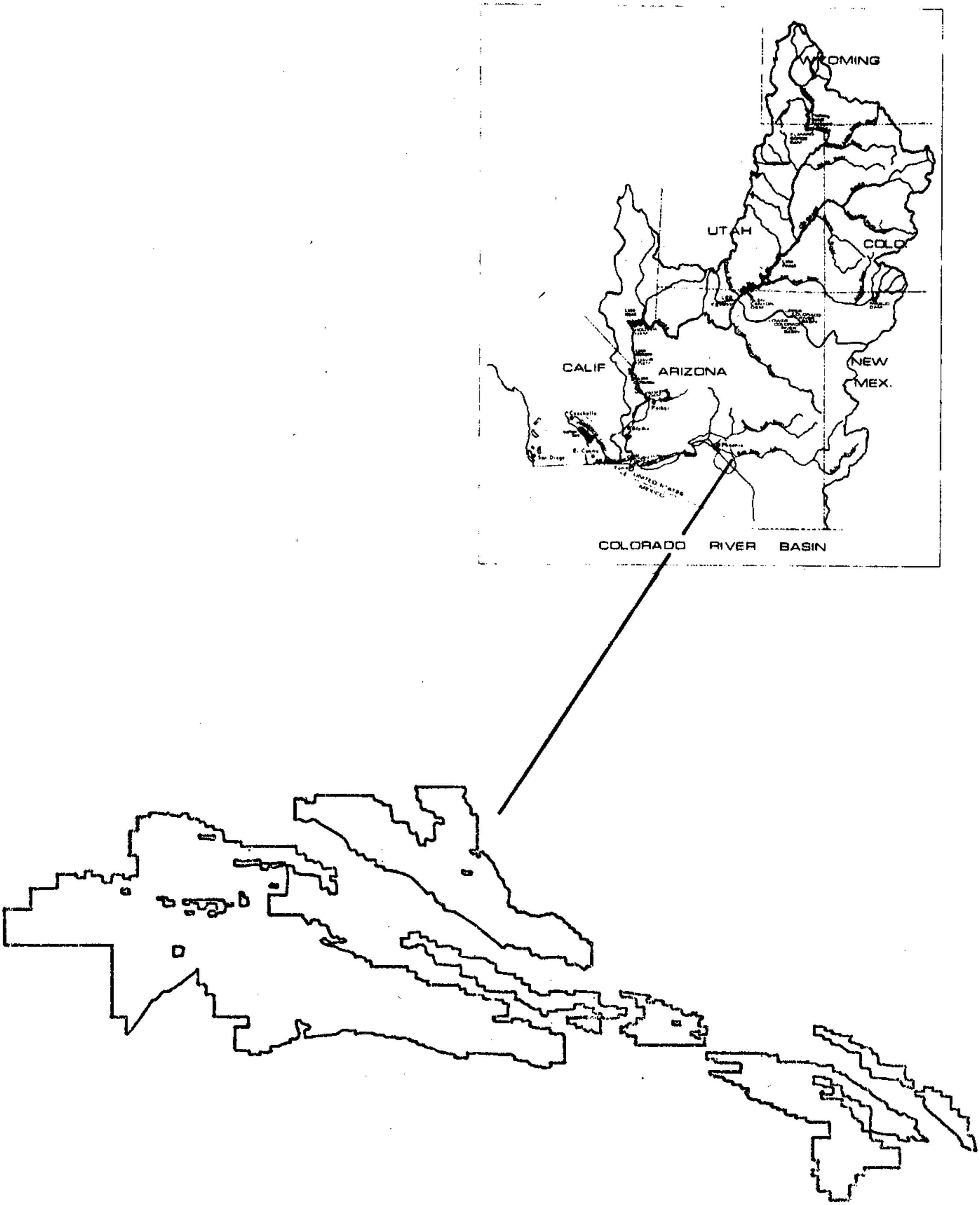
[a] Crops under these columns are those assumed to lead in the double cropping rotation.

Table 3-131. Yields of major crops in the San Carlos Irrigation Project (Indian), 1968-1973 (tons/acre).

	1968	1969	1970	1971	1972	1973	95 Percent Confidence Interval
Alfalfa Hay	2.13	6.00	5.61	5.00	6.00	5.89	5.11 ± 1.58
Barley	1.47	1.49	1.60	1.78	1.56	1.91	1.64 ± 0.18
Safflower	0.64	1.04	1.0	1.09	1.25	0.94	0.99 ± 0.21
Wheat	1.88	1.89	2.20	1.92	2.01	2.16	2.01 ± 0.15
Maize	1.14	1.00	1.00	1.13	1.25	1.25	1.13 ± 0.12
Upland Cotton	2.41	1.74	1.81	2.00	2.41	2.37	2.12 ± 0.33[a]
Upland Cotton Seed	0.94	0.84		0.82	0.96	0.91	0.89 ± 0.08
Long Staple Cotton	1.49	1.00	0.50	1.00	0.94	2.01	1.16 ± 0.55[a]
Long Staple Cotton Seed	0.64	0.84		0.50	0.33	0.87	0.64 ± 0.28
Watermelons			12.00	10.00	10.00	9.00	10.25 ± 2.00

[a] 480-pound bales per acre.

Source: San Carlos Irrigation Project annual crop reports.



Map 3-14. San Carlos Irrigation Project (Indian Lands).

Table 3-132. Cropping and production pattern changes, San Carlos Project (Indian).

Crops	Total Dissolved Solids (mg/l)													
	775		900		1000		1100		1200		1300		1400	
	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)	Production (Tons)	Land Use (Acres)
Alfalfa	16,220	3,174	16,220	3,174	16,220	3,174	16,220	3,174	16,220	3,174	16,220	3,174	16,220	3,174
Barley	12,621	7,696	12,621	7,696	12,621	7,696	12,615	7,692	12,622	7,696	12,622	7,696	12,622	7,696
Safflower	757	765	757	765	757	765	757	765	757	765	757	765	757	765
Wheat	4,853	2,414	4,853	2,414	4,853	2,414	4,853	2,414	4,853	2,414	4,853	2,414	4,853	2,414
Maize	2,250	2,104	2,250	2,104	2,250	2,104	2,250	2,109	2,250	2,104	2,250	2,104	2,250	2,104
Cotton	8,582	4,048	8,582	4,048	8,582	4,048	8,582	4,048	8,582	4,048	8,582	4,048	8,582	4,048
Pima	581	501	581	501	581	501	581	501	581	501	581	501	581	501
Watermelon	4,792	468	4,792	468	4,792	468	4,792	468	4,792	468	4,792	468	4,792	468
Total		21,170		21,170		21,170		21,170		21,170		21,170		21,170

Table 3-133. Shadow prices of land by class and level of TDS, San Carlos Project (Indian).

	775 mg/l (Dollars)	900 mg/l (Dollars)	1000 mg/l (Dollars)	1100 mg/l (Dollars)	1200 mg/l (Dollars)	1300 mg/l (Dollars)	1400 mg/l (Dollars)
Land 1	29	29	29	29	29	29	29
Land 2	29	29	29	29	29	29	29
Land 3	29	29	29	29	29	29	29
Double Cropped 1	9	9	9	9	9	9	9
Double Cropped 2	9	9	9	9	9	9	9
Double Cropped 3	9	8	8	8	7	7	7

Table 3-134. Ratio of amount of water used to land and profit all by level of TDS, San Carlos Project (Indian).

TDS (mg/l)	Acre Feet	Acre Feet Per Acre	Ratio of Net Dollar Return Per Acre Foot
775	89,245	4.216	20.83
900	89,245	4.216	20.83
1000	89,245	4.216	20.83
1100	89,245	4.216	20.83
1200	89,245	4.216	20.83
1300	89,245	4.216	20.83
1400	89,245	4.216	20.83

Table 3-135. Total and per acre net profit by TDS levels, San Carlos Project (Indian).

TDS (mg/l)	Profit (Dollars)	Per Acre (Dollars)
775	1,859,193	87.82
900	1,859,089	87.82
1000	1,859,089	87.82
1100	1,859,021	87.81
1200	1,858,969	87.81
1300	1,858,969	87.81
1400	1,858,969	87.81

Table 3-136. Summary statistics, San Carlos Project (Indian).

Total Acres	21,170
Double Cropped Acres	1,050
Annual Total Damages	$ 224
Annual Per Acre Damages	$ 0.011
Annual Damages Per mg/l	$ 0.0358
Annual Damages Per mg/l Per Acre	$0.0000169

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SUB-APPENDICES, A-N

Preface

The following appendix is intended to provide additional information concerning distribution of production and cropping patterns. Solutions of the LP models for the various study areas are presented as they pertain to these factors. A single table format is retained throughout which lists the respective crops along with the corresponding number of total acres occupied; crop status in the LP model; crop rotation sequences; and total acres by crop, technology, and land class.

In the column labeled "Total Land Use," the amount of acres for each crop and the total acres in production for that region and LP model are listed. For example, in Table A-1 the total number of producing acres is 507,518 which is produced by summing down the column or across the bottom row.

"Crop Status" in the model is determined on the basis of relative overall profitability of each crop. In addition, information is also supplied which allows a ranking order to be calculated, however, only the three general descriptors of "lower" (L), "slack" (S), and "upper" (U) are included in the present analysis. When a crop has a model status of L or U, this essentially means that production is at the lower or upper limit of the production range as described in the section dealing with the model description. The higher-value crops generally are located at the upper limit while lower-value crops comply principally with sufficient model conditions and end up at the lower limit. A slack condition does not imply zero production with respect to the status of a particular crop found under this circumstance. Actually, crop production occurs between the lower and upper limits and the term "slack" identifies the activity as not being constrained by limits at one extreme or the other. In terms of value, this is also the case, i.e., it is less profitable than upper limit crops but more so than lower limit crops.

Crop rotation is accomplished by defining feasible mixes of crops which "lead" and those which "follow." It is possible for one crop to be both, such as lettuce. Rotation sequences are identified by land class and position in the cycle. Two definitions are intended in the table under the columns labeled "single cropped." First, crops which are produced only once per growing season on a particular acre of ground are included under this heading. Second, in the case where double cropping exists, this column represents those crops which lead in the rotating cycle. The "double cropped" column specifies the crops which "follow" in the cycle and are always placed across from the crop which it succeeds on any specific land class. For example, in Table A-1, lettuce on land class 2 is the lead crop followed partially by carrots, lettuce, and cotton. Total acres occupied by the "following" crops can be equal to or less than the total number of acres of the lead crop.

The numbers under the crop names represent the acreage devoted to each crop under the respective land class and technological assumptions. A dash separates various letters from acreage totals which, as explained in a footnote at the bottom of Table A-1, signifies a certain type of technology selected as "most profitable" by the model under a given set of circumstances.

When scanning over the respective classes of land an absence of any activity is encountered in the case of some crops. For example, in Table A-1, totals for sorghum production cannot be found following across the row. Apparently an inconsistency exists in the table at this point because total land use shows a sum of 68,000 acres indicating that some activity has occurred. In such instances, total production is accomplished entirely through double cropping activities. In this case, sorghum would always be the "following" crop. The rotation sequence shows barley and wheat to be the "lead" crops in the cycle. Proper justification of the figure in the land use column is obtained by summing the sorghum activities following each associated lead crop.

Either by direct methods such as summing rows and columns or by the indirect method described in the paragraph above, all crop activities are tabulated and presented in the subsequent tables. A separate sub-appendix is set aside for each study area of this report.

SUB-APPENDIX A
IMPERIAL VALLEY IRRIGATION DISTRICT

Table A-1. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—900 mg/l.

Total land use (acres)	Crop	Crop status[1]	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
2,963	ASPARAGUS	L					Asparagus 2,963—B[2]			
14,028	CANTALOUPE	U								
4,804	CARROTS	U								
150,726	ALFALFA	L	Alfalfa 33,289—A		Alfalfa 48,755—A		Alfalfa 68,682—D			
2,529	TOMATO	U								
3,046	WATERMELON	U			Watermelon 3,046—A	Lettuce 3,046—C				
27,687	BARLEY	L					Barley 1,307—A	Sorghum 1,307—B	Barley 26,380—A	Sorghum 26,380—D
61,300	WHEAT	S					Wheat 61,300—A	Cantaloupe 14,028—D Tomato 2,529—D Sorghum 40,049—B		
66,331	SUGAR BEETS	L					Sugar beets 9,975—A		Sugar beets 56,355—A	
59,202	LETTUCE	U	Lettuce 15,583—A	Lettuce 15,583—A	Lettuce 13,809—C	Carrot 4,804—D Lettuce 5,214—C Cotton 3,791—A				
5,967	ONIONS (MKT)	U			Onion 5,967—B	Lettuce 5,967—C				
67,736	SORGHUM	S								
41,199	COTTON	U					Cotton 37,408—A			
[3]507,518	TOTAL		48,872	15,583	71,577	22,822	181,635	57,913	82,735	26,380

[1] Crop production status in the LP model where U = upper limit, S = slack activity, and L = lower limit.
[2] Letters A, B, C, and D represent irrigation frequencies at the annual rate of 16, 22, 29, and 35, respectively.
[3] Totals may differ due to rounding.

Table A-2. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
2,963	ASPARAGUS	L					Asparagus 2,963–D			
14,623	CANTALOUPE	U								
4,804	CARROTS	U								
153,972	ALFALFA	L	Alfalfa 33,289–A		Alfalfa 48,755–B		Alfalfa 71,928–D			
2,634	TOMATO	U								
3,046	WATERMELON	U			Watermelon 3,046–A	Carrot 3,046–D				
27,687	BARLEY	L					Barley 1,307–A	Tomato 1,307–D	Barley 26,380–A	Sorghum 26,380–D
58,054	WHEAT	S					Wheat 58,054–B	Cantaloupe 14,623–D Tomato 1,327–D Sorghum 40,656–C		
66,331	SUGAR BEETS	L					Sugar beets 9,975–A		Sugar beets 56,356–A	
59,202	LETTUCE	U	Lettuce 15,583–A	Lettuce 15,583–A	Lettuce 13,809–D	Carrots 1,758–D Lettuce 8,260–D Cotton 3,791–A				
5,967	ONIONS (MKT)	U			Onion 5,967–D	Lettuce 5,967–D				
67,036	SORGHUM	S								
41,199	COTTON	U					Cotton 37,408–A			
507,518	TOTAL		48,872	15,583	71,577	22,822	181,635	57,913	82,735	26,380

Table A-3. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
			Acres							
3,002	ASPARAGUS	L					Asparagus 3,002–D			
15,347	CANTALOUPE	U								
4,804	CARROTS	U								
156,710	ALFALFA	L	Alfalfa 33,289–A		Alfalfa 48,755–B		Alfalfa 74,666–D			
2,752	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L							Barley 27,687–A	Sorghum 26,380–D
60,500	WHEAT	S					Wheat 60,500–C	Cantaloupe 15,347–D Tomato 2,752–D Sorghum 39,813–D		
66,331	SUGAR BEETS	L					Sugar beets 11,282–A 3,002–D		Sugar beets 55,049–B	
15,347	CANTALOUPE	U								
4,804	CARROTS	U								
156,710	ALFALFA	L	Alfalfa 33,289–A		Alfalfa 48,755–B		Alfalfa 74,666–D			
2,752	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L							Barley 27,687–A	Sorghum 26,380–D
60,500	WHEAT	S					Wheat 60,500–C	Cantaloupe 15,347–D Tomato 2,752–D Sorghum 39,813–D		
66,331	SUGAR BEETS	L					Sugar beets 11,282–A		Sugar beets 55,049–B	
53,934	LETTUCE	U	Lettuce 9,616–A	Lettuce 9,616–A	Lettuce 22,822–S[1]	Watermelon 3,046–B Lettuce 10,717–S Cotton 8,999–A Sorghum 61–A				
5,967	ONIONS (MKT)	U	Onion 5,967–A	Carrot 4,804–A Lettuce 1,163–A						
66,264	SORGHUM	L								
41,184	COTTON	U					Cotton 32,186–A			
507,518	TOTAL		48,872	15,583	71,577	22,822	181,635	57,913	82,735	26,380

Table A-4. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
			Acres							
3,105	ASPARAGUS	L					Asparagus 3,105–D			
16,063	CANTALOUPE	U								
4,963	CARROTS	U								
160,323	ALFALFA	L	Alfalfa 33,289–A		Alfalfa 48,755–B		Alfalfa 78,279–D			
2,847	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L							Barley 27,687–B	Sorghum 26,380–D
66,227	WHEAT	S					Wheat 66,227–D	Cantaloupe 16,063–D Tomato 2,847–D Sorghum 39,003–D		
66,331	SUGAR BEETS	L					Sugar beets 11,282–A		Sugar beets 55,049–C	
43,057	LETTUCE	S	Lettuce 9,616–A	Carrot 4,963–A Lettuce 4,652–A	Lettuce 22,822–S	Watermelon 3,046–C Cotton 18,415–A Sorghum 1,362–A				
5,967	ONIONS (MKT)	U	Onion 5,967–A	Lettuce 5,967–A						
66,745	SORGHUM	L								
41,157	COTTON	U					Cotton 22,742–A			
507,518	TOTAL		48,872	15,583	71,577	22,822	181,635	57,913	82,735	26,380

Table A-5. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
						Acres				
3,215	ASPARAGUS	L					Asparagus 3,215—D			
16,941	CANTALOUPE	U								
5,234	CARROTS	U								
165,721	ALFALFA	L	Alfalfa 33,289—A		Alfalfa 48,755—D		Alfalfa 83,677—D			
2,949	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L							Barley 27,687—C	Sorghum 26,380—D
58,845	WHEAT	S					Wheat 58,845—D	Cantaloupe 16,941—D Tomato 2,949—D Sorghum 38,024—D		
66,331	SUGAR BEETS	L					Sugar beets 11,282—B		Sugar beets 55,049—D	
42,653	LETTUCE	S	Lettuce 9,482—A	Lettuce 9,482—A	Lettuce 22,822—S	Watermelon 3,046—D Sorghum 3,230—A Cotton 16,547—A				
6,101	ONIONS (MKT)	U	Onion 6,101—A	Lettuce 867—A Carrots 5,234—A						
67,633	SORGHUM	L								
41,163	COTTON	U					Cotton 24,616—B			
507,518	TOTAL		48,872	15,583	71,577	22,822	181,635	57,914	82,735	26,380

Table A-6. Total land use by crop, technology, land class, and rotation sequence—Imperial Valley—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres			
3,358	ASPARAGUS	L					Asparagus 3,358–D			
17,817	CANTALOUPE	U								
5,402	CARROTS	U								
170,331	ALFALFA	L	Alfalfa 34,739–A		Alfalfa 48,755–D		Alfalfa 86,838–D			
2,476	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L					Barley 1,307–A	Sorghum 1,307–D	Barley 26,380–C	Sorghum 26,380–D
59,787	WHEAT	S	Wheat 3,181–A	Lettuce 3,181–A			Wheat 56,606–D	Cantaloupe 17,817–D Sorghum 38,789–D		
67,356	SUGAR BEETS	L					Sugar beets 11,000–B		Sugar beets 56,356–D	
33,650	LETTUCE	L	Lettuce 10,952–A	Carrot 5,402–A Tomato 1,329–A Lettuce 887–A Sorghum 3,334–A	Lettuce 18,630–B	Cotton 18,630–A				
4,192	ONIONS (MKT)	U			Onion	Tomato 1,147–C				
2,476	TOMATO	U								
3,046	WATERMELON	U								
27,687	BARLEY	L					Barley 1,307–A	Sorghum 1,307–D	Barley 26,380–C	Sorghum 26,380–D
59,787	WHEAT	S	Wheat 3,181–A	Lettuce 3,181–A			Wheat 56,606–D	Cantaloupe 17,817–D Sorghum 38,789–D		
67,356	SUGAR BEETS	L					Sugar beets 11,000–B		Sugar beets 56,356–D	
33,650	LETTUCE	L	Lettuce 10,952–A	Carrot 5,402–A Tomato 1,329–A Lettuce 887–A Sorghum 3,334–A	Lettuce 18,630–B	Cotton 18,630–A				
4,192	ONIONS (MKT)	U			Onion 4,192–B	Tomato 1,147–C Watermelon 3,046–D				
69,810	SORGHUM	S								
41,157	COTTON	U					Cotton 22,527–B			
506,069	TOTAL		48,872	14,133	71,577	22,822	181,636	57,913	82,736	26,380

SUB-APPENDIX B
COACHELLA VALLEY IRRIGATION DISTRICT

Table B-1. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
						Acres				
12,062	GRAPES	U	Grape 9,760—A		Grape 2,292—A					
6,472	GRAPEFRUIT	L	Grapefruit 6,472—A							
7,792	CARROTS	U	Carrot 4,196—A							
2,129	ALFALFA	L	Alfalfa 1,884—A						Alfalfa 245—B	
4,070	DATES	U	Date 1,041—A				Date 3,029—A			
893	LEMON/LIME	L	Lem/Lim 893—A							
5,557	ORANGE/ TANGERINES	S	Ora/Tan 5,557—A							
249	ONIONS (MKT)	U								
5,561	SWEET CORN	U	Corn 5,561	Carrot 3,597—A Onion 249—A						
44,774	TOTAL		35,362	3,846	2,292		3,029		245	

Table B-2. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
						Acres				
12,062	GRAPES	U	Grape 9,760—A		Grape 2,292—A					
6,472	GRAPEFRUIT	L	Grapefruit 6,472—A							
7,792	CARROTS	U	Carrot 3,946—A							
2,129	ALFALFA	L	Alfalfa 1,884—A						Alfalfa 245—C	
4,070	DATES	U	Date 1,041—A				Date 3,029—A			
893	LEMON/LIME	L	Lem/Lim 893—A							
5,557	ORANGE/ TANGERINES	S	Ora/Tan 5,557—A							
249	ONIONS (MKT)	U	Onion 249—A							
5,561	SWEET CORN	U	Corn 5,561—A	Carrot 3,846—A						
44,774	TOTAL		35,362	3,846	2,292		3,029		245	

Table B-3. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
					Acres					
12,062	GRAPES	U	Grape 12,062–A							
6,472	GRAPEFRUIT	L	Grapefruit 6,472–A							
7,792	CARROTS	U	Carrot 3,946–A							
2,152	ALFALFA	L	Alfalfa 656–A		Alfalfa 1,251–C				Alfalfa 245–D	
4,070	DATES	U			Date 1,041–A		Date 3,029–A			
893	LEMON/ LIME	L	Lem/Lim 893–A							
5,534	ORANGE/ TANGERINES	S	Ora/Tan 5,534–A							
249	ONIONS (MKT)	U	Onion 249–A							
5,561	SWEET CORN	U	Corn 5,561–A	Carrot 3,846–A						
44,774	TOTAL		35,362	3,846	2,292		3,029		245	

Table B-4. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped	Land Class 4 Single cropped	Land Class 4 Double cropped
					Acres					
12,062	GRAPES	U	Grape 12,062–A							
6,472	GRAPEFRUIT	L	Grapefruit 6,472–A							
7,792	CARROTS	U	Carrot 3,946–A							
2,173	ALFALFA	L	Alfalfa 676–A		Alfalfa 1,251–D				Alfalfa 245–D	
4,070	DATES	U			Date 1,041–A		Date 3,029–A			
893	LEMON/ LIME	L	Lem/Lim 893–A							
5,509	ORANGE/ TANGERINES	S	Ora/Tan 5,509–A							
253	ONIONS (MKT)	U	Onion 253–A							
5,561	SWEET CORN	U	Corn 5,561–A	Carrot 3,846–A						
44,774	TOTAL		35,362	3,846	2,292		3,029		245	

Table B-5. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres				
12,052	GRAPES	U	Grape 12,052–A							
6,472	GRAPEFRUIT	L	Grapefruit 6,472–A							
7,792	CARROTS	U	Carrot 3,946–A							
2,152	ALFALFA	L	Alfalfa 656–A		Alfalfa 1,251–D				Alfalfa 245–D	
4,070	DATES	U			Date 1,041–A		Date 3,029–A			
893	LEMON/ LIME	L	Lem/Lim 893–A							
5,534	ORANGE/ TANGERINES	S	Ora/Tan 5,534–A							
249	ONIONS (MKT)	U	Onion 249–A							
5,561	SWEET CORN	U	Corn 5,561–A	Carrot 3,846–A						
44,774	TOTAL		35,362	3,846	2,292		3,029		245	

Table B-6. Total land use by crop, technology, land class, and rotation sequence—Coachella Valley—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres				
12,052	GRAPES	U	Grape 12,052–A							
6,472	GRAPEFRUIT	L	Grapefruit 6,472–A							
7,792	CARROTS	U	Carrot 3,946–A							
2,077	ALFALFA	L	Alfalfa 2,077–A							
4,070	DATES	U			Date 1,041–A		Date 3,029–A			
893	LEMON/ LIME	L	Lem/Lim 893–A							
5,373	ORANGE/ TANGERINES	L	Ora/Tan 5,373–A							
264	ONIONS (MKT)	U	Onion 264–A							
5,537	SWEET CORN	S	Corn 4,286–A	Carrot 3,846–A	Corn 1,251–D					
44,530	TOTAL		35,362	3,846	2,292		3,029			

SUB-APPENDIX C
PALO VERDE IRRIGATION DISTRICT

Table C-1. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
3,770	LETTUCE	U								
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,387	ONIONS (dry)	U	Onion 4,389–A	Lettuce 3,625–A	Onion 998–B	Lettuce 145–C Sorghum 853–A				
35,472	ALFALFA	S	Alfalfa 15,429–A		Alfalfa 19,677–A		Alfalfa 366–D			
8,168	SORGHUM	L			Sorghum 2,049–A	Cantaloupe 1,339–A Watermelon 710–A				
13,598	COTTON	U					Cotton 57–A		Cotton 13,541–A	
21,810	WHEAT	U			Wheat 393–A	Watermelon 393–A	Wheat 19,049–A	Sorghum 2,898–B	Wheat 2,368–C	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,117	3,440	19,472	2,898	15,909	2,368

Table C-2. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
3,770	LETTUCE	U								
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,387	ONIONS (dry)	U	Onion 4,389–A	Lettuce 3,625–A	Onion 998–D	Lettuce 145–D Sorghum 853–A				
35,106	ALFALFA	S	Alfalfa 15,429–A		Alfalfa 19,677–B					
8,535	SORGHUM	S			Sorghum 2,416–A	Cantaloupe 1,339–A Watermelon 1,076–A				
13,598	COTTON	U					Cotton 57–A		Cotton 13,541–A	
21,810	WHEAT	U			Wheat 27–A	Watermelon 27–A	Wheat 19,415–B	Sorghum 2,898–C	Wheat 2,368–D	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,117	3,440	19,472	2,898	15,909	2,368

Table C-3. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres				
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
3,770	LETTUCE	U			Lettuce 145–D	Cotton 145–A				
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,387	ONIONS (DRY)	U	Onion 4,629–A	Lettuce 3,625–A	Onion 758–D	Sorghum 758–A				
34,866	ALFALFA	S	Alfalfa 15,189–A		Alfalfa 19,677–C					
8,317	SORGHUM	L			Sorghum 2,198–A	Cantaloupe 1,339–B Watermelon 764–B Sorghum 95–A				
13,962	COTTON	U					Cotton 277–B		Cotton 13,541–A	
21,903	WHEAT	U			Wheat 339–A	Watermelon 339–B	Wheat 19,196–C	Sorghum 2,898–D	Wheat 2,368–D	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,117	3,440	19,472	2,898	15,909	2,368

Table C-4. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres				
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
3,774	LETTUCE	U			Lettuce 149–D	Cotton 149–A				
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,387	ONIONS (DRY)	U	Onion 5,381–A	Lettuce 3,625–A	Onion 6–D	Sorghum 6–A				
34,113	ALFALFA	S	Alfalfa 14,436–A		Alfalfa 19,677–D					
8,431	SORGHUM	L			Sorghum 2,316–A	Cantaloupe 1,213–C Watermelon 1,103–C				
13,598	COTTON	U					Cotton 13,449–C			
22,902	WHEAT	U			Wheat 969–A	Cantaloupe 126–C Sorghum 843–A	Wheat 6,023–D	Sorghum 2,898–D	Wheat 15,909–D	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,119	3,440	19,472	2,898	15,909	2,368

Table C-5. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
3,903	LETTUCE	U								
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,458	ONIONS (dry)	U	Onion 5,458–A	Lettuce 3,625–A						
33,291	ALFALFA	S	Alfalfa 14,360–A		Alfalfa 18,931–D					
8,549	SORGHUM	L			Sorghum 2,563–A	Cantaloupe 1,339–D Sorghum 720–A				
13,598	COTTON	U					Cotton 13,598–D			
23,407	WHEAT	U			Wheat 1,624–A	Lettuce 278–D Watermelon 1,103–D	Wheat 5,874–D	Sorghum 2,898–D	Wheat 15,909–D	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,118	3,440	19,472	2,898	15,909	2,368

Table C-6. Total land use by crop, technology, land class, and rotation sequence—Palo Verde—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3		Land Class 4	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres							
942	GRAPEFRUIT	U	Grapefruit 942–A							
3,600	LEMONS	U	Lemon 3,600–A							
4,039	LETTUCE	U								
1,339	CANTALOUPE	U								
1,103	WATERMELON	U								
5,700	ONIONS (dry)	U	Onion 5,700–A	Lettuce 3,625–A						
32,911	ALFALFA	L	Alfalfa 14,118		Alfalfa 18,793–D					
8,695	SORGHUM	L			Sorghum 2,845–A	Lettuce 414–D Watermelon 1,103–D Sorghum 584–A				
13,910	COTTON	U					Cotton 13,910–D			
22,950	WHEAT	S			Wheat 1,479–A	Cantaloupe 1,340–D	Wheat 5,562–D	Sorghum 2,898–D	Wheat 15,909–D	Sorghum 2,368–D
95,189	TOTAL		24,360	3,625	23,117	3,440	19,472	2,898	15,909	2,368

SUB-APPENDIX D
COLORADO RIVER INDIAN RESERVATION IRRIGATION DISTRICT

Table D-1. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
24,372	ALFALFA	S	Alfalfa 24,372–A					
15,864	COTTON	U			Cotton 15,606–A			
14,887	WHEAT	U	Wheat 3,748–A		Wheat 1,861–A		Wheat 9,279–A	Cantaloupe 856–D
4,677	SORGHUM	L	Sorghum 2,901–A	Lettuce 2,901–A	Sorghum 1,776–A	Cantaloupe 301–A Lettuce 1,475–C		
1,157	CANTALOUPE	U						
6,344	LETTUCE	U	Lettuce 1,968–A	Cotton 257–A				
1,238	ONIONS (DRY)	U	Onion 1,238–A					
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

Table D-2. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
24,338	ALFALFA	S	Alfalfa 24,338–A					
15,864	COTTON	U	Cotton 3,748–A		Cotton 3,693–A		Cotton 8,423–A	
14,887	WHEAT	U			Wheat 14,031–A	Cantaloupe 257–B	Wheat 856–B	Cantaloupe 856–D
4,677	SORGHUM	L			Sorghum 1,519–A	Cantaloupe 78–B Lettuce 1,441–D		
1,191	CANTALOUPE	U						
6,344	LETTUCE	U	Lettuce 4,903–A	Sorghum 3,158–A				
1,238	ONIONS (DRY)	U	Onion 1,238–A					
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

Table D-3. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
					Acres			
24,226	ALFALFA	S	Alfalfa 24,226—A					
15,864	COTTON	U	Cotton 3,090—A		Cotton 4,351—A		Cotton 8,423—A	
14,887	WHEAT	U	Wheat 3,158—A	Lettuce 3,158—A	Wheat 10,873—A	Cantaloupe 1,105—B Lettuce 671—D	Wheat 856—C	Sorghum 856—D
4,875	SORGHUM	L			Sorghum 4,019—A			
1,105	CANTALOUPE	U						
6,344	LETTUCE	U	Lettuce 2,515—A					
1,238	ONIONS (DRY)	U	Onion 1,238—A					
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

Table D-4. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
					Acres			
24,189	ALFALFA	S	Alfalfa 24,189—A					
15,864	COTTON	U	Cotton 6,267—A		Cotton 1,173—A		Cotton 8,423—A	
14,887	WHEAT	U			Wheat 14,031—A	Cantaloupe 1,105—C Lettuce 671—D	Wheat 856—D	Sorghum 856—D
4,895	SORGHUM	L			Sorghum 4,039—A			
1,105	CANTALOUPE	U						
6,361	LETTUCE	U	Lettuce 2,532—A	Lettuce 1,920—A				
1,238	ONIONS (DRY)	U	Onion 1,238—A	Lettuce 1,238—A				
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

Table D-5. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
23,985	ALFALFA	L	Alfalfa 23,985–A					
15,864	COTTON	U	Cotton 238–A		Cotton 15,180–A			
14,876	WHEAT	S	Wheat 5,597–A				Wheat 9,279–D	Sorghum 856–D
4,919	SORGHUM	L			Sorghum 4,063–A	Cantaloupe 1,105–D Lettuce 671–D		
1,105	CANTALOUPE	U						
6,539	LETTUCE	U	Lettuce 3,158–A	Cotton 448–A Lettuce 2,710–A				
1,250	ONIONS (DRY)	U	Onion 1,240–A					
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

Table D-6. Total land use by crop, technology, land class, and rotation sequence—Colorado River Indian Reservation—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
23,985	ALFALFA	L	Alfalfa 23,985–A					
15,864	COTTON	U	Cotton 1,948–A		Cotton 5,493–A		Cotton 8,423–B	
14,607	WHEAT	S			Wheat 13,751–A	Cantaloupe 1,105–D Lettuce 671–D	Wheat 856–D	Sorghum 856–D
4,944	SORGHUM	L	Sorghum 4,088–A					
1,105	CANTALOUPE	U						
6,758	LETTUCE	U	Lettuce 2,929–A	Lettuce 1,882–A				
1,276	ONIONS (DRY)	U	Onion 1,276–A	Lettuce 1,276–A				
68,539	TOTAL		34,226	3,158	19,243	1,776	9,279	856

SUB-APPENDIX E
CALIFORNIA COASTAL REGION

Table E-1. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
14,554	AVOCADOS	S	Avocado 7,874–S		Avocado 6,681–S			
785	STRAWBERRIES	U	Strawberries 785–A					
395	SUMMER TOMATOES	U	Summer Tom 395–A					
4,269	FALL TOMATOES	U			Fall Tom 4,269–A			
1,540	SPRING TOMATOES	U					Spring Tom 1,540–A	
2,162	LEMONS	L					Lemon 2,162–T[1]	
281	LIMES	L					Lime 281–T	
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 6,028–S		Valencia 1,832–T	
866	TANGERINES	L					Tangerine 866–T	
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U			Potato 762–A			
34,821	TOTAL		9,054		17,739		8,028	

[1] T = Trickle or drip irrigation.

Table E-2. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
			Acres					
14,559	AVOCADOS	S	Avocado 1,443–S		Avocado 13,116–S			
785	STRAWBERRIES	U	Strawberries 785–A					
395	SUMMER TOMATOES	U	Summer Tom 395–A					
4,269	FALL TOMATOES	U	Fall Tom 4,269–A					
1,535	SPRING TOMATOES	U			Spring Tom 1,535–A			
2,162	LEMONS	L	Lemon 2,162–S					
281	LIMES	L			Lime 281–S			
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 1,179–S		Valencia 6,680–T	
866	TANGERINES	L			Tangerine 866–S			
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U			Potato 762–A			
34,821	TOTAL		9,054		17,739		8,028	

Table E-3. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
14,559	AVOCADOS	S	Avocado 4,000–S		Avocado 10,559–S			
785	STRAW-BERRIES	U	Strawberries 785–A					
395	SUMMER TOMATOES	U			Summer Tom 395–A			
4,269	FALL TOMATOES	U	Fall Tom 4,269–A					
1,535	SPRING TOMATOES	U			Spring Tom 1,535–A			
2,162	LEMONS	L			Lemon 2,162–S			
281	LIMES	L					Lime 281–T	
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 2,326–S		Valencia 5,534–T	
866	TANGERINES	L					Tangerine 866–T	
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U			Potato 762–A			
34,821	TOTAL		9,054		17,739		8,028	

Table E-4. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
14,559	AVOCADOS	S	Avocado 442–S		Avocado 14,117–S			
785	STRAWBERRIES	U	Strawberries 785–S					
395	SUMMER TOMATOES	U	Summer Tom 395–A					
4,269	FALL TOMATOES	U	Fall Tom 4,269–A					
1,535	SPRING TOMATOES	U	Spring Tom 1,535–A					
2,162	LEMONS	L					Lemon 2,162–T	
281	LIMES	L					Limes 281–T	
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 3,622–S		Valencia 4,238–T	
866	TANGERINES	L	Tangerine 866–S					
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U	Potato 762–A					
34,821	TOTAL		9,054		17,739		8,028	

Table E-5. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
14,559	AVOCADOS	S	Avocado 442–S		Avocado 14,117–S			
785	STRAWBERRIES	U	Strawberries 785–S					
395	SUMMER TOMATOES	U	Summer Tom 395–A					
4,269	FALL TOMATOES	U	Fall Tom 4,269–A					
1,535	SPRING TOMATOES	U	Spring Tom 1,535–A					
2,162	LEMONS	L					Lemon 2,162–T	
281	LIMES	L					Lime 281–T	
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 3,622–S		Valencia 4,238–T	
866	TANGERINES	L	Tangerine 866–S					
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U	Potato 762–A					
34,821	TOTAL		9,054		17,739		8,028	

Table E-6. Total land use by crop, technology, land class, and rotation sequence—Coastal Area—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
14,559	AVOCADOS	S	Avocado 7,507–S		Avocado 7,052–T			
785	STRAWBERRIES	U	Strawberries 785–A 785–S					
395	SUMMER TOMATOES	U			Summer Tom 395–A			
4,269	FALL TOMATOES	U			Fall Tom 4,269–A			
1,535	SPRING TOMATOES	U			Spring Tom 1,535–A			
2,162	LEMONS	L			Lemon 2,162–S			
281	LIMES	L			Lime 281–S			
892	ORANGES (NAVEL)	L					Navel 892–T	
7,860	ORANGES (VALENCIA)	L			Valencia 2,045–S		Valencia 5,815–T	
866	TANGERINES	L					Tangerine 866–T	
456	GRAPEFRUIT	L					Grapefruit 456–T	
762	POTATOES	U	Potato 762–A					
34,821	TOTAL		9,054		17,739		8,028	

SUB-APPENDIX F
WELLTON-MOHAWK DIVISION

Table F-1. Total land use by crop, technology, land class, and rotation sequences—Wellton-Mohawk—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
11 131	COTTON	U	Cotton 11 131–A					
17,604	ALFALFA	S	Alfalfa 13,137–A		Alfalfa 4,467–A			
5,324	LETTUCE	U						
3,007	CANTALOUPE	U						
10,481	WHEAT	U	Wheat 8,218–A	Lettuce 5,324–A Cantaloupe 2,894–A	Wheat 389–A		Wheat 1,874–A	Sorghum 1,874–B
9,937	SORGHUM	U	Sorghum 5,784–A		Sorghum 1,196–A	Cantaloupe 113–A Sorghum 1,083–A		
7,637	GRASS SEED	U	Grass Seed 34–A				Grass Seed 7,603–A	
27	GRAPEFRUIT	U	Grapefruit 27–A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

Table F-2. Total land use by crop, technology, land class, and rotation sequence—Wellton-Mohawk—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
11,131	COTTON	U	Cotton 3,528–A				Cotton 7,603–A	
17,604	ALFALFA	S	Alfalfa 17,604–A					
5,324	LETTUCE	U						
3,007	CANTALOUPE	U						
10,481	WHEAT	U	Wheat 3,638–A	Cantaloupe 2,321–A	Wheat 4,969–A	Cantaloupe 113–B	Wheat 1,874–B	Sorghum 1,874–C
9,937	SORGHUM	U	Sorghum 5,897–A	Lettuce 5,324–A Cantaloupe 573–A	Sorghum 1,083–A	Sorghum 1,083–A		
7,637	GRASS SEED	U	Grass Seed 7,637–A					
27	GRAPEFRUIT	U	Grapefruit 27–A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

Table F-3. Total land use by crop, technology, land class, and rotation sequence—Wellton-Mohawk—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
11,131	COTTON	U			Cotton 3,528–A		Cotton 7,603–A	
17,543	ALFALFA	S	Alfalfa 17,543–A					
5,324	LETTUCE	U						
3,007	CANTALOUPE	U						
10,481	WHEAT	U	Wheat 6,083–A	Lettuce 5,324–A	Wheat 2,524–A	Cantaloupe 113–A Sorghum 1,083–A	Wheat 1,874–C	Sorghum 1,874–C
9,998	SORGHUM	U	Sorghum 7,041–A	Cantaloupe 2,894–A				
7,637	GRASS SEED	U	Grass Seed 7,637–A					
27	GRAPEFRUIT	U	Grapefruit 27-A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

Table F-4. Total land use by crop, technology, land class, and rotation sequence—Wellton-Mohawk—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
11,131	COTTON	U	Cotton 6,308–A		Cotton 4,822–A			
17,503	ALFALFA	S	Alfalfa 17,503–A					
5,324	LETTUCE	U	Lettuce 5,324–A	Sorghum 5,324–A				
3,007	CANTALOUPE	U						
10,481	WHEAT	U	Wheat 7,524–A	Cantaloupe 2,894–A	Wheat 1,083–A	Sorghum 1,083–A	Wheat 1,874–D	Sorghum 1,874–C
10,038	SORGHUM	U	Sorghum 1,644–A		Sorghum 113–A	Cantaloupe 113–C		
7,637	GRASS SEED	U			Grass Seed 34–A		Grass Seed 7,603–A	
27	GRAPEFRUIT	U	Grapefruit 27–A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

Table F-5. Total land use by crop, technology, land class, and rotation sequence—Wellton-Mohawk—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
11,131	COTTON	U	Cotton 11,131–A					
17,287	ALFALFA	S	Alfalfa 17,287–A					
5,488	LETTUCE	U						
3,007	CANTALOUPE	U						
10,516	WHEAT	U	Wheat 8,642–A	Lettuce 5,488–A Cantaloupe 2,730–A			Wheat 1,874–D	Sorghum 1,874–C
10,055	SORGHUM	U	Sorghum 1,210–A		Sorghum 6,052–A	Cantaloupe 277–D Sorghum 919–A		
7,637	GRASS SEED	U	Grass Seed 34–A				Grass Seed 7,603–A	
27	GRAPEFRUIT	U	Grapefruit 27-A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

Table F-6. Total land use by crop, technology, land class, and rotation sequence—Wellton-Mohawk—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
						Acres		
11,131	COTTON	U	Cotton 6,275–A		Cotton 4,856–A			
17,071	ALFALFA	S	Alfalfa 17,071–A					
5,631	LETTUCE	U	Lettuce 5,631–A	Sorghum 5,631–A				
3,007	CANTALOUPE	U						
10,560	WHEAT	U	Wheat 7,490–A	Cantaloupe 784–A	Wheat 1,196–A	Cantaloupe 419–D Sorghum 777–B	Wheat 1,874–D	Sorghum 1,874–C
10,086	SORGHUM	U	Sorghum 1,804–A	Cantaloupe 1,804–A				
7,637	GRASS SEED	U	Grass Seed 34–A				Grass Seed 7,603–A	
27	GRAPEFRUIT	U	Grapefruit 27–A					
3,013	ORANGES AND TANGERINES	U	Ora/Tan 3,013–A					
219	LEMONS	U	Lemon 219–A					
68,379	TOTAL		41,562	8,218	6,052	1,196	9,477	1,874

SUB-APPENDIX G
GILA AREA

Table G-1. Total land use by crop, technology, land class, and rotation sequence—Gila Area—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
1,831	COTTON	L					Cotton 1,831–A	
5,402	ALFALFA	L	Alfalfa 2,603–A		Alfalfa 2,799–A			
2,017	LETTUCE	S	Lettuce 1,526–A	Lettuce 491–A				
1,499	CANTALOUPE	L	Cantaloupe 1,315–A					
1,449	WHEAT	L			Wheat 402–A		Wheat 1,047–A	Cantaloupe 112–A
917	SORGHUM	L	Sorghum 845–A		Sorghum 72–A	Cantaloupe 72–A		
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,125	112

Table G-2. Total land use by crop, technology, land class, and rotation sequence—Gila Area—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
			Acres					
1,831	COTTON	L					Cotton 1,831–A	
5,402	ALFALFA	L	Alfalfa 4,765–A		Alfalfa 637–B			
2,017	LETTUCE	S	Lettuce 1,526–A	Lettuce 491–A				
1,499	CANTALOUPE	L			Cantaloupe 1,315–B			
1,449	WHEAT	L			Wheat 402–A		Wheat 1,047–B	Cantaloupe 112–D
917	SORGHUM	L			Sorghum 917–A	Cantaloupe 72–B		
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,125	112

Table G-3. Total land use by crop, technology, land class, and rotation sequence—Gila Area—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
1,831	COTTON	L					Cotton 1,831–A	
5,402	ALFALFA	L	Alfalfa 4,769–A		Alfalfa 633–C			
2,012	LETTUCE	S	Lettuce 1,521–A	Lettuce 491–A				
1,504	CANTALOUPE	L			Cantaloupe 1,321–B			
1,449	WHEAT	L			Wheat 402–A	Cantaloupe 72–B	Wheat 1,047–C	Cantaloupe 112–D
917	SORGHUM	L			Sorghum 917–A			
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,125	112

Table G-4. Total land use by crop, technology, land class, and rotation sequence—Gila Area—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
1,831	COTTON	L					Cotton 1,831–A	
5,402	ALFALFA	L	Alfalfa 4,774–A		Alfalfa 629–D			
2,007	LETTUCE	S	Lettuce 1,516–A	Lettuce 491–A				
1,509	CANTALOUPE	L			Cantaloupe 1,325–C			
1,449	WHEAT	L			Wheat 402–A	Cantaloupe 72–C	Wheat 1,047–D	Cantaloupe 112–D
917	SORGHUM	L			Sorghum 917–A			
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,125	112

Table G-5. Total land use by crop, technology, land class, and rotation sequence—Gila Area, 1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
1,831	COTTON	L					Cotton 1,831–B	
5,402	ALFALFA	L	Alfalfa 4,808–A		Alfalfa 594–D			
1,973	LETTUCE	S	Lettuce 1,482–A	Lettuce 491–A				
1,601	CANTALOUPE	L			Cantaloupe 1,417–D			
1,472	WHEAT	L			Wheat 425–A	Cantaloupe 72–D	Wheat 1,047–D	Cantaloupe 112–D
837	SORGHUM	L			Sorghum 837–A			
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,126	112

Table G-6. Total land use by crop, technology, land class, and rotation sequence—Gila Area—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
1,831	COTTON	L					Cotton 1,831–B	
5,408	ALFALFA	L	Alfalfa 4,835–A		Alfalfa 573–D			
1,946	LETTUCE	S	Lettuce 1,455–A	Lettuce 491–A				
1,489	CANTALOUPE	L			Cantaloupe 1,417–D	Cantaloupe 72–D		
1,490	WHEAT	L			Wheat 443–A		Wheat 1,047–D	Sorghum 112–D
952	SORGHUM	L			Sorghum 840–B			
2,247	GRASS SEED	L					Grass Seed 2,247–A	
1,409	GRAPEFRUIT	L	Grapefruit 1,409–A					
8,347	ORANGES AND TANGERINES	L	Ora/Tan 8,347–A					
6,431	LEMONS	L	Lemon 6,431–A					
31,549	TOTAL		22,476	491	3,273	72	5,125	112

SUB-APPENDIX H
YUMA VALLEY AREA

Table H-1. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
13,171	COTTON	U	Cotton 7,598–A		Cotton 1,142–A		Cotton 4,431–A	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,440	LETTUCE	U	Lettuce 5,532–A					
4,639	CANTALOUPE	L	Cantaloupe 3,179–A					
9,452	WHEAT	L	Wheat 8,561–A	Lettuce 3,908–A			Wheat 891–A	Cantaloupe 891–D
4,434	SORGHUM	L			Sorghum 4,434–A	Cantaloupe 569–A		
3,410	GRASS SEED	S					Grass Seed 3,410–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
1,023	ORANGES AND TANGERINES	U	Ora/Tan 1,023–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

Table H-2. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
13,171	COTTON	U	Cotton 3,669–A		Cotton 5,007–A		Cotton 4,496–A	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,440	LETTUCE	U	Lettuce 9,440–A	Sorghum 665–A				
4,703	CANTALOUPE	L						
9,452	WHEAT	L	Wheat 7,992–A	Cantaloupe 3,243–A	Wheat 569–A	Cantaloupe 569–A	Wheat 891–B	Cantaloupe 891–D
4,434	SORGHUM	L	Sorghum 3,769–A					
3,345	GRASS SEED	S					Grass Seed 3,345–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
1,023	ORANGES AND TANGERINES	U	Ora/Tan 1,023–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

Table H-3. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
13,171	COTTON	U	Cotton 8,668–A				Cotton 4,503–A	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,440	LETTUCE	U	Lettuce 5,532–A					
4,711	CANTALOUPE	L	Cantaloupe 3,251–A	Lettuce 3,251–A				
9,452	WHEAT	L	Wheat 2,985–A	Lettuce 657–A	Wheat 5,576–A	Cantaloupe 569–B	Wheat 891–C	Cantaloupe 891–D
4,434	SORGHUM	L	Sorghum 4,434–A					
3,338	GRASS SEED	S					Grass Seed 3,338–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
1,023	ORANGES AND TANGERINES	U	Ora/Tan 1,023–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

Table H-4. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
13,171	COTTON	U	Cotton 8,634–A				Cotton 4,538–A	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,440	LETTUCE	U	Lettuce 9,440–A	Sorghum 2,265–A				
4,746	CANTALOUPE	L	Cantaloupe 1,643–A	Cantaloupe 1,643–A				
9,452	WHEAT	L	Wheat 2,985–A		Wheat 5,576–A	Cantaloupe 569–C	Wheat 891–D	Cantaloupe 891–D
4,434	SORGHUM	L	Sorghum 2,169–A					
3,303	GRASS SEED	S					Grass Seed 3,303–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
1,023	ORANGES AND TANGERINES	U	Ora/Tan 1,023–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

Table H-5. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
12,996	COTTON	S	Cotton 8,143–A				Cotton 4,852–B	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,985	LETTUCE	U	Lettuce 6,077–A	Lettuce 3,908–A				
5,476	CANTALOUPE	L	Cantaloupe 4,016–A					
9,487	WHEAT	L	Wheat 3,020–A		Wheat 5,576–A	Cantaloupe 569–A	Wheat 891–D	Cantaloupe 891–D
3,849	SORGHUM	L	Sorghum 3,849–A					
2,989	GRASS SEED	L					Grass Seed 2,989–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
787	ORANGES AND TANGERINES	L	Ora/Tan 787–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

Table H-6. Total land use by crop, technology, land class, and rotation sequence—Yuma Area—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
13,171	COTTON	U	Cotton 3,312–A		Cotton 5,007–A		Cotton 4,852–B	
11,394	ALFALFA	L	Alfalfa 11,394–A					
9,729	LETTUCE	U	Lettuce 9,729–A	Sorghum 1,900–A				
5,476	CANTALOUPE	L	Cantaloupe 2,008–A	Cantaloupe 2,008–A				
9,470	WHEAT	L	Wheat 8,010–A		Wheat 569–A	Cantaloupe 569–D	Wheat 891–D	Cantaloupe 891–D
3,826	SORGHUM	L	Sorghum 1,926–A					
2,989	GRASS SEED	L					Grass Seed 2,989–A	
194	GRAPEFRUIT	L	Grapefruit 194–A					
908	ORANGES AND TANGERINES	S	Ora/Tan 908–A					
816	LEMONS	L	Lemon 816–A					
57,973	TOTAL		38,297	3,908	5,576	569	8,732	891

SUB-APPENDIX I
SALT RIVER PROJECT

Table I-1. Total land use by crop, technology, land class, and rotation sequence—Salt River Project—565 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
46,954	ALFALFA	S	Alfalfa 46,954–A					
31,084	COTTON	U			Cotton 20,634–A		Cotton 9,226–A	
16,237	BARLEY	L	Barley 5,750–A	Sorghum 341–A	Barley 10,488–A	Sorghum 10,488–A		
28,341	WHEAT	U	Wheat 15,085–A	Sorghum 15,085–A	Wheat 10,397–A		Wheat 2,859–A	Sorghum 2,859–A
30,393	SORGHUM	U	Sorghum 692–A	Onion 692–A	Sorghum 930–A	Carrot 930–A		
1,324	LETTUCE	U	Lettuce 1,324–A	Cotton 1,324–A				
692	ONIONS	U						
1,990	GRAPEFRUIT	U			Grapefruit 1,990–A			
3,987	ORANGES AND TANGERINES	U			Ora/Tan 3,987–A			
4,011	SUGAR BEETS	U	Sugar Beets 4,011–A					
929	CARROTS	U						
165,942	TOTAL		73,815	17,441	48,326	11,417	12,085	2,859

Table I-2. Total land use by crop, technology, land class, and rotation sequence—Salt River Project—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
46,954	ALFALFA	S	Alfalfa 43,956–A		Alfalfa 2,998–A			
31,084	COTTON	U			Cotton 29,760–A			
16,237	BARLEY	L	Barley 6,442–A		Barley 9,796–A	Sorghum 9,796–A		
28,341	WHEAT	U	Wheat 16,117–A	Sorghum 16,117–A	Wheat 4,150–A		Wheat 8,074–A	Sorghum 2,859–A
30,393	SORGHUM	U			Sorghum 1,621–A	Onion 692–A Carrot 929–A		
1,324	LETTUCE	U	Lettuce 1,324–A	Cotton 1,324–A				
692	ONIONS	U						
1,990	GRAPEFRUIT	U	Grapefruit 1,990–A					
3,987	ORANGES AND TANGERINES	U	Ora/Tan 3,987–A					
4,011	SUGAR BEETS	U					Sugar Beets 4,011–A	
929	CARROTS	U						
165,942	TOTAL		73,815	17,441	48,326	11,417	12,085	2,859

Table I-3. Total land use by crop, technology, land class, and rotation sequence—Salt River Project—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
			Acres					
46,954	ALFALFA	S	Alfalfa 46,954–A					
31,084	COTTON	U	Cotton 7,431–A		Cotton 18,010–A		Cotton 4,319–A	
16,237	BARLEY	L			Barley 8,472–A	Sorghum 8,472–A	Barley 7,766–A	Sorghum 2,859–A
28,341	WHEAT	U	Wheat 17,441–A	Sorghum 17,441–A	Wheat 10,900–A			
30,393	SORGHUM	U			Sorghum 1,621–A	Onion 692–A Carrot 929–A		
1,324	LETTUCE	U			Lettuce 1,324–A	Cotton 1,324–A		
692	ONIONS	U						
1,990	GRAPEFRUIT	U	Grapefruit 1,990–A					
3,987	ORANGES AND TANGERINES	U			Ora/Tan 3,987–A			
4,011	SUGAR BEETS	U			Sugar Beets 4,011–A			
929	CARROTS	U						
165,942	TOTAL		73,815	17,441	48,326	11,417	12,085	2,859

Table I-4. Total land use by crop, technology, land class, and rotation sequence—Salt River Project—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
			Acres					
46,954	ALFALFA	S	Alfalfa 14,033–A		Alfalfa 32,921–A			
31,084	COTTON	U	Cotton 31,084–A					
16,237	BARLEY	L	Barley 6,580–A	Lettuce 1,324–A	Barley 9,657–A	Sorghum 9,657–A		
28,341	WHEAT	U	Wheat 14,496–A	Sorghum 14,496–A	Wheat 1,760–A	Sorghum 1,760–A	Wheat 12,085–A	Sorghum 2,859–A
30,393	SORGHUM	U	Sorghum 1,621–A	Onion 692–A Carrot 929–A				
1,324	LETTUCE	U						
692	ONIONS	U						
1,990	GRAPEFRUIT	U	Grapefruit 1,990–A					
3,987	ORANGES AND TANGERINES	U			Ora/Tan 3,987–A			
4,011	SUGAR BEETS	U	Sugar Beets 4,011–A					
929	CARROTS	U						
165,942	TOTAL		73,815	17,441	48,326	11,417	12,085	2,859

SUB-APPENDIX J
LANDS SUPPLEMENTAL TO SALT RIVER PROJECT

Table J-1. Total land use by crop, technology, land class, and rotation sequence—Lands Supplemental to Salt River Project—565 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
2,304	ALFALFA	L	Alfalfa 2,304–A					
6,307	COTTON	U	Cotton 4,645–A		Cotton 1,015–A			
1,944	BARLEY	L	Barley 1,944–A	Lettuce 1,944–A				
3,014	WHEAT	U			Wheat 3,014–A	Sorghum 405–A		
4,535	SORGHUM	S	Sorghum 620–A	Sorghum 168–A Onions 451–A			Sorghum 1,071–A	
4,863	LETTUCE	U	Lettuce 648–A	Cotton 648–A	Lettuce 2,271–A	Sorghum 2,271–A		
451	ONIONS	U						
909	SUGAR BEETS	L					Sugar Beets 909–A	
24,327	TOTAL		10,160	3,211	6,300	2,676	1,980	

Table J-2. Total land use by crop, technology, land class, and rotation sequence—Lands Supplemental to Salt River Project—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
2,304	ALFALFA	L	Alfalfa 2,304–A					
6,307	COTTON	U	Cotton 1,477–A		Cotton 654–A			
1,944	BARLEY	L			Barley 1,944–A			
3,014	WHEAT	U			Wheat 3,014–A			
4,535	SORGHUM	S	Sorghum 1,294–A	Onion 451–A			Sorghum 1,980–A	Sorghum 574–A
4,863	LETTUCE	U	Lettuce 4,176–A	Cotton 4,176–A	Lettuce 687–A	Sorghum 687–A		
451	ONIONS	U						
909	SUGAR BEETS	L	Sugar Beets 909–A					
24,327	TOTAL		10,160	4,627	6,300	687	1,980	574

Table J-3. Total land use by crop, technology, land class, and rotation sequence—Lands Supplemental to Salt River Project—1,000 mg/l

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
2,304	ALFALFA	L	Alfalfa 2,304–A					
6,307	COTTON	U	Cotton 216–A		Cotton 5,404–A			
1,944	BARLEY	L	Barley 1,162–A	Lettuce 1,162–A	Barley 209–A		Barley 574–A	Sorghum 574–A
3,014	WHEAT	U	Wheat 3,014–A	Lettuce 3,014–A				
4,535	SORGHUM	S	Sorghum 2,555–A	Onion 451–A			Sorghum 1,406–A	
4,863	LETTUCE	U			Lettuce 687–A	Cotton 687–A		
451	ONIONS	U						
909	SUGAR BEETS	L	Sugar Beets 909–A					
24,327	TOTAL		10,160	4,627	6,300	687	1,980	574

Table J-4. Total land use by crop, technology, land class, and rotation sequence—Lands Supplemental to Salt River Project—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
2,304	ALFALFA	L	Alfalfa 2,304–A					
6,307	COTTON	U	Cotton 2,648–A		Cotton 3,624–A		Cotton 36–A	
1,944	BARLEY	L					Barley 1,944–A	
3,014	WHEAT	U	Wheat 338–A	Sorghum 338–A	Wheat 2,676–A	Lettuce 2,676–A		
4,535	SORGHUM	S	Sorghum 1,774–A	Sorghum 235–A Onion 451–A				
4,863	LETTUCE	U	Lettuce 2,187–A	Sorghum 2,187–A				
451	ONIONS	U						
909	SUGAR BEETS	L	Sugar Beets 909–A					
24,327	TOTAL		10,160	3,211	6,300	2,676	1,980	

SUB-APPENDIX K
ROOSEVELT WATER CONSERVATION DISTRICT

Table K-1. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Water Conservation District—775 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
8,250	ALFALFA	L			Alfalfa 8,250–A			
13,194	COTTON	S	Cotton 6,312–A		Cotton 517–A		Cotton 6,365–A	
2,569	BARLEY	L	Barley 2,569–A	Sorghum 1,686–A Lettuce 273–A Watermelon 610–A				
1,377	WHEAT	L	Wheat 5–A	Lettuce 5–A	Wheat 1,372–A	Sorghum 1,054–A		
2,859	SORGHUM	L			Sorghum 120–A			
278	LETTUCE	U						
610	WATERMELON	U						
1,429	GRAPEFRUIT	U	Grapefruit 1,429–A					
2,351	ORANGES AND TANGERINES	L			Ora/Tan 2,351–A			
316	SUGAR BEETS	L	Sugar Beets 316–A					
33,233	TOTAL		10,630	2,574	12,610	1,054	6,365	

Table K-2. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Water Conservation District—900-1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
8,250	ALFALFA	L			Alfalfa 8,250–A			
13,194	COTTON	S	Cotton 6,949–A				Cotton 6,245–A	
2,569	BARLEY	L			Barley 2,569–A	Sorghum 2,130–A		
1,377	WHEAT	L	Wheat 889–A	Watermelon 610–A Lettuce 278–A	Wheat 488–A	Sorghum 488–A		
2,859	SORGHUM	L					Sorghum 120–A	Sorghum 120–A
278	LETTUCE	U						
610	WATERMELON	U						
1,429	GRAPEFRUIT	U	Grapefruit 1,429–A					
2,351	ORANGES AND TANGERINES	L	Ora/Tan 1,048–A		Ora/Tan 1,303–A			
316	SUGAR BEETS	L	Sugar Beets 316–A					
33,233	TOTAL		10,630	888	12,610	2,618	6,365	120

SUB-APPENDIX L
ROOSEVELT IRRIGATION DISTRICT

Table L-1. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—775 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
7,030	ALFALFA	S	Alfalfa 7,030–A					
6,935	COTTON	U	Cotton 4,860–A		Cotton 2,075–A			
3,445	BARLEY	U	Barley 3,445–A	Ensilage 87–A				
2,216	WHEAT	U	Wheat 2,216–A	Lettuce 171–A				
314	SORGHUM	U	Sorghum 259–A	Ensilage 259–A	Sorghum 55–A	Ensilage 55–A		
171	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L	Ensilage 267–A	Ensilage 267–A				
6,814	PASTURE	L	Pasture 6,583–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-2. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
7,029	ALFALFA	S	Alfalfa 7,029–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,951–A		Barley 1,494–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 171–A Ensilage 614–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
171	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L			Ensilage 267–A			
6,815	PASTURE	L	Pasture 6,584–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-3. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—1,000 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
7,027	ALFALFA	S	Alfalfa 7,027–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,951–A		Barley 1,494–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 171–A Ensilage 613–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
171	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L			Ensilage 267–A			
6,817	PASTURE	L	Pasture 6,586–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-4. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
7,024	ALFALFA	S	Alfalfa 7,024–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,953–A		Barley 1,491–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 173–A Ensilage 611–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
173	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
936	ENSILAGE	L			Ensilage 269–A			
6,817	PASTURE	L	Pasture 6,586–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-5. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
7,022	ALFALFA	S	Alfalfa 7,022–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,953–A		Barley 1,491–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 173–A Ensilage 611–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
173	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L			Ensilage 269–A			
6,820	PASTURE	L	Pasture 6,589				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-6. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
7,018	ALFALFA	S	Alfalfa 7,018–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,956–A		Barley 1,489–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 176–A Ensilage 608–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
176	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L			Ensilage 272–A			
6,821	PASTURE	L	Pasture 6,590–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

Table L-7. Total land use by crop, technology, land class, and rotation sequence—Roosevelt Irrigation District—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
7,015	ALFALFA	S	Alfalfa 7,015–A					
6,935	COTTON	U	Cotton 6,935–A					
3,445	BARLEY	U	Barley 1,958–A		Barley 1,486–A			
2,216	WHEAT	U	Wheat 2,161–A	Lettuce 179–A Ensilage 605–A	Wheat 55–A	Ensilage 55–A		
314	SORGHUM	U			Sorghum 314–A			
179	LETTUCE	U						
2,571	ALFALFA SEED	L	Alfalfa Seed 2,571–A					
935	ENSILAGE	L			Ensilage 275–A			
6,821	PASTURE	L	Pasture 6,590–A				Pasture 231–D	
937	SUGAR BEETS	U	Sugar Beets 937–A					
31,368	TOTAL		28,168	784	2,130	55	231	

SUB-APPENDIX M
SAN CARLOS IRRIGATION DISTRICT (NON-INDIAN)

Table M-1. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Non-Indian)—775 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
5,929	ALFALFA	L	Alfalfa 5,929					
13,995	BARLEY	S	Barley 1,331–A		Barley 12,664–A			
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U	Wheat 3,554–A					
4,880	MAIZE	U	Maize 4,880–A					
20,820	COTTON (UPLAND)	U			Upland 42–A		Upland 20,778–A	
1,010	COTTON (PIMA)	U					Pima 1,010–A	
648	SUGAR BEETS	U			Sugar Beets 648–A			
85	GRAPES	U			Grapes 85–A			
52,499	TOTAL		17,271		13,440		21,788	

Table M-2. *Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Non-Indian)—900 mg/l.*

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,995	BARLEY	S	Barley 4,885–A		Barley 9,111–A			
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U					Wheat 3,554–A	
4,880	MAIZE	U	Maize 4,880–A					
20,820	COTTON (UPLAND)	U			Upland 3,596–A		Upland 17,224–A	
1,010	COTTON (PIMA)	U					Pima 1,010–A	
648	SUGAR BEETS	U			Sugar Beets 648–A			
85	GRAPES	U			Grapes 85–A			
52,499	TOTAL		17,271		13,440		21,788	

Table M-3. *Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Non-Indian)—1,000 mg/l.*

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,995	BARLEY	S			Barley 8,560–A		Barley 5,436–A	
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U					Wheat 3,554–A	
4,880	MAIZE	U			Maize 4,880–A			
20,820	COTTON (UPLAND)	U	Upland 9,031–A				Upland 11,789	
1,010	COTTON (PIMA)	U					Pima 1,010	
648	SUGAR BEETS	U	Sugar Beets 648–A					
85	GRAPES	U	Grapes 85–A					
52,449	TOTAL		17,271		13,440		21,788	

Table M-4. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Non-Indian)—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
					Acres			
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,995	BARLEY	S					Barley 13,995–A	
1,577	SAFFLOWER	U			Safflower 1,577–A			
3,554	WHEAT	U			Wheat 3,554–A			
4,880	MAIZE	U			Maize 4,880–A			
20,820	COTTON (UPLAND)	U	Upland 11,342–A		Upland 1,686–A		Upland 7,793–A	
1,010	COTTON (PIMA)	U			Pima 1,010–A			
648	SUGAR BEETS	U			Sugar Beets 648–A			
85	GRAPES	U			Grapes 85–A			
52,499	TOTAL		17,271		13,440		21,788	

Table M-5. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Non-Indian)—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
							Acres	
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,995	BARLEY	S	Barley 1,331–A		Barley 12,345–A		Barley 320–A	
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U	Wheat 3,554–A					
4,880	MAIZE	U	Maize 4,880–A					
20,820	COTTON (UPLAND)	U					Upland 20,820–A	
1,010	COTTON (PIMA)	U			Pima 1,010–A			
648	SUGAR BEETS	U					Sugar Beets 648–A	
85	GRAPES	U			Grapes 85–A			
52,499	TOTAL		17,271		13,440		21,788	

Table M-6. Total land use by crop, technology, land class, and rotation sequence — San Carlos Irrigation District (Non-Indian) — 1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
					Acres			
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,995	BARLEY	S	Barley 4,842–A		Barley 9,153–A			
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U			Wheat 3,554–A			
4,880	MAIZE	U	Maize 4,880–A					
20,820	COTTON (UPLAND)	U					Upland 20,820–A	
1,010	COTTON (PIMA)	U	Pima 42–A				Pima 968–A	
648	SUGAR BEETS	U			Sugar Beets 648–A			
85	GRAPES	U			Grapes 85–A			
52,499	TOTAL		17,271		13,440		21,788	

Table M-7. Total land use by crop, technology, land class, and rotation sequence — San Carlos Irrigation District (Non-Indian) — 1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
					Acres			
5,929	ALFALFA	L	Alfalfa 5,929–A					
13,996	BARLEY	S	Barley 4,109–A		Barley 9,887–A			
1,577	SAFFLOWER	U	Safflower 1,577–A					
3,554	WHEAT	U			Wheat 3,554–A			
4,880	MAIZE	U	Maize 4,880–A					
20,820	COTTON (UPLAND)	U					Upland 20,820–A	
1,010	COTTON (PIMA)	U	Pima 42–A				Pima 968–A	
648	SUGAR BEETS	U	Sugar Beets 648–A					
85	GRAPES	U	Grapes 85–A					
52,499	TOTAL		17,271		13,440		21,788	

SUB-APPENDIX N
SAN CARLOS IRRIGATION DISTRICT (INDIAN)

Table N-1. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—775 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 3,333–A	Maize 147–A Watermelon 468–A	Barley 4,363–A			
765	SAFFLOWER	U			Safflower 709–A		Safflower 56–A	Maize 56–A
2,414	WHEAT	U					Wheat 2,414–A	Maize 73–A
2,104	MAIZE	U	Maize 1,215–A		Maize 307–A	Maize 307–A		
4,048	COTTON (UPLAND)	U	Upland 4,048–A					
501	COTTON (PIMA)	U			Pima 501–A			
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-2. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—900 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
							Acres	
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 3,333–A	Maize 147–A Watermelon 468–A	Barley 4,308–A		Barley 56–A	
765	SAFFLOWER	U			Safflower 765–A			
2,414	WHEAT	U					Wheat 2,414–A	Maize 129–B
2,104	MAIZE	U	Maize 1,215–A		Maize 307–A	Maize 307–A		
4,048	COTTON (UPLAND)	U	Upland 4,048–A					
501	COTTON (PIMA)	U			Pima 501–A			
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-3. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 7,567–A	Watermelon 468–A			Barley 129–A	Maize 129–B
765	SAFFLOWER	U	Safflower 765–A					
2,414	WHEAT	U	Wheat 264–A	Maize 147–A	Wheat 311–A		Wheat 1,840–A	
2,104	MAIZE	U			Maize 1,521–A	Maize 307–A		
4,048	COTTON (UPLAND)	U			Upland 4,048–A			
501	COTTON (PIMA)	U					Pima 501–A	
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-4. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—1,100 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1		Land Class 2		Land Class 3	
			Single cropped	Double cropped	Single cropped	Double cropped	Single cropped	Double cropped
						Acres		
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,692	BARLEY	S	Barley 1,498–A	Maize 147–A Watermelon 468–A	Barley 4,354–A		Barley 1,840–A	
765	SAFFFLOWER	U	Safflower 636–A				Safflower 129–A	Maize 129–A
2,414	WHEAT	U	Wheat 2,414–A					
2,109	MAIZE	U			Maize 1,526–A	Maize 307–A		
4,048	COTTON (UPLAND)	U	Upland 4,048–A					
501	COTTON (PIMA)	U					Pima 501–A	
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-5. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—1,200 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
			Acres					
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 7,389–A	Maize 147–A Watermelon 468–A	Barley 307–A	Maize 307–A		
765	SAFFLOWER	U	Safflower 636–A				Safflower 129–A	Maize 129–A
2,414	WHEAT	U	Wheat 70–A		Wheat 2,345–A			
2,104	MAIZE	U			Maize 1,521–A			
4,048	COTTON (UPLAND)	U			Upland 1,707–A		Upland 2,341–A	
501	COTTON (PIMA)	U	Pima 501–A					
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-6. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—1,300 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
			Acres					
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 7,389–A	Maize 147–A Watermelon 468–A	Barley 307–A	Maize 307–A		
765	SAFFLOWER	U	Safflower 636–A				Safflower 129–A	Maize 129–A
2,414	WHEAT	U	Wheat 70–A		Wheat 2,345–A			
2,104	MAIZE	U			Maize 1,521–A			
4,048	COTTON (UPLAND)	U			Upland 1,707–A		Upland 2,341–A	
501	COTTON (PIMA)	U	Pima 501–A					
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

Table N-7. Total land use by crop, technology, land class, and rotation sequence—San Carlos Irrigation District (Indian)—1,400 mg/l.

Total land use (acres)	Crop	Crop status	Land Class 1 Single cropped	Land Class 1 Double cropped	Land Class 2 Single cropped	Land Class 2 Double cropped	Land Class 3 Single cropped	Land Class 3 Double cropped
					Acres			
3,174	ALFALFA	U	Alfalfa 3,174–A					
7,696	BARLEY	S	Barley 5,938–A	Watermelon 468–A			Barley 1,759–A	
765	SAFFLOWER	U	Safflower 636–A				Safflower 129–A	Maize 129–A
2,414	WHEAT	U			Wheat 2,414–A	Maize 307–A		
2,104	MAIZE	U	Maize 1,521–A	Maize 147–A				
4,048	COTTON (UPLAND)	U			Upland 3,466–A		Upland 583–A	
501	COTTON (PIMA)	U	Pima 501–A					
468	WATERMELON	U						
21,170	TOTAL		11,770	614	5,880	307	2,470	129

APPENDIX 4
MUNICIPAL AND INDUSTRIAL CONSEQUENCES OF SALINITY IN THE COLORADO RIVER SERVICE AREA OF CALIFORNIA

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INTRODUCTION AND SUMMARY

It has been recognized for some time that variations in the chemical constituents of water may induce differences in corrosion rates, thereby affecting the lifetimes of household water conveyance systems and household appliances using water. In this study an attempt is made to measure economic losses associated with variation in mineralization of water delivered to households. These losses are measured for the following household appliances and fixtures: water heaters, galvanized wastewater pipes, galvanized water pipes, brass faucets, dishwashers, washing machines, and garbage disposals. A statistical analysis was undertaken, comparing estimated lifetimes for these household materials and appliances between two locations in the Los Angeles area of California. The two locations were San Fernando Valley and Costa Mesa-Newport Beach. A third area, Long Beach, was also included in portions of the analysis. Each location was divided according to socio-economic units. These units were based on differences in median home value, median contract rent, number of persons per household, age of structure, etc. Plumbing contractors serving each of these areas for 12 years or more, along with local appliance dealers, were contacted to provide estimates of average lifetimes for the various plumbing fixtures and appliances. From this survey, a distribution of lifetime estimates by type of plumbing fixture or appliance was obtained for each socio-economic unit and location. A comparison of the distribution between Costa Mesa (728 mg/l TDS) and San Fernando Valley (210 mg/l TDS) indicated a statistically significant difference in estimated mean lifetimes. The Costa Mesa-Newport Beach area had a shorter estimated mean lifetime for dishwashers, washing machines, garbage disposals, brass faucets, water heaters, and galvanized pipes at the 10 percent level of significance. No significant difference was found for toilet flushing mechanisms, copper or plastic water pipes, or copper or cast iron wastewater pipes at that same level of significance.

A regression analysis examining the relationship between estimated lifetime, total dissolved solids, and the socioeconomic variables identified earlier was conducted. Other than the number of persons per household affecting the estimated lifetime of water heaters, none of the socio-economic variables were found to be statistically significant in accounting for the variations in estimated lifetimes. This observed result may have been due to a lack of substantial variation in household characteristics across the two locations or incorrect specification of the relevant economic variables. Further research is needed before it can be definitively concluded that differences in socio-economic characteristics have no impact on physical deterioration of household water systems.

Estimated economic losses for a typical Los Angeles household, utilizing an 8 percent discount rate, range from $620 to $1,010 in present value terms for an increase in total dissolved solids from 200 to 700 mg/l. The range in economic loss is due to whether an assumption is made that galvanized pipe is replaced by copper or galvanized pipe. Copper replacement yields a longer life and thereby a lower economic cost. Previous studies by Tihansky (for the U.S.) and the Orange County Municipal Water District (for Orange County, California) yield estimates, comparable to the above, of $250 and $325 per household respectively. Thus, the estimated economic losses developed in this study are two to three times higher than those previously reported in the water resource literature.

Aggregate damages to households in the Los Angeles metropolitan area due to utilization of Colorado River water rather than water of Owens River quality can be estimated, by rough extrapolation, to be between $880 million and $1.44 billion in present value terms, or approximately $70 to $115 million as an annual cost. An improvement of 10 mg/l TDS in Colorado River water delivered to Los Angeles residences, by implication, would lead to a cost saving of approximately $14 million in present value terms. This estimate is likely to be downward biased because it does not include all types of household savings such as those on purchases of soaps and detergents, acid rinses for swimming pools, and others. On the other hand, it is likely to be upward biased because it does not include potential technological advances such as using new types of pipes or water softening devices that partially ameliorate the physical damages at costs less than economic losses.

A CONCEPTUAL MODEL

There are fundamentally two approaches to analyzing consumer or household decision-making with respect to water quality. One is to assume that sufficient low cost information is available to home buyers such that water quality differences become a factor in locational preference. That is, with other attributes being equal, the purchaser would value more highly that location having a higher water quality rated according to odor, taste, or amount of damage to physical equipment (pipes, water heaters, etc.). Another assumption is that information costs are relatively high and/or water quality attributes are viewed by the home buyer to be insignificant in comparison with other locational considerations (travel time to work, depreciation rates, socio-economic attributes to the neighborhood, etc.). In this case the purchaser makes a two stage decision: first a decision on location and secondly a sequence of decisions on improving water quality and/or undertaking defensive expenditures to ameliorate the impacts of poor water quality. Under this second assumption, the purchaser only actively considers the question of an optimal mix of services and capital expenditures to achieve a given desired water quality after making the fundamental locational decision.

In the first case, it can be anticipated that the extended lifetimes of appliances and increased palatability of drinking water would be capitalized into property values. Thus, locations with higher water quality would, all else being equal, have higher property values by an amount equivalent to the economic savings associated with increased lifetime of water conveyance systems and appliances. In addition, there would be an implicit value from increased palatability, i.e., a value differential associated with savings resulting from not having to purchase bottled water and the convenience of being able to use any faucet for drinking purposes. In addition, a difference may arise because some or all potential purchasers place a value on higher water quality beyond the cost incurred in achieving equivalent substitutes.

Given full capitalization of water quality attributes into property values, it is conceivable that an equilibrium could be reached where purchasers have made trade off decisions between water quality and other attributes of the location. A disturbance of this equilibrium by worsening or improving water quality may or may not be measured by the estimated marginal damages (as assumed by property value differences) occurring at the equilibrium, since damages will shift because of changes of locational choice of residents. It can be established that, in this idealized world, the difference in property values will yield a maximum in the form of actual marginal damages (WL_D) since the equilibrium property value differentials do not adequately consider all substitution possibilities away from the equilibrium.[1] However, if differences in measured physical damages represented in economic terms (WL_W) are adequately capitalized into property values, then estimates of these differences should yield at least minimum estimates of corresponding changes in capitalized property values (WL_P) since palatability is not considered. It is unclear whether substitution possibilities in terms of defensive expenditures and locational choice identified by marginal changes may or may not be less than estimated differences in physical damages at two or more locations. Thus, as a tentative hypothesis between measures for this particular case, one can expect:

$$WL_P > WL_W \gtrless WL_D \quad \ldots\ldots\ldots\ldots (1)$$

Thus, marginal damages could be greater than or less than measured physical damages and measured physical damages would be less than the losses capitalized in property values.

Since the aggregate cost of water softening devices, bottled water, acid rinses or swimming pools, additional detergents, and other direct consumer expenditues for reducing the effect of poor quality are typically less than 2-3 percent of income, it would appear more realistic to presume that information costs on water quality might typically exceed expected benefits of such information. It would seem more realistic to presume that the home buyer makes his purchase decision independent of variations in water quality, except to estimable corrosion of faucets and pipes, and perhaps a query on age and condition of appliances. Once the location is selected the householder then considers combinations of defensive expenditures to achieve a desirable level of water quality. Given larger geographical distribution of homogeneous quantities of water, it is anticipated that variations in water quality will become even less important relative to other characteristics of location such as shopping convenience, work travel time, and "quality of life" indicators in the immediate and surrounding areas. Within the geographical area,

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[1] See Robert Lind, QJE (1975) and A.M. Freeman, JEEM (1974) for an elaboration and discussion of this argument.

however, defensive expenditures already incurred by the homeowner might be partially or completely capitalized into property values. For example, the installation cost of a water softening system could be reflected in the future selling price of the property.

It cannot be anticipated that property value differences would be a true measure of the exact marginal damages due to variations in water quality. However, defensive expenditures undertaken by individual households would partially reflect economic losses associated with physical damages or loss of palatability due to pipe or faucet deterioration. This is due both to visual perception and probable background knowledge. In consequence, one would anticipate that:

$$WL_P \gtreqless WL_D > WL_W \quad \ldots\ldots (2)$$

That is, actual marginal damages would exceed measured physical damages but may be either less than or greater than losses capitalized in property values.

Where the quality of water delivered to the household cannot be altered by the householder's decision, the householder will conceivably make a set of decisions so as to achieve suitable quality standards with various water use activities. This set may include such decisions as the purchase and operation of a water softener, bottled water purchases, increased lawn and shrub watering activity, etc. Each of these broad categories may contain a set of subdecisions such as softening all water, only water used within the dwelling, or only that water flowing through the water heater.

In order to provide some precision to this conceptual model, let u(y,w) denote a utility function for the household where 'y' is a vector of water related activities and 'w' is a vector of measures of water quality, i.e., taste, hardness, odor. Non-water related activities are not included since the household's choices are assumed to be separable among water related and non-water related activities.[2] This does not appear to be a highly qualifying assumption for water quality related activities, although types of entertainment, food consumption, and other activities may be slightly related. By making this assumption, decisions on water quality can be more easily examined in terms of economic models. Next, it is assumed that the household has available alternative combinations of technologies for directly improving water quality or for ameliorating its effects on water-using activities. For example, the addition of a water softening device to hot water yields a different set of water using activities with respect to the lifetime and maintenance of hot and cold water delivery systems. For simplification, all such possibilities are expressed in a transformation function $y = f(z,w)$ where 'z' is a vector of household activities to improve water quality. Finally, it is assumed that each of these households activities has a price per unit p_i such that p_z equals the total household expenditure for improving water quality, directly or indirectly, by altering water-using related activities.

The complete model can be expressed as a maximization problem for the household as follows:

$$\text{MAX } L = u(y,w) + \zeta\,[y - f(z,w)] + \lambda(k - p_z) \quad \ldots\ldots (3)$$

in which 'k' is the maximum amount budgeted for water quality improvement activities and ξ and λ are LaGrangean multipliers.

First order conditions for a maximum are:

$$\frac{\partial L}{\partial y_i} = U_{y_i} + \zeta \leqslant 0 \qquad i = 1, \ldots N \quad \ldots\ldots (4)$$

$$\frac{\partial L}{\partial z_j} = -\zeta f_{z_j} - \lambda p_j \leqslant 0 \quad j = 1, \ldots M$$

$$\zeta[y - f(z,w)] = 0$$

$$\lambda(k - p_z) = 0$$

For an interior solution these conditions yield:

$$U_{y_i} = U_{y_{i+e}} \;\forall e \quad \ldots\ldots (5)$$

$$U_{y_i} f_{z_j} = \lambda p_j \forall \text{ i and j}$$

That is, marginal utilities among water-using activities must be equalized and the marginal utility product resulting from increasing household water quality improvement activities must be the equivalent of the original price times the shadow price for increasing the total expenditure on water quality improvement. Note that the initial water quality w is presumed to be given to the household.

From these first order conditions, a "derived demand" function for w can be constructed (see Gören-Mäler, 1975). This function represents a maximum amount that the household would be willing to pay to have a marginal improvement in water quality. Let M_w denote the maximum price the household would be willing to pay. Then the willingness to pay (or expenditure) function would be of the form:

$$M_W = g(w,p,k) \quad \ldots\ldots (6)$$

This relationship denotes a new equilibrium y and x for each level of w. Note that water quality is now being tested as a scalar measure. If water quality

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[2] This is formally equivalent to the Leontieff concept of "functional separability." See Green, 1964, p. 12.

were characterized as a vector, then separate expenditure functions would be derived for each water quality attribute.

Since the household cannot directly purchase water of varying quality, a demand or expenditure function is not observable. In consequence, a method needs to be developed to indirectly estimate willingness to pay and thereby predict the economic benefits of improved water quality. One approach would be to directly question individuals in a sample of households. The approach taken in this study was to estimate physical damages in terms of expected lifetimes assuming that the household would be willing to pay up to the economic value of those physical damages to avoid them. Clearly this estimate does not consider how the household might, acting individually, avoid some or all of the consequences of poor water quality or be able to reduce physical deterioration, i.e., by purchase of appliances with shorter lifetimes.

REVIEW OF PREVIOUS EFFORTS

The research efforts of this study were focused on the problem of estimating damage functions relating water quality to certain direct household costs from surveys conducted in the Los Angeles metropolitan area. Direct household costs affected by water quality can be divided into two basic categories: 1) capital costs, and 2) operation and maintenance costs[3]. Capital costs increase when poor water quality requires more frequent replacement (due to mineral deposits, corrosion, etc.) of such items as washing machines, dishwashers, garbage disposals, water heaters, water softeners, steam irons, swimming pool equipment (heaters, pumps, and filters), clothing, cooking utensils, and lawns and shrubs.

Operation and maintenance costs may increase with poor water quality because of the need for more frequent repairs to capital-cost items, for additional soaps and detergents, and for more frequent swimming pool cleaning. These costs also rise as measures to circumvent the effects of poor water quality are taken: water softener and bottled water purchases, "over-watering" of lawns and shrubs, etc.

To date, there have been few attempts to establish a functional relationship between water quality and household costs. The most comprehensive studies are those done by Black and Veatch (1967), and Metcalf and Eddy (1972). A third study by the Orange County Municipal Water district (1972) is of interest since it deals with a similar area to that of the present study.

Black and Veatch, in arriving at their estimates, conducted surveys of 38 communities in the midwest. Water quality data were gathered from each community along with estimates of the average lifetimes of the following: galvanized water pipes, wastewater pipes, water heaters, faucets, toilet flushing mechanisms, garbage disposals, washing machines, and dishwashers. The sources for these estimates were surveys of water utility companies, plumbing contractors, and hardware and appliance dealers (usually one of each per community).

From these data, lifetimes were plotted as a function of total dissolved solids (TDS) in the water supply and curves were derived by "grouping of points." Annual capital costs were then calculated and amortized at 6 percent interest over an average lifetime for each of the water-related items in an "average" home and a "modern urban home" at TDS levels of 250 mg/l and 1750 mg/l. Operation and maintenance costs such as repairs on capital-cost items, soap and detergent purchases, bottled water purchases, and over-watering of lawns were also derived. Since field investigations yielded but few data on these costs, estimates are made on the basis of industry reports and personal experience.

Metcalf and Eddy (1972) differ considerably in their approach as contrasted to the Black and Veatch study. Interviews of consumers in 10 communities, mainly in the southwest, are supplemented by data from industry in assessing water quality effects. Various measures of water quality are statistically tested for their significance. Of the capital-cost items considered (plumbing, appliances, clothing, and water heaters), the only statistically significant relationship was found between chloride content of water and replacement of water heaters. Statistically significant relationships in the operation and maintenance cost category were found between bottled water purchases and TDS, and between soap and softening costs and water hardness. No relationship is found between lawn watering and water quality.

Using these derived relationships, Metcalf and Eddy constructed two exponential curves for total household costs versus water hardness, one with softening and one without.

The Orange County Water District study (1972) follows the pattern of Metcalf and Eddy in using consumer interviews as a main source of information for estimates of the average lifetimes of water heaters. However, for estimates of the lifetimes of galvanized water pipes, faucets, and water-using appliances, the primary source of information was a survey of an unspecified number of plumbing contractors. Annual capital costs are calculated for two levels of water quality (200 and 750 mg/l TDS) similar to Black and Veatch. Annual O&M costs for home water softeners, bottled water and swimming pool acid-cleanings are also calculated at 200 and 750 mg/l TDS. Annual cleaning product costs for home costs are calculated for 79 and 249 mg/l total hardness ($CaCO_3$).

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[3] Health costs due to poor water quality are notoriously difficult to assess and are not considered here.

In a fourth study, Tihansky (1974) attempts to integrate the findings of these three previous efforts. Drawing from their data where possible[4], he develops regression equations for the relationship between TDS and the expected lifetimes of washing appliances, garbage disposals, water heaters, water piping, wastewater piping, toilet facilities, sewage facilities, cooking utensils, and washable fabrics. O&M cost functions are also derived for all of the above except cooking utensils and washable fabrics. Damage functions for soap and detergent costs are given both in terms of TDS and hardness. Lifetime estimates and O&M costs for water softeners are in terms of relative hardness. In the last two estimates, Tihansky draws from several other sources in addition to the Orange County report (Aultman, 1958; De Boer and Larson, 1961; and the Metropolitan Water District of Southern California, 1970).

Annual costs were calculated by Tihansky for an "average" U.S. household (using 100,000 gallons of water per year) and adjusted proportionately to account for increased or decreased usage at incomes above or below "average" U.S. family incomes. These studies indicate in a general way the magnitude of the direct household costs of poor water quality. However, it was felt that direct application to the Los Angeles metropolitan area would not be possible for the following reasons:

1. Data sources are inadequate since consumers in general may not have an adequate knowledge of lifetimes or frequency of repair for many items in the home and this may be particularly true in Los Angeles where the population is highly transient. Plumbers are consulted in all of the above studies, but in such small numbers the chances of statistical error are great.

2. Other possible explanatory variables are omitted from consideration. Frequencies of replacement and repair may depend on income level, number of persons/unit, age of housing, etc. Several of the researchers identified earlier recognize possible relationships but do not attempt to quantify them or analyze their significance.

3. Variations in water quality over time are not explicitly dealt with. All the studies appear to assume that present conditions can be extended into the past indefinitely, but if this is not the case and water quality has varied over time, the use of water at the present quality alone introduces error in measurement of damage functions.

PRIMARY DATA COLLECTION

In this section a procedure is documented for obtaining primary data to estimate the effect of salinity on the lifetimes of water-related consumer goods. In particular, a survey questionnaire was developed and applied to plumbers and appliance servicemen in areas for which there were differing concentrations of salinity in the water supplies in an attempt to obtain useful estimates of typical lifetimes of those goods suspected to be affected by salinity.

There were several reasons for the decision to survey plumbing and appliance sales and repair people rather than surveying the consumers themselves. Since these people are in daily contact with those goods which were expected to be affected by salinity, they are able to draw on a background of professional knowledge and experience that would be unavailable to the average consumer. The decision to survey these professional people seemed further justified by the belief that the fairly high transiency rate of families in the southern California area would make consumer estimates subject to great uncertainty as to their reliability. It was felt that estimates from plumbers and appliance sales and repair people might allow the opportunity to reasonably cross check other damage estimates for the Los Angeles area which have been based primarily on consumer information.

The questionnaires were designed to obtain information in those areas where professional servicemen would be most helpful. Questions were aimed primarily at obtaining estimated typical lifetimes for the various capital-cost items that have been identified in previous studies as being affected by salinity concentrations. In addition, the questionnaires attempted to obtain estimates of repair costs to such items in those cases in which the impact of salinity could have been "corrected" by repair rather than replacement. Finally, the questions were arranged within the questionnaire in such a way that a rough check on the reliability of the typical lifetime estimates given by the respondent was obtained. Such a check was basically a crude examination on the "consistency" of the respondent's answers. In tabulating the data obtained by the questionnaires, this crude check of consistency was then utilized to determine if the information of a respondent should be discarded. A set of sample questionnaires is provided in sub-Appendix A.

A word should be said about the measure which was used for salinity. Typically, salinity is measured in terms of total dissolved solids (TDS), expressed in milligrams per liter (mg/l), which are present in the water supply. Note, however, that this is a "macro" measure which is calculated as the sum of each individual dissolved constituent in the water. Hence a single measure of 750 mg/l TDS in two different water quality samples would allow for a different array or composition of the constituent parts. It is necessary, therefore, to assume that the macro TDS measure is a better indication of the impact of salinity on water-using articles that would be a measure or

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[4] Since much of the data in the Orange County report and the Management and Economics report are not given in usable form it would appear that the work of Black and Veatch is the primary source. This is certainly true in Tihansky's example of water heater life versus TDS.

measures of the individual constituents. In previous studies the measure of TDS has been most frequently used even when the data were cross-sectional and the source of water supplies as well as the composition of the constituent parts differed widely.[5] However, it has not been suggested that TDS is not a good measure, nor has there been any indication of which, if any, sub-group of constituent parts would be a better measure.[6] In order that the estimates developed in this study may be more comparable with other work in this area, TDS has been used as the appropriate measure of salinity. However, precautions have been taken to insure that the types of water for which a range of TDS values are derived are reasonably similar so that possible effects, if there be any, of varying compositions of chemical constituents would be minimized.

In order to generate data which could be applied to regression studies, it was necessary to find various locations for which the TDS concentration (index) differed. That is, we wanted to segregate large areas for which there were differing water quality indices. The primary criteria for acceptance of various Los Angeles neighborhoods as possible survey locations were: 1) The extent to which the area in question received a single source of water supply; 2) the length of time over which the area received a single water supply; 3) the extent to which each differing water supply over all areas was similar in nature; and 4) the availability of water quality records.

An important requisite of any area accepted as a survey location was that it have only one source of water supply rather than a supply which fluctuated as to source either through the course of a single year or from year to year. Since the chemical nature of water originating from different sources would vary, the result in surveys obtained from areas in which water sources fluctuated would perhaps represent an unknown configuration of chemical constituents and reactions. More specifically, a given type of water will, after a short period of use in a plumbing system, cause the development of a protective layer which inhibits the rate of corrosion in the system. The introduction of a new water supply will cause the old protective film to be partially or completely removed, resulting in an increased corrosion rate until the new water supply yields its own protective film. Clearly, estimated lifetimes of plumbing materials for areas in which the water source fluctuated would not be representative of the relationship between total dissolved solids and lifetimes except in the case where continuous fluctuations are anticipated.

It was decided to use as survey locations areas having the same water supply for at least 15 to 20 years. First, this would allow for ample time for the build-up of a protective coating by the water supply to be accomplished. Second, it was necessary to have a sufficient length of time to allow most of the articles for which lifetime estimates were to be developed to have lived out their usefulness over the period for which water quality data were available.

The type of water originating from different sources was significant in that waters with different velocities, dissolved oxygen content, dissolved constituents, and ratios of TDS to total hardness would, of course, result in different rates of scale buildup and corrosion. Thus in order to generate as accurately as possible lifetime estimates and their relationship to various explanatory factors, it was necessary to select water supplies that were as similar as possible.

In order to quantify the effects of salinity, it was necessary to establish a lengthy and accurate time series of TDS concentrations for each water supply. The mean value for these yearly TDS concentrations was then used in the regression analyses as an explanatory variable.[7]

With these criteria in mind, three major locations were selected: San Fernando Valley, Costa Mesa-Newport Beach, and Long Beach. Each of these three locations had a constant water supply source for at least 20 years, and a long time series of water quality data were available from local officials. Each area had a different TDS concentration (taken as a 20-year average): San Fernando Valley, 210 mg/l: Costa Mesa-Newport Beach, 728 mg/l; Long Beach, 759 mg/l and 457 mg/l (measured at two locations). Both the Costa Mesa-Newport Beach and San Fernando Valley residences were untreated, while the water going to Long Beach residences was softened. The water in part of the Long Beach system was mixed with local well water, yielding 457 mg/l TDS. The San Fernando Valley received Owens River water, which is similar to Colorado River water in most of its characterisitcs.[8]

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[5] Recall that the discussion in the previous section pointed out the possible problems in utilizing estimates based on radically different types of water as being a major reason for obtaining primary data rather than using secondary sources to obtain cost estimates for areas serviced by Colorado River water.

[6] In Sub-Appendix D, a statistical analysis is made of the Black and Veatch (1967) data of the effect of various chemical constituent combinations on lifetime. It is concluded that different combinations yield significantly different lifetimes for certain household products or water systems.

[7] This is perhaps the most simple dependence structure between lifetimes and TDS that could be assumed. For example, there might be a lag structure for the effect of TDS on lifetimes or perhaps even a cumulative structure that might sume TDS values over an article's lifetime. This simple assumption about the mean was the only hypothesis tested in the following analysis.

[8] Discussions with Mr. Roy Kelly and other representatives of the Metropolitan Water District of Southern California were of enormous help in determining appropriate survey areas. The authors were assured that by using Owens River water for contrast with Colorado River water the possible impacts that different water types would have on typical lifetimes of household appliances and plumbing would probably be minimized.

The Long Beach water supply presented two possible problems in determining lifetime estimates. First, the application of a water softener reduced total hardness from approximately 325 mg/l to approximately 145 mg/l. Through the softening process, the TDS concentration increases perhaps as much as 50 mg/l, which could possibly bias the resulting estimates. A dummy variable was included in the regression estimates to account for this problem. Second, after the survey data had been collected, it was learned that water authorities in Long Beach had been adding a corrosion-inhibiting agent to the water supplies. An additional dummy variable was applied in an effort to pick up the influence of this factor.

The next step in preparation for the survey was to divide each of the water quality locations into smaller geographic areas to which socio-economic data could be applied. Failure to consider the effect of these variables on lifetime estimates appeared to be a major omission from earlier studies attempting to quantify the impact of salinity upon water-using equipment. One such economic variable is income: As income increases, it would be expected that purchases of clothes washing machines and dishwashers would also increase, independent of the influence of salinity. A similar argument might be given with regard to the influence of the number of people living in a typical household. It could be hypothesized that as the number of people per household increases, the appliance would be exposed to a greater volume of water, thus increasing the observed impact of salinity on that article's lifetime.

For the purpose of developing socio-economic data, census tracts were combined in each area into units which represent approximately twelve to seventeen thousand people. The size of these socio-economic units was considered small enough to meaningfully examine variations in socio-economic data, but large enough for survey respondents to be able to identify the nature of service work provided for a given socio-economic unit. The socio-economic variables attached to each unit were: median home value (MV), median contract rent (MCR), number of persons per household unit (PNU), percent renter occupied units (PCRO), percent of housing units ten years or older (PC10), and percent of housing units twenty years or older (PC20).[9] The number of socio-economic units in each water area were: San Fernando Valley, 20; Costa Mesa-Newport Beach, 22; Long Beach, 9 (at 759 mg/l TDS) and 16 (at 457 mg/l TDS). Information on TDS concentrations and socio-economic units, along with a graphical description of the survey locations, is given in Figure 4-1.

The final step in preparation for the survey was to develop a list of potential respondents. Current telephone books for each area were obtained and phone calls were made to potential respondents attempting to set appointments for a field researcher to go through the survey with the respondent. It was hoped that the respondent would be able to answer the survey questions on the basis of only a single socio-economic unit rather than the respondent's entire service area. For this reason it was thought necessary to have field researchers make direct contact with the respondents. At each of these field meetings, the researcher gave the respondent a map of a particular socio-economic unit, stating that responses be made for that unit only.

A major problem with this survey procedure was the difficulty in arranging appointments and in persuading the respondent to give up 30 to 45 minutes (sometimes as much as 1 hour or more) during the working day. In view of this difficulty, a second approach was used wherein survey questionnaires were mailed to the respondent with instructions to fit his answers to a given socio-economic unit. Detailed maps of socio-economic units were included in the mail survey and field researchers made follow-up phone calls asking that responses be made. As a result of these two procedures, a total of 87 responses were received, 48 from plumbing contractors and 39 from appliance sales and repair personnel. A description of survey responses is provided in Table 4-1.

Table 4-1. Surveys obtained.

	Plumbing	Appliances
San Fernando		
Area Specific	12	18
Non-Area Specific	7	4
Total:	19 (12%)[a]	22(≈35%)[a]
Long Beach		
Blended	7	3
Non-Blended	5	2
Non-Area Specific	8	4
Total:	20 (33%)	9 (38%)
Costa Mesa-Newport Beach		
Area Specific	9	6
Non-Area Specific	-	2
Total:	9 (≈25%)	8 (≈35%)
Surveys Obtained	48 (≈25%)	39 (≈33%)

[a] Percentage of total plumbing contractors or appliance dealers contacted with twelve or more years of experience in one location.

STATISTICAL TESTS

Since the sample size in each of the areas is less than 30, it is appropriate to use a t-statistic calculated as follows:

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[9] U.S. Bureau of Census, Census of Housing: California, 1970 (USGPO 1973). All socio-economic data were obtained from this census.

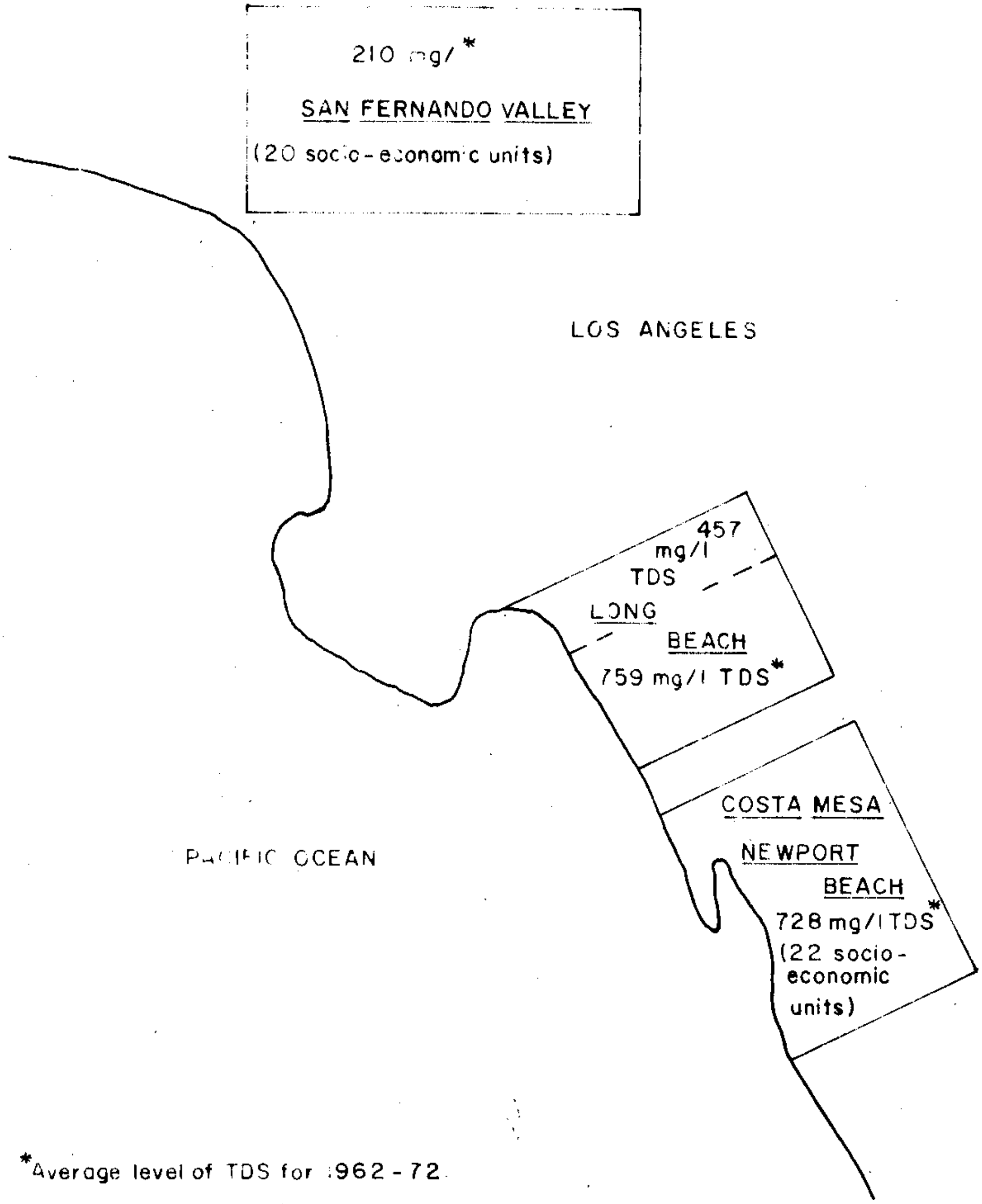

Figure 4-1. ***Survey areas: Location of TDS concentrations and socio-economic units.***

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{\eta_1} + \frac{1}{\eta_2}}} \quad \ldots\ldots\ldots \quad (7)$$

where

$$s = \sqrt{\frac{(\eta_1 - 1)s_1^2 + (\eta_2 - 1)s_2^2}{\eta_1 + \eta_2 - 2}}$$

and:

s_i^2 = variance of the observations, i=1,2

x_i = mean value of observations, i=1,2

n_i = number of observations, i=1,2

The calculations for statistical significance are reported in Table 4-2. These tests do not take into account alternative distributions, i.e., non-normal for the lifetimes. It also does not adequately consider socio-economic variables among sub-units of each area. However, the results do conform with subjective statements by plumbing contractors and water chemists that there is no substantial TDS related corrosion problem in pipes other than galvanized pipes. More importantly, the major impacts of higher salinity as measured by TDS are upon household appliances, faucets, and water heaters.

The next statistical test involved the use of multiple regression analyses to examine the relationship between water salinity and the estimated lifetimes of various appliances or water conveyance systems and to study the effect of certain socio-economic variables upon this relationship. The regressions were run in step-wise fashion, with TDS entered on the first step. These socio-economic variables which appeared to be the most significant were entered on succeeding steps. Regressions were run using both linear and log forms of the regression equation, with and without a dummy variable to take into account the Long Beach softened water In general, TDS tended to be the most significant predictor of lifetimes (in terms of significance of the coefficient for TDS), but appeared to have little influence on copper piping, toilet flushing mechanisms, and cast iron wastewater pipes. This might be anticipated on the basis of results from the simple statistical test reported in Table 4-2.

None of the socio-economic variables were consistently significant although "number of persons per unit" and "percent renter occupied" were often entered on either step number two or step three. Conceivably, these variables reflect the level of use that an item receives.

Employing the dummy variable dramatically improved the fit for water heaters and, to a lesser degree, for most of the other capital cost items considered. Use of the log form also improved the fit in most cases. For galvanized water pipes and clothes washers, however, a linear relationship appeared to be superior.

Based upon a test for significantly different population means, seven regression equations were selected as being useful in assessing the affects of water quality on lifetimes (Table 4-3).[10] For water heaters and galvanized wastewater pipes, both F statistics and R^2's (unadjusted) were sufficiently high to lead to reasonable confidence in the relationships. For the other relationships, the low F and R^2 are indicative of a substantial degree of scatter, which is to be expected since the regression is over a dependent variable which can take on only those values of 210, 457, and 728 mg/l. And at each of these points, a distribution of estimates is given.[11] For

Table 4-2. Test for significantly different sample means.

	Estimated Mean Lifetime		
	San Fernando Valley (210 mg/l)	Costa Mesa-Newport Beach (728 mg/l)	Statistical Significance
Water Heater	8.74	5.22	Different at .005
Galvanized Wastewater Pipes	30.94	10.14	Different at .005
Galvanized Water Pipes	17.28	11.25	Different at .100
Toilet Flushing Mechanism	7.68	6.63	No difference
Copper Water Pipes	44.08	47.50	No difference
Plastic Water Pipes	48.33	60.00	No difference
Copper Wastewater Pipes	43.82	43.78	No difference
Plastic Wastewater Pipes	42.50	53.00	No difference
Dishwashers	9.60	6.50	Different at .005
Washers	8.50	7.38	Different at .100
Garbage Disposals	8.47	6.86	Different at .100
Brass Faucets	10.40	6.00	Different at .050

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[10] A complete set of the estimated regression equations will be provided to the reader upon request to the authors.

[11] An alternative approach to using ordinary least squares regression would be to calculate the means of distributions at th two end points and calculate a line passing through these tw means. An unbiased estimation of the relationship betwee lifetime and TDS could be obtained. However, ordinary least squares appear to be superior because the variance of estimation is smaller (Kmenta, 1971.)

Table 4-3. Regression estimates for length of average lifetime and salinity.

Water Heaters

$\ln L = 5.43771 - .42435 (\ln TDS)\ .99322 (\ln \#PERS/UNIT)$
$\qquad (4.967)^{a,b} \qquad (3.925)^{a}$
$+ .36828 (DUMMY)$
$\qquad (2.406)^{a}$
$F = 13.34^{a}$
$R^2 = .60$

Galvanized Wastewater Pipes:

$\ln L = 7.42425 - .79571 (\ln TDS) + 1.05941 (DUMMY)$
$\qquad (4.227)^{a} \qquad (3.248)^{a}$
$F = 11.23^{a}$
$R^2 = .51$

Galvanized Water Pipes:

$L = 16.56015 - .00666 (TDS) - 3.78336 (DUMMY)$
$\qquad (1.584) \qquad (1.883)$
$F = 3.94^{c}$
$R^2 = .23$

Brass Faucets:

$\ln L = 6.35863 - .69277 (\ln TDS) + 1.28617 (DUMMY)$
$\qquad (1.351) \qquad (1.420)$
$F = 1.4$
$R^2 = .15$

Dishwashers

$\ln L = 4.05324\ .34538 (\ln TDS) + .42955 (DUMMY)$
$\qquad (3.175)^{a} \qquad (1.870)$
$F = 5.18^{c}$
$R^2 = .30$

Washers.

$L = 9.62161 - .00360 (TDS) + 1.45762 (DUMMY)$
$\qquad (1.933) \qquad (1.305)$
$F = 2.07$
$R^2 = .15$

Garbage Disposals:

$\ln L = 2.82352 - .13076 (\ln TDS) + .03794 (\ln DUMMY)$
$\qquad (1.013) \qquad (.145)$
$F = .55$
$R^2 = .05$

[a] Denotes statistically different from zero at the 99% level of a 1-tailed test.

[b] The values in parentheses are T-Statistics.

[c] Denotes statistically different from zero at the 95% level of a 1-tailed test.

water heaters, the signs of all coefficients appear to conform with prior expectations. That is, the sign for TDS is negative, indicating that an increase in TDS will reduce lifetime, as will an increase in number of persons per unit while pre-softening will lengthen lifetime. A negative relationship between TDS and lifetime for all other appliances was also discovered. However, the dummy variable reflecting water softening alternated in sign depending on the type of appliance.

Recorded in Table 4-4 are the estimated relationships of the Tihansky and Orange County studies. A graphical comparison of results is given in sub-Appendix E. An examination of sub-Appendix E indicates that the estimations made in this study yield markedly lower lifetimes for given TDS levels than estimates from Tihansky or the Orange County Municipal Water District study. In addition, the slopes of the relationships for galvanized wastewater pipes, water heaters, dishwashers, and brass faucets are higher in absolute value, suggesting that physical damages due to salinity may not be strictly proportional over the 200-700 mg/l range of TDS.

Table 4-4. Estimated equations of the Tihansky and Orange County Studies.[a]

Tihansky Study[b]	
Water Heater	$L=5+11\exp(-.0014\ TDS)$
Wastewater Pipes	$L=10+44\exp(-.0006\ TDS)$
Water Pipes	$L=12+30\exp(-.0018\ TDS)$
Faucets	$L=11.5-.0028\ (TDS)$
Dishwashers	$L=5.00+6.00\exp(-.0008 TDS)$
Washers	$L=5.00+6.00\exp(-.008 TDS)$
Garbage Disposal	$L=5.00+5.00\exp(-.0021 TDS)$
Toilet Flushing Mechanisms	$L=2+11\exp(-.0015\ TDS)$
Orange County Study[c]	
Water Heater	$L=10.87 - .005\ (TDS)$
Wastewater Pipes	$L=38.636 - .0182\ (TDS)$
Water Pipes	$L=38.636 - .0182\ (TDS)$
Faucets	$L=2.091 - .0055\ (TDS)$
Dishwashers	$L=11.091\ .0055\ (TDS)$
Washers	$L=11.091 - .0055\ (TDS)$
Garbage Disposals	$L=8.727 - .0036\ (TDS)$
Toilet Flushing Mechanisms	$L=11.091\ .0055\ (TDS)$

[a] L represents lifetime; TDS represents total dissolved solids; exp represents exponential.

[b] Dennis P. Tihansky, "Damage Assessment of Household Water Quality," *Journal of the Environmental Engineering Division*, ASCE, Volume 100, No. EE4 (August 1974).

[c] *Water Quality and Consumer Costs*, Orange County Water District, Orange, California (1974).

ECONOMIC DAMAGE COMPUTATIONS

Damage cost functions were developed by estimating costs for each water affected appliance or pipe identified earlier for a typical Los Angeles household. Cost estimates were presumed to have a time horizon equal to the economic lifetime of a typical housing unit. As such, the present value of any given cost would be related to TDS through the relationship between the lifetime of an article and the TDS concentration. In the discussion which follows, the example of water heaters will be used in developing a representative cost calculation. First, the assumption is made that the cost stream will be calculated over the total time horizon of 60 years, which represents an approximation to the economic lifetime of a housing unit.[12] Second, cost streams are calculated assuming

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[12] This estimate is the value which is used in various calculations made by the U.S. Department of Housing and Urban Development.

that payments for replacement occurs at the end of the lifetime of the previous unit.[13] Third, a separate cost stream associated with each TDS concentration was estimated. Costs were calculated over the range 100 to 1000 mg/l TDS. Note, however, that estimates outside the range of 210 mg/l to 728 mg/l may be unreliable since they are outside the range of values used in the regression analysis. It is also assumed that each TDS concentration remains constant over the 60-year period beginning in 1975. Therefore, the lifetime of each article can be taken from the regression estimates corresponding to each TDS concentration. For example, a separate cost stream will be developed for water heaters corresponding to TDS concentrations of 100 mg/l, 200 mg/l, etc. Corresponding to each TDS concentration is an estimated lifetime for water heaters, i.e., 11.71 years, 8.73 years, etc. Fourth, a discount rate in real terms of eight percent is assumed. The present value of the cost stream for water heaters associated with a TDS concentration of 200 mg/l can be written:

$$PV = C + C/(1+0.08)^{8.73} + C/(1+0.08)^{17.46} + \ldots + C/(1+0.08)^{52.38} \qquad \ldots . (8)$$

in which C is the cost to replace and install a water heater and PV is the present value of the cost stream. (Estimates of replacement costs for the appliances and water conveyance systems can be found in sub-Appendix B). The present value of this cost stream represents the amount which, if put into savings in the present period at an 8 percent interest rate, would be just sufficient to provide one water heater for a housing unit at all times over the unit's lifetime.[14] Fifth, after the present value of a cost stream is calculated it is then weighted appropriately to represent cost figures for the typical household in the Los Angeles-Long Beach Standard Metropolitan Statistical Area (SMSA). A summary of the statistics defining the typical household can be found in sub-Appendix B. For example, a typical household has one water heater. Therefore, the appropriate present value cost figure for a water heater is $324.05 in 1975 dollars. In sub-Appendix C the present value cost figures corresponding to each TDS concentration and the estimated lifetime of each article are recorded. Also summarized in the tables in sub-Appendix C are the marginal damage costs by type of household appliance or conveyance system. The total (or sum) of all the damage estimates for types of household damages examined in this study are summarized in Tables 4-5 and 4-6.

The figures in these tables represent only partial damage to the typical household in the Los Angeles-Long Beach SMSA resulting from the use of water with alternative TDS concentrations.[15] In order to facilitate comparisons with other research studies, a comparable set of cost streams was developed from estimates found in Tihansky and Orange County.[16]

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[13] This procedure may tend to bias downward estimates of actual economic cost.

[14] Note that operating and maintenance costs are not included nor are the effects of such costs on lifetimes. Adequate estimates of this relationship were not obtainable from plumbing contractors or appliance dealers. However, one might anticipate that regular repairs and servicing would prolong the average lifetime. If the estimates of average lifetime include a schedule of normal servicing, then the estimated damages are likely to be biased downward by an amount equal to whatever component of the servicing is attributable to salinity.

[15] Items not included are: costs of detergents, costs or benefits of potential health effects, costs of increased lawn and shrub care, swimming pool maintenance, bottled water purchases and others.

[16] The specific forms for the estimating equations associated in the table with the Orange County research were not all specifically reported in that study. That is, the equations for water piping, faucets, toilet flushing mechanisms, garbage disposals, wshers, and dishwashers were derived as linear functions on the basis of two point estimates (at 200 mg/l and 750 mg/l TDS) which were reported in the Orange County Study.

Table 4-5. ***Household total damage: Present value 1975 (8 percent discount rate) (1975 Dollars).***

TDS mg/l	Estimates Developed Here	Copper Replacement Assumption[a]	Tihansky[b]	Orange County[b]
100	1725.00	1718.00	1685.00	1747.00
200[c]	1946.00	1890.00	1725.00	1788.00
300	2115.00	2043.00	1769.00	1838.00
400	2264.00	2172.00	1823.00	1890.00
500	2407.00	2293.00	1871.00	1954.00
600	2568.00	2451.00	1923.00	2029.00
700[c]	2684.00	2511.00	1975.00	2113.00
800	2819.00	2613.00	2029.00	2205.00
900	2956.00	2715.00	2080.00	2317.00
1000	3095.00	2812.00	2120.00	2449.00

[a] All pipe is assumed to be replaced by copper at the first replacement. Copper is assumed to last, on the average, 46 years. See Table 4-3.

[b] Only items covered in this study were included in recomputing the Tihansky and Orange County results.

[c] Estimates are extrapolated below 200 and above 728 mg/l TDS.

Table 4-6. ***Household marginal damages: Present value 1975, (8 percent discount rate) (1975 Dollars).***

TDS mg/l	Estimates Developed Here	Copper Replacement Assumption[a]	Tihansky[b]	Orange County[b]
100				
200[c]	221.00	172.00	40.00	41.00
300	168.00	153.00	44.00	50.00
400	150.00	130.00	54.00	52.00
500	143.00	121.00	48.00	64.00
600	160.00	158.00	52.00	75.00
700[c]	116.00	59.00	52.00	84.00
800	135.00	103.00	54.00	91.00
900	137.00	101.00	51.00	112.00
1000	140.00	98.00	40.00	132.00

[a] All pipe is assumed to be replaced by copper at the first replacement. Copper is assumed to last, on the average, 46 years. See Table 4-3.

[b] Only items covered in this study were included in recomputing the Tihansky and Orange County results.

[c] Estimates are extrapolations below 200 and above 728 mg/l TDS.

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SUB-APPENDIX A

Municipal Damages Survey, Plumbing Contractors

The primary purpose of this survey is to gather data related to the cost of municipal water users for using water of differing quality. Data are to be gathered for different areas which are homogeneous in socioeconomic characteristics, but for which a different quality of water is being used. We would like each respondent to this survey to base his/her responses on his/her <u>professional</u> experience. Each respondent will be shown a certain area and asked to base his/her responses on that area alone. Throughout the survey the respondent must keep in mind that each question is to be answered only in terms of the specific area in question. (If an answer cannot be given for the specific area, please attempt to answer the same question for your entire service area. If an answer is given which is for your entire service area, please indicate so.)

I. Plumbing

1. Estimate the typical age at the replacement of water pipes made of the following materials. Also, estimate the percentage of total water pipes in service which are made of each material:

   a. galvanized iron ____________years ____________percent
   b. copper ____________years ____________percent
   c. plastic ____________years ____________percent
   d. other (specify) ____________years ____________percent
   ____

2. Estimate the number of water heaters you have replaced in the last

   a. 5 years_______________ b. 1 year_______________
   (area/total area)

3. Estimate the typical age at replacement of wastewater pipes made of the following materials. Also, estimate the percentage of total wastewater pipes in service which are made of each material.

   a. galvanized iron ____________years ____________percent
   b. copper ____________years ____________percent
   c. cast iron ____________years ____________percent
   d. plastic ____________years ____________percent
   e. other (specify) ____________years ____________percent
   ____

6. Estimate the typical age at replacement of a water heater. ____________years. List the most frequent reasons for replacing a water heater, and estimate the percentage which each reasons represents of total reasons for replacement.

____________________ ____________percent

____________________ ____________percent

7. Estimate the typical age at replacement of a toilet flushing mechanism ____________years.

8. Estimate the number of water piping systems made of each of the following materials which you have replaced in the last 5 years, 1 year.

a. galvanized iron a) 5 years____________ b) 1 year____________

b. copper a) 5 years____________ b) 1 year____________

c. plastic a) 5 years____________ b) 1 year____________

d. other (specify) a) 5 years____________ b) 1 year____________

____

(specific area/total area)

9. Estimate the number of wastewater piping systems made of each of the following materials which you have replaced in the last 5 years and 1 year.

a. galvanized iron a) 5 years____________ b) 1 year____________

b. copper a) 5 years____________ b) 1 year____________

c. cast iron a) 5 years____________ b) 1 year____________

d. plastic a) 5 years____________ b) 1 year____________

e. other (specify) a) 5 years____________ b) 1 year____________

____

(specific area/total area)

10. Estimate the percentage of households which have home water softeners. ____________percent

11. Estimate the percentage of residential plumbing systems in which different metals are connected in situations <u>other</u> than in connections to faucets. ____________percent.

List the most frequent connections of this sort, and for each, estimate the percentage of plumbing systems in which each type of connection occurs.

____________________ ____________percent

____________________ ____________percent

12. For each water piping system of the following materials, estimate what percent require water-caused repair in any given year. Also list the most frequent repair to each material, and estimate the percentage of water pipes of each material which require each type of repair.

a. galvanized iron ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

____________________ ____________percent

b. copper ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

c. plastic ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

d. other (specify) _______________ ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

13. For each wastewater piping system of the following materials, estimate what percent require water-caused repair in any given year. Also, list the most frequent repair to each material, and estimate the percentage of wastewater pipes of each material which require each type of repair.

a. galvanized iron ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

b. copper ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

c. cast iron ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

d. plastic ____________percent repaired/year

____________________ ____________percent

____________________ ____________percent

e. other (specify) ____________ ____________percent repaired/year

____________ ____________percent

____________ ____________percent

14. Estimate the number of toilet flushing mechanisms you have replaced in the last

a. 5 years____________ b) 1 year____________

15. Estimate the typical age at replacement for a faucet made of the following materials:

a. galvanized iron a) 5 years____________ b) 1 year____________

b. copper a) 5 years____________ b) 1 year____________

c. brass a) 5 years____________ b) 1 year____________

d. other (specify) a) 5 years____________ b) 1 year____________

____

16. Estimate the typical annual operation cost for a home water softener $____________.

What percentage of this estimated cost is attributable to chemical inputs in the operation of a home water softener? ____________percent

17. For each of the following materials, estimate the number of water-related repair you have made to water pipes made of each material in the last 5 years and 1 year.

a. galvanized iron a) 5 years____________ b) 1 year____________

b. copper a) 5 years____________ b) 1 year____________

c. plastic a) 5 years____________ b) 1 year____________

d. other (specify) a) 5 years____________ b) 1 year____________

____

(specific area/total area)

18. For each of the following materials, estimate the number of water-related repairs you have made to wastewater pipes made of each material in the last 5 years and 1 year.

a. galvanized iron a) 5 years____________ b) 1 year____________

b. copper a) 5 years____________ b) 1 year____________

c. cast iron a) 5 years____________ b) 1 year____________

d. plastic a) 5 years____________ b) 1 year____________

e. other (specify) a) 5 years____________ b) 1 year____________

____

(specific area/total area)

19. Estimate the number of faucets made of each of the following materials which you have replaced in the last 5 years and 1 year. Also list the most frequent cause for replacement, and indicate the percentage which each reason represents of total reasons for replacement.

a. galvanized iron a) 5 years____________ b) 1 year____________

____________________ ____________percent

____________________ ____________percent

b. copper a) 5 years____________ b) 1 year____________

____________________ ____________percent

____________________ ____________percent

c. brass a) 5 years____________ b) 1 year

____________________ ____________percent

____________________ ____________percent

d. other (specify) a) 5 years____________ b) 1 year____________

____

____________________ ____________percent

____________________ ____________percent

(specific area/total area)

20. Estimate the percentage which your plumbing jobs represent of all plumbing jobs required by consumers in the specific area in question. ____________percent

21. Estimate the percentage of your total jobs which are done in the specific area in question. ____________percent

Municipal Damages Survey, Water Using Appliance Dealers

The primary purpose of this survey is to gather data related to the cost of municipal water users for using water of differing quality. Data are to be gathered for different areas which are homogeneous in socio-economic characteristics, but for which a different quality of water is being used. We would like each respondent to this survey to base his/her responses on his/her professional experience. Each respondent will be shown a certain area and asked to base his/her responses on that area alone. Throughout the survey the respondent must keep in mind that each question is to be answered only in terms of the specific area in question. (If an answer cannot be given for the specific area, please attempt to answer the same question for your entire service area. If an answer to a question is given which is for your entire service area, plase indicate so.)

II. APPLIANCES

22. Estimate the typical age of replacement of a clothes washing machine. ____________ years.

23. Estimate the typical age of replacement of a dishwashing machine ____________ years.

24. How many garbage grinders have you replaced in the past
a. 5 years _______________ b) 1 year _______________?

List the most frequent reasons for replacing a garbage grinder, and indicate the percentage which each reason represents of all reasons for replacement.

____________________ ____________percent

____________________ ____________percent
(specific area/total area)

25. Estimate the typical age at replacement for an evaporative air conditioner. ____________years.

26. For each of the following appliances estimates the percentage of each which require water related repair in any given year.
a. clothes washing machine _________________percent
b. dishwashing machine ______________________percent
c. garbage grinder __________________________percent
d. evaporative air conditioner _____________percent

27. How many dishwashing machines have you replaced in the past
a) 5 years _______________ b) 1 year _______________?

List the most frequent reasons for replacing a dishwashing machine, and estimate the percentage which each reason represents of all reasons for replacement.

____________________ ____________percent

____________________ ____________percent

28. How many clothes washing machines have you repaired for water-related reasons in the past
a) 5 years _______________ b) 1 year _______________?

List the most frequent water-related repairs to clothes washing machines estimate the percentage which each repair is of total water-related repairs per year, and estimate the typical length of time to complete the repair.

____________________ ____________percent ____________hours
____________________ ____________percent ____________hours

29. Estimate the typical age at replacement of a garbage grinder ____________years.

30. How many evaporative air conditioners have you replaced in the past
a) 5 years ______________ b) 1 year ______________?

List the most frequent reasons for replacing an evaporative air conditioner, estimate the percentage which each reason represents of all reasons for replacement, and estimate the typical length of time necessary to complete the replacement.

____________________ ____________percent ____________hours
____________________ ____________percent ____________hours

31. How many dishwashing machines have you repaired (water related) in the past
a) 5 years ______________ b) 1 year ______________?

List the most frequent water related repairs to dishwashing machines, estimate the percentage which each repair is of total water related repairs for the year, and estimate the typical length of time to complete the repair.

____________________ ____________percent ____________hours
____________________ ____________percent ____________hours

32. How many garbage grinders have you repaired (water related) in the past
a) 5 years ______________ b) 1 year ______________?

List the most frequent water related repairs to garbage grinders, estimate the percentage which each repair represents of total water related repairs per year, and estimate the typical length of time to complete the repair.

____________________ ____________percent ____________hours
____________________ ____________percent ____________hours

33. Estimate the percentage which your repair jobs on each of the following appliances represents of all repair jobs for each appliance in the specific area in question.

a. clothes washing machine ____________________percent

b. dishwashing machine ____________________percent

c. garbage grinders ____________________percent

d. evaporative air conditioners ______________percent

34. How many evaporative air conditioners have you repaired in the past
a) 5 years ______________ b) 1 year ______________

List the most frequent water related repairs to evaporative air conditioners, estimate the percentage which each repair represents of total water related repairs per year, and estimate the typical length of time to complete the repair.

____________________ ____________percent ____________hours
____________________ ____________percent ____________hours

35. Estimate the percentage which your sales and installation of each of the following appliances represents of all sales and installations of each appliance in the specific area in question.
    a. clothes washing machines ____________________percent
    b. dishwashing machines ____________________percent
    c. garbage grinders ____________________percent
    d. evaporative air conditioners ______________percent

36. Estimate the percentage of homes which have a garbage grinder ____________percent.

37. Estimate the percentage of your total business which is transacted with consumers in the specific area in question. ____________percent.

SUB-APPENDIX B

Estimates of Replacement Costs and Characteristics of Typical Household Units

Table B-1. Replacement costs.[a]

Water Heater	$160
Washer	$250
Dishwasher	$225
Garbage Disposal	$ 65
Faucet	$ 45
Toilet Flushing Mechanism	$ 25
Galvanized Water Pipe	$600
Galvanized Wastewater Pipe[b]	$600
Copper Water Pipe[b]	$600
Copper Wastewater Pipe[b]	$600

[a] These cost estimates represent the mean value of a sample of estimates provided by local sales personnel.

[b] These categories of replacement cost represent the replacement cost for the entire water or wastewater piping system.

Table B-2. Typical household unit: Los Angeles-Long Beach SUS14.

Rooms:[a]	4.51
Bedrooms:[a]	2.04
Persons:[a]	2.8
Flush Toilets:[a]	1.31
Water Heater:[a]	1.00
Bath/Shower:[a]	1.00
Kitchen Sink:[a]	1.00
Bathroom Sink:[a]	1.00
Washing Machine:[a]	0.57
Dishwasher:[a]	0.21
Faucet:[a]	5.00
Garbage Disposal:[a]	1.00
Galvanized Water Pipes:[b]	0.70
Galvanized Wastewater Pipes:[b]	0.25

[a] Census of Housing, 1970, U.S. Census Bureau (U.S. GPO, Washington, D.C., 1974).

[b] These estimates are the mean values of our survey data.

SUB-APPENDIX C

Calculated Lifetimes, Household Total and Marginal Damages for Different Levels of Water Salinity by Type of Appliance or Water Conveyance System

Table C-1. Water heaters: lifetimes and costs.

TDS mg/l[a]	Lifetime (Years)	PV[b] (Total Damages–1975$)	Marginal Damages (1975$)
100	11.7	268.00	56.00
200	8.7	324.00	44.00
300	7.4	368.00	35.00
400	6.5	403.00	31.00
500	5.9	434.00	26.00
600	5.5	461.00	26.00
700	5.1	486.00	23.00
800	4.9	510.00	22.00
900	4.6	532.00	19.00
1000	4.4	551.00	

[a] Twenty year average total dissolved solids.

[b] Present value of total damages based on 8 percent discount rate.

Table C-2. Galvanized wastewater pipes: lifetimes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	42.9	156.00	
200	24.7	176.00	60.00
300	17.9	200.00	24.00
400	14.3	224.00	25.00
500	11.9	249.00	24.00
600	10.3	271.00	23.00
700	9.1	295.00	24.00
800	8.2	318.00	23.00
900	7.4	341.00	23.00
1000	6.9	362.00	21.00

Table C-3. Galvanized water pipes: lifetimes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	15.9	591.00	
200	15.2	603.00	12.00
300	14.6	621.00	18.00
400	13.9	636.00	15.00
500	13.2	654.00	17.00
600	12.6	672.00	19.00
700	11.9	697.00	25.00
800	11.2	722.00	24.00
900	10.6	749.00	27.00
1000	9.9	784.00	35.00

Table C-4. Brass faucets: lifetimes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	23.8	267.00	
200	14.7	331.00	64.00
300	11.1	389.00	58.00
400	9.1	444.00	54.00
500	7.8	495.00	51.00
600	6.9	543.00	49.00
700	6.1	590.00	47.00
800	5.6	634.00	45.00
900	5.2	678.00	43.00
1000	4.8	720.00	43.00

Table C-5. Dishwashers: lifetimes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	11.7	79.00	
200	9.2	92.00	13.00
300	8.0	102.00	10.00
400	2.3	110.00	8.00
500	6.7	116.00	6.00
600	6.3	122.00	6.00
700	6.0	127.00	5.00
800	5.7	132.00	5.00
900	5.5	136.00	4.00
1000	5.3	140.00	4.00

Table C-6. Washers: lifetimes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	9.3	278.00	
200	8.9	285.00	7.00
300	8.5	294.00	9.00
400	8.2	303.00	9.00
500	7.8	313.00	10.00
600	7.5	324.00	12.00
700	7.1	336.00	12.00
800	6.7	349.00	13.00
900	6.4	365.00	16.00
1000	6.0	381.00	16.00

Table C-7. Garbage disposals: lifetmes and costs.

TDS mg/l	Lifetime (Years)	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	9.2	127.00	
200	8.4	136.00	8.00
300	8.0	141.00	5.00
400	7.7	144.00	4.00
500	7.5	148.00	4.00
600	7.3	150.00	3.00
700	7.2	153.00	2.00
800	7.0	155.00	2.00
900	6.9	156.00	2.00
1000	6.8	158.00	2.00

Table C-8. Wastewater pipes: costs under copper replacement assumption.[a]

TDS mg/l	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	156.00	
200	172.00	17.00
300	188.00	15.00
400	200.00	12.00
500	212.00	11.00
600	220.00	8.00
700	226.00	7.00
800	232.00	6.00
900	237.00	5.00
1000	241.00	4.00

[a] It is assumed that copper pipe is used when the first replacement occurs.

Table C-9. Water pipes: costs under copper replacement assumption.[a]

TDS mg/l	PV (Total Damages–1975$)	Marginal Damages (1975$)
100	544.00	
200	550.00	6.00
300	561.00	11.00
400	569.00	7.00
500	576.00	8.00
600	585.00	8.00
700	593.00	9.00
800	602.00	9.00
900	612.00	10.00
1000	622.00	10.00

[a] From Table C-8.

SUB-APPENDIX D

A Test of the Importance of Different Compositions of Constituent Parts on Estimated Lifetimes

A simple multiple regression analysis was run using the Black and Veatch data for three functional forms: linear, log-linear, and quadratic. Examination of these preliminary results for the presence of autocorrelation was then undertaken. The Cochrance-Orcutt technique of correction for autocorrelation was then utilized when the Durbin-Watson statistic suggested the possibility of autocorrelation.[17] Note that the primary concern of the analysis is to test the significance of a number of variables in the explanation of lifetimes and not necessarily to develop an unbiased estimate of lifetimes themselves; that is, analyzing the difference between the means associated with the estimated coefficients to determine if the variable is a "significant" explanatory variable, and as such if there is a need to correct for the influence of autocorrelation when it is present because it will tend to bias the test for the difference between means.

The hypothesis that is to be considered now is that the ratio of TDS to total hardness (TH), to sulfates (S), and to chlorides (C) is important to the relationship which describes the lifetimes of water quality affected articles. This hypothesis was suggested because the range of the ratio TDS/TH in the Black and Veatch data was 1.35 to 87.72, while the value of this ratio is approximately 2.0 for Colorado River water. This observation suggested the following question: Would the estimated lifetime relationships developed in the Black and Veatch study, which did not attempt to control for the influence of differences in compositions of constituent parts, represent an accurate estimate of the lifetime relationships for Colorado River water? The same question could, of course, be asked about the ratio of TDS to sulfates, chlorides, or any other constituent part. Information useful in answering such questions can be obtained from a multiple regression analysis which attempts to discover the statistical significance of the estimated type of analysis.[18] For future studies total hardness should probably be used alone as an independent variable in the regression analysis. The practice of dividing TH and other variables into TDS may well mask the true contribution of each constituent to the overall variability.

In each of the regressions, TDS was a significant explanatory variable and it had the expected sign in all but the regression on wastewater pipes. The explanation for the positive sign in this regression would apparently be related to the Cochrane-Orcutt procedure utilized to correct for the biasing influence of autocorrelation. Due to the nature of the data set and the computer regression package (Copper, 1971) utilized in this analysis, the Cochrane-Orcutt procedure required the deletion of five observations from the data set. This corresponds to falling from thirteen to eight observations and is explained by "gaps" in the data matrix. The significance of these gaps to the programmed correction procedure is that for each gap there was a loss of one of the observations.[19] The apparent result of this loss in observations was, in effect, to bias the analysis by perhaps leaving observations on TDS which were grouped in such a fashion that a positive influence was picked up by the regression. This may perhaps be an explanation for the rather startling result that under an ordinary least squares regression, the coefficient was negative and significant, as expected; but it flipped to positive after employing the Cochrane-Orcutt procedure to correct for the apparent presence of autocorrelation. It is possible that this type of behavior was exhibited because of the small number of observations with which the researchers were working. The major significance of this regression to the analysis at hand is the statistical significance of (TDS/TH), (TDS/S), and (TDS/C). Note that in half of the regressions (TDS/S) was a significant variable and that (TDS/TH) was significant in two of the six regressions.

These results are not conclusive proof that the configuration of constituent parts is a major explanatory factor in the lifetimes of water quality affected goods; however, they do support the view that the configuration of the constituents must be considered, as well as the view that it was necessary to obtain data specifically relevant to the Colorado River rather than attempting to obtain meaningful estimates from secondary sources which had obtained relationships from data generated for waters differing in characteristics from that of Colorado River water.

Several final observations should be made concerning the set of dummy variables which are listed at the beginning of this appendix. In very general terms, the results of specifying regressions with this set of dummy variables identified the dissolved oxygen content and softening of the water supply as being relevant explanatory variables for the relationships under study. As a particular example, using the linear specification and the Cochrane-Orcutt correction, the variable for softening was significant and indicated that softening the water supply would increase the lifetime of galvanized piping within the range of 16 to 27 years.

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[17] For a description of the Cochrance-Orcutt technique, see Kmenta (1971, p. 287-289). A description of the Durbin-Watson test for autocorrelation may be found in the same reference, pp. 294-296, or in Thiel (1971, p. 199-201).

[18] Note that washing machines were excluded from the table because we were unfortunately unable to obtain any meaningful results because of limited number of observations.

[19] The loss of observation was necessitated in this procedure by attempting to estimate l in the relationship $\varepsilon = l\varepsilon_{a-1} + u_{\alpha}$ where ε denotes the error term in the ordinary least squares regression equation, us is a random error with zero mean and constant variance, and a denotes the observation. Each time there is a gap the observation immediately following the gap is effectively the a-1 observation and thus lost from the analysis, which calculates the parameters of the regression under analysis.

Table D-1. ***Summary of regression analysis testing the importance of different compositions of constituent parts.***

		Ordinary Least Squares[a,b]	$\bar{R}^2$[c]	D.W.[d]
1)	ln W.H.	= 4.181 - .277[ln TDS] + .089[ln(TDS/TH)] - .179[ln(TDS/S)] - .018[ln(TDS/C)] (.570)***(.077)*** (.066) (.076)** (.067)	.3928	2.261
2)	ln TFM	= 4.770 - .475[ln TDS] - .090[ln(TDS/TH)] - .002[ln(TDS/S)] + .015[ln(TDS/C)] (.799)***(.107)*** (.081) (.083) (.080)	.5881	1.147^{I}
3)	ln G.G.	= 3.782 - .246[ln TDS] + .121[ln(TDS/TH)] - .276[ln(TDS/S)] - .011[ln(TDS/C)] (.876)***(.123)* (.064)* (.078)*** (.075)	.5735	2.357^{I}
4)	F	= 10.874 - .004[TDS] - .003[TH] + .009[S] + .003[C] (1.511)***(.002)* (.004) (.005) (.005)	.2739	2.076
		Cochrane-Orcutt Correction for Autocorrelation		
5)	ln W.W.	= 2.072 + .256[ln TDS] - .077[ln(TDS/TH)] - .098[ln(TDS/S)] - .198[ln(TDS/C)] (.186)***(.013)*** (.032)* (.041)* (.050)**	.9296	1.755^{I}
6)	ln G.P.	= 4.853 - .354[ln TDS] + .045[ln(TDS/TH)] - .048[ln(TDS/S)] + .193[ln(TDS/C)] (.676)***(.092)*** (.088) (.133) (.096)*	.4640	2.680^{I}

Footnotes:

[a] Definition of variables.

W.H. = lifetime of water heaters
TFM = lifetime of toilet flushing mechanisms
G.G. = lifetime of garbage grinders
F = lifetime of faucets
W.W = lifetime of wastewater pipes
G.P. = lifetime of galvanized pipes
TDS = total dissolved solids (ppm)
TH = total hardness (ppm)
S = sulfates (ppm)
C = chlorides (ppm)

[b] Values in parentheses are the standard errors of the estimated coefficients. T-statistics can be obtained by dividing the estimated coefficient by its standard error. T-statistics are used to test the hypothesis that the estimated coefficient is significantly different from zero. The results of such tests are indicated by placing asterisks on the coefficient's standard error indicating that the coefficient is statistically different from zero at the following levels of confidence for a two-tailed test:

* 90% confidence level
** 95% confidence level
***99% confidence level

[c] Corrected R^2. This value is a correction on the R^2 taking account of the fact that including irrelevant explanatory variables will increase the R^2

[d] Durbin-Watson statistic. See Henri Theil (1971) *Principles of Econometrics*, John Wiley and Sons, Inc., p. 199-201, for a description of this test for autocorrelation. This test is not always conclusive, and when it is inconclusive, this will be indicated by superscripting the Durbin-Watson statistic with I, otherwise the test indicated no autocorrelation at the 95% level of confidence

Source. Black and Veatch (1967). *Economic Effects of Mineral Content in Municipal Water Supplies*, Office of Saline Water. Research and Development Progress Report No. 260, May 1967.

SUB-APPENDIX E

Graphical Comparisons of Estimated Lifetime Relationships

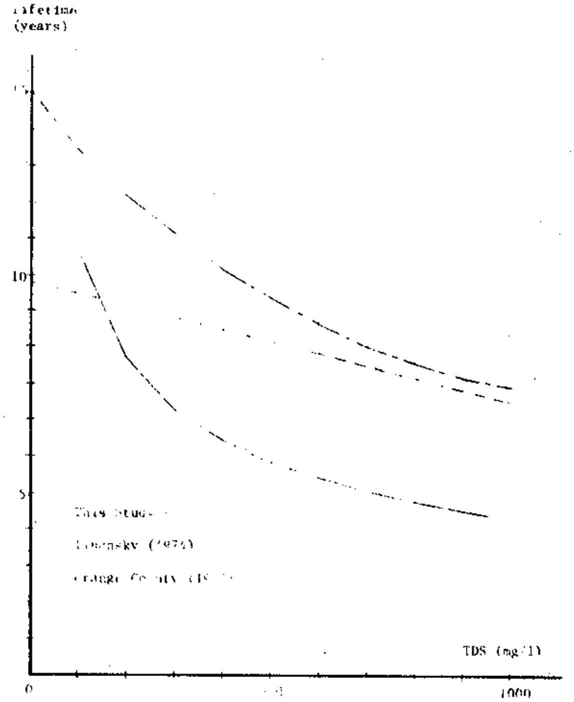

Figure E-1. *Graphical comparison of estimated lifetime relationships for water heaters.*

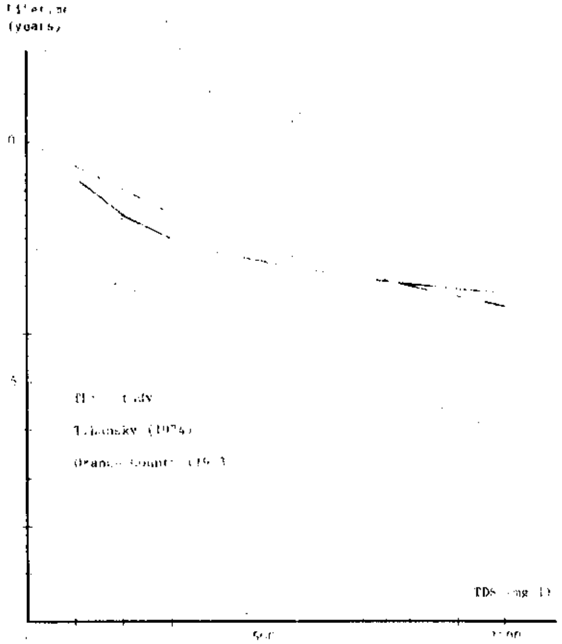

Figure E-2. *Graphical comparison of estimated lifetime relationships for garbage disposals.*

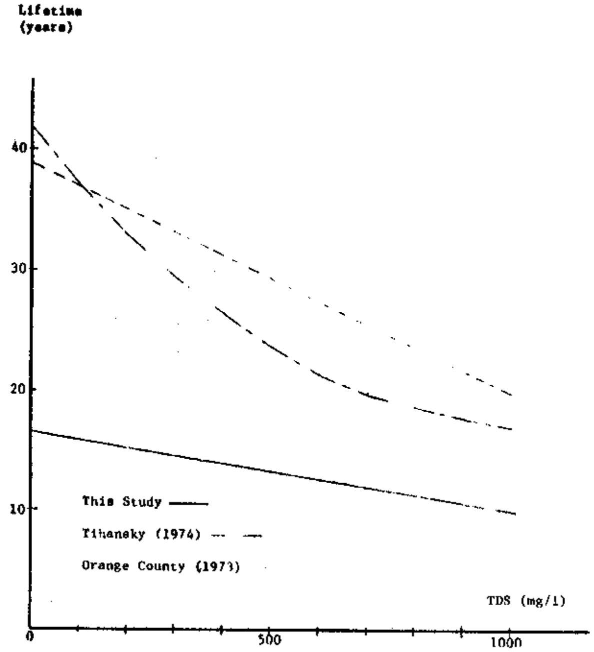

Table E-3. *Graphical comparison of estimated lifetime relationships for galvanized water pipes.*

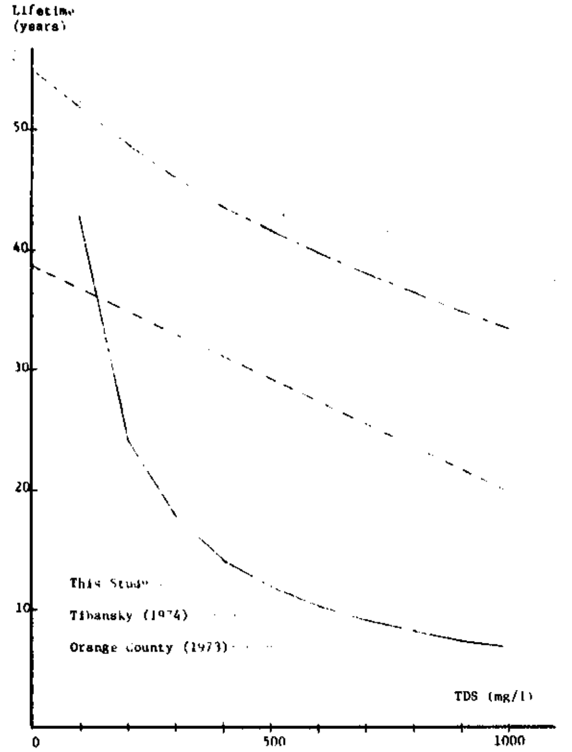

Figure E-4. *Graphical comparison of estimated lifetime relationships for galvanized wastewater pipes.*

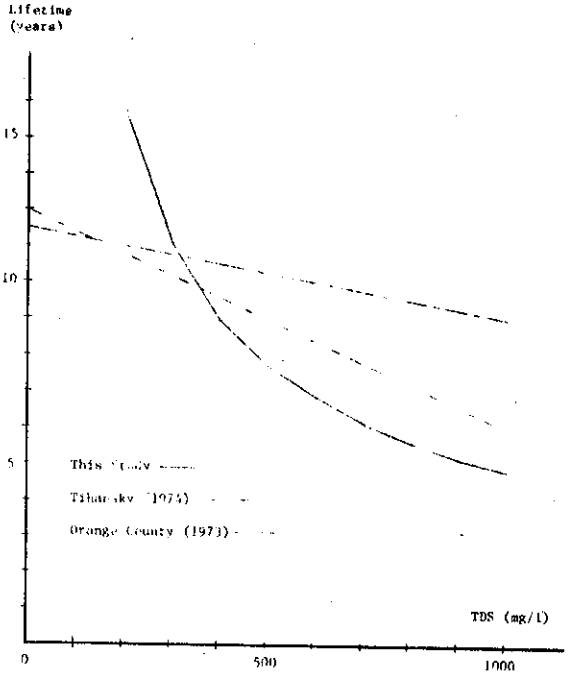

Figure E-5. ***Graphical comparison of estimated lifetime relationships for brass faucets.***

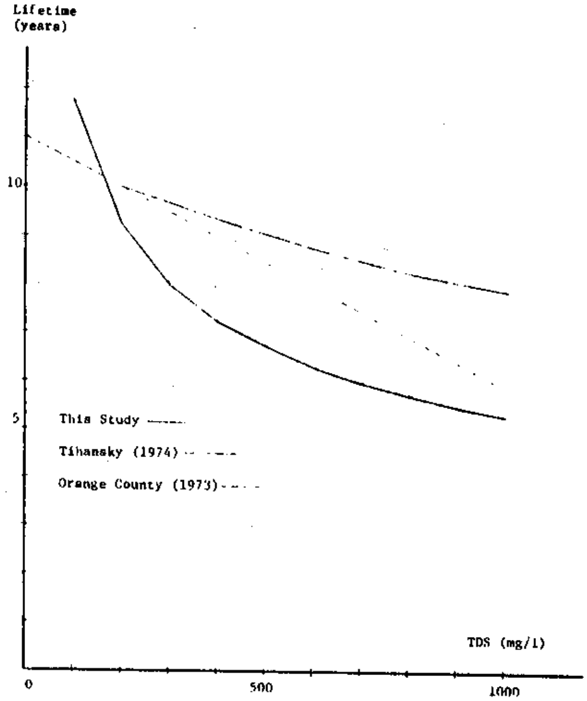

Figure E-6. ***Graphical comparison of estimated lifetime relationships for dishwashers.***

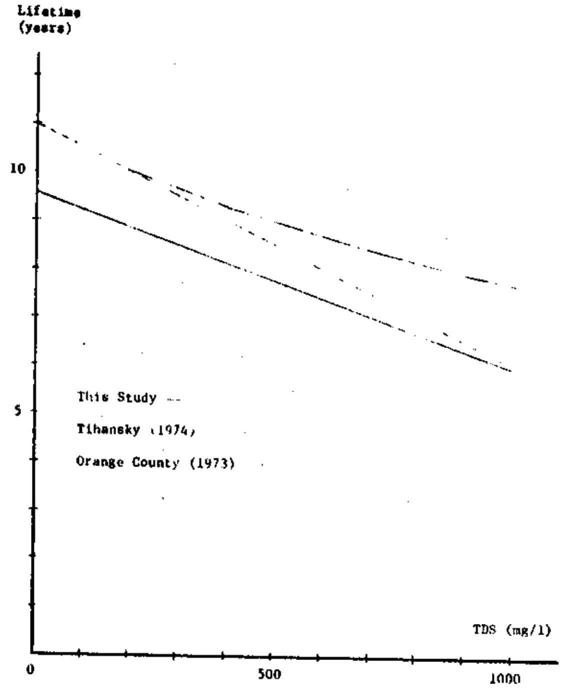

Figure E-7. ***Representation of estimated lifetime relationships for washers.***

APPENDIX 5

ECONOMIC IMPACTS OF SELECTED SALINITY CONTROL MEASURES IN THE UPPER COLORADO: A CASE STUDY OF THE GRAND VALLEY, COLORADO

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INTRODUCTION

Where soils are high in soluble salts, the practice of crop irrigation can have a deleterious effect on water quality. Mineral solids in the water are concentrated as a part of it is evaporated away, and more may be leached from the soil profile or underlying geologic structure and be picked up in large quantities in irrigation drainage water. Since drainage water or "return flows" contribute appreciably to the volume of many rivers and streams in the west, the importance of saline irrigation return flow on water quality is readily apparent.

This appendix reports a preliminary evaluation of on-farm water management techniques for reducing salt pickup from saline irrigation return flows in the Colorado River. A major problem area in western Colorado is selected as a case study. Preliminary identification of separate area contributions to salinity has been accomplished in a number of reconnaisance surveys by various agencies over the past several years (U.S. Bureau of Reclamation, 1972). Deep percolating return flows from irrigated land situated over shale formations which contain very high levels of soluble salts are reported to be the chief contribution from man made sources. The Grand Valley in western Colorado and the Price River Valley in Utah have the highest annual rates of salt pickup in the Upper Basin, averaging over 8 tons per acre. The Uncompaghre and Lower Gunnison Valleys, also in western Colorado, contribute somewhat less, but are significant sources. Total loading and concentration from crop irrigation is said to account for about 38 percent of the total salt load in recent years.

CHARACTERISTICS OF THE STUDY AREA

The Grand Valley is an interesting and challenging area to physical and social scientists alike for investigating salinity abatement measures for future implementation in the valley and elsewhere. Constraining factors have been encountered at all levels of study: in modeling physical and hydrosalinity relationships, institutional inflexibilities governing private water use and ownership, and identification of socio-economic consequences for communities directly and indirectly affected.

Irrigated Agriculture

The Grand Valley is located in West Central Colorado at the confluence of the Gunnison and Colorado Rivers in Mesa County (Figure 5-1). Paralleling the Colorado River for about 30 miles, the valley averages 7 miles in width and about 4400 feet in elevation. Summer weather is characteristically hot and dry and the winters cold. Beginning in April, the normal frost-free season averages about 190 days. With an annual precipitation averaging 8 to 10 inches, irrigation is necessary to maintain a viable commercial agriculture in the valley.

Grand Junction, with a population of about 25,000, is the principal commercial center in the valley. Agriculture is an important source of employment and income to a local population of about 60,000 people in Mesa County. However, in recent years basic manufacturing and service industries have become the mainstay for an otherwise traditional agricultural community. Approximately 60,000 acres of land is presently cultivated out of a total arable area exceeding 100,000 acres. Urban and industrial expansion, service roads and farmsteads, and idle and abandoned lands account for most of the balance not farmed (Walker and Skogerboe, 1971).

The diversified agricultural industry in the valley is comprised of both livestock and crop production activities. Major crops grown include corn, alfalfa, sugar beets, small grains and permanent pasture. Slightly less than 15 percent of the irrigated acreage is planted to pome and deciduous orchards, the produce of which, processed locally, may be shipped as far as

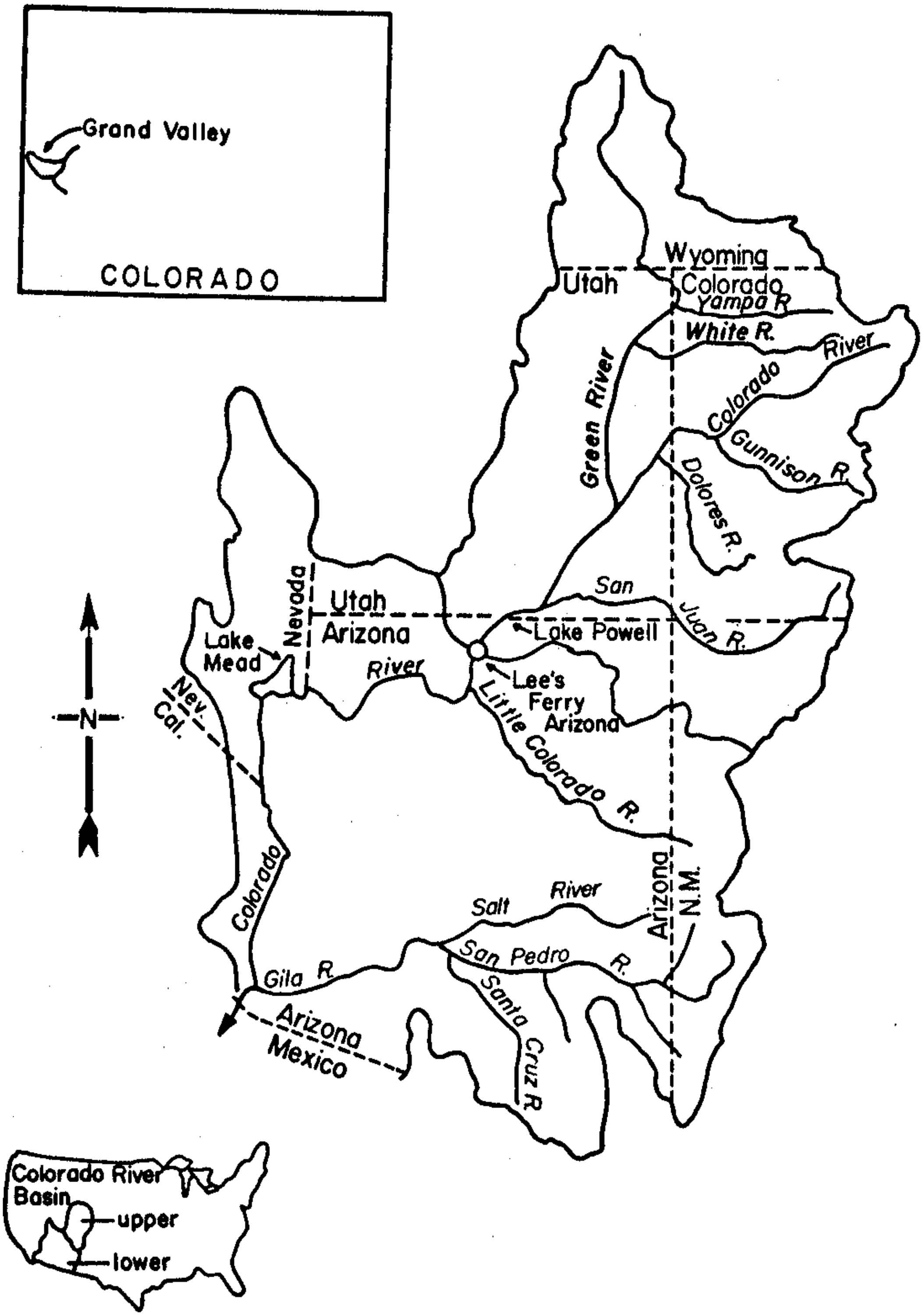

Figure 5-1. The Colorado River Basin.

the Atlantic seaboard. The Grand Valley has long been a favored wintering area for cattle and sheep grazed on high mountain summer range to the east.

Following settlement in the late 1870s, irrigation companies were organized to divert water for agricultural use. Many of the original companies have since been consolidated leaving five which presently supply all the water diverted under original decrees: The Grand Valley Irrigation Company (1882), the Grand Valley Water Users Association, using water developed by the U.S. Bureau of Reclamation in about 1916, the Palisade and Mesa County Irrigation District (1890s), and the Redlands Water and Power Company (Skogerboe and Walker, 1972). Because irrigable acreages were typically overestimated within the newly formed irrigation districts, and due partially to a gradual decline in irrigated acreage due to waterlogging, and more recently to urbanization, Grand Valley farmers have always had an abundant supply of water.

Early evaluations of irrigation efficiency which were initiated in response to immediate drainage problems in the lower-lying lands, documented valley-wide efficiencies of 30 to 40 percent (USDA and Colorado Ag. Experiment Station, 1957; and Decker, 1951). However, the threat of rising water tables and salinity problems encountered on water-logged soils was not enough incentive to reduce the use of very low priced project water. Average charges in 1974 were less than $2 per ac ft. Average river diversions frequently exceed 600,000 ac ft annually, but only 175,000 ac ft are required to meet normal crop consumptive use (Skogerboe et al., 1974).

Soils vary throughout the valley in surface textures ranging from loam to fine silty clay but share a common parent material in subsurface structure derived from Mancos shale (Soil Conservation Service, 1955). Being low in organic matter, these soils are prone to nutrient leaching (especially nitrates) and have restricted internal drainage at lower elevations. The prevailing topographical slope of the Grand Valley ranges between 50 to 80 feet per mile, which effectively limits irrigation methods to furrow and corrugation techniques (Bishop et al., 1967).

Hydrosalinity Aspects

Selected Geological Survey gaging stations located above and below the valley have been the chief source for estimates of annual salt pickup in recent years (U.S. Environmental Protection Agency, Appendix A, 1971). Average annual salt pickup attributable to irrigated agriculture is estimated at 600,000 tons of total dissolved solids. Historical data suggest a range in annual contributions of less than 400,000 tons in low flow years to over 1,000,000 tons in years of high water flow (U.S. Bureau of Reclamation, 1973).

The primary source of salinity is thought to be the extremely saline aquifers (as high as 10,000 mg/l) overlying a marine-deposited Mancos shale formation. Lenses of salts contained in the shale are dissolved by water entering and coming into chemical equilibrium with this formation before returning to the river channel. Water enters these aquifers by seepage from the irrigation conveyance system (delivery canals, laterals, and drains) and by irrigation practices which lead to excessive deep percolation from irrigated fields. Westesen (1975) reported that proportionate contributions to total salt loading are 55 percent and 45 percent, respectively.

Proposed Salinity Controls

Degraded irrigation return flows, by way of seepage and deep percolation through saline soils and underlying geologic formations which return increased salt loads to the river system, make the Grand Valley one of the most significant man-made sources in the entire river basin. Until the initiation of the present study, research concentrated on various structural control technologies including lining of conveyance systems and on-farm drainage improvements. Although a program of scientific irrigation scheduling designed to improve on-farm water management has been under study since 1972, feasibility analysis have been limited to a few selected farms with no detailed valley-wide evaluations being attempted. Other nonstructural control possibilities have had little serious consideration.

Several lengths of canals and laterals have been lined since 1970 in a demonstration area on the east side of the valley (Skogerboe and Walker, 1972). These researchers estimate that 70 to 80 pecent of total seepage losses could be prevented by lining all canals and laterals (including on-farm delivery ditches). However, the costs of such a program could be quite high; $14 to $100 per ton of salts removed.

Inefficiency in on-farm water use, stemming from a combination of abundant supply, low water charges, and problematic soil-topographic characteristics, has encouraged interest in irrigation scheduling as a valley-wide possibility (Bureau of Reclamation, 1974a). The results of irrigation scheduling are presently inconclusive, but the program holds much promise as a low-cost control measure (Skogerboe and Walker, 1973; and Anderson et al., 1974). Improved on-farm efficiencies may possibly have local benefits, including increased yields and additional productivity on previously water-logged soils, in addition to reduction in downstream damages.

Research on the use of drainage technologies has emphasized interception of deep percolating water below the root zone before it has reached chemical equilibrium in the saline aquifers. Because the deep open ditch-type drains in use since the early 1920s are largely ineffective for this purpose, a drainage program would also have to include extensive renovation of existing structures to be effective. Costs of field drainage and renovation appear to be quite high, and resulting water quality improvement uncertain. Additionally, drainage improvements without improving on-farm water use efficiency would possibly make matters worse than they are (Skogerboe et al., 1974).

OBJECTIVE, APPROACH, AND SCOPE OF STUDY

The principal objective of this study is to measure the direct costs which would be imposed on farmers from adoption of selected nonstructural means of reducing salt pickup. Nonstructural control alternatives examined are the changes in irrigation and crop management practices which increase the efficiency of irrigation water use and reduce deep percolation, which in turn reduces the amount of salt-saturated water displaced back to the river.

The general approach of the analysis was to develop a representative firm model of crop farms in the valley in a linear programming format. The model incorporates alternative processes or activities, which represent the cost, income water use and salt pickup consequences of alternative methods of irrigating crops. A detailed field survey of a sample of farms provided data for the model. The representative model thus developed is then solved on a digital computer for a range of constraints on estimated salt pickup. Net income for each level of the salt pickup is computed, and the cost of a given salt pickup reduction measured in terms of the reduction in net farm income as compared with the benchmark (unregulated) situation.

This study is confined to field crop producing farms in the Grand Valley, and the 15 percent of the area's irrigated acreage devoted to orchard and other specialty crops (mostly peaches) is not considered. Nonstructural alternative, other than adjusted irrigation practices and crop substitutions, are not examined. Leathers and Young (1975) report a preliminary investigation of land retirement as a more drastic nonstructural means (1975 WAEA).

RESEARCH PROCEDURES: CONCEPTS, ASSUMPTIONS AND METHODS

Conceptual Framework

The analysis is based on a three-component model consisting of a) a control variable set; b) an interactions structure, and c) an objective function. The control variable set consists of those factors or policy instruments subject to human control which are identified as having an influence on the objective. In the present instance, control variables can be distinguished as "structural" and nonstructural. Structural measures are those involving capital expenditures for tangible structures while "nonstructural" are involving changes in the institutional system (incentives, constraints, penalties) which influence those members of the economy utilizing the resource system under study. This report considers only a nonstructural control method, that of adjusting irrigation practices for the purpose of reducing saline irrigation return flows.

The interactions structure consists of the interrelationships among several submodels. One of these is a behavioral economic model, which purports to predict the optimal (profit maximizing) response of the "representative farmer" to changes in physical relationships, legal constraints and net profit. Another sub-model specifies water-soil relationships; in particular, it allocates the applied irrigation water into its components: evapotranspiration, surface runoff (tailwater) and most important, deep percolation (drainage water). The third submodel describes drainage water-salt pickup relationships.

The objective function falls within the economic efficiency framework, in that willingness-to-pay values, measured in dollars of gains, losses, or damages to affected parties, is the assumed policy criterion. A national accounting stance is assumed. Regional income impacts are reported elsewhere in this volume by Charles Howe and Jeffry Young. Other possible objectives, such as equitable income distribution, are not considered. The objective function considers only the net incomes of Grand Valley irrigation water users, as it is affected by changing practices. The report will attempt to integrate these findings with estimates of the dollar value of damages imposed. From a basin-wide economic efficiency point of view, the control program should proceed to the point where the marginal net income losses to the upstream sources are equated to the marginal losses avoided by downstream recipients of salinity damages.

Hypothesized Means of Reducing Salt Pickup

Two hypothesized practices which influence deep percolation, and hence salt pickup, are studied in this report. The first has to do with irrigation practices, which means, in effect, the quantity of water applied. Irrigators may, given factors such as size of field, slope, soil texture, vary the rate of water applied per unit area in the crop season by a) changing the length of time water is allowed to run in each furrow, b) by changing the size of siphon tubes (so that the rate of application is changed), c) by changing the interval between irrigations, or by a combination of these.

The predominant soils in the Grand Valley exhibit unusual infiltration characteristics. Walker's (1974) studies found that infiltration rates tend to fall as the growing season progresses. Early in the year, when soils are open and loose following pre-plant tillage operations, the soils permit rapid infiltration of water, and a relatively large amount is lost to deep percolation when water is run for long periods in order to achieve adequate wetting in the lower end of fields. Later on in the year, the soil "tightens up" and the proportion of deep percolation falls while tailwater losses increase. It is hypothesized that a relatively simple adjustment of irrigation practices, namely: reducing the time that water flows in each furrow, could achieve uniform wetting while effectively reducing deep percolation.

The second farm management practice which could affect rates of deep percolation is an adjustment in crop patterns. Crops vary as to deep percolation even within a given set of irrigation practices, so percolation can be reduced by cutting back acreage of crops which are high contributors in favor of those which create less of a problem.

Each of these alternatives is incorporated into the linear programming model to measure effects on farm income of a forced reduction in salt pickup from implementation of existing water quality regulations.

Water-soil Submodel

A simplified soil-water-crop budget was developed in order to trace the effects of various salinity control mechanisms on water utilization and deep percolation[1]. An estimate of deep percolation is described, which in turn is used to develop an estimate of salt pickup under alternative irrigation practices.

In order to predict the consequences of modifying irrigation practices on deep percolation and eventual salt pickup, detailed data on actual soil-water-crop relationships in the Grand Valley are required. Considerable heterogeneity in soils, topography and farm production practices is observed. The assumptions used in the model reflect a careful selection of available information and is thought to be broadly representative.

Perhaps the most critical assumption deals with seasonal variations in water intake rates. Two seasonal conditions, early and mid-late season, are used to present the gradual decrease in water infiltration as the irrigation season progresses. A more precise approach would call for a specified rate for each sub-period (say, 15 day intervals) but information available to us does not warrant further refinement (see Skogerboe et al., 1973; Skogerboe et al., 1974; and Gilley, 1968).

The results of the soil-water model assumptions and calculations are given in Tables 5-1 and 5-2. The crucial estimate in these tables in the amount of deep percolation per unit area in Table 5-2. This estimate falls between those of Skogerboe et al. (1974) and Kruse et al. (1975).

Salt Pickup Mechanisms

Soils in the Grand Valley were formed residually from Mancos Shale and from alluvial materials deposited by the Colorado and Gunnison Rivers. The alluvium covers thick beds of porous gravelly and cobbly sand that extend from the head (east end) of the valley to past Fruita. This gravel-cobble layer conducts water rapidly and a high water table occurs in the area near the river.

There is not yet agreement as to the precise source or sources of salt at the present time. Three basic mechanisms are considered: 1) irrigation drainage water which dissolves and transports salts from sub-surface sources; 2) irrigation waters which dissolve and transport surface salts; and 3) salts added by runoff water from rain and snowmelt. Prevailing opinion holds that over 90 percent of salt pickup in the study reach arises from the first category.

The ionic constituents and ion ratios of drainage, aquifer, and river water entering and leaving the Grand Valley were compared in an attempt to derive estimates of salt pickup. To calculate a salt pickup rate which is representative of mixed return flows, i.e., some combination of surface drainage and aquifer water, it is necessary to weight the relative concentrations by the appropriate magnitude of flow. Return flow from deep percolation and seepage water was assumed to comprise about 80 percent and water from surface drains about 20 percent. The resulting estimate of average salt pickup rate was 5.04 tons/ac ft, which is rounded to 5 tons in subsequent computations. This reflects a compromise among possible alternative estimates. A detailed discussion of the salt pickup mechanisms and procedures for estimating pickup rates is also contained in the Leathers-Franklin manuscript (Leathers and Franklin, 1975).

BEHAVIORAL ECONOMIC MODEL

Conventional theory of the firm and linear programming comprise the formal framework of the economic submodel and subsequent empirical analysis. The approach followed makes use of the "representative firm" concept (Day, 1963). An economic model of the irrigated agricultural industry, composed of representative farm types, was designed to approximate as closely as possible actual production levels and activity in the Grand Valley. Under alternative price and cropping assumptions, models of representative farms have proven useful in assessing production response and decision behavior relating to a broad range of policy issues (Kelso et al., 1973).

Data Base and Sampling Method

Actual production information collected from Grand Valley farmers during the summers of 1972 and 1973 was the principal source of data for this study. Personal interview participants were randomly selected from water user lists provided by the irrigation companies and associations which divert Colorado and Gunnison River water for agricultural use in the valley. Since these lists typically include numerous small users (one to three acres in size) as well as commercial farms, all users with less than a 40-acre water appropriation were excluded from the population of farmers surveyed. Subsequently, from a population of approximately 350 irrigated farms, 98 complete interviews were secured representing a sampling rate of about 28 percent.

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[1] The model is described in Leathers and Franklin (1975).

Table 5-1. Irrigation and soil moisture relationships for selected crops, a normal growing season, and traditional irrigation practices in the Grand Valley.

Item	Crop				
	Corn	Small Grains	Sugar Beets	Pasture	Alfalfa
Number of Irrigations	8	6	9	7	7
Number of Pre-irrigations	1	—	—	---	---
Cumulative ET (Inches)	26.5	20.9	31.6	30.12	32.16
Mean ET Per Irrigation[a]	3.35	3.45	3.48	4.30	4.59
Root Zone Storage Capacity	9.2	9.2	9.2	9.2	14.0
Soil Moisture Depletion[b] at Each Irrigation	38%	38%	38%	47%	33%
Irrigation Interval (Days)[c]					
Longest	42	27	34	31	25
Shortest	9	9	12	19	18
Length of Irrigation Set (Hours)					
First Two Irrigations	24	24	24	48	48
All Others	24	24	24	24	24

[a] Cumulative ET ÷ number of irrigations per season.

[b] Mean ET per irrigation ÷ root zone storage capacity.

[c] Number of days between irrigations where cumulative ET reduces the percent available soil moisture to the indicated levels (above).

Table 5-2. Water budget summary for traditional irrigation practices in the Grand Valley: annual water use and losses for selected crops.

Item	Crop				
	Corn	Small Grains	Sugar Beets	Pasture	Alfalfa
	Annual Ac Ft/AC				
Water Applied[a]	3.74	2.98	5.28	4.80	4.80
Root Zone Additions	2.94	2.40	3.27	3.06	3.06
Crop Consumptive Use	2.21	1.74	2.63	2.51	2.68
Deep Percolation	0.73	0.66	0.64	0.55	0.38
Field Tail Water	0.80	0.58	2.10	1.74	1.74
Farm Irrigation Efficiency[b]	59%	58%	50%	52%	56%
Leaching Fraction[c]	25%	28%	20%	18%	12%

[a] "Net" of on-farm delivery losses.

[b] Crop consumptive use ÷ water applied.

[c] Deep percolation ÷ root zone additions.

The interview schedule was designed to obtain information concerning the numbers and sizes of farms; land tenure, planning and management practices; resource inventories and production technology; crops and livestock grown, cropping patterns and cultural practices; prices paid and received; and related data specific to the study area. Detailed enterprise budgets were derived to estimate and compare expected costs and returns for representative farm practices. Emphasis was placed on the principal crops grown in the valley. Orchard and other specialty crop enterprises (about 15 percent of the total irrigated acreage) were excluded from the analysis since they are typically very diverse in production techniques, processing and tenure arrangements.

The Analytical Model

The linear programming model, which reflects aggregate (valley-wide) production response, was designed to simulate optimal farmer response to various nonstructural salinity control measures that could be implemented by farmers in the Grand Valley. Typical resource limitations faced by farmers, including land, water, limits on crop acreage among others, are used to constrain the model and add some realism to the policy implications derived from it. The analysis was directed to two aspects of on-farm controls dealing with the use efficiency of irrigation water: 1) the expected costs of reduced saline return flow as a result of modifying traditional crop rotation or cropping patterns; and 2) the costs incurred by farmers when the rate of irrigation water applied (deep percolation losses) was reduced by modifying traditional irrigation practices. Altering the rate of water applied is achieved simply by changing (a) the length of time water is allowed in contact with the soil, or (b) the size or number of siphon tubes per set for a given water head.

The direct costs of both options is estimated on the basis of the incremental reduction in net returns above production costs over a range of constraints on deep percolation losses. It could not conclusively be established that crop yields would be adversely affected by the more efficient irrigation practices proposed, so these direct costs do not include yield decrements.

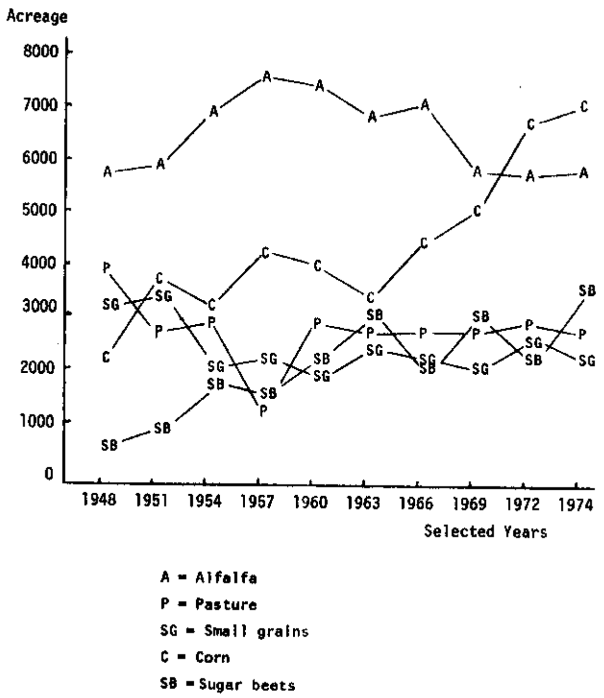
Production Possibilities

A moderately-long growing season (190 days) permits the production of a wide range of field crops, vegetables and forages in the Grand Valley. In terms of planted acreages, the most significant crops are corn, small grains (including wheat, feed and malting barley, and oats), sugar beets, permanent pasture, and alfalfa hay. The relative acreages of these crops have remained fairly stable in recent years as indicated in Figure 5-2. No attempt was made to analyze in detail the many kinds of livestock enterprises found in the valley or include them in the model with the crop enterprises listed above. Additionally, the model does not include orchard and specialty-type crops with small acreages.

Costs and Returns

Detailed unit budgets were developed for each principal crop to provide the necessary technical and revenue coefficients for the analysis. Costs of production were calculated from 1974 input prices, and included all variable, fixed and overhead costs directly chargeable to a particular crop enterprise on an annual per acre basis. Various fixed and overhead costs not directly chargeable to a crop were omitted.

Crop revenues were estimated by using average yields for the valley (1973 production year) and 5-year (1970-1974) average product prices. These average prices were thought to be more accurate for planning and evaluative purposes than using any particular set of prices since late 1972 when the general price level began to rise. Table 5-3 presents a summary of the estimated costs and returns for each production activity included in the model. A detailed explanation of the budgeting procedure and price indexing technique used in estimating these data is described elsewhere (Leathers, 1975).



SOURCE: Grand Valley Water Users Association project records (selected annual production reports), Bureau of Reclamation project office, Grand Junction, Colorado (1974b).

Figure 5-2. Harvested acreages of selected crops grown on Bureau of Reclamation project lands (Garfield Gravity Division) in the Grand Valley, 1948-1974.

Resource and Other Constraints

Land available for irrigated crop production in the valley has changed very little in recent years. Any future decline in the present irrigated area of approximately 57,000 acres would be primarily a consequence of suburban growth near Grand Junction and other smaller towns located within the valley. It has been estimated that as much as 20 percent of the irrigable land is idle (abandoned) due to high salinity and seepage problems resulting from poor drainage (Robinson, 1969). Renovation of the drainage system (currently a proposed control measure) could eventually increase the present irrigated acreage base by as much as 15 percent. This potential increase in the land resource was not accounted for in the model, nor was the possibility of developing new lands for irrigation. Further, since all orchard and specialty crop acreage was excluded from the analysis, available crop land was limited to the irrigated acreage of principal crops that prevailed in 1973 (about 50,000 acres).

Water availability has rarely been an important constraint on crop production in the Grand Valley. With a possible exception of peak consumptive use

Figure 5-3. Price and yield assumptions used in estimating Grand Valley crop production costs and returns.

Crop	Unit	Average Yield Per Acre	Unit Price	Forage Value of Crop Residue Per Acre	Total Gross Revenue Per Acre	Operating Costs Per Acre	Net Return Per Acre
Corn (Grain)	Bu.	115	$2.50	$11.00	$298.50	$160.89	$137.61
Small Grains:							
Malting Barley	Bu.	65	$3.00		$195.00	$114.20	$ 80.80
Milling Wheat	Bu.	70	$2.65		$185.50	$105.97	$ 79.53
Sugar Beets	Tons	21	$30	$6.00	$636.00	$318.75	$318.25
Permanent Pasture	7 Months Pasture Rent @ $15/mo./ac.				$105.00	$ 89.20	$ 15.80
Alfalfa Hay	Tons	4.5	$45	$9.00	$211.50	$118.98	$ 92.52

Source: Leathers, K. L. (1975) "The Economics of Managing Saline Irrigation Return Flows in the Upper Colorado River Basin: A Case Study of Grand Valley, Colorado," Ph.D. dissertation (in preparation), Department of Economics, Colorado State University, Fort Collins, Colorado.

periods during July and August when some farmers may experience water rationing in the Bureau of Reclamation project area, which includes about 45 percent of the valley acreage, there is normally a supply well in excess of irrigation and carriage requirements. The water constraint used in the model is approximately 5 ac ft per acre on an annual basis. Since ample water is available from the beginning of the irrigation season in April to the end in October, it was not particularly useful to delineate water supplies in a monthly or multiperiod format. Because of high groundwater salinity, pump water has a very limited potential for augmenting surface flows for agricultural or other consumptive uses should such a new demand arise in the future.

Acreage restrictions were placed on each crop in an attempt to maintain an aggregate (valley wide) cropping pattern reasonably close to the historical trend. Since relative acreages of forages, cash crops and feed grains grown over the past thirty years have remained reasonably stable (Figure 5-2), this perhaps indicates a degree of self-sufficiency or balance in the region's agriculture.

The cropping pattern in 1973 was chosen as the base year for setting the limits on allowable shifts in crop acreage. A minimum acreage base was established for feed grains and forages since these crops have been shown to generate lower net returns above production costs in relation to sugar beets (Table 5-3). Possible reductions in small grains and corn acreage was limited to not more than 25 percent of the 1973 base for those crops, and a similar minimum was set for alfalfa and pasture at 25 percent. For sugar beets, a maximum limit was used so as not to exceed the potential refining capacity of the only sugar processing plant in the immediate area—about 6,000 acres.

These limits on crop acreage, which allow some substantial shifting in crop mix to take place in response to constraints on salt pickup, still maintain a degree of realism with respect to "other factors" (besides profit and efficiency criteria) involved in farm decisions but that cannot be explicitly considered in the programming model. In a later phase of the analysis, these acreage limits were changed to approximately 50 percent of the 1973 base acreage to check the significance and sensitivity of the estimated costs.

Besides tractor and machine work, irrigation is perhaps the most time-consuming activity on crop farms in the Grand Valley. Many small operations—farms in the range of 40 to 120 acres in size—are managed by part-time owners. These farmers, who frequently maintain part-time or full-time (40 hours per week) employment off the farm, attempt to accomplish as much work as they can with their own labor after normal working hours and on weekends. Owing to the small size of most fields in the valley—10 to 15 acres is typical— and the high evapotranspiration demands during the mid-summer months which may require irrigating as frequently as every 10 days for some crops, it is apparent that this type of farmer would be reluctant to change his irrigation practices if such a change required more of his time or the additional expense of hired labor.

The traditional irrigation practice noted in Table 5-1 requires the least amount of labor as compared with other options. A shorter irrigation set time, e.g., reducing the standard practice of 24-hour sets to 12 hours for the purpose of reducing deep percolation losses, would undoubtedly be a more costly practice for some and an inconvenience for most farmers to adopt. A number of assumptions regarding present irrigation labor requirements were made to facilitate an estimate of the additional labor (and/or inconvenience) required to make the necessary modifications in early season irrigation set times. These assumptions, in the form of labor input coefficients for a given irrigation set under specified operations and conditions, are summarized in Table 5-4.

Basically, the procedure followed was first to specify a reasonable labor input requirement for each irrigation situation (i.e., for a particular crop or row spacing, siphon discharge rates per furrow, water supply at the farm headgate, and irrigation timing during the season). Labor input for a given irrigation was specified on the basis of two components: 1) setup time, which includes moving canvases or portable

Table 5-4. Assumptions used in estimating the additional labor cost to farmers for reducing deep percolation losses.

Item	Discharge Rate Per Furrow[a]		
	8 gpm		4 gpm
A. Labor Required Per Set:[b]			
	Hours		
Set Up Time	1.5		2.0
Monitor Time:			
First Two Irrigations (ea.)	3.0		4.0
Other Irrigations (ea.)	1.5		2.0
Total Labor Time:			
First Two Irrigations (ea.)	4.5		6.0
Other Irrigations (ea.)	3.0		4.0
B. Acres Irrigated Per Set:[c]			
	Acres		
Furrow Spacing:			
24 Inches	2.06		4.11
30 Inches	2.57		5.12
C. Hours of Labor Per Acre:[d]			
	Hours/Acre		
First Two Irrigations (ea.)			
24 Inch Spacing	2.18		1.46
30 Inch Spacing	1.75		1.17
Other Irrigations (ea.):			
24 Inch Spacing	1.46		0.97
30 Inch Spacing	1.17		0.78
D. Annual Irrigation Labor Cost by Crop:[e]			
	Present Practices	Modified Practices	Additional Cost
	$ Per Acre		
Corn	18.44	22.38	3.94
Small Grains	14.92	18.86	3.94
Sugar Beets	22.14	27.05	4.91
Perm. Pasture	16.68	20.62	3.94
Alfalfa	16.68	20.62	3.94

[a] Assumes water supplied at the farm headgate at a rate of 1 cfs per 40 acres with no on-farm conveyance loss.

[b] Assumed labor requirements.

[c] Number of acres capable of being irrigated with 1 cfs per 40 acres water supply.

[d] Labor requirements per set (part A) ÷ acres irrigated per set (part B).

[e] All cost estimates based on $2.25 per hour wage rate.

dams, starting the siphon tubes, and adjusting siphon flow, and 2) monitor time, which includes clearing clogged furrows, managing field tailwater, and periodic checks of the field. A further refinement was made to allow for variations due to seasonal conditions. The first two irrigations in the spring typically require more attention (monitor time) than those that follow primarily because of differences in soil characteristics and cultural practices. The assumed labor inputs reported earlier are not experimental but are thought to be reasonable and valid for the purposes at hand.

The additional cost of reducing the length of an irrigation set (reducing the amount of water applied and the soil intake opportunity time) for the first two irrigations of each crop was estimated with the use of and "inconvenience cost." This concept is illustrated with an example. Irrigation set times were reduced from 24 to 12 hours for corn, small grains and sugar beets and from 48 to 24 hours for permanent pasture and alfalfa. Under typical practices, if a field was irrigated in two 24-hour sets, the operator would now have to set up and monitor his water twice a day in 12-hour intervals rather than once a day as before. This inconvenience—the additional time required each day to take care of the second set—was placed in monetary terms by multiplying the labor time of the second set in the same day by a charge at twice the normal wage of $2.25 per hour. A similar (though weaker) supposition holds for changing alfalfa and pasture irrigation from two to one day sets. Hence, the procedure allows for increasing irrigation labor costs to farmers as a result of adopting a more efficient irrigation practice while the actual labor time on a per unit basis (the total irrigation labor input per acre per

year) remains the same. The annual costs of this modification is compared to present irrigation labor costs reported earlier.

The net additional costs for each crop were deducted from the revenue coefficients in Table 5-3, and in this manner reflect an implicit constraint on the model. By not taking into consideration the inconvenience of the modified irrigation practice, the cost of improved practices would be essentially the same as the cost of traditional practices. Therefore, the production processes are expanded from 5 to 10 activities reflecting the option of incurring an additional cost to reduce potential salt pickup for each crop.

The last constraint on the solution of the model was the allowable level of deep percolation associated with the various production activities and irrigation methods. In the first computer run, deep percolation was nonlimiting since it was desired to establish an initial solution providing information on aggregate net income, water utilization and salt pickup from which comparisons could be made. In subsequent runs, the aggregate level of deep percolation (hence salt pickup) derived in the initial solution was reduced until a level as low as 5 or 10 percent of the initial value was obtained. Thus, by parametric variation of deep percolation on a valley-wide scale, the needed information to evaluate changing cropping patterns and irrigation methods was developed in terms of the direct costs of achieving a broad range of salt removal reflected in reduced net crop income.

The basic programming tableau summarizing the above discussion on technical and revenue coefficients, production processes and resource levels is presented in Table 5-5.

DISCUSSION OF RESULTS

Some important results regarding the possible consequences of implementing nonstructural salinity controls, emphasizing the modification of present irrigation and crop production practices, are reported in Table 5-6. The initial solution in which salt pickup is nonlimiting in the model is the first row in the table, and depicts the benchmark condition with respect to the salt load carried in irrigation return flows attributable to on-farm irrigation practices, aggregate net crop income, and the irrigation water requirement at this level of crop production. The initial level of salt pickup is based on the estimated rate of five tons TDS per acre foot of deep percolating irrigation water. Aggregate net crop income and water use are optimal for the Grand Valley as a whole, subject to the constraints placed on land and water resources and potential change of the valley cropping pattern.

Several inferences can be drawn from the linear programming results. First, it is readily apparent, given the assumptions of our model, that nonstructural controls applied on farms can bring about substantial reductions in salt pickup. The optimal (least cost) response of farmers to limits imposed on salt pickup via deep percolation would be first to adopt the more efficient irrigation practice, namely to experience the inconvenience of having to irrigate twice in 24 hours rather than once thus reducing deep percolation losses. This additional cost amounts to about $1.40 per ton of salt removed from an initial level of 146,510 tons down to about 100,000 tons. Beyond this level costs increase slightly until a point is reached where approximately 81 percent of the initial salt load is removed at an incremental cost of $2.54 per ton.

Second, the alternative strategy of substituting crops, i.e., crops which contribute less to deep percolation for those which are more of a problem, becomes an efficient solution only following the complete adoption of the more efficient irrigation process for all of the crop activities. It was noted in Table 5-5 that corn contributes more to deep percolation than alfalfa: .16 ac ft and .02 ac ft, respectively. If substitution takes place (alfalfa for corn), the net change in income per acre, $89 minus $134 or -$45, divided by the net exchange of salt pickup (.16 minus .02 acre feet of deep percolation times five tons per acre foot), or .7 tons, gives a cost of $64.29 per ton. Although this is comparatively high, substituting lower value crops for corn would generate even higher costs. Conversely, substituting sugar beets for corn would yield negative direct costs of removing some salts. Institutional and market constraints on the expansion of crop production (especially sugar beets) however, limits this type of crop trade off to a minimum in this analysis.

Possible reduction of salt loading attributable to changing the cropping mix begins at the level of 27,551 tons of salt discharge and terminates at approximately 12,500 tons, or about 10 percent of the initial 146,510 tons. The incremental costs range upward from $64.29 per ton, substantially higher than the costs associated with modified irrigation practices.

Third, recent estimates of the costs of salt removal by canal lining in the Grand Valley to avoid pickup via seepage losses have been reported to range from $14 to $30 per ton (Utah State University, 1975). Other structural options, including drainage systems renovation, will likely top $30 per ton (Skogerboe et al., 1974). Direct benefits to control programs in the Grand Valley, using one recent estimate of downstream damages, appear to be about $20 per ton of salt removed at the margin downstream. If this preliminary estimate turns out to be supported by further study of the problem, then nonstructural control measures such as improved irrigation efficiency are feasible alternatives, from an economic efficiency standpoint, while the more costly structural measures posed for possible implementation as soon as 1977 appear to be, at best, marginal. The Bureau of Reclamation's proposed canal lining and drainage program for the Grand Valley may cost in excesses of $60 million (1973 dollars), or over $1,000 per irrigated acre.

Fourth, crop substitutions occur first with alfalfa replacing corn followed by sugar beets (two crops with

Table 5-5. L.P. tableau for crop production model representing Grand Valley, Colorado.

Item	Unit	Crop Production Activities and Irrigation Processes (A = Present Practices, B = Modified Practices)										Constraint Levels	
		Corn		Small Grains		Sugar Beets		Perm. Pasture		Alfalfa			
		A	B	A	B	A	B	A	B	A	B	Maximum	Minimum
Net Revenue	$/Acre	138.00	134.00	81.00	77.00	318.00	313.00	16.00	12.00	93.00	89.00		
Irrigable Land	Acres	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	= 49,757	
Crop Acreage	Acres	1.00	1.00										
Corn												≤ 17,200	
Small Grains	Acres			1.00	1.00							≤ 8,000	4,800
Sugar Beets	Acres					1.00	1.00					≤ 6,000	
Perm. Pasture	Acres							1.00	1.00			≤ 15,900	9,500
Alfalfa	Acres									1.00	1.00	≤ 16,700	
Irrigation Water	AF/AC	3.74	3.02	2.98	2.31	5.28	4.32	4.80	3.36	4.80	3.36	≤250,000	
Deep Percolation	AF/AC	0.73	0.16	0.66	0.06	0.64	0.07	0.55	0.19	0.38	0.02	≥ 0	

Table 5-6. Consequences of implementing on-farm, nonstructural salinity controls in the Grand Valley: selected summary of results of the linear programming model.

Salt Discharge in Irrigation Return Flows	Total Net Crop Income	Irrigation Water Requirement	Incremental Direct Cost of Salt Removal	Cropping Pattern				
				Corn	Small Grains	Sugar Beets	Pasture	Alfalfa
-----Tons-----	-----$-----	---Acre Feet---	-$ Per Ton-	---Acres---				
146,510	5,962,301	214,745	1.40	17,200	4,800	6,000	9,500	12,257
125,000	5,932,107	209,311	1.40	17,200	4,800	6,000	9,500	12,257
100,000	5,897,019	202,995	1.53	17,200	4,800	6,000	9,500	12,257
75,000	5,858,839	196,177	2.07	17,200	4,800	6,000	9,500	12,257
50,000	5,807,160	180,015	2.22	17,200	4,800	6,000	9,500	12,257
37,500	5,779,383	170,015	8.55	17,200	4,800	6,000	9,500	12,257
25,000	5,593,299	163,294	64.29	13,556	4,800	6,000	9,500	15,901
20,000	5,271,871	165,723	149.24	6,413	4,800	6,000	9,500	23,044
15,000	4,525,686	165,942	171.19	–0–	4,800	3,957	9,500	31,500
12,500	4,097,702	162,144		–0–	4,800	–0–	7,723	37,234

no minimum acreage restrictions) and lastly by permanent pasture. It is unlikely that changes in the crop mix would go this far in the Grand Valley, however, especially with alfalfa production increasing to a level in excess of 37,000 acres. Rather it is more likely that crop substitutions would terminate at a level of higher salt discharge than indicated in Table 5-6 (possibly 20,000 tons or more). Nonstructural salinity controls could result in significant savings in irrigation water diversion, the value of which might partially offset program costs if alternative, nonpolluting uses for the remaining water materializes in the future.

LIMITATIONS

It is important to emphasize the tentative and problematic nature of the reported findings. The noneconomic considerations, both the hydrological and the political/administrative are not firmly grounded, and additional time and research resources are necessary to resolve these uncertainties.

Several specific limitations should be recognized in interpreting the results of this analysis. First, neither the amount of drainage water associated with specified irrigation practices nor the rate of salt pickup per unit of drainage water are well established. In fact, considerable disagreement is found on these points among hydrology and soils specialists. A better understanding of the relative salt contribution of field percolation losses versus seepage from conveyance systems is also necessary before any definitive assessment of nonstructural controls can be achieved. Similarly, the relative contribution of the various crops needs to be established more precisely before the crop substitution alternative is rejected.

Second, it may not be possible to increase irrigated efficiency to the degree assumed without some sacrifice in crop yield. A small decrement in yield can have a significant impact on net returns to farmers. Similarly, unstable farm prices could make reliable estimation of program costs and benefits still more uncertain.

Third, indirect costs may be substantial depending upon the type of nonstructural control in question.

Finally, the regulatory and social costs of imposing water quality standards have not been dealt with in this sort of situation where the effluent of individual irrigators is not identifiable. Present water distribution policies in the area and Colorado water law do not provide any incentive for reducing return flows, and relatively drastic penalties might be required to implement nonstructural measures. The technical and economic feasibility of the approach has been analyzed, but the political-administrative procedures for implementation remain to be specified and evaluated. The structural measures may be expensive, but they would be relatively straight-forward to implement.

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APPENDIX 6

ECONOMIC IMPACTS OF SELECTED SALINITY CONTROL MEASURES IN THE UPPER COLORADO BASIN

Modeling the Soil-Water-Plant Relationships in Irrigation Return Flows in the Colorado River Basin in Utah

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INTRODUCTION

This study is concerned with modeling of one of the possibilities for ameliorating the salinity problem of downstream Colorado River waters. The study deals with the physical nature and the cost effectiveness of an irrigation management approach to reducing salinity in the river.

Irrigation return flow constitutes a large portion of the water in streams and rivers of the western United States. In some river basins, such as the Colorado River Basin, some water may be "used" for irrigation several times before entering the ocean. Since this "use" involves the evapotranspiration process which accounts for the major loss of water by crops, there is an inevitable buildup of salt concentration in irrigation return flows. This is seen in the salinity of the Colorado River which ranges from less than 50 mg/l (total dissolved solids) in the Upper Basin mountains to about 850 mg/l at the Imperial Dam in lower California. While irrigation return flow is involved in only part of this salinity concentration, it has been suggested to be one of the major areas capable of management. Little research work has been done on management of irrigation water to influence downstream salinity and, therefore, relatively little is known about the manifold effects of such management. This study is an attempt to evaluate some of these effects. Specifically, the study involves 1) the development of a physical model to predict the response of soil, water, and crop factors to irrigation, and 2) the development of an economic model which, using the physical model for basic data, assesses the cost effectiveness of irrigation management as related to return flow salinity.

Economic Background of the Study

The salinity problem in river basins, especially in large ones like the Colorado River Basin, is an interesting and difficult challenge to policy makers. The well-being of some users of the river conflicts with the well-being of others in river use programs that have been or may be undertaken. An ideal competitive economy would yield an allocation of resources such that no alternative pattern of resource use would make anyone better off without making someone worse off. This ideal situation does not exist in the matter of allocation of water and the quality aspects of water for at least two reasons. First, prices do not correctly reflect the social value of resources and commodities. Misallocations of resources occur. The individual decision-maker has no incentive (except from his conscience or good will) for taking all costs or benefits into account in making a resource allocation decision. Second, producers of "public goods," such as cleaner water, are unable to collect revenues from beneficiaries, since users cannot be excluded for nonpayment of the price. Each user may expect to reap the benefits whether or not he pays the cost. The private market is, therefore, unable to supply optimal amounts of goods with collective consumption characteristics. The salinity problem in the Colorado River exhibits both of these aspects of market failure. More than half of the salinity concentration in the river is due to natural causes, but if there was no man-made effects, the concentrations would probably not be sufficient to trouble downstream users.

General Procedure

The study was done in two phases. The first phase involved the development of the physical model to be used to supply basic data. The second phase involved the development of an economic model to analyze cost effectiveness. While these two phases were carried out somewhat independently at the beginning of the study, it soon became apparent that much interchange was necessary. The physical model originally produced much information not needed for the economic model and did not supply some basic data needed. Thus, considerable modification of the physical model was necessary. Similarly, the economic model originally devised assumed availability of basic physical data that could not be obtained. Thus, the economic model had to be adjusted to use the obtainable basic data.

The details of the two models are discussed separately for purposes of organization. This will allow the reader to consider only one of the models according to his interest; however, we have found much to be gained by interchange of ideas and methods necessary to develop answers to a particular problem and would advise considering both models together.

THE PHYSICAL MODEL

Recent field work has shown that many situations are much more complicated than can be handled by present models of plant response to salinity. The field situation discussed in this paper, for example, was studied by Gupta (1972) and King and Hanks (1973). They found the models used previously gave good prediction for the water portion but poor prediction for the salt portion. Where water of different salt concentrations had been added as irrigation water, there was a very small effect on the salt concentration of the soil solution. It appeared that the soil acted like a large buffer that was influenced only slowly by relatively small salt additions or removals through irrigation and drainage. It became evident that the inclusion of complicated reactions used by Dutt et al. (1972) were of little practical use because they were not completely accurate and they required considerable computer time. Consequently, a simplified salt flow model was devised to simulate the long time effects of salt buildup by varying the initial conditions.

The model is based on the work of Nimah and Hanks (1972a, b) which is concerned with the soil water flow in response to varying irrigation management inputs. The general equation for water flow is given as equation (6-1):

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K \frac{\partial H}{\partial z}\right) + a(z) \qquad \text{(6-1)}$$

in which θ is the water content, H is the matric potential, K is the hydraulic conductivity, t is time and z is depth, and a(z) is the root extraction term. The root extraction term is somewhat more complicated because it has plant and soil characteristics in it as the following equation shows:

$$a(z) = \frac{[H_{root} + 1.05z - h(z,t) - s(z,t)] \cdot RDF(z) \cdot K}{\Delta z \cdot \Delta x} \qquad \text{(6-2)}$$

in which H_{root} is the water potential at the surface of the root which is modified to have a different water potential due to gravity and a small friction resistance term of 0.05, h(z,t) is the soil solution matric potential, s(z,t) is the osmotic potential, and RDF(z) is a root density function. Δx is the distance between the plant root and the point in the soil where K is realized (assumed equal to 1.0).

Depending on the climate and the plant and soil conditions, water may be extracted from the soil without any limitations so that the transpiration would be equal to that potential transpiration. However, if the osmotic concentration or the matric potential is sufficiently low, keeping in mind the negative sign, the soil water system will not be able to supply sufficient water to the plant to maintain the transpiration at potential transpiration and then the transpiration falls off. These equations have been discussed in considerably more detail in Nimah and Hanks (1973a) and Childs and Hanks (1975).

The salt flow portion of the model is given as follows:

$$\frac{\partial (C\theta)}{\partial t} = \frac{\partial}{\partial z}\left(D \frac{\partial C}{\partial z}\right) - \frac{d(Cq)}{dz} \qquad \text{(6-3)}$$

in which C is the salt concentration, D is the combined diffusion and dispersion coefficients, and q is the mass flux of water.

Salt is assumed to move within the soil profile according to mass flow of water and subject to the diffusion restrictions. No consideration in taken for source or sink term where precipitation or solution of salts could come out of the solid phase of the soil. A numerical approximation of both the water flow and moisture flow parts of the model have been written as described by Nimah and Hanks (1973) and Childs and Hanks (1975), as well as Hanks et al. (1974). To determine the influence of the salinity on crop yield, another component of the model has to be added. This is done by using the assumptions described by Hanks (1974) and Childs and Hanks (1975) where the relative yield of a crop is related to the relative transpiration. The validity of this assumption for saline conditions is substantiated by the data of Lunin and Gallatin (1965), Bingham and Garber (1970) and Shelhavet and Bernstein (1968). A linear relationship between relative transpiration and relative yield is indicated. Relative yield is here restricted to the dry matter yield and does not include the yield of grain which might be considerably more complicated.

The estimation of a relative yield is necessary to interface with the economic model discussed later. The variations that are sensed by the model are the result of various initial conditions or boundary conditions that change with time at the top and bottom of the soil. The soil conditions also influence the results as well as the crop conditions because soil properties influence water uptake and water infiltration in the soil. The plant grown also influences root uptake as well as the boundary conditions of the surface.

As described in detail by Childs and Hanks (1975), it is necessary to determine what the potential evapotranspiration or the potential infiltration rate for the soil would be for any kind of management system that is imposed. This is done by either measurement of the potential evapotranspiration such as described by Nimah and Hanks (1973b) or by using some method such as described by Jensen (1973) to compute potential evapotranspiration. This model does not require an estimation of the crop coefficient but requires that the potential evapotranspiration be broken into potential evaporation and potential transpiration as described by Childs and Hanks (1975).

The basic input data required for the model are given in detail by Nimah and Hanks (1973) and Childs and Hanks (1975), but are summarized as follows: 1) Hydraulic conductivity, water content and matric potential water content data covering the range of water content to be encountered during the period of interest (soil property); 2) air dry soil water contents (soil property); 3) root water potential below which the root will not go where presumably the plant wilts and the actual transpiration will be less than the potential transpiration (plant property); 4) root distribution function for the period of study (plant property); 5) water content and soil solution concentration data at the beginning as a function of depth (initial condition); 6) potential transpiration, potential evapotranspiration rate and potential irrigation or rainfall as a function of time for the whole period of the run (boundary condition) [potential evapotranspiration assumed equal to that from a free water surface could be calculated by the use of the Penman or some other equation as described by Jensen (1966)]; 7) osmotic potential of irrigation water (boundary condition); and 8) presence or absence of a water table at the bottom of the soil profile (boundary condition). The root density function may be changed as a function of time and depth as the root system grows as described by Childs and Hanks (1975).

The output data can be selected from among many variables that are computed within the model from a list of the following: 1) Cumulative evapotranspiration, transpiration and evaporation as a function of time; 2) volumetric soil water content and soil pressure head as a function of time and depth; 3) cumulative water flow upward or downward through any boundary within the profile or at the surface; and 4) the value of H_{root} as a function of time, or many other factors. The main item of interest in this computation is the relative transpiration which is the transpiration computed from the particular management system compared to what the potential transpiration would have been at the same condition if soil water were not limiting.

THE ECONOMIC MODEL

The economic model is designed to suggest ways to minimize the income losses imposed by restraints on salt outflow due to irrigation on the farm. It is based on the physical model and a set of cost and return data for the farm. The beginning point is to assume that any amount of salt can be allowed to leave the farm. The model is set to maximize income under this assumption which has been the policy in the past. The model is then successively constrained to allow smaller and smaller amounts of salt to leave the farm. Of primary concern is the income reduction which accompanies this constraint on resource use. Also of concern are the crops grown, irrigation management practices, and quantity of water applied. As the salt outflow and incomes incrementally change, the model develops as a by-product the marginal relationship between salt outflow and income. This value can then be compared with alternative ways of reducing salinity in the river or the damages that accrue to downstream users. The implementation of the economic model is in the form of the linear programming model of economic behavior.

The Linear Programming Model of Salt Outflow

The linear programming model used in this study is a profit maximizing model which has the algebraic form of:

$$\begin{aligned} &\text{maximize} && Z = CX \\ &\text{subject to} && AX \geqslant B \\ & && X \geqslant 0 \end{aligned}$$

in which:

Z = net revenue (or profit)
C = the row vector of net revenue per unit of activity
X = the set of activities or production processes
A = matrix of technical coefficients (or production relationships)
B = the column vector of constraints of resource availability

Linear programming and the economic concepts utilized are discussed by Leftwich (1970). The application to the present study is as follows: 1) Select the combination of crops produced and management practices subject to the constraints in certain fixed inputs such as land. The selection is based on the operating costs and the relative prices of the crops. 2) Many of the inputs are not fixed, thus the optimal combination of these variable inputs is selected for the production of the crops produced based on their productivity and the cost of inputs. 3) The level of output per acre is selected based on producing up to but no more than the level where the value of the incremental unit of production equals the cost of the incremental inputs unit of input.

In this study, the various components of the model are defined and constructed as follows:

Processes and Activities

Production activities (the x_i) have been developed which are most relevant. These are activities like growing corn silage, or oats or alfalfa hay. Each of these can also be treated in alternative ways such as with different quantities of irrigation applied by sprinkling or flooding. All combinations of these alternative actions were used in this study except that flood irrigation was not used in the lowest three levels of water application. It would be impossible to distribute the small amounts of water uniformly over the season by flooding.

Resource Constraints

Limits on resource availability (the b_i) used in this study include the quantities of each of three land classes based on the beginning salinity levels of the soil profile. It was assumed that the farmer had 10 acres with each of three soil salinity characteristics. Unlimited salt outflow was allowed in the drainage water (which level was subsequently reduced to determine the profitability to the farm operator of letting salt flow into the drains and streams). There were also constraints to force growing of crops in rotation such as to provide for nurse crops for new seedings of alfalfa, and limits on corn production for disease control, and diversity of crops according to farmer preference.

Yields and Prices

Net profitability for each unit of production was based on approximately current prices for products and the costs of various farming supplies and operations. Yields were estimated using the 1971 data for the farm as a base with the relative yields predicted in the physical model to give specific values for the rates of water applied as influenced by the initial salt concentrations shown in Tables 6-10 and 6-11. The profit function is based on the price of alfalfa at \$45/ton, corn silage at \$13/ton, and oats at \$1.60/bushel. These prices represent approximately the current prices but are adjusted somewhat to a normal long run relationship to each other.

SITUATIONS STUDIED

There were several situations studied in terms of water management. The data for Vernal, Utah, 1971, as described by Nimah and Hanks (1973b) were taken for the initial conditions and water was applied in different amounts but at the same frequency as given in the 1971 data. The irrigation water quality which was used throughout was 6.35 meq/liter, which was equivalent to the present conditions at the Vernal, Utah, farm.

To simulate the effects of soil salinity storage within the root profile, three different levels of soil salinity were studied—20 meq/l uniform throughout, which is approximately the condition on most of the farm at present, 50 meq/l uniform throughout and 200 meq/l uniform throughout.

Because data were collected from various sources for the three crops that were studied on the farm, the root distribution functions were arbitrarily chosen as shown in Table 6-1 for the three crops studied. The corn and oats were modeled as annual crops with different values of crop cover as a function of time during the year. This had an influence on the potential evapotranspiration distribution as described by Childs and Hanks (1975).

Table 6-1. Relative proportion of roots at different depths, increments at maturation assumed for the calculations.

Depth	Corn	Alfalfa	Oats
2.5 to 10.5 cm.	0.09	0.14	0.18
10.5 to 25.5	0.20	0.30	0.40
25.5 to 52.5	0.34	0.33	0.42
52.5 to 91.5	0.25	0.23	0
92.5 to 140.0	0.12	0	0
140.0 to 235.0	0	0	0

Two different irrigation systems were studied. The first was a solid set sprinkler system with a coefficient of uniformity of .88 which is approximately the same as now in place on the experimental farm being studied. This was compared to a poor gravity system which was on the farm before the sprinkler system was applied. The coefficient of uniformity of the gravity system was 0.42 which is a poor system but is useful for comparison of the effect of a range of application uniformities.

RESULTS

The Physical Relationships

The results of modeling a variation in the water added and initial salt concentration on various soil and water properties for corn are shown in Table 6-2. The data on T/T_p are of primary interest because they are assumed to correspond to relative yield. The data of Table 6-2 show that T/T_p increases as the irrigation applied is increased up to about 50 cm after which the ratio was 1.0 for all initial salt concentrations. The ratio T/T_p was smaller, however, where irrigation was limited for the higher initial salt concentrations. There was relatively little difference among the values for T/T_p when the initial salt concentrations were 20 or 50 meq/l, indicating that yield differences were due to water influences only. Note that where the irrigation and rain was less than about 20 cm, there was an upward flow. The amount of flow was limited by soil water transmission and plant root extraction. In cases where the initial salt concentration was 200 meq/l, upward flow was about 2.5 cm less than for the lower initial salt concentrations. However, drainage (downward flow) was influenced very little by initial salt concentrations.

One feature of the data shown in Table 6-2 that may be somewhat unique is the large influence of water movement up from the water table (at a depth of 235 cm). The soil properties at the Vernal farm seem to be especially conducive to high water flow in both directions. Other situations with other soils would probably not result in as much upward flow.

The data shown in Table 6-2 are only a small part of the data collected in attaining these summary values. Each line represents one season where data have been computed at several depth increments and at no greater than 2- to 3-hour increments. Thus, data

Table 6-2. Comparison of irrigation water applied and initial salt concentration on relative transpiration of corn (T/T_p), total water used, drainage, salt flow to the groundwater, and average final salt concentration.

Irrig. and Rain cm	ET cm	T	T/T_p	Drainage cm	Salt Flow to Groundwater meq	Initial Salt Concentration meq/l	Final Salt Concentration Average meq/l
5.6	40.3	35.3	0.81	-14.2	- 284	20	62
5.6	38.6	33.5	0.77	-14.2	- 710	50	127
5.6	26.2	20.6	0.48	-11.6	-2320	200	305
10.3	43.9	36.6	0.89	-14.1	- 282	20	60
10.3	42.1	35.1	0.86	-14.0	- 700	50	120
10.3	30.1	22.3	0.55	-11.4	-2280	200	296
15.0	47.7	38.6	0.97	-14.0	- 280	20	56
15.0	46.3	37.2	0.93	-13.9	- 695	50	116
15.0	34.6	25.1	0.64	-11.4	-2280	200	296
22.0	49.0	38.5	0.98	-13.6	- 272	20	40
22.0	49.2	38.7	0.98	-13.5	- 675	50	95
22.0	41.2	30.9	0.78	-11.3	-2260	200	291
40.8	50.4	37.6	0.99	- 8.7	- 174	20	27
40.8	48.3	35.9	0.98	- 7.1	- 355	50	604
40.8	48.1	35.8	0.97	- 6.2	-1240	200	227
56.4	51.9	37.3	1.00	+ 0.91	19	20	23
56.4	52.2	37.3	1.00	+ 1.0	49	50	50
56.4	56.7	37.3	1.00	+ 1.1	214	200	189
66.7	51.7	37.3	1.00	+10.5	210	20	20
66.7	51.6	37.3	1.00	+10.6	532	50	42
66.7	51.6	37.3	1.00	+10.8	2160	200	153

Note: Each line represents a computation with the same irrigation frequency but different amounts of water applied for climatic conditions of 1971 at Vernal, Utah. A negative sign indicates upward flow of salt and water. Rain was 5.6 cm.

within the season are also available. Figure 6-1 shows a comparison of cumulative evapotranspiration as influenced by initial salt concentration for two different irrigation levels.

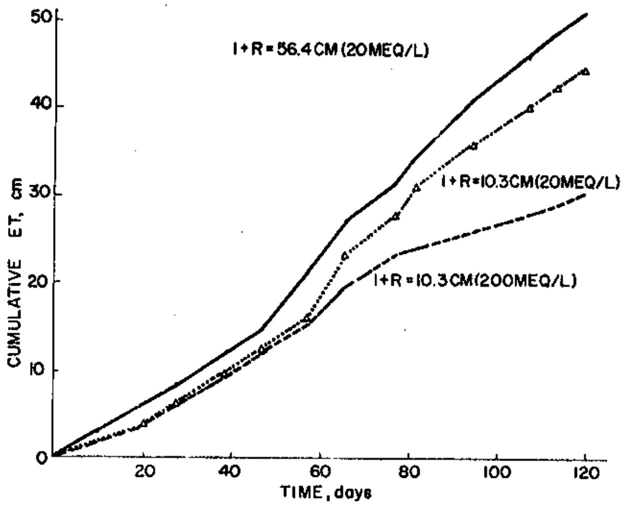

Figure 6-1. Cumulative evapotranspiration as a function of time for two levels of irrigation, I, and rain, R, at two different initial salt concentrations.

Table 6-3 shows the computations of T/T_p made for alfalfa. The data show more decrease of T/T_p for low irrigation rates than was shown for corn. This was due to a longer season for active water use by alfalfa and for a much greater proportion of transpiration to evapotranspiration for alfalfa than for corn—especially during early season when corn was just planted. Upward water flow was less for alfalfa than corn, probably due to alfalfa's assumed shallow root distribution. This result is probably not representative of other situations where alfalfa normally roots deeper than corn. The alfalfa root distribution was measured at the site where there is upward water movement, but the corn root depths were measured at another location. Like corn, the alfalfa data show little difference between the 20 and 50 meq/l initial salt concentrations but fairly large differences with 200 meq/l initial salt concentrations. Thus, the T/T_p depression at 20 meq/l initial salt concentration is due to inadequate irrigation. The differences in T/T_p at any one irrigation level, for initial salt concentrations between 20 and 200 meq/l, were due strictly to a salt effect—where 15 cm of irrigation and rain was applied, T/T_p was 0.68 because water was insufficient to maintain transpiration. A further reduction of T/T_p from 0.68 to 0.49 resulted from the high initial salt concentration.

Table 6-4 shows the computed data for oats when irrigation water was managed in a manner similar to

Table 6-3. ***Comparison of irrigation water applied and initial salt concentration of relative transpiration of alfalfa, T/T_p, evapotranspiration, ET, drainage, salt flow to the groundwater, and average final salt concentration.***

Irrig. and Rain cm	ET cm	T	T/T_p	Drainage cm	Salt Flow to Groundwater meq	Initial Salt Concentration meq/l	Final Salt Concentration Average meq/l
5.6	29.5	25.8	0.52	-9.7	- 195	20	43
5.6	28.2	26.6	0.50	-9.4	- 472	50	97
5.6	19.8	16.0	0.33	-7.8	-1561	200	277
10.3	33.2	29.2	0.61	-9.5	- 189	20	42
10.3	32.1	28.1	0.58	-9.3	- 466	50	94
10.3	24.2	20.0	0.42	-7.7	-1860	200	269
15.0	37.6	32.8	0.68	-9.3	- 154	20	43
15.0	36.5	31.8	0.66	-9.2	- 458	50	94
15.0	28.8	23.7	0.49	-7.6	-1840	200	268
22.0	43.9	38.6	0.80	-9.4	- 148	20	41
22.0	42.9	37.6	0.78	-9.2	- 461	50	92
22.0	35.3	30.1	0.63	-7.5	-1840	200	263
40.8	51.7	46.7	1.00	-7.4	- 148	20	30
40.8	51.3	46.3	1.00	-6.7	- 370	50	64
40.8	48.1	43.2	0.93	-5.6	-1340	200	228
56.4	53.4	48.2	1.00	0.0	0	20	24
56.4	53.9	47.9	1.00	0.4	22	50	52
56.4	53.9	47.9	1.00	0.3	61	200	195
66.7	53.5	48.3	1.00	8.8	178	20	22
66.7	53.1	48.3	1.00	9.3	467	50	44
66.7	53.2	48.3	1.00	9.4	1882	200	158

Note: Each line represents a computation with the same irrigation frequency but different amounts of water applied for climatic conditions of 1971 at Vernal, Utah. A negative sign indicates upward flow of salt and water. Rain was 5.6 cm.

Table 6-4. ***Comparison of irrigation water applied and initial salt concentration on relative transpiration, for oats, T/T_p, evapotranspiration, ET, drainage, salt flow to the groundwater, and average final salt concentration.***

Irrig. and Rain cm	ET cm	T	T/T_p	Upward Flow cm	Salt Flow to Groundwater meq	Initial Salt Concentration meq/l	Final Salt Concentration Average meq/l
5.6	18.3	13.3	0.29	-3.8	- 74	20	33
5.6	18.0	12.9	0.28	-3.8	-191	50	78
5.6	14.3	8.2	0.18	-3.6	-718	200	248
10.3	22.7	16.4	0.37	-3.8	- 76	20	33
10.3	22.2	16.1	0.36	-3.8	-190	50	76
10.3	18.4	10.2	0.24	-3.5	-700	200	242
15.0	27.1	20.2	0.46	-3.8	- 76	20	33
15.0	26.7	19.4	0.44	-3.8	-189	50	76
15.0	22.9	13.3	0.32	-3.5	-700	200	242
22.0	33.8	25.6	0.59	-3.8	- 76	20	33
22.0	33.4	25.3	0.58	-3.8	-190	50	76
22.0	29.5	19.3	0.46	-3.3	-660	200	240
40.8	46.0	35.2	0.89	-2.5	- 50	20	26
40.8	45.7	35.1	0.88	-2.4	-120	50	58
40.8	42.3	31.5	0.80	-1.2	-240	200	208
56.4	53.6	38.5	0.97	+1.3	26	20	24
56.4	53.4	38.8	0.98	+1.3	66	50	52
56.4	51.4	37.0	0.93	+2.5	490	200	185
66.7	52.5	38.6	0.99	+10.0	198	20	20
66.7	52.5	38.6	0.99	+10.0	495	50	43
66.7	52.5	38.6	0.99	+9.9	1975	200	157

Note: Each line represents a computation with the same irrigation frequency but different amounts of water applied for climatic conditions of 1971 at Vernal, Utah. A negative sign indicates upward flow of salt and water. Rain was 5.6 cm.

corn and alfalfa. The values of T/T_p were smaller for oats for a given irrigation regime than for corn or alfalfa. This was due mainly to a more shallow root depth, but was also partly due to a difference in the relation of T_p to ET_p. Because of the shallow root zone, upward flow was less than 4 cm. This caused the ratio, T/T_p, to be less than 0.9 (for 20 meq/l initial salt concentration) when irrigation and rain was less than about 52 cm. As was the case for alfalfa and corn, the T/T_p results with 50 meq/l initial salt concentration were only slightly different than for 20 meq/l, whereas the changes in T/T_p from 50 meq/l to 200 meq/l were considerably larger.

There is a feature of the computation that is especially noticeable in Table 6-2 for corn. The model allows for the possibility that, if evaporation is less than potential evaporation, the difference, E_p - E, can be used in transpiration. Thus, potential transpiration is not a constant in Table 6-2 but increases as the irrigation and rain applied decreases. For a rain of 5.6 cm, T_p for corn was 40.3 and for irrigation and rain of 56.4 cm, T_p was 37.3 cm. Hanks et al. (1971) have demonstrated that this energy "trading" occurs, but it may be that the model computation overcorrects for it.

Figure 6-2 shows the salt concentration profiles for corn at the end of the season compared to the beginning for three different levels of water application. Where irrigation was insufficient to cause drainage, there was a higher concentration of salt throughout the profile at the end of the season. There was a pronounced peak in salt concentration just below the root zone, especially for the low water levels.

Figure 6-2 also shows the salt concentration profiles at the end of the year for oats. These concentrations are higher in the profile than those for corn because a more shallow root distribution for oats was assumed. There was relatively little water available for transpiration and the salt peak was lower with 5.6 cm of rain than when 22 cm of irrigation and rain provided for more transpiration and thus more concentration of salt. Where sufficient water for some leaching was available, the salt concentration in the profile was essentially constant.

Figure 6-3 shows a 10-year computation during which irrigation and rain were about one-half ET. The data indicate no decrease in the T/T_p ratio until the 7th year after which it fell rapidly, leveling off at the 10th year. Figure 6-3 shows the average salt concentration building up to about 260 meq/l at the 10th year. When T/T_p decreases, the transpiration also decreases. After the 10th year of cropping, ET had decreased by 15 cm which was only 9 cm above the water added. The difference between the water added and ET came from soil water storage and flow upward from the water table. Note that the particular results computed for a simulated run of years, shown in Figure 6-3, are highly dependent on the particular situation. If a crop with more shallow roots had been used, an entirely different situation would have resulted.

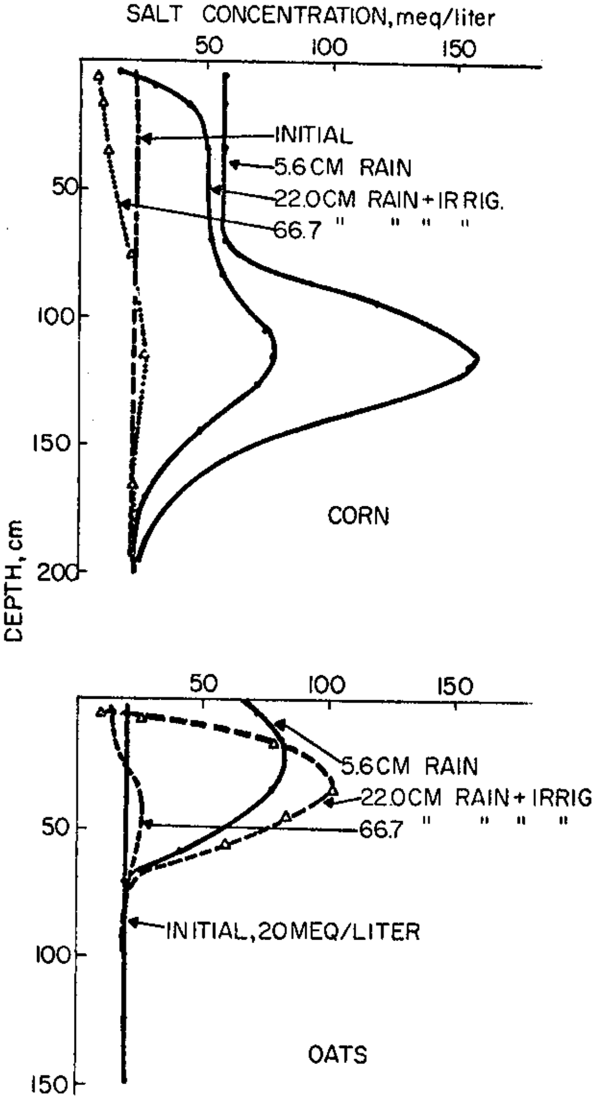

Figure 6-2. Salt concentration as a function of depth, irrigation and rain at the end of one season. Corn was assumed to have deep root distribution and oats were assumed to have shallow root distribution.

One of the purposes of the computation shown in Figure 6-3 was to see how these results compared with the data of Table 6-2 where different initial salt concentrations were used to simulate salt buildup. For the same irrigation schedule, the data of Table 6-2 indicate a T/T_p ratio of 0.90 for an initial salt concentration of 200 meq/l and ending up with an average concentration of 296 meq/l. Thus, using a uniform salt concentration profile as the initial condition gives the same result as using the profile existing at the end of the previous crop years. In fact, the uniform profile is probably more accurate since the upward and downward diffusion and mass flow due to evaporation and drainage tends to equalize the salt in the profile over the winter.

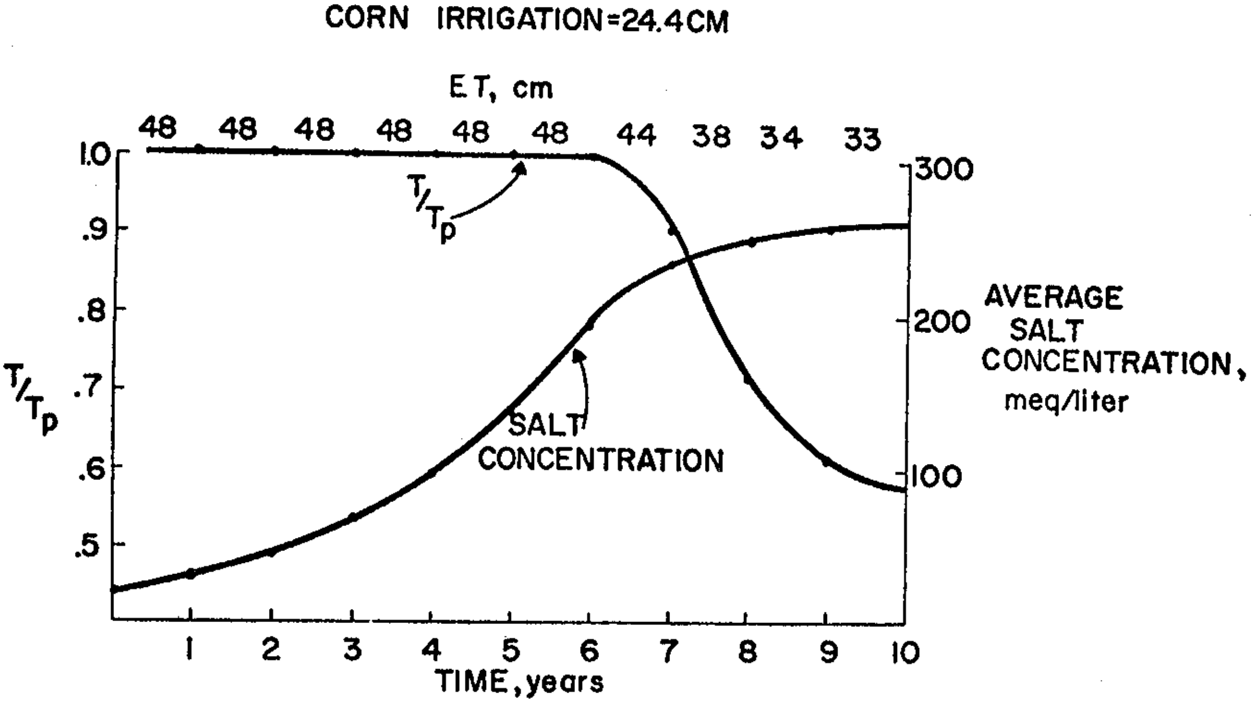

Figure 6-3. Relative transpiration and average salt concentration for corn with deep roots irrigated at a rate of 24.4 cm/year as influenced by year.

The single point values, relating water added to the T/T_p, are somewhat unrealistic in a real field situation because water is not distributed uniformly. Even in the best system there are parts of the field that receive more water than others. To account for this, engineers have defined a uniformity coefficient Cu as follows:

$$Cu = 1 - \frac{D}{M} \quad \text{(6-4)}$$

in which M is the average irrigation rate and D is the average deviation (sign ignored) above the average rate. If Cu = 1.0, water application would be completely uniform. To add this factor to the computations, it was necessary to assume a distribution pattern and the extent of coverage that might apply for some mean water application rate. From the distribution pattern, a new value of T/T_p results from integrating T/T_p over the water distribution pattern. This also provides salt outflow information. These data were calculated assuming a uniformity of 1.0 for all of the data presented up to this point. Considering nonuniform coverage, the relationship of T/T_p to average water added by irrigation can then be constructed. These data are shown in Tables 6-5, 6-6, and 6-7 for the three crops for three different uniformities. The amount of salt outflow is also shown. These tables show essentially the same ratio of T/T_p for all uniformities provided the water application is insufficient to allow any drainage (and thus salt outflow). However, once the irrigation rate is high enough to result in some drainage, the ratio of T/T_p decreases as the uniformity decreases. Thus, for alfalfa T/T_p is 1.0, 0.98, and 0.90 for a Cu of 1.0, 0.88, and 0.42, respectively, (20 meq/l initial salt concentration). This ratio variation results from poor uniformity due to irrigation greater or less than ET. The same result is also shown in Table 6-8 where the average water application is greater than ET. For this situation, some part of the field received water at less than ET resulting in T/T_p less than 1.0.

These results point out another situation of great practical importance involving some present concepts of low leaching ratios. If water distribution is nonuniform and the average leaching ratio is low, then there will be part of the field which is not leached at all and salts will accumulate. This could be a serious problem when the same uniformity distribution pattern prevails year after year. A 10-year simulation of this effect shows a salt buildup in a portion of the wetted area getting less water than ET and a consequent decrease in T/T_p (Table 6-8). Where irrigation is greater than ET, essentially steady state conditions prevailed.

The Economic Comparisons

The physical relationships discussed above are the basic data for the economic analysis. From the physical data, the relevant information on growing corn silage, oats, or alfalfa hay was accumulated. Decision options which included water application by sprinkler or by flooding at rates (from irrigation and rain) of 10.3, 15.0, 22.0, 40.8, 56.4, and 66.7 centimeters for each of the crops were utilized.

Limits on resource availability (the B_i) or right-hand-side values used in the linear programming study include the quantities of each of three land classes based on the beginning salinity levels in the

Table 6-5. Relative yield of corn, equal to T/T pot, as influenced by three different values of Cu, water applied and initial salt concentration.

Irrig. & Rain	Initial Salt	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow
		Cu = 1		Cu = 0.88		Cu = 0.42	
	meq/l		meq/cm^2		meq/cm^2		meq/cm^2
10.3	20	0.89	0	0.89	0	0.89	0
10.3	50	0.86	0	0.86	0	0.85	0
10.3	200	0.55	0	0.56	0	0.56	0
15.0	20	0.97	0	0.94	0	0.93	0
15.0	50	0.93	0	0.92	0	0.91	0
15.0	200	0.64	0	0.64	0	0.64	0
22.0	20	0.98	0	0.99	0	0.97	0
22.0	50	0.98	0	0.98	0	0.95	0
22.0	200	0.78	0	0.78	0	0.76	0
40.8	20	0.99	0	1.0	0	0.98	89
40.8	50	0.98	0	0.99	0	0.97	216
40.8	200	0.97	0	0.96	0	0.88	892
56.4	20	1.0	19	1.0	60	0.99	357
56.4	50	1.0	49	0.99	158	0.98	821
56.4	200	1.0	214	1.0	644	0.91	3563
66.7	20	1.0	210	1.0	239	0.99	703
66.7	50	1.0	532	1.0	581	0.98	1575
66.7	200	1.0	2160	1.0	2398	0.92	7099

Table 6-6. Relative yield of alfalfa, equal to T/T pot, as influenced by three different values of Cu, water applied and initial salt concentration.

Irrig. & Rain	Initial Salt	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow
		Cu = 1		Cu = 0.88		Cu = 0.42	
cm	meq/l		meq/cm^2		meq/cm^2		meq/cm^2
10.3	20	0.61	0	0.60	0	0.60	0
10.3	50	0.58	0	0.58	0	0.58	0
10.3	200	0.42	0	0.41	0	0.41	0
15.0	20	0.68	0	0.68	0	0.68	0
15.0	50	0.66	0	0.66	0	0.65	0
15.0	200	0.49	0	0.49	0	0.49	0
22.0	20	0.80	0	0.81	0	0.79	0
22.0	50	0.67	0	0.79	0	0.77	0
22.0	200	0.63	0	0.64	0	0.64	0
40.8	20	1.0	0	0.98	0	0.90	86
40.8	50	1.0	0	0.97	0	0.89	212
40.8	200	0.93	0	0.91	0	0.81	804
56.4	20	1.0	0	1.0	44	0.92	449
56.4	50	1.0	22	1.0	124	0.92	996
56.4	200	1.0	61	0.99	512	0.86	3492
66.7	20	1.0	178	1.0	232	0.94	1007
66.7	50	1.0	467	1.0	571	0.93	2128
66.7	200	1.0	1882	1.0	2170	0.89	7158

soil profile. It was assumed that the farm under study had 10 acres with each of the three soil characteristics (20, 50, and 200 meq/l) described earlier. Also, a unlimited quantity of salt outflow was allowed in the drainage water (which level was sequentially reduced to determine the loss in profitability to the farm from restricting salt flow into the drains and streams). There were also constraints to force growing of crops in rotation such as to provide for nurse crops for new seedings of alfalfa and limits on corn production for disease control.

The net profit values for each unit of production were based on approximate current prices for

Table 6-7. Relative yield of oats, equal to T/T pot, as influenced by three different values of Cu, water applied, and initial salt concentration.

Irrig. & Rain	Initial Salt	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow	T/T Pot	Salt Outflow
		Cu = 1		Cu = 0.88		Cu = 0.42	
cm	meq/l		meq/cm^2		meq/cm^2		meq/cm^2
5.6	20	0.29	0	--	--	--	--
5.6	50	0.28	0	--	--	--	--
5.6	200	0.18	0	--	--	--	--
10.3	20	0.37	0	0.37	0	0.37	0
10.3	50	0.36	0	0.36	0	0.36	0
10.3	200	0.24	0	0.24	0	0.24	0
15.	20	0.46	0	0.45	0	0.45	0
15.	50	0.44	0	0.43	0	0.43	0
15.	200	0.32	0	0.31	0	0.32	0
22.	20	0.59	0	0.61	0	0.60	0
22.	50	0.58	0	0.59	0	0.59	0
22.	200	0.46	0	0.47	0	0.48	0
40.8	20	0.89	0	0.87	0	0.79	84
40.8	50	0.88	0	0.87	0	0.78	209
40.8	200	0.80	0	0.78	17	0.71	818
56.4	20	0.97	26	0.97	63	0.84	365
56.4	50	0.98	66	0.97	157	0.84	918
56.4	200	0.93	490	0.93	738	0.79	3161
66.7	20	0.99	198	0.99	225	0.87	780
66.7	50	0.99	495	0.99	563	0.87	1967
66.7	200	0.99	1975	0.98	2178	0.82	6492

Table 6-8. Relation of time and irrigation rate, for Cu = 0.42 (square) to relative transpiration, T/T_p, and average salt content Sf at different positions within the uniformity pattern with beginning soil salinity at 20 meq/l.

Relative Area	0.20		0.20		0.20		0.20		0.20		
Relative I Rate	0.10		0.30		0.50		0.70		0.90		Average T/Tp
Year	T/Tp	Sf	T/Tp	Sf	T/Tp	Sf	T/Tp	Sf	T/Tp	Sf	
1	0.45	33	0.75	30	0.96	24	0.96	24	1.0	20	83
2	0.44	53	0.72	37	0.96	28	0.96	26	1.0	21	82
3	0.43	81	0.70	43	0.96	32	0.96	28	1.0	21	81
4	0.42	117	0.69	47	0.96	35	0.96	29	1.0	21	81
5	0.39	162	0.68	50	0.96	39	0.96	29	1.0	21	80
6	0.35	208	0.67	53	0.96	42	0.96	29	1.0	21	79
7	0.30	249	0.67	56	0.96	45	0.96	29	1.0	21	78
8	0.26	280	0.66	58	0.96	49	0.96	29	1.0	21	77
9	0.22	298	0.66	60	0.96	52	0.96	29	1.0	21	76
10	0.20	306	0.65	61	0.96	55	0.96	29	1.0	21	75

products and the costs of various operations. Yields were estimated using the 1971 data for the farm as a base and the relative yields predicted in the physical model to give specific values for the rates of water applied as influenced by the initial salt concentration in the soil as shown in Tables 6-9 and 6-10.

The profit function is based upon a price for alfalfa of $45/ton; for corn silage, $13/ton; and for oats, $1.60/bushel. These represent approximately the current prices, but are adjusted somewhat to a normal long-run relationship to each other. The cost of raising crops was computed as shown in Table 6-11.

Single Year Analysis

Two main sets of results were desired in order to draw conclusions. These were the set of production activities that would maximize farm profit at each level of salt outflow and the loss in income from not allowing an incremental ton of salt to flow out. The latter may also be characterized in its mirror image, the value to the farm of allowing an additional ton of salt outflow. A number of different situations were modeled to determine the effects of irrigation method and rate of application, and restrictions on the crop combinations.

Table 6-9. Predicted yield of crops under sprinkler irrigation by initial salt content of soil, by water application rates.[a]

Initial Salt Content of Soil	Water Level (Irrigation Plus Rain)	Crop Yield		
		Alfalfa (Medium Roots)	Oats (Shallow Roots)	Corn Silage (Deep Roots)
	Centimeters	Tons	Bushels	Tons
20 Meq./L.	10.3	3.3	34.0	20.5
	15.0	3.7	44.2	21.6
	22.0	4.4	55.7	22.8
	40.8	5.3	80.1	22.8
	56.4	5.5	89.0	22.8
	66.7	5.5	91.3	22.8
50 Meq./L.	10.3	3.2	32.8	19.7
	15.0	3.6	39.8	21.1
	22.0	4.3	54.4	22.6
	40.8	5.3	79.8	22.8
	56.4	5.5	89.2	22.8
	66.7	5.5	91.4	22.8
200 Meq./L.	10.3	2.2	22.2	12.9
	15.0	2.7	28.8	14.7
	22.0	3.5	43.3	17.9
	40.8	4.9	71.9	22.8
	56.4	5.4	85.3	22.8
	66.7	5.5	90.1	23.0

[a] Based on Tables 6-5, 6-6, and 6-7, above, and assuming a coefficient of uniformity of application (CU) = 0.88.

Table 6-10. Predicted yield of crops under flood irrigation by initial salt content of soil, by water application rates.[a]

Initial Salt Content of Soil	Water Level (Irrigation Plus Rain)	Crop Yield		
		Alfalfa (Medium Roots)	Oats (Shallow Roots)	Corn Silage (Deep Roots)
	Centimeters	Tons	Bushels	Tons
20 Meq./L.	40.8	4.9	72.4	22.6
	56.4	5.0	77.5	22.7
	66.7	5.1	80.0	22.7
50 Meq./L.	40.8	4.9	71.9	22.4
	56.4	5.0	77.1	22.5
	66.7	5.1	79.7	22.6
200 Meq./L.	40.8	4.5	65.4	20.2
	56.4	4.7	72.3	20.9
	66.7	4.9	75.7	21.3

[a] Based on Tables 6-5, 6-6, and 6-7, above, and assuming a coefficient of uniformity of application (CU) = 0.42.

Situation 1. Unrestricted corn in the rotation, corn roots deep, alfalfa roots shallow, sprinkle or flood irrigation. Without any constraint on corn in the rotation, the production activities in the optimal production pattern included nothing other than corn. In Figure 6-4, the most profitable production activities are summarized. Note that the tons of salt outflow for the entire 30 acres is on the scale at the bottom of the figure. The set of crops which is optimal is plotted for the 10 acre units by soil type (where initial soil salt is at the high, medium, or low level) for each level of salt outflow. For instance, at a level of 60 tons of salt outflow, the model indicates that for the low soil salt condition, the entire 10 acres should be in corn irrigated at the fifth level (next to highest) by flooding. For the medium salt condition, there should be about 4 acres of corn at the fourth level of water application. On the saltiest land, there should be 10 acres of corn irrigated at the fifth level by sprinkling.

In meeting the requirement for low salt outflow, sprinkler systems and low rates of water application were required in the model. As the allowable salt outflow was increased, the irrigation rates were increased and the method of irrigation changed to flooding. Net profit increased by about $900 (or $30 per acre) as the salt outflow constraint was relaxed. Almost all of this profit increase occurred in the first 20 ton increment. Only about $100 of additional profit (Figure 6-5) for the 30 acre block of land could be attained beyond this first 20 ton increment. In a practical management situation, all 30 acres would be irrigated by sprinkling or by flooding, rather than a combination of systems.

There are two main reasons for obtaining these results. First, it was assumed that corn was a deep-rooting plant so that this crop was profitable at low levels of irrigation, since in the physical model the corn obtained considerable water from deep soil moisture or underground supply. In a static 1-year analysis with a light application of water, there would be no outflow of salts, but there would be an accumulation in the soil profile. Second, corn was the most profitable crop assuming that yields can be maintained.

In Figure 6-6, the value to the farm of an additional ton of salt outflow as a function of salt outflow is shown. Note that the cost to the farm of reducing the outflow of salt (or value for letting an additional ton flow out) is very low compared to any possible costs of removal by desalination or other methods.

Situation 2. Corn restricted to one-half of the acreage, corn roots shallow, alfalfa roots deep, sprinkle or flood irrigation. This situation was tested for several reasons. Corn could probably not be grown exclusively for several years due to varied needs for livestock feed, disease and fertility problems on the land, and grower preference for multiple crops. Also, the depth of corn roots may be somewhat shallower than the perennial alfalfa crop. The data which indicated corn was deep-rooted and alfalfa somewhat shallower were from separate experimental plots that may not be appropriate for the area of this study.

Under these assumptions, the cropping patterns over the range of salt outflow are as shown in Figure 6-7. Alfalfa would be profitable and the required nurse crop would accompany low salt outflows since alfalfa roots are assumed deep where more soil moisture or

Table 6-11. Cost components of crop production by crop and by method of water application.

Crop	Fixed Cost	Growing Cost	Irrigation Costs				Harvest Cost
			Water Level (Irrig. Plus Rain)	Sprinkler Construction Cost	Energy Cost	Flood	
	$ Per Acre	$ Per Acre	cm	$ Per Acre	$ Per Acre	$ Per Acre	$
Alfalfa Hay	13.65	27.09		24.22		9.63	7.50/ton
			10.3		1.22		
			15.0		1.65		
			22.0		3.30		
			40.8		6.59		
			56.4		8.91		
			66.7		10.71		
Oats	13.65	58.11		24.22		9.55	0.16/bu.
			10.3		1.22		
			15.0		1.65		
			22.0		3.30		
			40.8		6.59		
			56.4		8.91		
			66.7		10.71		
Corn Silage	13.65	70.39		24.22		-	--
			10.3		1.22		
			15.0		1.65		
			22.0		3.30		
			40.8		6.59		
			56.4		8.91		
			66.7		10.71		

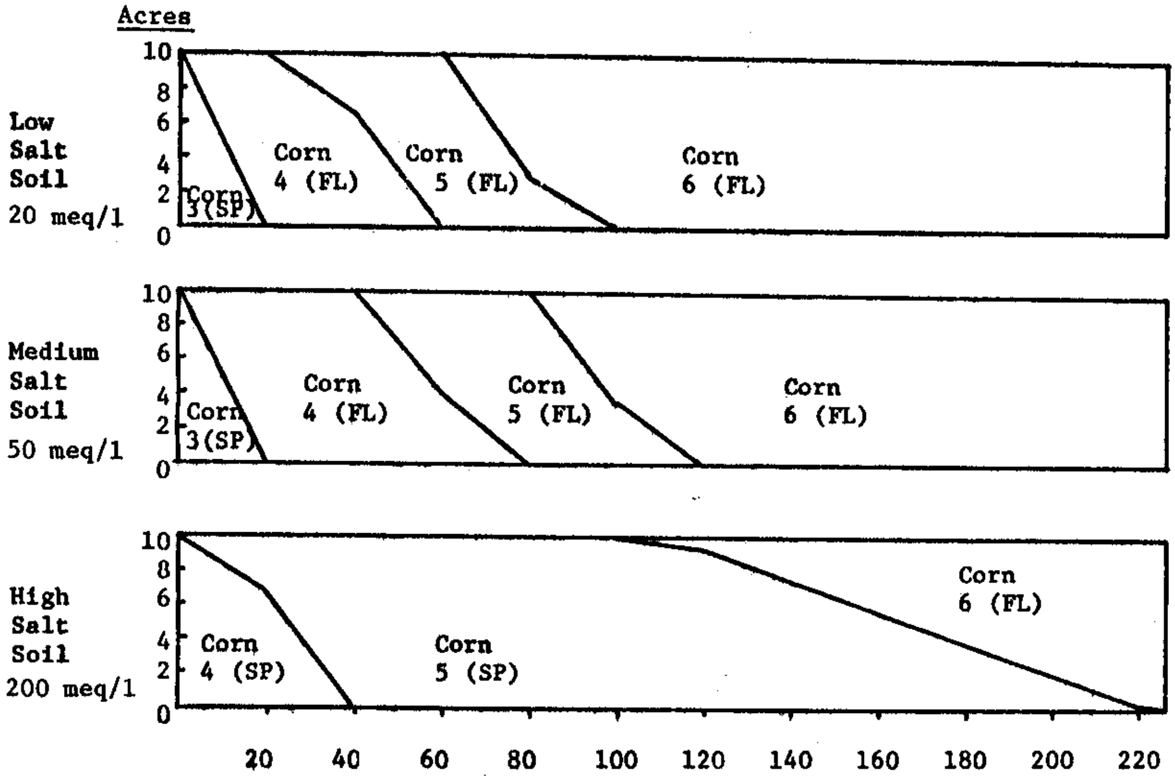

Figure 6-4. Optimal cropping and irrigating pattern for high, medium, and low initial soil salt conditions where corn roots are deep and alfalfa shallow and either flooding or sprinkling is allowed as an irrigation method.

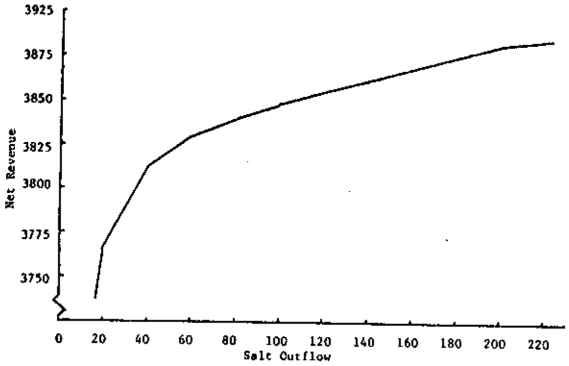

Figure 6-5. Net revenue by amount of salt outflow for the 30 acres as shown in Figure 6-4.

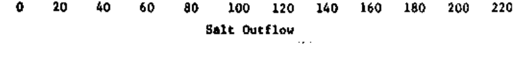

Figure 6-6. Shadow price or value of an additional ton of salt outflow for the 30 acres as shown in Figure 6-4.

groundwater can be obtained, and heavy water application is not required for reasonably good yields. Low levels of irrigation are again optimal at low levels of salt outflow. Higher levels of water application are most profitable for high salt outflow. Note that compared to the previous situation in which corn was unrestricted and the corn roots were deeper than alfalfa a higher total salt outflow is more profitable than if there are no restrictions on these factors. This higher level of salt outflow is caused by the requirement for a mix of crops and by shallow corn roots which do not tap the underground water supply. As before, the most restrictive constraints in salt outflow are the most costly to the farm plan. Very high levels of additional salt outflow add little to the profit (Figures 6-8 and 6-9).

Situation 3. Corn restricted to one-half of the acreage, corn roots shallow, alfalfa deep, flood irrigation only. Under this assumption (flooding only), a relatively small amount of corn would be produced except at high levels of water application and for high levels of salt outflow (Figure 6-10). This result is due to alfalfa being able to obtain water from underground sources so that fairly good yields can be obtained without high levels of salt output resulting from the leaching due to heavy water application.

Note that for a given total level of salt outflow the water application levels on alfalfa are largest on the low salt soil and then lower successively to the high salt soil and the land remains idle at low levels of permissible salt outflow because it is unprofitable to operate without applying water. The system cannot meet the tight constraint on salt if all land is used, since flood irrigation is possible only at the three highest levels of water application.

The highest levels of salt output is much higher, nearly 100 tons, than with the previous situations in which sprinkling is one of the options. The highest penalties for restricting salt output, as usual, are where the salt constraint is most restrictive as shown in Figure 6-11 and 6-12. But, once the constraint is relaxed to more than three tons per acre, the value is less than $1 per ton.

Situation 4. Corn restricted to one-half of the acreage, corn roots shallow, alfalfa deep, sprinkler irrigation only. Under sprinkler irrigation, the most noticeable difference is that corn is produced to the maximum allowed in the rotation at all levels of salt outflow (Figure 6-13). As usual, the irrigation rate increases as the allowable salt outflow is increased. In Figures 6-14 and 6-15, it can be seen that as salt outflow reaches one ton per acre, there can be little additional profit by applying higher levels of water with the resultant higher salt outflow.

Comparison and evaluation of situations. In comparing the different situations studied, it is clear that the crop which has the assumed deep roots is generally more profitable. As mentioned, this results from extraction of water from underground sources alleviating the demand for the heavy applications of water and the salt leaching that accompanies heavy

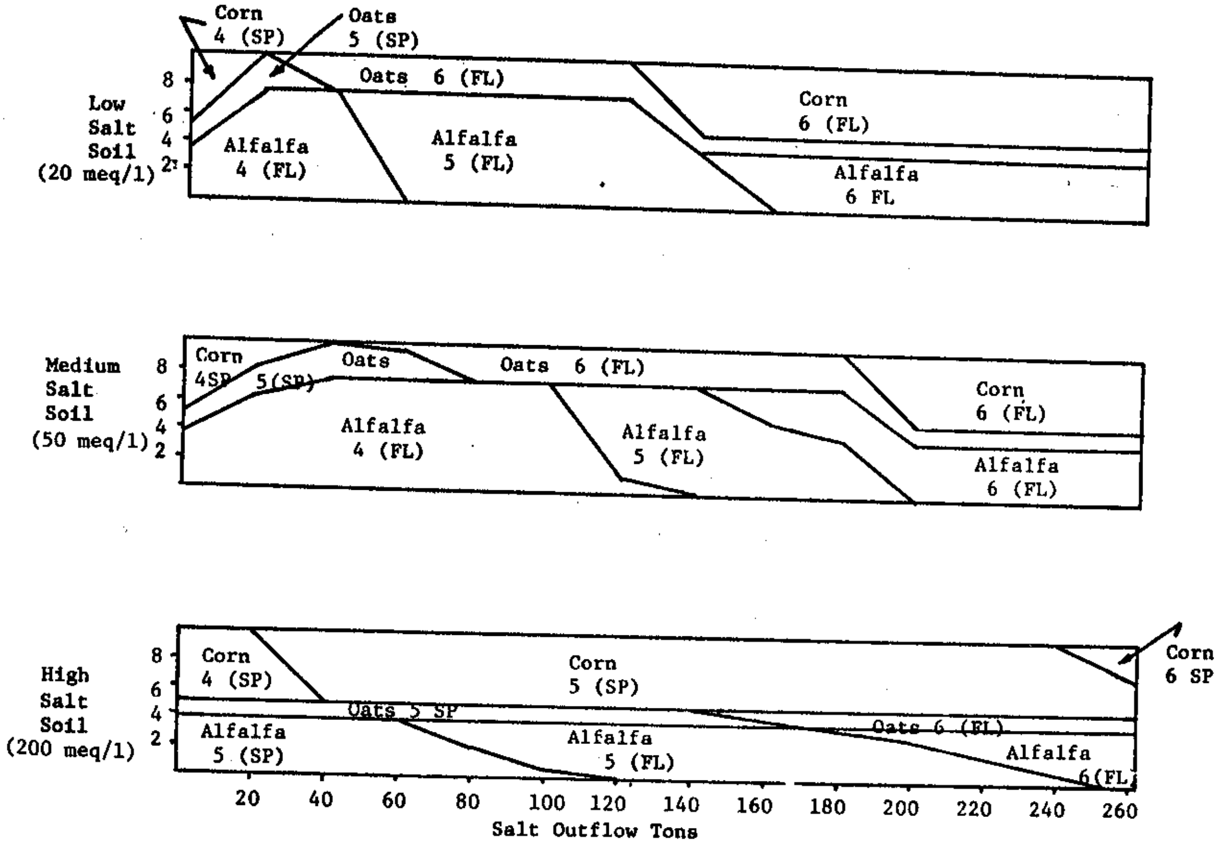

Figure 6-7. Optimal cropping and irrigating pattern for high, medium, and low initial soil salt conditions where corn roots are shallow, and alfalfa deep and either flooding or sprinkling is allowed as an irrigation method.

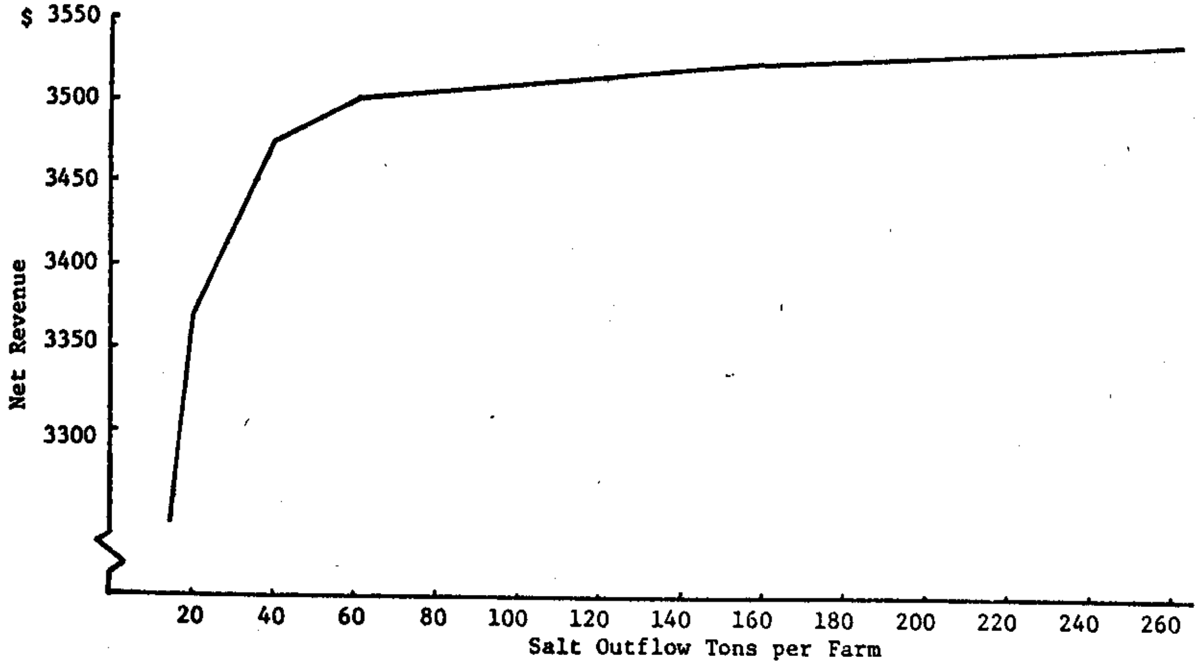

Figure 6-8. Net revenue by amount of salt outflow for the 30 acres as shown in Figure 6-7.

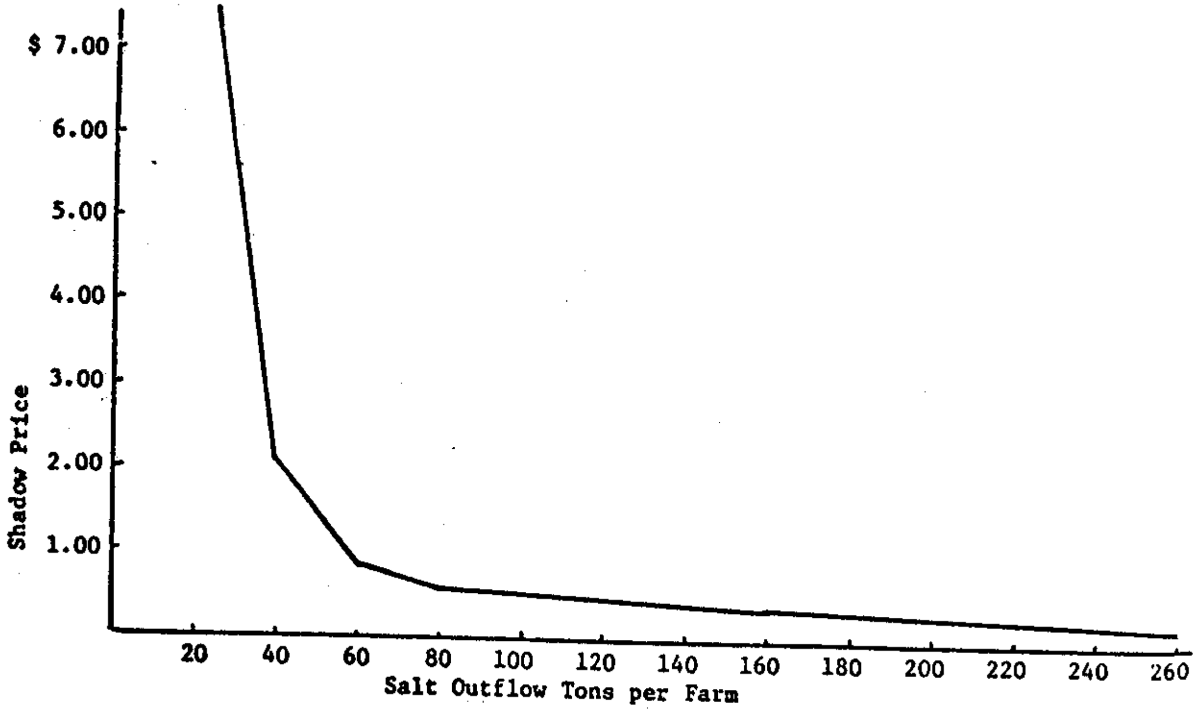

Figure 6-9. Shadow price or value of an additional ton of salt outflow for the 30 acres as shown in Figure 6-7.

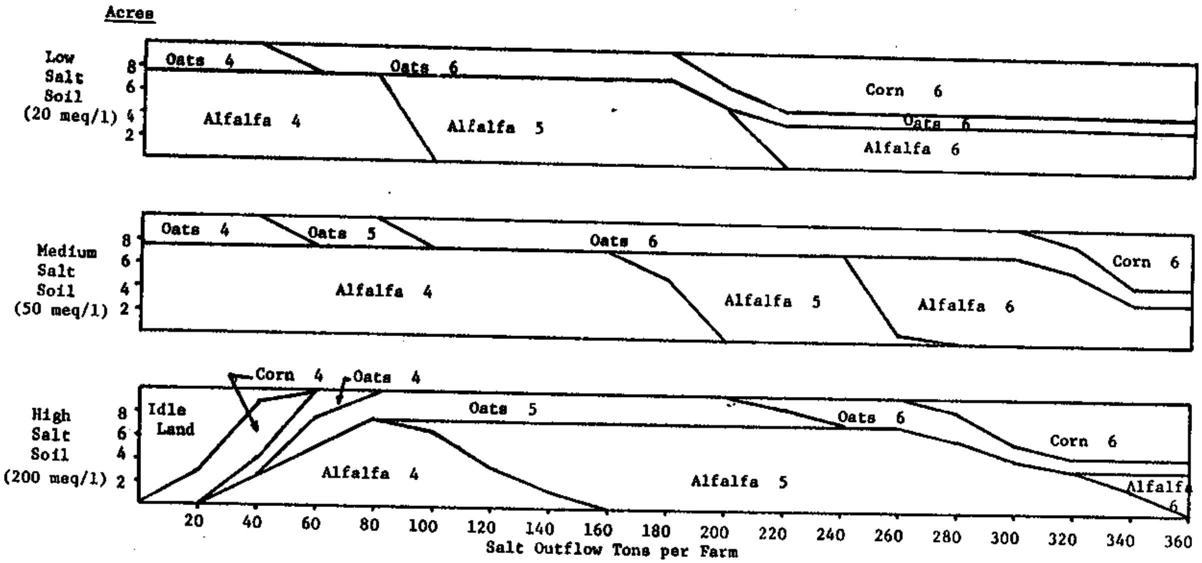

Figure 6-10. Optimal cropping and irrigating pattern for high, medium, and low initial soil salt conditions where corn roots are shallow and alfalfa deep where flood irrigation only is allowed.

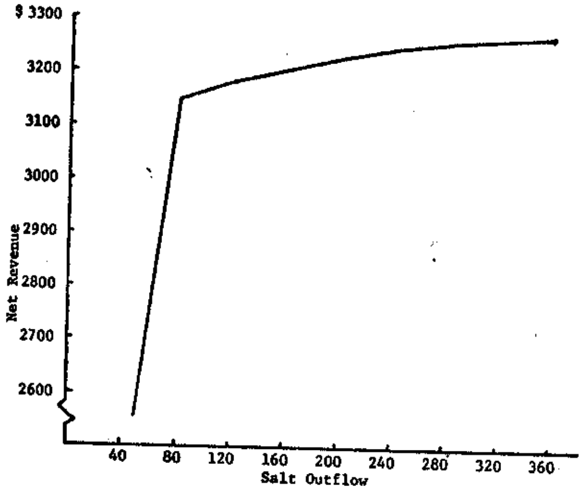

Figure 6-11. *Net revenue by amount of salt outflow for the 30 acres as shown in Figure 6-10.*

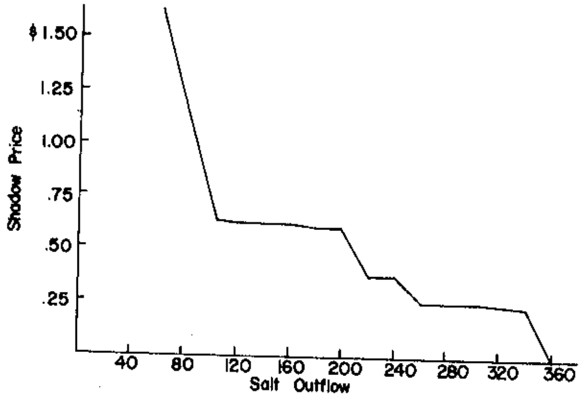

Figure 6-12. *Shadow price or value of an additional ton of salt outflow for the 30 acres as shown in Figure 6-10.*

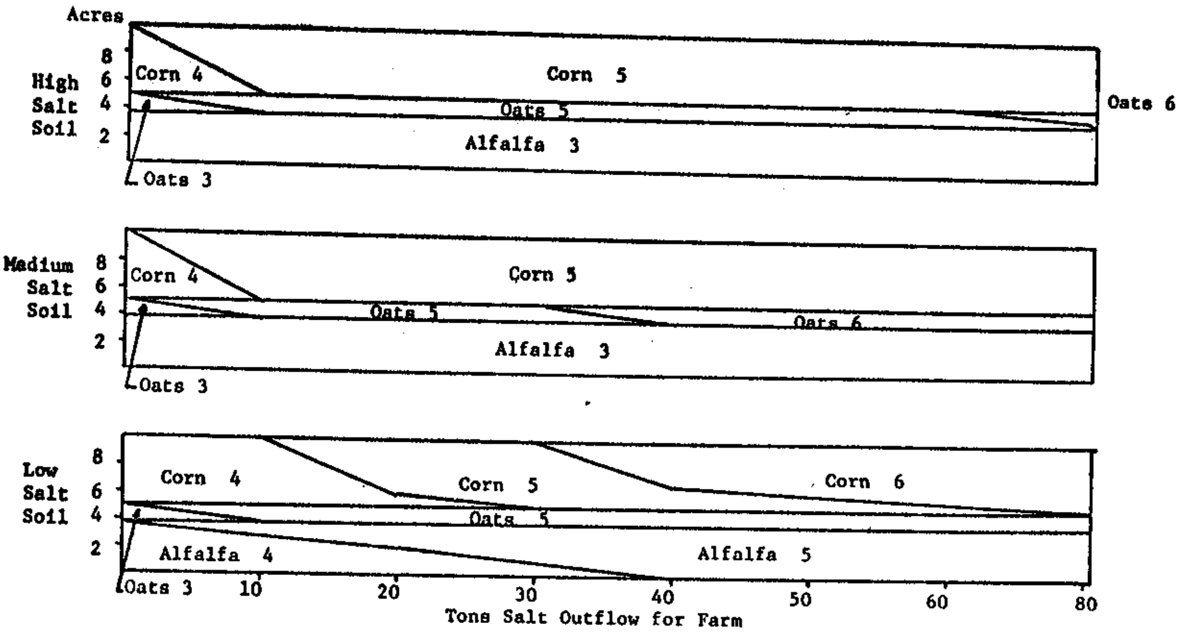

Figure 6-13. *Optimal cropping and irrigating pattern for high, medium, and low initial soil salt conditions where corn roots are shallow and alfalfa deep where sprinkler irrigation only is allowed.*

watering. This net upward flow leads to salt accumulation with time so these one year results do not apply for a period of years where net leaching does not occur. In other situations in which groundwater would not be available, such a result would not be expected. Without constraints on salt outflow, it appears that flood irrigation is most profitable to the farm. The advantages of better yields and the lower water use cost were not sufficient to make sprinkling generally profitable. It was found that net profit at the maximum was about $8 per acre less ($250 for the 30 acres) is the irrigation system was constrained to sprinkling. If the farm was constrained to one ton salt output per acre, sprinkling would be more profitable by a few hundred dollars. At 2 tons per acre, sprinkling would be more profitable than flooding by about $300 ($10 per acre). This difference depends on leaving some land idle under flooding to meet the restriction in addition to the yield advantages and lower water costs due to sprinkling.

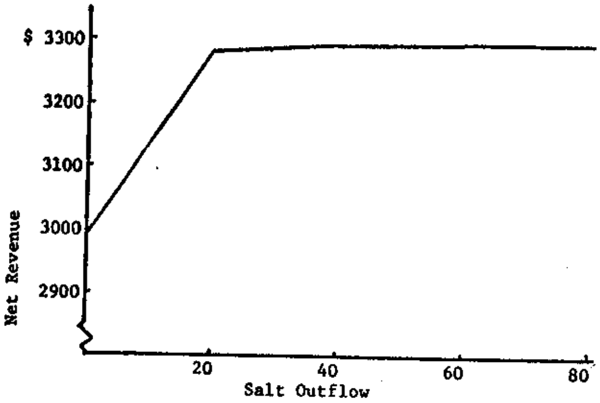

Figure 6-14. Net revenue by amount of salt outflow for the 30 acres as shown in Figure 6-13.

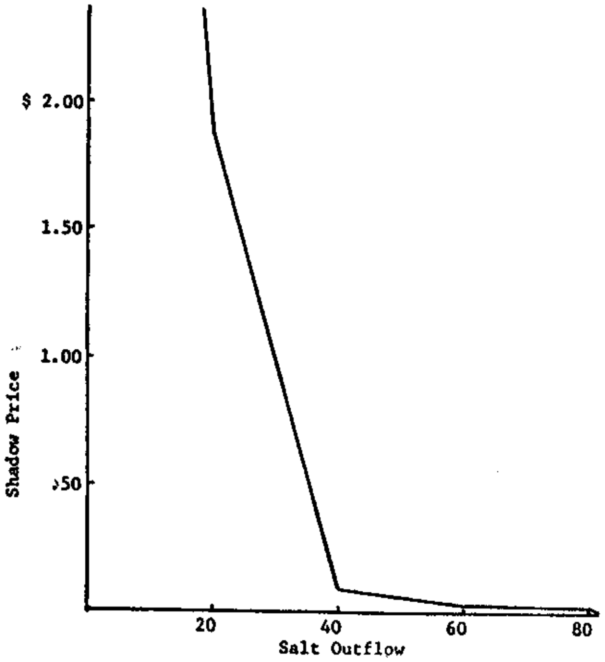

Figure 6-15. Shadow price or value of an additional ton of salt outflow for the 30 acres as shown in Figure 6-13.

In evaluating the shadow prices of salt output (value to the farm of an additional ton of salt output), it is clear that the first ton or two of salt per acre under any assumptions are most critical. It is not known just how much salt is presently coming from cultivation of lands of this type, but the amount is likely somewhat higher than one or two tons. Therefore, it may well be possible under any set of management objectives to reduce salt outflow considerably with minimum cost (usually less than $1 per ton). This value surely is much less than other cost estimates of salt reduction in the Colorado River. The Bureau of Reclamation currently estimates other control measures at $9 to $30 per ton of salt (U.S. Bureau of Reclamation, 1974). But, these conclusions are limited to a single year in which soil salinity buildup is not accounted for.

Multi-Year analysis

A multi-year analysis of management practices was developed by using the final conditions of the previous year for the initial soil salinity conditions of the current year subject to the assumptions of the physical model. Four levels of water application were used in the modeling. The initial soil salinity figures of 20, 50, and 200 meq/l were prime data for this analysis. The final soil salinity for each year, salt outflow, and yields depended heavily on the beginning soil salinity as well as on water application and other factors.

Initial soil salinity. In the following discussion, we present the results of initial soil salinity and water application level combinations. Results will be presented as final soil salinity, salt outflow, and net revenue per acre. A brief commentary on cropping patterns will also be included.

Initial soil salinity at 20 meq/l. A number of somewhat expected results occurred in the multi-year simulation of soil salinity (Figure 6-16). First, the lowest level of water application (20 cm) resulted in a salt buildup in the soil profile. Second, this buildup tended to taper off in the last few years of the 6-year period. This was caused by the profit optimizing model letting a few acres remain idle and heavier water application being available for the remainder. This heavier application reduced the salt in the profile on part of the acreage and also for the average. Farmers would be expected to be doing exactly this if water was restricted for salt control purposes. Third, the heaviest water application rates resulted in no particular change in soil salinity over time. Note that the water application rates were an average for the several acres of soil with this initial condition. Some, depending on the crop, may have received more and some less or even none as noted above if some land were left idle. This resulted in the slightly erratic patterns shown especially for the intermediate water application levels.

The simulation of salt outflow over time is shown in Figure 6-17. As might be expected, the heavier water applications flush the salt through the soil. Lighter applications of water lead to salt buildup to a severe degree.

Alfalfa with the necessary nurse crop of oats dominates the cropping pattern where minimum water application is allowed. Application is by sprinkler. The reason is the assumed deep rooting of alfalfa which enables it to obtain additional water from the groundwater. Corn with flood irrigation dominates the high level water application situation.

The net revenue (gross income less variable costs) comparisons for the multi-year period are shown in Figure 6-18. At heavier rates of water application the net revenue is maintained, but at lower rates of water

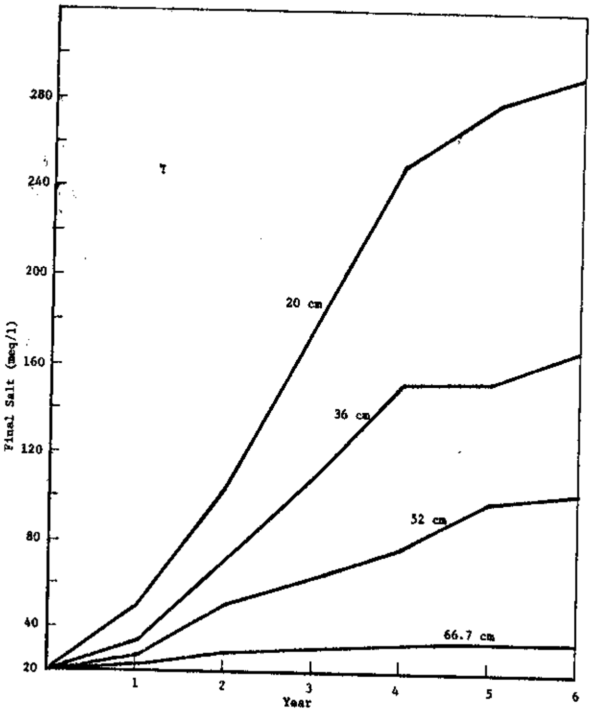

Figure 6-16. ***Multi-year final soil salinity comparisons for four average rates of water application at initial soil salinity of 20 meq/l.***

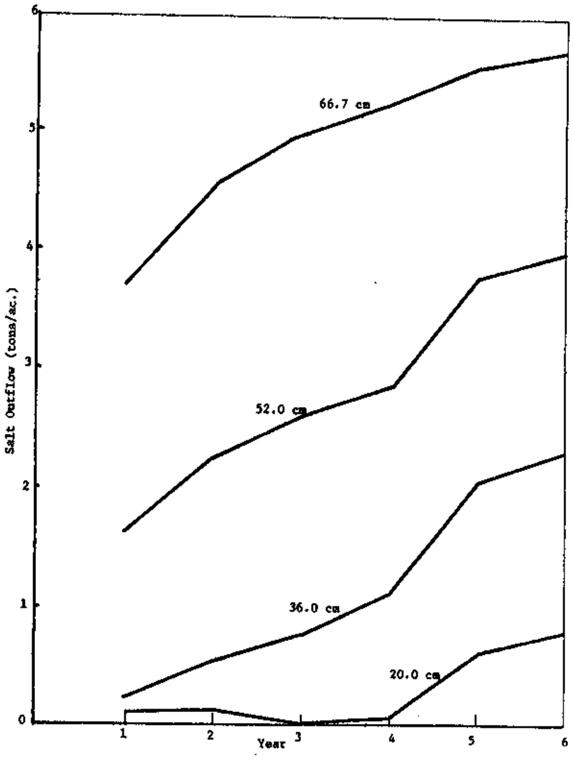

Figure 6-17. ***Multi-year salt outflow comparisons for four average rates of water application at initial soil salinity of 20 meq/l.***

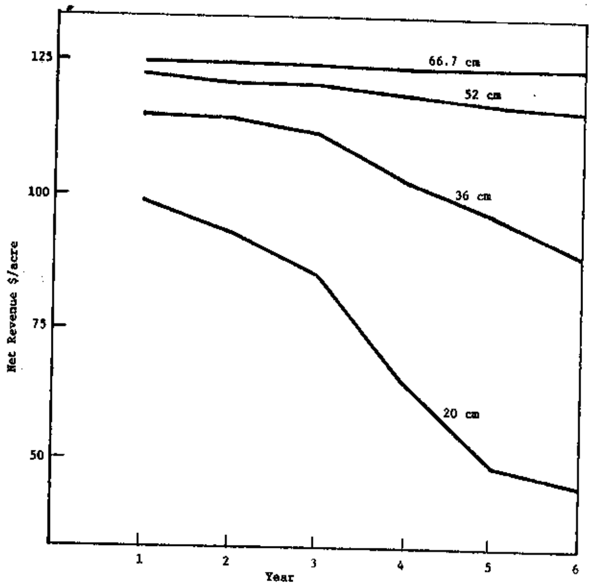

Figure 6-18. ***Net revenue comparisons for four rates of water application at initial soil salinity of 20 meq/l.***

application the revenue declines sharply over time because of higher soil salinity and falling yields.

Initial soil salinity at 50 meq/l. Again, several comparisons have been made with initial soil salinity at this higher level. The ending soil salinity over a period of years is in much the same pattern as shown earlier. The heaviest average water application rate results in a slight decline in soil salinity. See Figure 6-19. Salt outflow as shown in Figure 6-20 is fairly stable at the lowest rate of water application, is higher and increases at intermediate rates of application and is quite high but declines as leaching occurs at the highest rate of water application. Net revenue follows much the same pattern as with 20 meq/l soil salinity for high rates of water application, but is more depressed at low water application (Figure 6-21). Cropping pattern is nearly identical to the situation with soil salinity at 20 meq/l.

Initial soil salinity at 200 meq/l. The changes in soil salinity over time are shown in Figure 6-22. The two heaviest water application rates result in declines in soil salinity over time. Low water application results in an ever greater buildup.

Salt outflow ranges up to high amounts of 15 to 16 tons per year for heavy water application, but is fairly minimal for light applications of water since little or no water goes through the profile. Net revenue is depressed by one-third or more because of the saline conditions, but improves slightly in cases where leaching is accomplished.

POLICY IMPLICATIONS OF THE STUDY

This study, although done for a specific site in Eastern Utah, indicates a number of management possibilities for irrigation water may be quite useful in

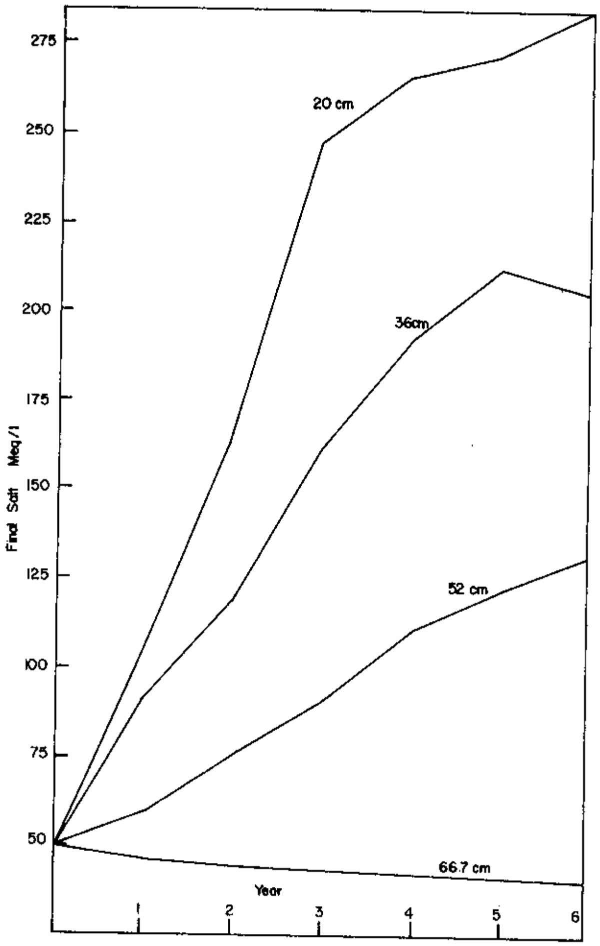

Figure 6-19. Multi-year final soil salinity comparisons for four average rates of water application at initial soil salinity of 50 meq/l.

reducing Colorado River water salinity. Assume that the range of current average estimates of salinity outputs from irrigated agriculture is 1.5 to 3.0 tons per acre. Then, it appears that costs of reducing this level to one ton per acre or a little less may be fairly minimal. This is based on the single year analysis, however, and may lead to further increases in soil salinity and either greater salt outflow in the future or even greater losses in income from attempting to reduce the salinity. It is readily apparent that a zero discharge standard is at best immensely costly or totally impossible. Moderate rates of improvement may be possible with limited cost to producers. The multi-year study showed that low rates of water application cause excessive salt buildup in the soil profile and reduce net revenue very significantly. High rates of water application, of course, alleviate this problem but cause continued large salt outflow.

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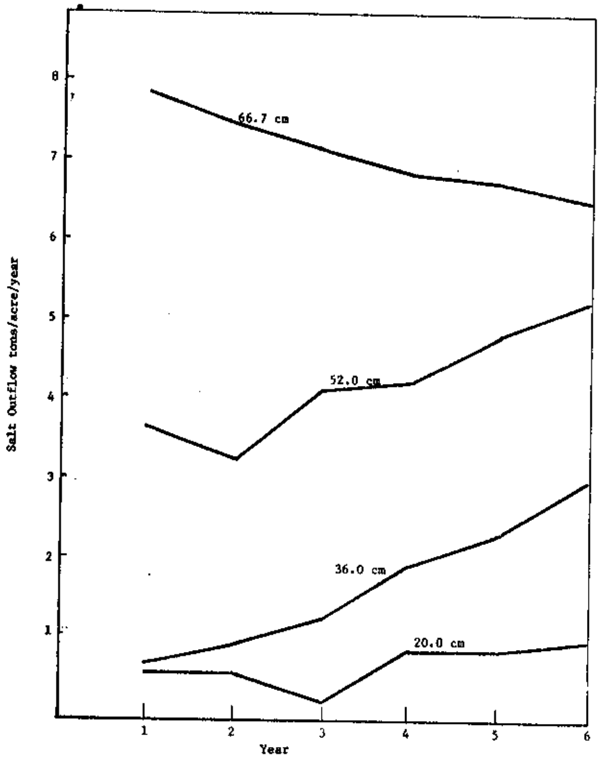

Figure 6-20. Multi-year salt outflow comparisons for four average rates of water application at initial soil salinity of 50 meq/l.

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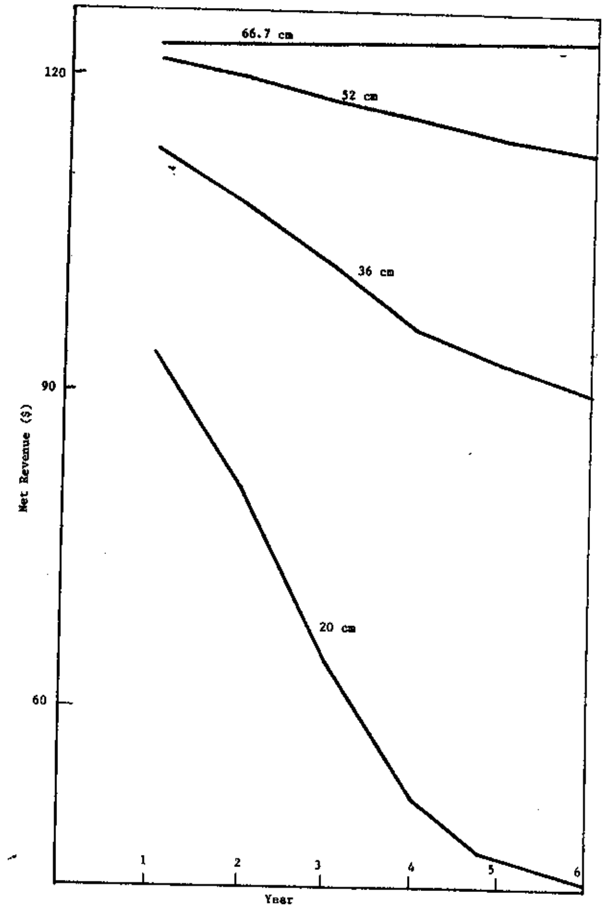

Figure 6-21. Net revenue comparisons for four rates of water application at initial soil salinity of 50 meq/l.

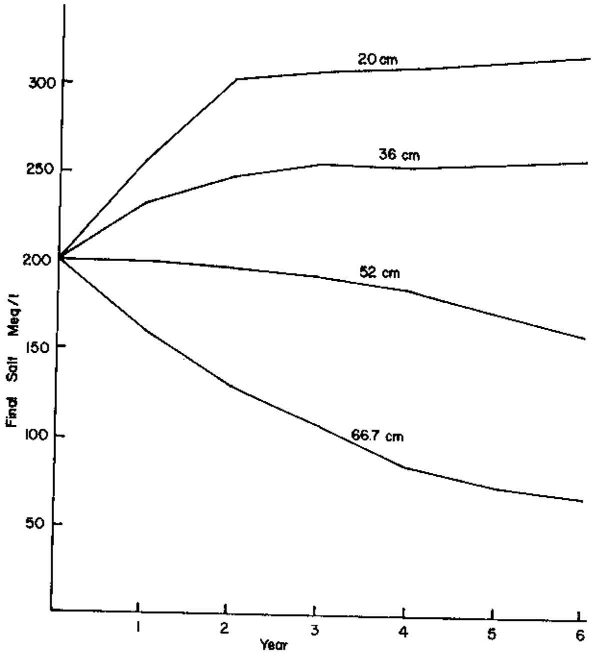

Figure 6-22. Multi-year salt outflow comparisons for four average rates of water application at initial soil salinity of 200 meq/l.

APPENDIX 7

INDIRECT ECONOMIC IMPACTS FROM SALINITY DAMAGES IN THE COLORADO RIVER BASIN

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SUMMARY OF REPORT

The purpose of this part of the regional research project "Salinity Management Options for the Colorado River" has been to trace the total regional economic impacts caused either by salinity-induced damages to agriculture and municipal-industrial activities or by programs aimed at reducing salinity in the areas of origin. Geographically, these two sets of events correspond to the lower Colorado River Basin and the upper basin, respectively.

Total regional economic impacts include not only the direct damages or the explicit steps taken to reduce salinity but include changes in outputs and incomes generated by sectors of the regional economy which provide supplies for or are dependent upon outputs from the sector directly impacted. The tools of analysis used to trace these indirect effects have been input-output models—of the California-Arizona regional economy for lower basin damages and of the upper main stem subbasin of the Colorado River for salinity reduction programs. While regional output and income changes are not necessarily the same as net national changes, they are extremely important items of information for the public decision-making process.

The structure of the overall salinity management project required the sequencing of sub-project outputs: basic crop response data had to precede the calculation of crop losses; the modeling of farm management response had to incorporate the crop response data and produce estimates of net crop losses and changes in farm management practices for incorporation in the secondary impacts analysis; and upper basin irrigation and salinity management studies also had to feed into the secondary impact analysis. The relatively short period available made such sequencing difficult, so the secondary impacts analyses were based on simplified independent estimates of crop losses reported upon in detail. Inputs from the upper basin farm management studies consisted of estimates of acreages and associated cropping patterns which appeared to be likely candidates for phase-out and these results are reported. The nexus of this study with the municipal and industrial losses study consists of the discussion of issues related to M&I secondary impacts.

The crop loss analysis for California and Arizona was based upon data provided by Robinson for California (1974, Appendicies 1,2) and Jackson for Arizona (1975). These data related yields of major crops to the total dissolved solids (TDS) concentration in the irrigation water for three classes of soil types in each major agricultural production area served by Colorado River water: Imperial Valley, Coachella Valley, Palo Verde Irrigation District, and the San Diego Coastal Area for California; and Gila/Yuma, the Colorado River Indian Reservation, and the Central Arizona Project service area for Arizona. Both because of timing problems and uncertainties surrounding future use of Colorado River water, the San Diego coastal area and the Central Arizona project area were eliminated from the secondary impacts analysis.

The model used to estimate crop losses (in 1974 dollars) was a simple profit maximizing model with frequency and method of irrigation (furrow and sprinkler) as the only farm management options. Long-run profitability (deducting full costs) and short-run profitability (deducting only variable costs) were both used as criteria to permit estimation of short-run and long-run effects. By either criterion, when a given crop became unprofitable, its acreage was dropped from production. While crop substitution could be important, data and time limitations prevented the formulation of more complete programming models which could incorporate such alternatives (see the Kleinman-Brown portion of the project report for the results of detailed programming models for some of the study areas). Thus, present estimates of crop losses must be interpreted as **upper bounds** since numerous modes of response to increased salinity were neglected.

The aggregated direct crop losses expressed in 1974 dollar values are given in Table 7-1 for Case 1 (long-run profitability) and Case 2 (short-run profitability).

It will be noted that the predicted crop output changes due to the 900 (present) to 1000 mg/l increase are **positive**. Two factors explain this. The dominant factor is a methodological one, namely that the analysis moves from current cultivational practices and yields (largely furrow irrigation and an annual frequency of irrigation of 16) to those estimated to be optimal at 1000 mg/l. This usually involves an increase in the frequency of irrigation. When the frequency of irrigation increases in response to higher salinity, gross output (yield) may increase, although farm profitability falls.

The effect that these changes in agricultural outputs can be expected to have on other sectors of the regional California-Arizona economy was traced through the two-state input-output (I-O) and trade model constructed by Ireri and Carter (1970). That 27 sector model was changed to make the household-government sector an active (endogenous) part of the model and to up-date prices to 1974 levels.

Two somewhat different types of crop losses had to be distinguished in the analysis: 1) Reductions in yields with the acreage remaining profitable and in production; 2) the dropping of acreages when they become unprofitable. When the latter occurs, especially before substantial increases in salinity have occurred, the usual kind of backward I-O impacts on supplying industries can be expected to occur and the existing I-O model can be assumed to remain appropriate for the analysis. However, when yields are substantially changed by salinity with production continuing, the I-O linkages as represented by the technical coefficients change. This requires a revision of the I-O model for each salinity increment as detailed in a later section. In fact, under 1974 agricultural prices, very little acreage was predicted to be dropped.

A second major consideration in the analysis is the existence or nonexistence of "forward linkages," i.e. the extent to which other industries in the region, especially agricultural products processing industries, are dependent upon locally produced agricultural products as inputs. Under some conditions, forward linkages can be expected to be inflexible, especially in the shortrun under sudden output changes. An additional multiplier effect may then occur as forward-linked industries are forced to reduce their levels of operation.

The following Table 7-2 summarizes the projected annual regional income losses from the full 900 to 1400 mg/l increase in salinity. Regional income losses are approximated by changes, direct and indirect, in payments to the household-government sector.

Table 7-2. Projected annual regional income losses from an increase in Colorado River salinity from 900 to 1400 mg/l under alternative cases (millions of 1974 dollars).

	California	Arizona	Total
Case 1 (Long-run Adjustment):			
No Forward Linkages	117	19	136
1-Stage Forward Linkages	492	39	531
Case 2 (Short-run Adjustment):			
No Forward Linkages	54	10	64
1-Stage Forward Linkages	201	15	216

An inspection of the detailed Tables 7-22 through 7-30 indicates that the incidence of income losses as a function of increases in salinity level is quite uneven, i.e. these losses do not increase uniformly with salinity level. Some of this may be due to the discrete steps in TDS chosen for the analysis.

Translating the incremental regional income losses into dollars per mg/l results in the following figures for Case 1 (long-term adjustment).

Table 7-1. Summary of changes in crop output: California and Arizona (1,000's of 1974 dollars).

	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
Case 1 (LR Profitability)						
California	11,054	-25,231	-3,490	- 5,832	-24,748	-48,247
Arizona	3,389	- 3,166	- 849	- 6,380	- 1,562	- 8,568
Total	14,443	-28,397	-4,339	-12,212	-26,310	-56,815
Case 2 (SR Profitability)						
California	13,607	- 4,964	-5,094	-18,877	- 6,197	-21,525
Arizona	3,537	- 1,186	- 919	- 6,507	- 438	- 5,513
Total	17,144	- 6,150	-6,013	-25,384	- 6,635	-27,038

Table 7-3. Regional income loss per mg/l (dollars).

	900-1100	1100-1200	1200-1300	1300-1400
Case 1 (LT Profitability):				
No Forward Linkage	80,000	239,000	290,000	643,000
1-Stage Forward Linkage	805,000	543,000	608,000	2,556,000

Table 7-3a. Regional income multipliers (dollars reduction in payments to households and government per dollar direct income loss in agriculture).

	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Long-Run Adjustment and No Forward Linkages					
California	3.6	2.6	3.3	3.0	2.5
Arizona	2.8	2.2	2.7	1.9	2.0
Long-Run Adjustment and 1-Stage Forward Linkages					
California	7.7	10.0	7.6	8.5	9.8
Arizona	4.9	5.7	5.6	1.8	8.5

The progression of losses per mg/l and the extreme importance of the forward linkage assumption are clearly shown in these figures.

A final set of insights into the regional income effects of salinity is provided by regional income multipliers which express the ratio of total direct and indirect regional income losses to the direct income losses in agriculture.

The final substantive phase of this part of the study dealt with the evaluation of agricultural acreage phase-out in the upper basin as a measure for reducing the salt load in the river. Other steps such as control of point sources, canal lining programs, and changes in irrigation practice would also have some regional income effects, especially during the construction phase. Such effects can be expected to be relatively small and would disappear altogether after project construction. The present analysis has been confined to permanent agricultural acreage phase-outs.

The origins of the salinity concentrations in the lower Colorado River have been estimated by EPA (1971, also see Table 7-33 of this report). Of the 1960 concentration at Hoover Dam of 697 mg/l, 37 percent was attributable to irrigation above the dam—26 percent to added salt load, and 11 percent to consumptive water use (EPA, 1971, Table 1, p. 15). In terms of the total salt load, irrigation accounted for 3.5 million tons per year out of a total of 10.7 million tons. The same study estimated that the average salt pickup above Hoover Dam averaged 2 tons per irrigated acre per year, while some particular areas contributed 4 to 8 tons per acre per year. When it is observed that much irrigated agriculture is economically marginal because of poor soils, steep terrain, and short growing season, the potential importance of acreage phase-out as a part of a basin-wide salinity control program stands out.

The particular acreages studied here were identified by Robert A. Young and others in their part of this study and consist of 8800 acres of marginal irrigated land in the Grand Valley and 10,200 acres in the Uncompaghre Valley. The average gross value of output was estimated to be $150 per acre in 1974 prices or about $100 per acre in 1970 prices, the latter being the price level in which the analysis was conducted. The crops consisted of corn, grains, alfalfa, and pasture, which fall partially into the Range Cattle sector of the I-O model. Three cases were studied: the Grand Valley phase-out, the Uncompaghre phase-out and both together. Key results are shown in Table 7-4. In interpreting these figures, it must be remembered that the present impact analysis had to assume a

Table 7-4. Summary of upper basin impacts of agricultural acreage phase-out.

	8800 Acres in Grand Valley	10,200 in Uncompaghre	Total
Direct Loss in Value of Output ($/yr)	$892,000	$1,034,000	$1,926,000
Direct + Indirect Loss of Regional Income ($/yr)	954,000	1,104,000	2,058,000
Regional Income Loss Per Acre	108	108	108
Total Annual Reduction in Consumptive Uses of Water	14,800	16,000	30,800
Regional Income Loss Per Acre-Foot of Water Saved	64	70	67
Range of Reduced Salt Loads[a]	35,200 to 70,400	40,800 to 81,600	76,000 to 152,000

[a] Using the EPA range of 4 to 8 tons/acre/year.

non-selective choice of acreage from the hydrologic viewpoint, i.e. that the acreages phased out were, in fact, average in withdrawal and consumptive use. It was also assumed that no new economic activity replaced the phased-out acreages, i.e. that any compensation received by landowners was not re-invested in the region.

In the section "Indirect Impacts of Municipal and Industrial Salinity Related Losses" the issues involved in estimating the secondary effects of M&I damages are discussed. Because one pattern of expenditure is substituted for another somewhat similar pattern, it is concluded that secondary effects will be nil.

CROP LOSS ANALYSIS

This section covers the methodology and results of the crop loss analysis. This analysis determines the direct economic impact in agriculture using a simple profit maximization scheme. These results are aggregated into sectors conformable to the input/output table to calculate direct and indirect economic impacts in the Arizona and California economies. The discussion is presented in three parts. First, the raw data and sources are discussed. Second, the profit maximization technique is elaborated upon and the results are displayed for each region. Finally, these are aggregated by region and by input/output sector to serve as a basis of comparison to other estimates and to be used for the indirect analysis.

The Basic Data

The data inputs into the direct agricultural analysis consist of physical yield data which present total crop output as a function of salinity, number of annual irrigations, and soil type; crop production guildelines which give best-practice crop budgets; annual production reports which give crop prices; sprinkler cost estimates; a monthly breakdown for annual irrigation; and price indexes.

The physical yield data were provided in Appendices 1 and 2. A detailed discussion of methodology and results is presented by Robinson for California in the "Agricultural Consequences" subsection of this report. Essentially, by finding a statistical relationship between electrical conductivity and total dissolved solids (TDS) in the irrigation water and by estimating the electrical conductivity in the root zone, it was possible to determine a relationship between TDS in the irrigation water and relative yield for each crop, using the California Committee of Consultant's yield declination curves. To show the impact of different irrigation practices, the zone from which water was extracted was varied. The average pure water yields and estimated acreage to determine output on each soil type as a function of TDS in the irrigation water and the frequency of irrigation, holding the total quantity applied constant. Since many crops are not grown the entire year, Robinson (Appendix 2) provides Table 2-21, p. 96, which shows the monthly frequency of irrigation.

Optimum production practices are given by the "Guidelines to Production Costs and Practices" compiled by the Agricultural Extension Service of the University of California (September 1973). These guildelines also provide the crop budgets used in the profit calculation. Specifically, they provide labor costs and the breakdown between fixed and variable costs. Similar budgets were used for all study areas in Arizona and California (Ag. Extension Service, 1968; Ag. Extension Service, 1972; Hathorne, 1974). In those cases where the same crop appeared in different irrigation districts, the budgets were assumed to be the same.

Crop prices were taken from the annual crop reports which are published for each irrigation district (Office of Agricultural Commissioner, 1968-1972 inclusive; Shackleford, 1968-1972 inclusive; Bureau of Reclamation, 1968-1972 inclusive). These were adjusted for changes in the agricultural price level using the U.S. Department of Agriculture's "Prices Received by Farmers" price index (USDA, 1968-1974 inclusive). Similarly, the "Prices Paid" index was used to adjust cost figures (USDA, 1968-1974 inclusive). All price figures are expressed in 1974 dollars.

The last data item used is the cost of using sprinkler irrigation. This was provided by Robinson and was estimated at $93 per acre per year for full season sprinkler irrigation.

Optimal Choice of Irrigation Regime

The output of each crop as a function of TDS is determined on the basis of profit calculations. For each level of TDS there are five irrigation regimes, each giving a different level of output. That which maximizes total profit is assumed to be the one chosen.

A computer program was written to calculate total profit for each irrigation frequency and sprinkler application and then to select the maximum value. Total profit is calculated as the difference between cost and revenue at the initial TDS level. This is assumed to be 900 mg/l and an annual rate of 16 irrigations. Incremental profits for moving to annual frequencies of 22, 29, and 35 furrow irrigations or to 35 sprinkler applications are calculated by comparing incremental cost to incremental revenue. Incremental cost is determined by the additional labor required to increase the frequency of irrigation. This is the only variable cost since the physical yield tables were constructed holding total annual water usage constant. Labor cost per irrigation is determined from the "Guidelines" and is assumed the source for all levels of irrigation.

As mentioned above, the annual irrigation number does not give the actual number of irrigations for crops whose growing period is less than 12 months. Thus, Robinson's monthly breakdown is used in conjunction with the best-practice growing period for each crop to determine the actual number of irrigations. The number of incremental irrigations is then determined by the difference between these actual numbers for each level of annual irrigation. The incremental cost is thus labor cost per irrigation multiplied by the number of incremental irrigations.

Total cost figures were given by the "Guildelines." These costs included the return to land as a cost to the individual firm. Since land rents are not resource costs and since the non-agricultural value of the land is near zero, land rents were excluded from the total cost figures.

In the case of shifting to sprinkler irrigation, Robinson's estimate of $93 per acre per year is entered as an addition to total cost. This includes labor and fuel cost. Hence, the irrigation labor cost already included in total cost is subtracted to avoid double counting of irrigation labor.

Incremental revenue is calculated analogously to total revenue by replacing total output with incremental output. However, since agricultural prices fluctuate from year to year, a 5-year average was calculated and adjusted for inflation to 1974 dollars. This was the price used in these calculations for each crop.

Economic theory and observed farming practice suggest that any farm will attempt to operate at a position of approximate maximum profit. Hence, this is the criterion used to select the preferred irrigation scheme for each level of salinity. However, as salinity increases, some crops on some types of soil will begin to show negative profits. In the short term, the farm may continue to grow the crop if it can cover all variable costs and a portion, no matter how small, of fixed cost. Thus, a farm might still operate with negative long-run profit. In the long run, however, all costs are variable and all costs must be covered. To reflect this difference between the long and short run shut down criteria, two cases were run. Case I incorporates the long-run profitability criterion. Acreage is taken out of cultivation as soon as profit becomes zero or negative. Case II reflects the short-run criterion. In this case acreage is left under cultivation as long as variable costs are covered. Each case generates estimates of output for each crop on each soil type at each level of salinity. Since Case I is a more stringent test for phasing out acreage, it is not surprising that output falls more rapidly under this case than under Case II. An example of the computer output for this part of the analysis is presented in Table 7-5.

It is frequently the case that output increases rather than decreases when salinity increases from 900 mg/l to 1000 mg/l. An example of this pattern is given in Table 7-6. This is partly the result of assuming that 900 mg/l and 16 annual irrigations are the initial positions. In many cases this is not the profit maximizing position. The level of output for 900 mg/l is that which obtains at 16 annual irrigations regardless of the profit criterion. When salinity increases to 1000 mg/l, the profit maximization criterion comes into play and production becomes more efficient. Better irrigation practice is used. In many cases, this effect more than counter balances the salinity increase, causing total output to rise.

Other cases where output rises with salinity occur when a greater irrigation frequency becomes profitable and counteracts the falling outputs caused by salinity. Such instances are sufficiently insignificant so that they disappear when results are aggregated by irrigation district or by input/output sector.

There is one other peculiarity of the assumptions made concerning the initial position. Since this is not a profit maximizing position, it is possible (and indeed it does occur) that this position violates the shutdown criterion for both Case I and Case II. Since this position is assumed to reflect current practice, this type of acreage is phased out only if losses become worse than they are initially.

In reality when acreage is shut down, a farm will attempt to use that acreage to produce an alternative crop which is still profitable on that soil type under the prevailing salinity. To try to capture this effect without building a complete programming model, some experimentation was done with crop substitution. With no effective method for gaging market or other constraints on acreage, the results obtained were often unmeasurable. Therefore, the subsequent analysis deals only with the results of Cases I and II. In the absence of a complete linear programming model, the farm management variable is irrigation practice and the major decision is whether or not to shut down certain acreage. Therefore, our crop loss estimates represent an upper bound on the actual crop losses.

Aggregation and Presentation of Results

The results of the crop loss analysis are presented in Tables 7-7 through 7-15 and 7-20 through 7-24. These show the total estimated output in a variety of ways.

For purposes of the secondary impacts analysis using an input-output model of the Arizona-California regional economy, it was desirable to partition total crop losses into those associated with the phasing out of acreage on one hand and with yield reductions for given input levels on the other. The need for partitioning losses in this way arises from the fact that if acreage is phased out, all inputs also cease, whereas under yield changes the relationships of crop outputs to the various inputs also change. The ways of handling these changes within the I-O framework are different. An illustration for the Gila/Yuma area is given in Table 7-15.

Finally, Tables 7-16 to 7-19 show the total crop losses aggregated by state into the appropriate sectors of the I-O model used in the further analysis.

Table 7-5. Sample output of profit maximizing program, Colorado River Indian Reservation, Case 2, alfalfa (all figures are in 1974 dollars).

Soil Type 1 Irrigation Increment	Total Dissolved Solids					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
	Marginal Profit Per Acre					
16 to 22 Annual Irrigations	- 9.69	- 9.69	- 9.69	- 9.69	- 9.69	- 9.69
22 to 29 Annual Irrigations	-11.30	-11.30	-11.30	-11.30	-11.30	-11.30
29 to 35 Annual Irrigations	- 9.69	- 9.69	- 9.69	- 9.69	- 9.69	- 9.69
	Total Profit Per Acre					
16 Irrigations	198.62	198.62	198.62	198.62	198.62	198.62
22 Irrigations	188.94	188.94	188.94	188.94	188.94	188.94
29 Irrigations	177.64	177.64	177.64	177.64	177.64	177.64
35 Irrigations	167.95	167.95	167.96	167.95	167.95	167.95
35 Irrigations by Sprinkler	131.21	131.21	131.21	131.21	131.21	131.21
	Total Output at Maximum Profit in 10^3 Dollars					
	9993	9993	9993	9993	9993	9993
Irrigation Frequency for Maximum Profit	16	16	16	16	16	16
	Marginal Output Loss					
	0.00	0.00	0.00	0.00	0.00	0.00

Table 7-6. Sample output of profit maximization program showing increased output at 1000 mg/l, Gila/Yuma, Case 1, alfalfa (all figures are in 1974 dollars).

Marginal Profit Per Acre	Total Dissolved Solids					
Soil Type 3 Irrigation Increments	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
16 to 22 Annual Irrigations	12.01	12.08	18.37	19.87	19.95	23.02
22 to 29 Annual Irrigations	2.03	-71.40	2.03	3.60	5.10	5.18
29 to 35 Annual Irrigations	5.79	83.86	10.43	12.08	12.08	15.15
	Total Profit Per Acre					
16 Irrigations	-25.56	-41.30	-60.18	-75.84	-93.15	-111.96
22 Irrigations	-13.56	-29.22	-41.81	-55.97	-73.20	-88.94
29 Irrigations	-11.53	-100.62	-39.78	-52.37	-68.10	-83.76
35 Irrigations	- 5.74	-16.76	-29.35	-40.29	-56.02	-68.61
35 Irrigations by Sprinkler	-49.17	-67.98	-85.29	-96.30	-110.39	-124.55
	Total Output at Maximum Profit					
	1618469.0	1749722.3	0.0	0.0	0.0	0.0
	Marginal Output Loss					
	0.00	-131,253.30	1,749,722.31	0.0	0.00	0.00

Table 7-7. Coachella Valley, Case 1.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	1,382,511.5	1,387,708.9	1,372,116.7	1,372,116.7	1,335,734.8	1,320,142.6
Carrots	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6
Corn	4,399,234.2	4,574,203.7	4,524,212.4	4,474,221.1	4,449,225.5	4,349,242.9
Dates	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1
Grapefruit	14,010,409.8	13,789,483.5	13,660,609.8	13,550,146.6	12,629,620.4	12,629,620.4
Grapes	23,763,518.4	23,916,831.4	23,840,174.9	23,840,174.9	23,763,518.4	23,686,861.9
Lemon/Limes	1,925,773.3	1,976,451.5	1,951,112.4	1,951,112.4	1,824,416.8	1,824,416.8
Onions	944,179.6	944,179.6	944,179.6	944,179.6	931,420.4	944,179.6
Oranges/Tangerines	57,011,712.8	57,161,237.7	57,118,516.3	56,798,105.8	56,392,252.4	56,392,252.4

Table 7-8. Gila/Yuma District, Case 1.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	10,090,580.0	10,221,833.3	8,460,047.3	8,460,047.3	8,472,111.0	8,460,047.3
Cantaloupe	9,184,273.8	9,896,785.4	9,752,501.8	9,649,187.6	9,529,841.9	9,399,808.6
Cotton	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5
Grapefruit	2,992,284.3	2,997,773.1	2,997,773.1	2,997,773.1	2,997,773.1	2,997,773.1
Lemons	17,596,546.1	17,642,379.7	17,642,379.7	17,642,379.7	17,642,379.7	17,642,379.7
Lettuce	20,057,105.8	21,698,141.7	21,201,945.0	20,798,411.6	16,766,066.5	16,664,435.9
Oranges/Tangerines	9,406,613.0	9,419,531.7	9,098,411.3	9,098,411.3	9,098,411.3	9,098,411.3
Sorghum	1,958,683.6	1,963,663.3	1,963,663.3	1,956,193.8	1,947,064.3	1,937,104.9
Wheat	5,187,316.9	5,187,316.9	5,187,316.9	5,187,316.9	5,167,483.3	5,147,649.7

Table 7-9. Imperial Valley, Case 1.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	51,625,294.5	53,780,525.2	49,219,455.5	47,565,441.2	46,763,494.9	24,459,362.8
Asparagus	6,054,313.8	6,258,851.4	6,177,036.4	6,258,851.4	6,013,406.3	5,808,868.6
Barley	8,196,485.4	8,196,485.4	8,196,485.4	8,161,269.6	8,090,837.9	8,196,485.4
Cantaloupe	17,184,438.9	18,037,200.5	17,727,105.4	17,391,169.0	17,132,756.4	16,951,867.6
Carrots	8,047,797.4	8,650,223.7	8,650,223.7	8,650,223.7	8,511,202.3	8,294,946.7
Cotton	33,907,492.0	33,907,492.0	33,907,492.0	33,800,431.8	33,754,548.9	33,678,077.3
Lettuce	51,023,729.1	57,411,553.0	41,008,252.2	41,008,252.2	41,008,252.2	40,377,356.0
Onions	3,673,796.9	3,856,783.0	3,856,783.0	3,856,783.0	3,814,555.4	3,814,555.4
Sorghum	9,554,057.7	9,631,662.8	9,485,075.3	9,502,320.9	9,338,487.8	9,174,654.7
Sugar Beets	39,942,009.2	39,942,009.2	39,942,009.2	39,769,100.1	39,942,009.2	39,596,190.9
Tomatoes	5,656,080.3	6,016,440.0	5,895,014.4	5,746,170.2	5,656,080.3	5,565,990.4
Wheat	9,035,313.3	9,176,022.9	9,026,519.0	8,824,249.0	8,789,071.6	8,595,595.9

Table 7-10. Colorado River Indian Reservation, Case 1.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	13,683,422.2	13,765,611.6	13,688,309.2	13,563,914.4	13,607,896.8	12,646,058.9
Cantaloupe	3,660,536.0	3,760,177.3	3,721,827.4	3,691,181.7	3,656,683.8	3,618,333.9
Lettuce	12,409,121.7	13,463,179.2	13,258,177.5	13,091,636.9	11,272,555.5	11,293,919.1
Onions	632,021.1	394,437.0	268,829.6	268,829.6	0.0	0.0
Sorghum	910,215.2	757,309.6	757,309.6	757,309.6	757,309.6	433,779.6
Wheat	4,367,781.6	4,357,563.6	4,360,707.6	4,347,345.7	4,352,061.7	4,340,271.7
Cotton	14,055,243.3	14,055,243.3	14,055,243.3	14,055,243.3	14,028,828.2	14,055,243.3

Table 7-11. Palo Verde Irrigation District, Case 1.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	10,510,509.0	8,716,154.1	6,079,755.6	5,984,524.4	6,119,852.9	6,079,755.6
Cantaloupe	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0
Onions	6,963,691.4	7,285,711.8	7,285,711.8	7,285,711.8	7,232,041.8	7,205,206.7
Sorghum	883,836.6	881,249.7	818,303.3	807,093.7	685,512.3	685,512.3
Wheat	3,544,122.3	3,579,299.7	3,543,242.9	3,498,391.7	3,487,838.5	3,444,746.2
Lettuce	11,291,554.3	12,445,377.7	12,099,230.6	11,832,657.7	9,429,522.1	9,314,139.7
Watermelon	1,079,044.7	1,079,044.7	1,079,044.7	1,074,809.8	1,079,044.7	1,079,044.7
Cotton	6,265,774.2	6,265,774.2	6,229,392.2	6,199,074.0	6,140,458.7	6,095,991.9
Grapefruit	3,209,133.6	3,226,294.8	3,226,294.8	3,226,294.8	3,226,294.8	3,226,294.8
Lemons	11,297,350.3	11,343,181.3	11,343,181.3	11,343,181.3	11,343,181.3	11,343,181.3

Table 7-12. Gila/Yuma District, Case 2.

Crop (TDS)	Acreage					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	33,410.0	33,410.0	33,410.0	33,410.0	33,410.0	33,410.0
Cantaloupe	7,630.0	7,630.0	7,630.0	7,630.0	7,630.0	7,630.0
Cotton	19,880.0	19,880.0	19,880.0	19,880.0	19,880.0	19,880.0
Grapefruit	2,300.0	2,300.0	2,300.0	2,300.0	2,300.0	2,300.0
Lemons	10,700.0	10,700.0	10,700.0	10,700.0	10,700.0	10,700.0
Lettuce	13,250.0	13,250.0	13,250.0	13,250.0	9,670.0	9,670.0
Oranges/Tangerines	17,600.0	17,600.0	17,600.0	17,600.0	17,600.0	17,600.0
Sorghum	12,130.0	12,130.0	12,130.0	12,130.0	12,130.0	12,130.0
Wheat	29,060.0	29,060.0	29,060.0	29,060.0	29,060.0	29,060.0

Table 7-13. Aggregate output by district, Case 1 (thousands of 1974 dollars).

	Acreage					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Coachella	129,426	129,739	129,399	128,919	127,315	127,135
Gila/Yuma	87,018	89,572	86,849	86,335	82,166	81,893
Imperial Valley	243,900	254,865	233,091	230,534	228,814	204,513
Indian Reservation	49,718	50,553	50,110	49,775	47,675	46,387
Palo Verde	57,277	57,054	53,936	53,484	50,976	50,706

Table 7-14. Aggregate output by district, Case 2 (thousands of 1974 dollars).

	Acreage					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Coachella	129,426	130,291	129,952	129,727	128,624	128,076
Gila/Yuma	87,018	89,572	88,834	88,254	83,984	83,630
Imperial Valley	243,900	254,865	250,759	246,566	231,521	227,920
Indian Reservation	49,718	50,701	50,252	49,913	47,675	47,592
Palo Verde	57,277	59,054	58,534	67,874	55,148	53,101

Table 7-15. Illustration of crop losses factored into acreage and yield reductions (1974 dollars).

Crop (TDS)	Acreage					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
	Marginal Output Loss Caused by Acreage Reduction					
Alfalfa	0	0	1,749,722	0	0	0
Cantaloupe	0	0	0	0	0	0
Cotton	0	0	0	0	0	0
Grapefruit	0	0	0	0	0	0
Lemons	0	0	0	0	0	0
Lettuce	0	0	0	0	4,032,345	0
Oranges/Tangerines	0	0	321,120	0	0	0
Sorghum	0	0	0	0	0	0
Wheat	0	0	0	0	0	0
	Marginal Output Loss Caused by Yield Reduction					
Alfalfa	0	-131,253	12,064	0	-12,064	12,064
Cantaloupe	0	-712,512	144,284	103,314	119,346	130,033
Cotton	0	0	0	0	0	0
Grapefruit	0	-5,489	0	0	0	0
Lemons	0	-45,834	0	0	0	0
Lettuce	0	-1,641,036	496,197	403,533	0	101,631
Oranges/Tangerines	0	-12,919	0	0	0	0
Sorghum	0	-4,980	0	7,470	9,129	9,959
Wheat	0	0	0	0	19,834	19,834

Table 7-16. ***Changes in crop output, California, Case 1 (1,000's of 1974 dollars).***

Sector	Crops	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
4	Barley, Wheat, Sorghum, Corn	426	-445	-326	-427	-392	-1,164
5	Cotton	0	-36	-137	-104	-121	-398
6	Asparagus, Onions, Lettuce, Tomatoes, Watermelon, Cantaloupe	10,067	-17,263	-674	-3,241	-1,452	-12,563
7	Dates, Grapes	153	-77	0	-77	-77	-78
8	Grapefruit, Lemons, Limes, Oranges, Tangerines	42	-197	-431	-1,453	0	-2,039
9	Alfalfa	366	-7,213	-1,749	-703	-22,360	-31,659
10	Sugar Beets	0	0	-173	173	-346	-346
	Total Value	11,054	-25,231	-3,490	-5,832	-24,748	-48,247

Table 7-17. ***Changes in crop output, California, Case 2 (1,000's of 1974 dollars).***

Sector	Crops	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
4	Barley, Wheat, Corn, Sorghum	426	-388	-349	-298	-459	-1,068
5	Cotton	0	-36	-137	-104	-121	-398
6	Asparagus, Onions, Lettuce, Tomatoes, Watermelon, Cantaloupe	10,067	-2,752	-2,109	-16,316	-1,452	-12,562
7	Dates, Grapes	153	-77	0	-77	-77	-78
8	Grapefruit, Lemons, Limes, Oranges, Tangerines	595	-197	-171	-992	-363	-1,128
9	Alfalfa	2,366	-1,514	-2,155	-1,263	-3,379	-5,945
10	Sugar Beets	0	0	-173	173	-346	-346
	Total Value	13,607	-4,964	-5,094	-18,877	-6,197	-21,525

Table 7-18. ***Changes in crop output, Arizona, Case 1 (1,000's of 1974 dollars).***

Sector	Crops	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
4	Barley, Wheat, Corn, Sorghum	-158	-3	-21	-24	-365	-565
5	Cotton	0	0	0	-26	+ 26	0
6	Asparagus, Onions, Lettuce, Cantaloupe, Tomatoes, Watermelon	3270	-1009	-704	-6274	-249	-4966
8	Grapefruit, Lemons, Limes, Oranges, Tangerines	64	-321	0	0	0	-257
9	Alfalfa	213	-1839	-124	-56	-974	-2780
	Total Value	3389	-3166	-849	-6380	-1562	-8568

Table 7-19. ***Changes in crop output, Arizona, Case 2 (1,000's of 1974 dollars).***

Sector	Crops	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
4	Barley, Wheat, Corn, Sorghum	-10	-2	-25	-162	-45	-244
5	Cotton	0	0	0	-26	+ 26	0
6	Asparagus, Lettuce, Onions, Cantaloupe, Tomatoes, Watermelon	3270	-1009	-704	-6274	-249	-4966
8	Grapefruit, Lemon, Limes, Oranges, Tangerines	64	-5	5	0	0	64
9	Alfalfa	213	-170	-195	-45	-170	-367
	Total Value	3537	-1186	-919	-6507	-438	-5513

Table 7-20. Coachella District, Case 2.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	1,382,511.5	1,387,708.9	1,372,116.7	1,372,116.7	1,372,116.7	1,351,327.0
Carrots	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6	12,894,185.6
Corn	4,399,234.2	4,574,203.7	4,524,212.4	4,474,221.1	4,449,225.5	4,349,242.9
Dates	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1	13,094,791.1
Grapefruit	14,010,409.8	14,341,799.2	14,212,925.5	14,102,462.4	13,181,936.1	13,181,936.1
Grapes	23,763,518.4	23,916,831.4	23,840,174.9	23,840,174.9	23,763,518.4	23,686,861.9
Lemon/Limes	1,925,773.3	1,976,451.5	1,951,112.4	1,951,112.4	1,925,773.3	1,925,773.3
Onions	944,179.6	944,179.6	944,179.6	944,179.6	931,420.4	944,179.6
Oranges/Tangerines	57,011,712.8	57,161,237.7	57,118,516.3	57,054,434.2	57,011,712.8	56,648,580.9

Table 7-21. Gila/Yuma, Case 2.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	10,090,580.0	10,221,833.3	10,128,701.4	10,058,249.2	9,968,977.7	9,875,845.8
Cantaloupe	9,184,273.8	9,896,785.4	9,752,501.8	9,649,187.6	9,529,841.9	9,399,808.6
Cotton	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5	10,545,481.5
Grapefruit	2,992,284.3	2,997,773.1	2,997,773.1	2,997,773.1	2,997,773.1	2,997,773.1
Lemons	17,596,546.1	17,642,379.7	17,642,379.7	17,642,379.7	17,642,379.7	17,642,379.7
Lettuce	20,057,105.8	21,698,141.7	21,201,945.0	20,798,411.6	16,766,066.5	16,664,435.9
Oranges/Tangerines	9,406,613.0	9,419,531.7	9,414,610.3	9,419,531.7	9,419,531.7	9,419,531.7
Sorghum	1,958,683.6	1,963,663.3	1,963,663.3	1,956,193.8	1,947,064.3	1,937,104.9
Wheat	5,187,316.9	5,187,316.9	5,187,316.9	5,187,316.9	5,167,483.3	5,147,649.7

Table 7-22. Imperial Valley District, Case 2.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	51,625,294.5	53,780,525.2	52,377,119.1	50,522,618.3	49,470,063.7	47,866,171.1
Asparagus	6,054,313.8	6,258,851.4	6,177,036.4	6,258,851.4	6,013,406.3	5,808,868.6
Barley	8,196,485.4	8,196,485.4	8,196,485.4	8,161,269.6	8,090,837.9	8,196,485.4
Cantaloupe	17,184,438.9	18,037,200.5	17,727,105.4	17,391,169.0	17,132,756.4	16,951,867.6
Carrots	8,047,797.4	8,650,223.7	8,650,223.7	8,650,223.7	8,511,202.3	8,294,946.7
Cotton	33,907,492.0	33,907,492.0	33,907,492.0	33,800,431.8	33,754,548.9	33,678,077.3
Lettuce	51,023,729.1	57,411,553.0	55,518,864.5	54,083,575.6	41,008,252.2	40,377,356.0
Onions	3,673,796.9	3,856,783.0	3,856,783.0	3,856,783.0	3,814,555.4	3,814,555.4
Sorghum	9,554,057.7	9,631,662.8	9,485,075.3	9,502,320.9	9,338,487.8	9,174,654.7
Sugar Beets	39,942,009.2	39,942,009.2	39,942,009.2	39,769,100.1	39,942,009.2	39,596,190.9
Tomatoes	5,656,080.3	6,016,440.0	5,895,014.4	5,746,170.2	5,656,080.3	5,565,990.4
Wheat	9,035,313.3	9,176,022.9	9,026,519.0	8,824,249.0	8,789,071.6	8,595,595.9

Table 7-23. Colorado River Indian Reservation District, Case 2.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	13,683,422.2	13,765,611.6	13,688,309.2	13,563,914.4	13,607,896.8	13,530,594.4
Cantaloupe	3,660,536.0	3,760,177.3	3,721,827.4	3,691,181.7	3,656,683.8	3,618,333.9
Lettuce	12,409,121.7	13,463,179.2	13,258,177.5	13,091,636.9	11,272,555.5	11,293,919.1
Onions	632,021.1	394,437.0	268,829.6	268,829.6	0.0	0.0
Sorghum	910,215.2	904,965.2	899,715.3	895,121.5	757,309.6	754,028.3
Wheat	4,367,781.6	4,357,563.6	4,360,707.6	4,347,345.7	4,352,061.7	4,340,271.7
Cotton	14,055,243.3	14,055,243.3	14,055,243.3	14,055,243.3	14,028,828.2	14,055,243.3

Table 7-24. Palo Verde District, Case 2.

Crop (TDS)	Total Output (1974 Dollars)					
	900 mg/l	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
Alfalfa	10,510,509.0	10,716,007.7	10,620,776.6	10,320,046.7	10,109,535.8	8,355,278.2
Cantaloupe	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0	2,232,685.0
Onions	6,963,691.4	7,285,711.8	7,285,711.8	7,285,711.8	7,232,041.8	7,205,206.7
Sorghum	883,836.6	881,249.7	875,213.8	861,417.3	868,315.5	804,506.8
Wheat	3,544,122.3	3,579,299.7	3,543,242.9	3,498,391.7	3,487,838.5	3,444,746.2
Lettuce	11,291,554.3	12,445,377.7	12,099,230.6	11,832,657.7	9,429,522.1	9,314,139.7
Watermelon	1,079,044.7	1,079,044.7	1,079,044.7	1,074,809.8	1,079,044.7	1,079,044.7
Cotton	6,265,774.2	6,265,774.2	6,229,392.2	6,199,074.0	6,140,458.7	6,095,991.9
Grapefruit	3,209,133.6	3,226,294.8	3,226,294.8	3,226,294.8	3,226,294.8	3,226,294.8
Lemons	11,297,350.3	11,343,181.3	11,343,181.3	11,343,181.3	11,343,181.3	11,343,181.3

INDIRECT IMPACT ANALYSIS

This section presents a discussion of ways in which regional input-output models can be used to estimate indirect effects of salinity-caused crop losses. It then presents the results of applying the methodology to the lower Colorado Basin, in particular the two state region of California and Arizona.

Methodology

The basic task of the indirect impact analysis was to find existing models which would permit the estimation of the region-wide effects of crop losses. Input-output (I-O) models have been the prevalent tool of regional analysis and the existence of numerous state and multi-state models made this approach attractive. On the other hand, the appropriateness of I-O analysis for the salinity problem, involving as it does, changes in the input-yield relations and in farm management practices, could very well be questioned.

The technique of input-output analysis has been presented in so many excellent sources that it will not be repeated here (see Miernyk, 1965, or Baumol, 1972). Suffice it to say that the basic model is static and assumes a fixed technology. Thus investment demands, public and private, which may be generated by adaptations of the regional economy and by farm managers to changing salinity conditions, are either ignored or taken into account in some ad-hoc way. Further, changes in input-yield relations must be entered as non-standard phases of the I-O analysis.

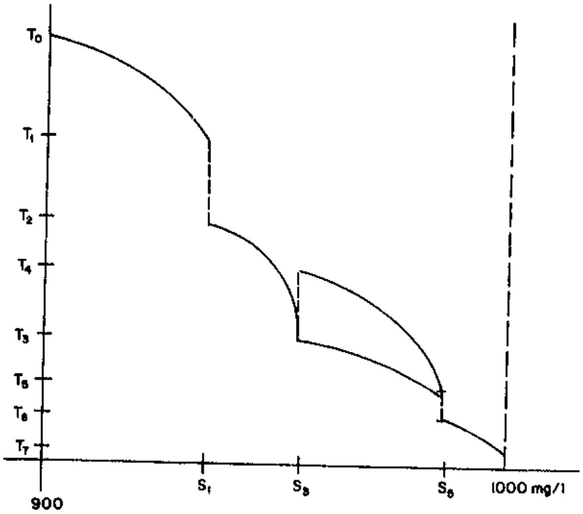

Figure 7-1. Typical change in crop output (T) in response to salinity levels (S).

Consider what happens to the total output of a particular crop as salinity increases over some finite interval, say 900 mg/l to 1000 mg/l. Figure 1 illustrates a hypothetical situation. In the salinity interval 900 to S_1, yields are changing for a given management scheme (i.e. inputs remain constant, including the frequency of irrigation). At S_1, the poorest soil type becomes unprofitable, so all of that soil type is phased out of production. Between S_1 and S_2, the production relationship on soil types 1, 2, and 3 continues to change. However, at S_3 it becomes profitable to increase the frequency of irrigation and total crop output jumps up (although farm profits continue to fall). Between S_3 and S_5, yields continue to be impacted by salinity until, at S_5, soil type 3 becomes unprofitable.

What would the data show using this discrete process of analyzing profitability only at 900 and 1000 mg/l? First, the data would show all of soil type 4 being taken out of production. The total initial production on that land has been lost and will be accounted for as an "acreage change." Secondly, all of soil type 3 is shown as being dropped from production and all the associated crop output will be listed as "acreage change." For soil types 1 and 2, yield reductions will be calculated on a net basis, including the jump in production which occurred at S_3. Clearly, the present discrete method of analysis will not uncover the detailed order of these events as they occur in reality. The data will show that at 1000 mg/l, soil types 3 and 4 become unprofitable and that a change in the frequency of irrigation becomes profitable on the remaining lands.

The importance to secondary impact analysis of the distinction between yield changes without acreage reduction and acreage reductions should be fairly clear from the following observations:

1. Pure yield reductions do not change the demands for agricultural inputs, given existing cultivational practices.
2. Pure yield reductions do, however, reduce income payments to (farm) households and thus affect the expenditures of households.
3. Under pure yield reduction, the direct loss in (farm) household income equals the loss of crop value, while under acreage reduction the difference between crop value and input costs constitutes the (farm) household income loss.
4. Acreage reduction reduces the demand for inputs from all sectors including the household sector.
5. Both types of output reduction affect "forward linked" industries in the same manner, unless product quality varies significantly with salinity levels.

Refer again to Figure 1. Let A represent the I-O technical coefficients matrix. A is a function of S, A(S). As S varies from 900 to S_1, A(S) is continuously changing. "Backward linked" industries are not affected, however, since the production process and input rates continue as before. If forward linked industries exist, they are affected by the reduced supplies of their inputs according to their own technologies (which remain unchanged).

At S_1, the relevant technology is $A(S_1)$ and a discrete output loss of $(T_1\text{-}T_2)$ occurs. The "backward linkage effects" are appropriately analyzed by taking $(T_1\text{-}T_2)$ as a reduction in deliveries to final demand and calculating

$$[I - A(S_1)]^{-1}(T_1 - T_2) \qquad \text{(7-1)}$$

in which $(T_1\text{-}T_2)$ is interpreted as the vector of various crop losses associated with the acreage phase out.

If important forward linkages are present, the losses $(T_0\text{-}T_1)$ and $(T_1\text{-}T_2)$ are both translated into the reductions in deliveries to final demand imposed on the forward linked industries, call it $(\hat{T}_1\hat{T}_2)$, and processed through the inverse above. These calculations are only approximate for the losses $(T_0\text{-}T_1)$.

Difficulties arise in the application of this analysis since we know only A(900) and can only approximate A(1000). Which matrix is more appropriate to the analysis of acreage phase-out depends upon whether the important phase-outs occur with S close to 900 or close to 1000.

Another complexity (point 2 above) is added by the fact that while pure yield changes do not affect backward linked industries, they do cause an equal drop in (farm) household incomes (although not a drop in needed labor input). This causes reductions in farm household expenditures which affect the rest of the economy. Thus farm household income reductions due to yield changes must be reflected in the analysis.

The procedures actually used to accommodate these features of the changing economic structure can best be illustrated with a small example. Let the initial values (corresponding to S - 900 mg/l) of the intermediate flows, deliveries to final demand, and total gross outputs (TGO) of a 2-sector economy consisting of "agricultural" and "household" sectors be laid out as below:

$$\begin{array}{llll} \text{Agriculture:} & X_{11}X_{12} & F_1 & X_1 \\ \text{Households:} & X_{21}X_{22} & F_2 & X_2 \end{array} \qquad \text{(7-2)}$$

Let the crop losses experienced between 900 and 1000 mg/l be ΔX_1. We assume that ΔX_1 has resulted primarily from pure yield reductions (a fact of our empirical findings with 1974 prices) and that it is manifested in reductions in deliveries to final demand, i.e.

$$\Delta X_1 = \Delta F_1 \qquad \text{(7-3)}$$

We now calculate the new A(1000) matrix, taking cognizance only of the direct output losses, not of reduced outputs of forward linked industries, if any, since only the agricultural sectors are assumed to be experiencing changing technology. The new values replacing those in (7-2) are:

$$\begin{array}{llll} X_{11} & X_{12} & F_1 - \Delta X_1 & X_1 - \Delta X_1 \\ X_{21} - \Delta X_1 & X_{22} & F_2 & X_2 \end{array} \qquad \text{(7-4)}$$

The new A(1000) matrix is then given by

$$A(1000) = \begin{bmatrix} \dfrac{X_{11}}{X_1 - \Delta X_1} & \dfrac{X_{12}}{X_2} \\[2ex] \dfrac{X_{21} - \Delta X_1}{X_1 - \Delta X_1} & \dfrac{X_{22}}{X_2} \end{bmatrix} \qquad \text{(7-5)}$$

The new a_{11} element is larger than before and the a_{21} element is smaller than before, the latter capturing the reduced payments to (farm) households.

The analysis is completed by introducing any forward-linked reductions in deliveries to final demand (call the new levels of deliveries to final demand F_1' and F_2') and carrying out the following calculation:

$$[I - A(1000)]^{-1} \begin{bmatrix} F_1' \\ F_2' \end{bmatrix} = \begin{bmatrix} X_1' \\ X_2' \end{bmatrix} \quad \ldots\ldots\ldots\ldots(7\text{-}6)$$

In this example, the new level of X_1 would reflect the direct and indirect impacts of the salinity-induced reduction in agricultural output on agricultural TGO, while the new X_2 would reflect direct and indirect reductions in the income (output) of the household sector.

The Input-Output Model Used

The two-state input-output-trade model utilized in the present study was taken from Ireri and Carter, **California-Arizona Economic Interdependence and Water Transfer Problems** (October, 1970). The California State model had originally been constructed by Martin and Carter (1962) for 26 endogenous sectors (emphasizing agriculture) on the basis of 1954 data, but was up-dated to 1958 by Ireri and Carter. The Arizona model was construqted by Tijoriwala, Martin, and Bower (November 1968) from 1958 data on a sector basis comparable to the California model.

The definitions of the commodities or industries included in each endogenous sector are given as follows:

1. Meat Animals and Products—beef, hogs, sheep and lambs, wool and mohair.
2. Poultry and Eggs—chickens, eggs, broilers, turkeys and turkey eggs, other poultry and eggs, and hatcheries.
3. Farm Dairy Products—milk, cream, and dairy animals sold for meat.
4. Food and Feed Grains—wheat, rye, rice, corn, barley, oats, sorghum, corn, and sorghum silage.
5. Cotton—cotton lint and cottonseed.
6. Vegetables—Irish potatoes, sweet potatoes, melons, dry beans and peas, strawberries, and all other vegetables.
7. Fruit (excluding citrus) and Tree Nuts—apples, apricots, cherries, nectarines, peaches, pears, persimmons, plums, prunes, pomegranates, avacados, dates, figs, olives, grapes, tree nuts, and bush berries.
8. Citrus Fruits—oranges tangerines, lemons, grapefruit, limes, and satsumas.
9. Forage Crops—hay and pasture.
10. Miscellaneous Agriculture—legume and grass seed, vegetable seeds, greenhouse and nursery products, on-farm forest products, sugar beets, oil crops, miscellaneous crops, horses and mules, honey and beeswax, agricultural services, and hunting and fishing.
11. Grain Mill Products—flour and meal, cereal breakfast foods, rice milling, blended and prepared flour, and prepared animal feeds.
12. Meat and Poultry Processing—meat packing, prepared meats, and poultry dressing plants.
13. Dairy Products—creamery butter, natural cheese, concentrated milk, ice cream and ices, special dairy products, and fluid milk.
14. Canning, Preserving, and Freezing—canned seafood, cured fish, canning and preserving food, dehydrated fruits and vegetables, pickles and sauces, packaged seafood, and frozen fruit and vegetables.
15. Miscellaneous Agricultural Processing—bakery products (including bread baked at single retail outlets), sugar, miscellaneous food preparations, alcoholic beverages, and tobacco products.
16. Chemicals and Fertilizers.
17. Petroleum.
18. Fabricated Metals and Machinery.
19. Aircraft—aircraft and parts.
20. Primary Metals.
21. Other Manufacturing.
22. Mining.
23. Utilities.
24. Selected Services.
25. Trade and Transportation.
26. Unallocated Services.

The endogenous section of the model was constructed symmetrically, i.e., each sector had both an output row and an input column. In contrast, there were five rows and ten columns in the exogenous portion of the California and Arizona models. The exogenous sectors are as follows:

27. Scrap and By-Products.
28. Net Imports and Net Exports.

29. Maintenance Construction.

30. New Construction.

31. State and Local Government.

32. Federal Government.

33, 34. Inventory Change.

35. Gross Private Capital Formation.

36. Households.

The four "quadrants" of the 1958 table as taken from Ireri and Carter are presented in Table 7-36 at the end of this section.

Two major changes have been made in the Ireri and Carter model for purposes of the present analysis: 1) the transactions table was up-dated to reflect 1974 prices; and 2) the household sector was "endogenized" i.e. brought into the active transactions part of the I-O matrix. The up-dating to 1974 prices naturally constitutes only a partial up-dating since

$$X_{ij}^{1958} = p_{i'1958} \cdot Q_{ij'} \quad \text{.......................} (7\text{-}7)$$

The price up-dated transactions (and final demands) can be calculated as

$$X_{ij}^{1974} = \frac{p_{i'1974}}{p_{i'1958}} \cdot X_{ij}^{1958} \quad \text{.....................} (7\text{-}8)$$

Endogenizing the household sector required certain approximations. The household column contained the expenditures for goods and services by individuals, thus approximating, in sum, personal consumption expenditure. The household row, on the other hand, consisted of wage and salary payments, proprietors' income, interest, and depreciation by each transactions sector. Unfortunately, in the original study, the household and government rows were added together. The sum of the resultant "household plus government" row exceeded the total of the government and household columns (a condition holding also for the household row and column) by approximately $6 million. This discrepancy was allocated to the elements of the "household plus government" column in the proportions of the original household expenditure patterns.

Endogenizing the "household plus government" sector was necessary to capture the Keynesian-type expenditure multiplier impacts stemming from decreases in (farm) household incomes related to salinity.

Handling Forward Linkages

Significant quantities of the outputs of the agricultural sectors impacted directly by salinity go to other sectors as inputs rather than being delivered to final demand. A glance at the 1958 transactions table (Table 7-36) shows, for example, that the Food and Feed Grains sector delivers large quantities of its output to Meat Animals and Products, Poultry and Eggs, Farm Dairy Products, and consumes substantial portions of its own output. The technical coefficients matrix indicates a fixed relationship between each of these intermediate inputs and the output of the using sector—one of the basic assumptions incorporated in I-O models. Insofar as this relationship holds, a reduction in availability of an input will cause a multiple reduction in the output of the using industry. For example, if $a_{12}=0.5$ and sector 1 reduces its flow of output to sector 2 by $1, sector 2 must reduce its output by $2. The forward linkage multipler would be $1/a_{12}=1/0.5=2$ for this particular industry pair.

When a supplying industry suffers an output loss, it must choose which customers are to take the cut. If the "final demand customers"—in our case exports out of the California-Arizona region—take the cut, there is no forward linkage effect. But if an endogenous sector takes the cut, there may be a forward linkage effect. This depends on the options which the endogenous using sector has for finding substitutes for the diminished input supply. These options may include finding alternative sources of identical input, substituting different materials, or increasing the efficiency of use of the input (a step usually requiring more of other inputs). If none of these steps is available, production operations will be phased out in proportion to the input reduction.

The impact of reduced input supplies depends greatly on the time frame—on the rate of change. If the cut-off occurs suddenly, there will be short-term difficulties in finding new supplies and the impact may be quite disruptive. On the other hand, if the shortage develops slowly and if it is anticipated, the customer plants have a much greater opportunity to devise solutions.

Identifying from the I-O table the forward linkages which are likely to be important is difficult in theory but simple in practice! A very small a_{ij} coefficient could be interpreted to mean that the input from sector i to sector j was quite unimportant. We know that the demands for inputs which constitute only a small part of total cost are highly inelastic. Thus the using industry will find substitutes somewhere, somehow. For this really to follow, however, it would have to be known that other sources did exist at "reasonable" prices—that the old source wasn't the sole source. Since these conditions are difficult to ascertain for faraway regions, the actual criterion tended to be a "relatively large direct input coefficient (from 0.02 to 0.20)" combined with an impressionistic evaluation of the nature of the product.

Another practical consideration was the base period distribution of the supplying sector's output: how much in absolute terms went to the various intermediate uses and how much to final demand? Only those sectors receiving approximately 5 percent or more of a supplying sector's output were considered for possible forward linkages.[1]

The results of applying these considerations to the California-Arizona I-O table are shown in Table 7-25. For example, if California Sector 7 (Fruit, excluding Citrus, and Tree Nuts) suffers a reduction in output of $100, it is postulated (on the basis of base period data) that California Sector 14 (Canning, Preserving, and Freezing) will suffer a reduction in inputs of $66, California Sector 15 (Misc. Ag. Processing) a reduction of $11, and deliveries to final demand (FD) will be reduced by $23. The forward multiplier for Sector 15 looks pretty large and might well be judged unreasonably large. The final result of the $100 loss of output in Sector C7 then is postulated to be reduced deliveries to final demand of $399 by Sector C14, $445 by Sector C15, and $23 by Sector C7 itself. These are the quantities which were run through the appropriate $(I\text{-}A)^1$ when the "1 Stage Forward Linkage" cases are analyzed.

Indirect Impacts

The reader will recall that the analysis has covered four combinations of situations: Case 1—the long-run full costs profitability criterion; Case 2—the short-run profitability criterion; the no forward linkage case; and the forward linkage case. Obviously, the Case 2-forward linkage case is most likely to represent the very short-run, quick phase-out results, while the Case 1-no forward linkage combination is more likely to represent the actual impact of gradual salinity increase.

These four possible cases are exhibited in detail in Tables 7-26 through 7-33 which show for each change of salinity the associated sectoral changes in TGO. Two important features of these tables should be emphasized: 1) the 900 to 1000 mg/l column consists almost exclusively of positive changes; 2) sector 27

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[1] In spite of these criteria, a few anomolies crept into the analysis. See Table 7-25 in which a few forward multipliers in excess of 100 appear! We feel these did not affect the analysis significantly.

Table 7-25. One-stage forward linkages: California—Arizona.

Originating Sector	Forward-Linked Sectors	Distribution of Outputs (%)	Forward Multipliers ($1/a_{ij}$)	Reduction in Del. to FD Per $ in Orig. Sec.
C4	C1	0.18	16.78	3.02
	C2	0.16	12.34	1.97
	C3	0.12	21.19	2.54
	C4	0.54	5.02	2.71
C6	C14	0.31	9.45	2.93
	FD	0.69	–	–
C7	C14	0.66	6.05	3.99
	C15	0.11	46.49	4.45
	FD	0.23	–	–
C9	C1	0.50	4.82	2.41
	C3	0.48	4.23	2.03
	FD	0.02	–	–
C10	C5	0.14	7.93	1.11
	C6	0.11	17.54	1.93
	C14	0.20	28.57	5.72
	C15	0.17	38.76	6.59
	FD	0.38	–	–
A4	A1	0.13	43.67	5.67
	A2	0.06	5.67	0.34
	A3	0.12	8.00	0.96
	A11	0.26	3.50	0.91
	C11	0.04	400.00	15.92
	FD	0.39	–	–
A9	A1	0.72	6.11	4.40
	A3	0.14	5.71	0.80
	A10	0.06	14.49	0.87
	C1	0.04	344.83	13.79
	C3	0.04	303.03	12.12

Table 7-26. Changes in TGO, California, Case 1, no forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	100	- 100	- 100	0	- 100	- 200
2	300	- 400	- 100	- 200	- 300	- 700
3	400	- 600	- 200	- 100	- 600	- 1,100
4	600	- 700	- 3,400	- 600	- 600	- 4,700
5	0	0	- 200	- 100	- 100	- 400
6	10,500	-17,900	- 800	- 3,500	- 2,000	-13,700
7	400	- 500	- 100	- 200	- 400	- 800
8	700	- 300	- 500	- 400	- 100	- 600
9	2,500	- 7,400	- 800	- 800	-21,500	-28,000
10	200	- 1,300	- 300	- 100	- 1,600	- 3,100
11	700	- 800	- 300	- 300	- 700	- 1,400
12	200	- 300	- 100	- 100	- 200	- 500
13	1,000	- 1,300	- 500	- 300	- 1,300	- 2,400
14	900	- 1,200	- 400	- 600	- 900	- 2,200
15	2,500	- 3,500	- 1,100	- 1,100	- 3,200	- 6,400
16	1,000	- 2,100	- 500	- 600	- 1,900	- 4,100
17	3,100	- 5,300	- 1,400	- 1,400	- 5,300	-10,300
18	2,700	- 4,600	- 700	- 1,300	- 4,700	- 8,600
19	800	- 1,200	- 400	- 300	- 1,100	- 2,200
20	600	- 1,000	- 200	- 200	- 1,000	- 1,800
21	4,200	- 6,300	- 1,900	- 1,700	- 5,700	-11,400
22	200	- 400	- 100	- 100	- 300	- 700
23	3,100	- 4,500	- 1,400	- 1,200	- 4,200	- 8,200
24	2,800	- 4,000	- 1,300	- 1,100	- 3,700	- 7,300
25	11,200	-16,000	- 5,000	- 4,400	-15,100	-29,300
26	11,200	-16,100	- 5,100	- 4,300	-15,400	-29,700
27	48,300	-65,400	-21,500	-17,300	-61,200	-117,100

Table 7-27. Changes in TGO, Arizona, Case 1, no forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	100	- 100	0	- 100	- 100	- 200
2	100	- 100	0	0	0	0
3	0	- 100	0	- 100	0	- 200
4	- 200	0	- 100	- 100	- 400	- 800
5	0	0	0	0	0	0
6	1,700	-1,000	- 800	-6,300	- 300	-6,700
7	0	0	0	0	0	0
8	100	- 300	0	- 100	0	- 300
9	200	-1,900	- 100	0	-1,000	-2,800
10	- 200	0	0	- 100	0	- 300
11	0	0	- 100	- 100	0	- 200
12	100	- 200	0	- 200	- 100	- 400
13	100	- 200	0	- 200	- 100	- 400
14	0	0	0	- 100	0	- 100
15	100	- 100	- 100	- 200	- 100	- 400
16	0	0	- 100	- 100	0	- 200
17	0	0	0	0	0	0
18	0	- 100	0	- 100	- 100	- 300
19	100	0	- 100	0	0	0
20	0	0	0	0	- 100	- 100
21	200	- 300	0	- 500	- 100	- 700
22	0	0	0	0	- 100	- 100
23	200	-1,600	- 100	- 800	- 200	-2,500
24	200	- 300	- 100	- 500	- 100	- 800
25	900	-1,400	- 400	-2,200	- 600	-3,700
26	900	-1,700	- 600	-2,900	- 800	-5,100
27	5,000	-6,900	-2,400	-11,700	-3,100	-19,100

Table 7-28. Changes in TGO, California, Case 2, no forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	89	- 32	- 32	- 94	- 33	- 102
2	299	- 106	- 108	- 318	- 103	- 336
3	438	- 159	- 162	- 442	- 178	- 503
4	670	- 475	- 418	- 556	- 551	- 1,330
5	1	- 37	- 138	- 105	- 121	- 400
6	10,505	- 2,910	- 2,270	-16,820	- 1,622	-13,117
7	435	- 176	- 101	- 377	- 174	- 393
8	657	- 219	- 194	- 1,056	- 388	- 1,200
9	2,501	- 1,563	- 2,205	- 1,416	- 3,434	- 6,117
10	244	- 88	- 263	- 996	- 509	- 1,612
11	598	- 214	- 219	- 622	- 227	- 684
12	204	- 74	- 75	- 211	- 82	- 238
13	977	- 355	- 362	- 987	- 397	- 1,124
14	963	- 337	- 343	- 1,048	- 309	- 1,074
15	2,536	- 914	- 932	- 2,630	- 987	- 2,927
16	1,061	- 384	- 392	- 1,748	- 463	- 1,926
17	3,149	- 1,142	- 1,166	- 3,928	- 1,367	- 4,454
18	2,800	- 1,012	- 1,033	- 3,479	- 1,196	- 3,920
19	843	- 306	- 312	- 898	- 347	- 1,020
20	575	- 208	- 212	- 701	- 242	- 788
21	4,206	- 1,524	- 1,556	- 4,802	- 1,709	- 5,385
22	236	- 85	- 87	- 273	- 98	- 307
23	3,062	- 1,110	- 1,134	- 3,346	- 1,255	- 3,783
24	2,777	- 1,008	- 1,030	- 2,933	- 1,142	- 3,366
25	11,104	- 4,020	- 4,105	-11,852	- 4,502	-13,375
26	11,024	- 4,001	- 4,086	-11,856	- 4,555	-13,474
27	46,912	-17,037	-17,403	-47,294	-19,110	-53,932

Table 7-29. Changes in TGO, Arizona, Case 2, no forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	111	- 35	- 36	- 142	- 14	- 116
2	22	- 7	- 7	- 28	- 3	- 23
3	91	- 29	- 29	- 115	- 11	- 93
4	54	- 23	- 275	- 248	- 54	- 546
5	0.2	- 0.1	- 0.1	- 27	26	- 1.4
6	3323	-1027	- 721	-6,366	- 256	-5047
7	5	- 2	- 2	- 7	- 1	- 7
8	75	- 8	- 8	- 13	- 2	44
9	253	- 183	- 208	- 100	- 176	- 414
10	14	- 7	- 5	- 80	- 2	- 80
11	94	- 30	- 30	- 121	- 12	- 99
12	182	- 58	- 58	- 231	- 22	- 187
13	182	- 58	- 58	- 232	- 22	- 188
14	17	- 5	- 5	- 21	- 2	- 16
15	204	- 65	- 65	- 260	- 25	- 211
16	46	- 17	- 15	- 121	- 6	- 113
17	9	- 3	- 3	- 15	- 1	- 13
18	108	- 35	- 35	- 151	- 17	- 130
19	32	- 10	- 10	- 43	- 4	- 35
20	27	- 9	- 9	- 38	- 4	- 33
21	299	- 98	- 97	- 462	- 37	- 395
22	11	- 4	- 4	- 16	- 2	- 15
23	580	- 186	- 187	- 791	- 72	- 656
24	393	- 125	- 126	- 504	- 48	- 410
25	1849	- 589	- 594	-2,368	- 230	-1932
26	2317	- 741	- 745	-3,075	- 286	-2530
27	9646	-3066	-3092	-12,231	-1183	-9926

Table 7-30. Changes in TGO, California, Case 1, 1 stage forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	5,338	-44,906	-11,419	-3,893	-69,094	-123,974
2	1,574	-2,467	-1,097	-1,355	-2,291	-5,636
3	5,588	-41,791	-6,540	-3,783	-62,170	-108,696
4	2,719	-10,456	-3,582	-1,684	-16,306	-29,309
5	2	- 41	- 331	87	- 546	- 829
6	11,171	-14,762	-1,601	-3,894	-4,505	-13,591
7	5,773	-10,043	- 816	-2,226	-2,416	-9,728
8	1,023	-1,023	- 524	-1,627	- 372	-2,523
9	2,694	-20,794	-4,359	-1,879	-31,667	-56,005
10	2,668	-5,843	-1,001	-1,232	-4,520	-9,928
11	6,493	-12,845	-7,754	-3,441	-22,445	-39,992
12	657	-1,463	- 263	- 311	-1,176	-2,556
13	2,320	-5,623	-1,074	-1,123	-5,163	-10,663
14	32,297	-55,562	-3,879	-12,023	-10,226	-49,393
15	7,844	-16,319	-4,357	-5,022	-16,741	-34,595
16	3,912	-8,920	-1,741	-1,898	-7,799	-16,446
17	8,647	-21,442	-4,161	-4,230	-20,288	-41,474
18	10,760	-24,916	-4,216	-4,977	-19,997	-43,346
19	2,015	-5,036	- 976	- 988	-4,794	-9,779
20	2,062	-4,788	- 828	- 963	-3,915	-8,432
21	11,948	-27,995	-5,224	-5,708	-24,421	-51,400
22	697	-1,647	- 314	- 334	-1,463	-3,061
23	7,644	-19,164	-3,699	-3,759	-18,220	-37,198
24	6,440	-16,167	-3,148	-3,166	-15,506	-31,547
25	28,762	-71,778	-13,947	-14,342	-68,054	-139,359
26	26,926	-67,447	-13,118	-13,219	-64,429	-131,287
27	100,537	-251,944	-49,166	-49,466	-242,259	-492,298

Table 7-31. Changes in TGO, Arizona, Case 1, 1 stage forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	142	-8,286	-2,079	- 3	-6,511	-16,737
2	- 40	- 41	- 111	- 36	- 170	- 398
3	101	-1,684	- 408	- 90	-1,292	-3,373
4	- 50	- 901	- 478	- 109	-1,141	-2,679
5	0.3	1	- 0.2	- 27	26	- 1.9
6	+1,699	-1,144	- 738	-6,367	- 333	-6,883
7	+ 5	- 10	- 3	- 6	- 7	- 21
8	+ 79	- 352	- 7	- 14	- 19	- 313
9	2,707	-2,237	- 527	- 45	-1,931	-2,033
10	250	-1,781	- 154	- 33	- 970	-2,678
11	- 98	- 415	- 413	- 138	- 746	-1,810
12	162	- 345	- 98	- 215	- 253	- 749
13	162	- 346	- 99	- 215	- 255	- 753
14	15	- 32	- 9	- 20	- 23	- 69
15	180	- 391	- 115	- 243	- 292	- 861
16	75	- 153	- 55	- 120	- 124	- 377
17	12	- 23	- 7	- 14	- 18	- 50
18	150	- 335	- 82	- 149	- 256	- 672
19	30	- 68	- 19	- 40	- 50	- 147
20	31	- 69	- 18	- 36	- 52	- 144
21	295	- 624	- 185	- 441	- 458	-1,413
22	13	- 29	- 8	- 16	- 23	- 63
23	550	-1,262	- 359	- 741	- 932	-2,744
24	353	- 773	- 220	- 469	- 569	-1,678
25	1,679	-3,806	-1,076	-2,205	-2,829	-8,237
26	2,183	-4,914	-1,395	-2,868	-3,636	-10,630
27	8,582	-18,194	-5,168	-11,367	-13,323	-39,470

Table 7-32. Changes in TGO, California, Case 2, 1 stage forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	10,232	- 7,301	- 9,015	- 4,968	-12,042	-23,094
2	1,636	- 1,191	- 1,077	- 1,587	- 1,451	- 3,670
3	9,843	- 6,775	- 8,277	- 5,513	-11,014	-21,736
4	3,034	- 2,146	- 2,517	- 2,788	- 3,413	- 7,830
5	2	- 37	- 331	85	- 507	- 788
6	11,252	- 3,241	- 3,042	-18,343	- 2,963	-16,337
7	5,813	- 1,715	- 1,536	- 9,305	- 1,544	- 8,287
8	1,035	- 340	- 309	- 1,671	- 511	- 1,796
9	4,874	- 3,399	- 4,177	- 2,637	- 5,580	-10,919
10	2,864	- 1,065	- 1,217	- 4,189	- 1,505	- 5,112
11	4,745	- 3,401	- 3,931	- 6,757	- 5,460	-14,804
12	695	- 270	- 293	- 996	- 362	- 1,226
13	2,511	- 1,043	- 1,144	- 3,437	- 1,420	- 4,533
14	32,419	- 9,282	- 8,133	-52,440	- 7,660	-45,096
15	8,223	- 3,396	- 4,470	-12,180	- 6,750	-18,573
16	4,156	- 1,683	- 1,818	- 5,852	- 2,227	- 7,424
17	9,444	- 4,001	- 4,385	-12,732	- 5,441	-17,115
18	11,543	- 4,519	- 4,782	-16,268	- 5,720	-19,746
19	2,204	- 934	- 1,031	- 2,967	- 1,286	- 4,014
20	2,212	- 872	- 928	- 3,109	- 1,117	- 3,814
21	12,802	- 5,194	- 5,613	-17,837	- 6,876	-22,718
22	747	- 306	- 332	- 1,036	- 408	- 1,335
23	8,374	- 3,553	- 3,915	-11,260	- 4,880	-15,234
24	7,055	- 3,002	- 3,316	- 9,471	- 4,142	-12,876
25	31,429	-13,328	-14,743	-42,437	-18,485	-57,564
26	29,468	-12,517	-13,832	-39,635	-17,283	-53,799
27	110,051	-46,832	-51,802	-147,808	-64,743	-201,134

Table 7-33. Changes in TGO, Arizona, Case 2, 1 stage forward linkages (1,000's of 1974 dollars).

Sector	900-1000 mg/l	1000-1100 mg/l	1100-1200 mg/l	1200-1300 mg/l	1300-1400 mg/l	Total Change
1	974	- 802	-1,040	-1,280	-1,034	-3,182
2	15	- 9	- 17	- 94	- 23	- 128
3	243	- 175	- 218	- 331	- 209	- 690
4	153	- 113	- 158	- 364	- 182	- 664
5	0.3	- 0.1	- 0.2	- 27	26	- 1
6	3,344	-1,037	- 730	-6,402	- 269	-5,094
7	4	- 2	- 2	- 8	- 1	- 9
8	79	- 11	- 0.5	- 24	- 5	39
9	307	- 238	- 302	- 341	- 316	- 890
10	251	- 176	- 198	- 146	- 170	- 439
11	94	- 59	- 92	- 360	- 107	- 524
12	154	- 65	- 63	- 264	- 48	- 286
13	154	- 65	- 63	- 265	- 48	- 287
14	14	- 6	- 6	- 24	- 4	- 26
15	173	- 74	- 72	- 300	- 55	- 328
16	78	- 32	- 31	- 144	- 23	- 152
17	10	- 4	- 4	- 18	- 3	- 19
18	143	- 60	- 61	- 230	- 56	- 264
19	29	- 13	- 12	- 60	- 9	- 55
20	30	- 13	- 13	- 50	- 11	- 55
21	303	- 125	- 119	- 530	- 88	- 559
22	13	- 6	- 6	- 22	- 5	- 26
23	537	- 232	- 227	- 922	- 174	-1,018
24	337	- 144	- 140	- 580	- 107	- 827
25	1,621	- 700	- 686	-2,774	- 534	-3,073
26	2,083	- 901	- 881	-3,576	- 679	-3,954
27	8,113	-3,446	-3,327	-13,961	-2,518	-15,139

represents the "government and household" sector defined earlier, so the TGO changes for Sector 27 represent the changes in payments to households and government—our approximation to the changes in regional income.

Regarding item 1 and its impact on the total TGO change occurring over the 900-1400 mg/l range, the cause of these increases in TGO is largely our shift from actual farm practice to "most profitable" farm practice as we calculated it for 1000 mg/l—a shift frequently involving an increase in the number of irrigations and a physical output (but not profit) increase. If we want to rationalize this, we could say that it indicates the ease of dealing with the salinity problem in the neighborhood of present salinity levels (if we're so smart, why aren't we farming?). The aggregated TGO changes are all negative above 1000 mg/l.

The following observations can be made regarding Tables 7-26 to 7-33: 1) The longer term profitability criterion implies a much more extensive reduction in outputs than might occur in the short term (Case 1 versus Case 2); 2) the effects of salinity on the sectoral TGO's and on regional income (Sector 27) are not proportional to the salinity increments and are quite irregular; 3) the effects of assuming the one-stage forward linkages listed in Table 7-25 are to raise the total regional income losses over the 900-1400 mg/l range as follows:

	California	Arizona
	(income losses in $\$10^6$)	
Case 1:		
FL	492	39
NFL	117	19
Case 2:		
FL	201	15
NFL	54	10

4) The multiplier effects are much stronger in the more highly integrated and developed California economy.

Regional income multipliers can be derived from these figures by comparing the total loss in regional income (direct and indirect) to the direct loss of income in agriculture and the forward linked sectors, if applicable. In the no forward linkage case, the multiplier is simply the ratio of the relevant element from row 27 of the preceding tables to the direct farm income loss, the latter being the same as the TGO loss in the pure yield reduction case. With forward linkages, the multiplier is the ratio of the appropriate figure from the preceding tables to the sum of net income losses in agriculture and the forward linked industries. The results are summarized in Table 7-34.

Given the very gradual nature of salinity increases, the most plausible case can be argued to be "No Forward Linkages: Case 1." In the event of a very sudden, unanticipated change in salinity, the "1 Stage Forward Linkage: Case 2" situation might be obtained. Such may have been the Wellton-Mohawk Project impacts on Mexicali.

Table 7-34. Regional income multipliers (dollars reduction in payments to households and government per dollar direct income loss[a]).

	1000 mg/l	1100 mg/l	1200 mg/l	1300 mg/l	1400 mg/l
			No Forward Linkages: Case 1		
California	3.55	2.59	3.34	2.96	2.47
Arizona	2.83	2.17	2.67	1.85	1.98
			No Forward Linkages: Case 2		
California	3.44	3.43	3.42	2.50	3.08
Arizona	2.72	2.58	2.66	1.87	2.70
			1 Stage Forward Linkages: Case 1		
California	7.72	9.98	7.64	8.48	9.78
Arizona	4.90	5.74	5.64	1.81	8.53
			1 Stage Forward Linkages: Case 2		
California	8.08	9.43	10.20	7.82	10.44
Arizona	2.29	2.90	2.87	2.14	5.75

[a] Under 1974 prices, little acreage reduction takes place. Most agricultural output losses thus approximately equal direct reductions in farm income. This is not true for forward-linked industries.

Before presenting the final table giving total regional costs per mg/l, two points require reemphasis: 1) The agricultural areas relative to which the regional income losses were computed; and 2) the nature of regional income losses versus national income (national economic efficiency) losses.

In California, the districts for which crop losses were aggregated include Imperial, Coachella, and Palo Verde. Excluded were the coastal (San Diego) areas which receive some Colorado River water for irrigation. The exclusion of these areas may be justified on the grounds that they have alternative sources of water (groundwater and Metropolitan Water District) which, when mixed with Colorado River water, have the capability of preventing significant salinity increases. Partly due to the cropping pattern, full sprinkler irrigation is also widely used so that salt build-up can be better controlled.

In Arizona, the entire Gila-Yuma complex of districts was covered, plus the Colorado River Indian Reservation. The omission was the Central Arizona Project area, an area to be partially served in the future by Colorado River water. The uncertainties regarding the areas to be served and the differences between the qualities of presently used irrigation water (mostly groundwater) and Colorado River water made analysis of that area impossible. A recent report by Jackson (April, 1975) outlines potential

Table 7-35. Estimated reductions in regional income (1,000's of 1974 dollars).

	900-1100	1100-1200	1200-1300	1300-1400
Case 1, NFL:				
California	17,100	21,500	17,300	61,200
Arizona	1,900	2,400	11,700	3,100
Total	19,000	23,900	29,000	64,300
$/mg/l[a]	80,000	239,000	290,000	643,000
Case 2, NFL:				
California	- 29,875	17,403	47,294	19,110
Arizona	- 6,580	3,092	12,231	1,183
Total	- 36,455	20,495	59,525	20,293
$/mg/l[a]	-182,275	204,950	595,250	202,930
Case 1, FL:				
California	151,407	49,166	49,466	242,259
Arizona	9,612	5,168	11,367	13,323
Total	161,019	54,334	60,833	255,582
$/mg/l[a]	805,095	543,340	608,330	2,555,820
Case 2, FL:				
California	- 63,219	51,802	147,808	64,743
Arizona	- 4,667	3,327	13,961	2,518
Total	67,886	55,129	161,769	67,261
$/mg/l[a]	-339,430	551,290	1,617,690	672,610

[a] This row is in *dollars* per mg/l.

impacts in the CAP region, but was received too late to be utilized in this study. The most important relevant observation is, however, that the salinity of the Colorado River at Parker Dam is generally already above the average for present Central Arizona supplies. Thus substituting CAP water for present supplies will increase salinity on the average. Average post CAP TDS levels appear, nonetheless, to remain low enough to avoid significant losses.

The second point is a caveat regarding regional income losses as a measure of salinity costs. Losses incurred by a region may well be made up in other parts of the nation, especially in the case of agriculture. It is well known that, except for unusual periods like 1973-74, markets for agricultural commodities are limited. Federal programs also limit production. Thus the development of western irrigated agriculture has had the effect of displacing agricultural production from other regions, especially the South and Southeast (see Howe and Easter, 1971, especially Chapter 6). The effect of increasing salinity in western irrigation water supplies may be to reverse some of this trend, to increase the extent of viable agriculture in those other areas. To the extent that this happens, the southwestern income losses will be offset by income gains in other regions, leaving only the interregional distribution effects as impact.

With these caveats in mind, we present the cost estimates in terms of dollars of regional income loss per mg/l of TDS. Again, in terms of the very gradual nature of anticipated salinity increases, we feel that Case 1, no forward linkages, is the most applicable case, but the other cases are presented for comparison. The 900-1000 and 1000-1100 steps have been combined to approximate the net effect of greater salinity combined with improved salt management techniques.

THE DIRECT AND INDIRECT ECONOMIC AND HYDROLOGIC IMPACTS OF AGRICULTURAL ACREAGE REDUCTION IN THE UPPER COLORADO BASIN AS A SALINITY CONTROL MEASURE

Preceding sections of this study dealt with downstream losses, both direct and indirect, which were predicted to be associated with various levels of salinity in the Colorado River. The upper basin of the Colorado River must also be given consideration since it is the source of both the water used for irrigation in the lower basin and the salt which is impairing the usefulness of that water. This section calculates the regional economic impact of a hypothetical program of phasing out economically marginal irrigated land which is thought to contribute heavily to the salt load of the river. Estimates of net amounts of water released for other purposes are also given.

The Origins of the Total Dissolved Solids Load in the Upper Colorado River Basin

The water quality problems of the Colorado River have been studied and modeled extensively. Among the more significant reports dealing with the origins and management of salinity are Hyatt et al. (July, 1970), U.S. Department of Interior (January, 1971), U.S. Environmental Protection Agency (1971), U.S.

Table 7-36. (Section 1.) Interindustry flows of goods and services by sector and region of origin and destination, California-Arizona Economy, 1958.[a]

Sector Number	Section Title	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19	Sector Number
		Meat Animals	Poultry and Eggs	Farm Dairy Prod.	Grains	Cotton	Veg.	Fruit and Nuts	Citrus	Forage	Misc. Agri.	Grain Mill Prod.	Meat & Poultry Prod.	Dairy Prod.	Canning, Preserving, Freezing	Misc. Agri. Prod.	Chem. and Fert.	Petro-leum	Fab. Metals & Mach.	Air-craft	
												Thousand Dollars									
C 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	452,644	-0	-0	-0	-0	-0	-0	-0	C 1
C 2	Poultry and Eggs	-0	57,836	-0	-0	-0	-0	-0	-0	-0	-0	-0	62,919	33	6	2,634	-0	-0	-0	-0	C 2
C 3	Farm Dairy Products	-0	-0	10,401	-0	-0	-0	-0	-0	-0	-0	-0	-0	319,831	-0	-0	-0	-0	-0	-0	C 3
C 4	Food and Feed Grains	28,412	26,445	18,710	4,948	-0	-0	-0	-0	-0	479	87,879	-0	-0	-0	4,967	-0	-0	-0	-0	C 4
C 5	Cotton	-0	-0	-0	-0	697	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 5
C 6	Vegetables	-0	-0	-0	-0	-0	1,783	-0	-0	-0	-0	-0	-0	-0	171,683	-0	-0	-0	-0	-0	C 6
C 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	268,344	46,259	180	-0	-0	-0	C 7
C 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	15,616	-0	-0	-0	-0	-0	C 8
C 9	Forage	98,709	-0	93,447	-0	-0	-0	-0	-0	-0	5,909	5,068	-0	-0	-0	-0	-0	-0	-0	-0	C 9
C 10	Miscellaneous Agriculture	2,000	-0	2,910	7,467	37,754	31,280	11,697	3,888	8,221	12,725	-0	50	-0	54,768	48,252	10,954	-0	-0	-0	C 10
C 11	Grain Mill Products	35,517	88,135	32,456	-0	-0	-0	-0	-0	-0	384	4,808	-0	305	6,268	60,810	2,299	-0	-0	-0	C 11
C 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	785	46,273	-0	10,425	17,681	3,873	-0	-0	-0	C 12
C 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1,438	3,233	61,815	9,938	7,961	988	-0	-0	-0	C 13
C 14	Canning, Preserving, Freezing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	25,403	6,811	516	-0	-0	-0	C 14
C 15	Miscellaneous Agri. Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	23,020	-0	48,787	75,014	132,756	40,324	848	39	-0	C 15
C 16	Chemicals and Fertilizers	810	985	332	7,587	7,336	20,750	22,840	5,378	4,733	3,994	10,875	3,300	15,149	25,460	33,708	285,841	61,937	39,272	5,066	C 16
C 17	Petroleum	381	3,067	158	8,116	3,420	10,634	12,792	2,454	5,039	3,280	1,046	2,444	3,752	9,153	-0	-0	1,431,437	17,018	4,848	C 17
C 18	Fabricated Metals and Machinery	5,874	4,317	4,223	13,949	5,015	16,695	18,755	3,781	9,391	5,672	3,466	5,985	4,629	170,714	34,109	57,208	57,208	832,824	188,945	C 18
C 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	24,464	719,662	C 19
C 20	Primary Metals	38	25	20	8	8	32	32	4	9	9	-0	23	16	1,547	1,103	10,537	944	531,734	78,933	C 20
C 21	Other Manufacturing	1,445	1,860	1,146	1,233	915	12,536	11,302	2,727	791	2,043	15,232	4,519	25,719	81,586	31,588	40,448	15,191	150,112	47,601	C 21
C 22	Mining	-0	-0	-0	15	8	58	26	7	10	19	1,000	564	697	1,452	1,325	11,979	39,473	3,283	412	C 22
C 23	Utilities	2,572	2,190	2,434	949	1,644	3,672	4,082	954	727	2,991	1,601	5,900	4,748	10,312	9,684	17,708	35,333	35,607	16,279	C 23
C 24	Selected Services	2,476	1,687	1,166	2,423	1,339	4,599	4,959	1,041	1,643	1,720	1,320	37,616	6,934	8,256	8,592	11,731	9,147	13,644	3,888	C 24
C 25	Trade and Transportation	19,337	20,810	25,137	7,203	5,504	11,712	9,989	2,287	4,482	6,219	20,796	63,772	65,552	136,503	382,674	140,134	147,336	248,824	55,958	C 25
C 26	Unallocated	10,467	5,760	9,080	16,274	19,502	21,172	11,869	2,635	9,383	9,629	10,742	64,909	31,850	69,130	107,545	100,593	288,415	211,680	38,498	C 26
C 27	Scrap and By-Products	13,782	14,306	5,771	-0	-0	-0	-0	-0	-0	-0	7,428	55,425	26,766	48,187	69,272	1,202	13,194	6,597	1,005	C 27
C 28	Net Trade from Outside	217,533	81,596	53,140	13,487	7,782	25,334	25,594	5,811	7,492	7,291	61,477	250,356	40,929	165,317	146,004	182,890	94,098	855,623	172,134	C 28
C 29	Maintenance Construction	5,806	4,261	4,126	3,937	3,390	7,798	10,470	2,283	2,678	3,490	1,029	14	3,195	7,924	7,906	2,299	3,860	6,009	3,973	C 29
C 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 30
	Households and Government	28,984	12,368	129,338	89,301	205,630	379,958	261,084	125,550	151,913	276,319	180,500	171,455	108,221	246,277	707,496	547,001	957,466	2,022,872	2,231,017	
A 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	128	-0	-0	-0	-0	-0	-0	-0	A 1
A 2	Poultry and Eggs	-0	13	-0	-0	-0	-0	-0	-0	-0	-0	-0	15	-0	-0	1	-0	-0	-0	-0	A 2
A 3	Farm Dairy Products	-0	-0	15	-0	-0	-0	-0	-0	-0	-0	-0	-0	463	-0	-0	-0	-0	-0	-0	A 3
A 4	Food and Feed Grains	358	333	236	62	-0	-0	-0	-0	-0	-0	1,107	-0	-0	-0	63	-0	-0	-0	-0	A 4
A 5	Cotton	-0	-0	-0	-0	42	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 5
A 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	694	-0	-0	-0	-0	-0	A 6
A 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 7
A 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	234	-0	-0	-0	-0	-0	A 8
A 9	Forage	1,368	-0	1,295	-0	-0	-0	-0	-0	-0	-0	82	70	-0	-0	-0	-0	-0	-0	-0	A 9
A 10	Miscellaneous Agricultural	3	-0	4	11	55	46	17	6	12	19	-0	-0	-0	83	70	16	-0	-0	-0	A 10
A 11	Grain Mill Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 11
A 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 12
A 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 13
A 14	Canning, Preserving, Freezing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 14
A 15	Miscellaneous Agri. Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 15
A 16	Chemicals and Fertilizers	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 16
A 17	Petroleum	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 17
A 18	Fabricated Metals and Machinery	23	17	17	55	20	66	74	15	37	22	14	23	18	670	134	103	225	3,269	742	A 18
A 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 19
A 20	Primary Metals	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 20
A 21	Other Manufacturing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 21
A 22	Mining	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	3	2	2	4	4	37	121	10	1	A 22
A 23	Utilities	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 23
A 24	Selected Services	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 24
A 25	Trade and Transportation	18	20	24	7	5	11	9	2	4	4	20	60	62	129	362	132	139	235	53	A 25
A 26	Unallocated	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 26
A 27	Scrap and By-Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 27
A 28	Net Trade from Outside	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 28
A 29	Maintenance Construction	6	4	4	4	3	7	10	2	3	3	1	-0	3	8	8	2	4	6	4	A 29
A 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 30
	Households and Government	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	
	GROSS OUTLAY	475,913	326,035	395,590	177,030	300,069	548,150	485,601	158,825	206,568	342,311	440,725	1,231,629	769,476	1,623,105	1,869,689	1,437,277	3,156,418	5,003,122	3,569,019	G.O.

Table 7-36. (Section 2.)

Sector Number	Sector Title	C 20	C 21	C 22	C 23	C 24	C 25	C 26	C 27	C 28	C 29	C 30	C 31	C 32	C 33	C 34	C 35	C 36	Sector Number
		Primary Metals	Other Mfg.	Mining	Utilities	Selected Services	Trade and Trans.	Unal-located	Scrap & By-Prod.	Net Trade to Outside	Maint. Constr.	New Constr.	State & Local Gov.	Federal Gov.	Inven-tory Addit'n	Inven-tory Deplet'n	Gross Pri. Cap. Form.	All House-holds	
					Thousand Dollars								Thousand Dollars						
C 1	Meat Animals and Products	-0	67	-0	-0	-0	-0	-0	212	-13,026	-0	-0	-0	-0	19,669	-0	-0	3,320	C 1
C 2	Poultry and Eggs	-0	-0	-0	-0	-0	-0	-0	-0	-19,350	-0	-0	-0	-0	1,243	-0	-0	281,364	C 2
C 3	Farm Dairy Products	-0	-0	-0	-0	-0	-0	-0	51,465	-212	-0	-0	-0	-0	2,928	-0	-0	10,964	C 3
C 4	Food and Feed Grains	-0	-0	-0	-0	-0	-0	-0	-0	-2,105	-0	-0	-0	-0	5,190	-0	-0	-0	C 4
C 5	Cotton	-0	470	-0	-0	-0	-0	-0	26,211	284,242	-0	-0	-0	-0	-0	-11,751	-0	-0	C 5
C 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	2,475	126,349	-0	-0	-0	2,756	69	-0	-0	242,948	C 6
C 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	53,899	-0	-0	-0	-0	-0	-704	-0	35,077	C 7
C 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	104,024	-0	-0	-0	-0	-0	-0	-0	38,740	C 8
C 9	Forage	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	3,441	-0	-0	-0	C 9
C 10	Miscellaneous Agriculture	-0	3,732	-0	-0	-0	-0	-0	-0	49,893	-0	-0	-0	-0	-0	-1,985	-0	56,493	C 10
C 11	Grain Mill Products	-0	15	-0	-0	-0	196	128	2,583	-5,488	-0	-0	1,933	-0	1,760	-0	-0	203,128	C 11
C 12	Meat and Poultry Processing	-0	1,879	-0	-0	158	2,306	35,289	15,488	-0	-0	1,818	8,420	-0	4,904	-0	-0	1,083,131	C 12
C 13	Dairy Products	-0	126	-0	-0	106	1,566	969	-0	-0	-0	-0	5,807	-0	3,064	-0	-0	672,466	C 13
C 14	Canning, Preserving, Freezing	-0	139	-0	-0	77	1,164	741	-0	1,023,180	-0	-0	12,436	-0	6,462	-0	-0	475,325	C 14
C 15	Miscellaneous Agri. Processing	191	1,621	2	-0	139	1,196	8,431	8,329	-34,215	-0	-0	10,598	-0	7,051	-0	-0	1,511,322	C 15
C 16	Chemicals and Fertilizers	11,411	163,245	4,682	471	17,310	5,603	49,668	24,284	-15,977	93,217	51,374	53,937	-0	102	-0	-0	406,620	C 16
C 17	Petroleum	7,388	24,603	6,967	15,578	21,510	183,465	49,698	3,186	391,021	46,258	113,091	59,504	-0	-0	-26,712	-0	739,299	C 17
C 18	Fabricated Metals and Machinery	47,231	127,697	15,152	14,774	142,103	60,841	125,501	70,288	-63,433	122,006	736,102	128,791	-0	-0	-73,152	940,959	1,133,144	C 18
C 19	Aircraft and Parts	81	9,879	-0	-0	501,860	22,140	136,615	39,386	2,074,241	-0	-0	-0	-0	-0	-6,534	42,619	4,539	C 19
C 20	Primary Metals	193,444	69,780	6,899	1,593	573	4,475	16,597	34,552	-14,141	44,160	228,630	-0	-0	-0	-5,122	-0	1,432	C 20
C 21	Other Manufacturing	17,177	981,267	13,541	43,098	133,659	109,334	504,302	35,937	-22,305	101,274	660,438	88,186	-0	-0	-1,262	93,024	1,009,430	C 21
C 22	Mining	111,675	52,688	34,054	128	783	2,665	15,999	-0	35,375	18,510	8,203	21,803	-0	-0	-2,841	-0	28,434	C 22
C 23	Utilities	25,665	57,987	8,646	325,422	48,224	240,093	206,122	-0	-3,070	3,991	22,441	95,420	41,423	-0	-0	24,720	971,255	C 23
C 24	Selected Services	4,750	26,423	706	2,890	269,031	205,750	200,739	-0	481,913	33,140	7,235	25,054	543,903	-0	-0	1,129	1,891,063	C 24
C 25	Trade and Transportation	91,901	347,737	14,932	28,622	135,355	386,059	500,444	21,969	-13,072	202,484	789,771	99,734	201,668	-0	-0	295,460	6,573,771	C 25
C 26	Unallocated	30,589	160,746	19,199	178,506	599,660	1,478,300	1,793,134	-0	-0	24,143	402,475	220,479	296,422	-0	-0	88,513	7,609,534	C 26
C 27	Scrap and By-Products	42,232	10,264	671	18,586	9,916	10,156	-0	-0	-0	1,643	8,973	-0	-0	-0	-0	-29,668	657	C 27
C 28	Net Trade from Outside	177,414	252,671	24,461	121,975	209,598	288,549	591,699	-1,944	-0	180,366	909,066	172,849	37,057	-123	1,000	465,368	-12,465	C 28
C 29	Maintenance Construction	5,486	8,355	432	528,808	29,159	185,218	729,446	-0	-12,272	135	860	580,644	118,268	-0	-0	-0	4,994	C 29
C 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-36,803	-0	-0	1,097,368	334,846	-0	-0	5,138,191	-0	C 30
	Households and Government	454,781	2,734,773	244,500	941,976	1,705,970	7,923,370	8,973,479	-0	-0	1,404,199	2,626,266	2,344,207	5,653,978	-0	-0	-0	-0	
A 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1	A 1
A 2	Poultry and Eggs	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	47	A 2
A 3	Farm Dairy Products	-0	-0	-0	-0	-0	-0	-0	75	-0	-0	-0	-0	-0	-0	-0	-0	16	A 3
A 4	Food and Feed Grains	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	65	-0	-0	-0	A 4
A 5	Cotton	-0	40	-0	-0	-0	-0	-0	1,563	16,950	-0	-0	-0	-0	-0	-701	-0	-0	A 5
A 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	10	511	-0	-0	-0	11	-0	-0	-0	982	A 6
A 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 7
A 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	1,567	-0	-0	-0	-0	-0	-0	-0	501	A 8
A 9	Forage	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	48	-0	-0	-0	A 9
A 10	Miscellaneous Agriculture	-0	-0	-0	-0	-0	-0	-0	-0	73	-0	-0	-0	-0	-0	-0	-0	83	A 10
A 11	Grain Mill Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 11
A 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 12
A 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 13
A 14	Canning, Preserving, Freezing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 14
A 15	Miscellaneous Agri. Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 15
A 16	Chemicals and Fertilizers	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 16
A 17	Petroleum	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 17
A 18	Fabricated Metals and Machinery	185	501	59	58	558	239	493	276	-0	479	2,890	506	-0	-0	-287	3,694	4,448	A 18
A 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 19
A 20	Primary Metals	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 20
A 21	Other Manufacturing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 21
A 22	Mining	342	161	104	-0	2	8	49	-0	130	57	25	67	-0	-0	-9	-0	87	A 22
A 23	Utilities	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 23
A 24	Selected Services	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 24
A 25	Trade and Transportation	87	329	14	27	128	345	473	21	44	191	747	94	191	-0	-0	279	6,215	A 25
A 26	Unallocated	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 26
A 27	Scrap and By-Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 27
A 28	Net Trade With Outside	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 28
A 29	Maintenance Construction	5	5	-0	505	28	177	697	-0	-0	-0	1	555	113	-0	-0	-0	5	A 29
A 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1,024	312	-0	-0	4,795	-0	A 30
	Households and Government	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	
	GROSS OUTLAY	1,222,035	5,037,408	395,021	2,222,817	3,811,907	11,113,323	13,942,913	336,366	4,387,937	2,276,253	6,570,406	5,029,416	7,230,948	55,883	-130,065	7,069,083	25,708,450	G.O.

Table 7-36. (Section 3.).

Sector Number	Sector Title	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A 10	A 11	A 12	A 13	A 14	A 15	A 16	A 17	A 18	A 19	Sector Number
		Meat Animals	Poultry and Eggs	Farm Dairy Prod.	Grains	Cotton	Veg.	Fruit and Nuts	Citrus	Forage	Misc. Agri.	Grain Mill Prod.	Meat & Poultry Prod.	Dairy Prod.	Canning, Preserving, Freezing	Misc. Agri. Prod.	Chem. and Fert	Petro-leum	Fab. Metals & Mach.	Air-craft	
												Thousand Dollars									
C 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	2,670	-0	-0	-0	-0	-0	-0	-0	C 1
C 2	Poultry and Eggs	-0	2,075	-0	-0	-0	-0	-0	-0	-0	-0	-0	212	-0	-0	-0	-0	-0	-0	-0	C 2
C 3	Farm Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	170	-0	-0	-0	-0	-0	-0	C 3
C 4	Food and Feed Grains	245	108	241	57	-0	-0	-0	-0	-0	22	496	-0	-0	-0	7	-0	-0	-0	-0	C 4
C 5	Cotton	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 5
C 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 6
C 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	163	-0	-0	-0	-0	C 7
C 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 8
C 9	Forage	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 9
C 10	Miscellaneous Agriculture	9	-0	1	5	114	5	-0	5	4	3	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 10
C 11	Grain Mill Products	374	701	436	-0	-0	-0	-0	-0	-0	-0	175	-0	7	6	1,172	180	-0	-0	-0	C 11
C 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 12
C 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 13
C 14	Canning, Preserving, Freezing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	460	545	133	-0	-0	-0	C 14
C 15	Miscellaneous Agri. Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	283	-0	49	32	714	555	-0	-0	-0	C 15
C 16	Chemicals and Fertilizers	15	3	5	422	1,010	358	14	61	129	46	214	12	77	36	433	963	11	60	22	C 16
C 17	Petroleum	6	4	-0	57	88	30	3	10	27	7	2	3	7	1	9	25	6	10	7	C 17
C 18	Fabricated Metals and Machinery	56	3	15	208	201	87	5	22	103	107	8	6	17	1	14	30	4	6,050	3,591	C 18
C 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 19
C 20	Primary Metals	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1	7	20	-0	517	265	C 20
C 21	Other Manufacturing	7	3	1	4	12	112	2	7	2	5	37	11	100	10	48	41	1	247	198	C 21
C 22	Mining	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	4	-0	-0	-0	C 22
C 23	Utilities	13	1	4	3	25	7	-0	1	2	3	2	6	6	1	5	13	1	15	14	C 23
C 24	Selected Services	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 24
C 25	Trade and Transportation	175	-0	136	3	19	5	1	2	2	29	101	462	361	32	370	247	16	518	246	C 25
C 26	Unallocated	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 26
C 27	Scrap and By-Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 27
C 28	Net Trade from Outside	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 28
C 29	Maintenance Construction	47	2	10	18	80	22	1	4	13	5	6	10	20	2	27	10	-0	14	10	C 29
C 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	C 30
	Households and Government	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	
A 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	29,278	-0	-0	-0	-0	-0	-0	-0	A 1
A 2	Poultry and Eggs	-0	370	-0	-0	-0	-0	-0	-0	-0	-0	-0	89	-0	-0	-0	-0	-0	-0	-0	A 2
A 3	Farm Dairy Products	-0	-0	678	-0	-0	-0	-0	-0	-0	-0	-0	-0	20,640	-0	-0	-0	-0	-0	-0	A 3
A 4	Food and Feed Grains	3,276	1,442	3,224	765	-0	-0	-0	-0	-0	296	6,632	-0	-0	-0	100	-0	-0	-0	-0	A 4
A 5	Cotton	-0	-0	-0	-0	189	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 5
A 6	Vegetables	-0	-0	-0	-0	-0	291	-0	-0	-0	-0	-0	-0	-0	71	-0	-0	-0	-0	-0	A 6
A 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	109	-0	-0	-0	-0	A 7
A 8	Citrus	-0	-0	-0	-0	-0	-0	-0	9	-0	-0	-0	-0	-0	168	-0	-0	-0	-0	-0	A 8
A 9	Forage	23,342	-0	4,520	-0	-0	-0	-0	-0	-0	1,847	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 9
A 10	Miscellaneous Agriculture	638	-0	116	688	14,428	602	34	601	447	928	-0	-0	-0	-0	773	45	-0	-0	-0	A 10
A 11	Grain Mill Products	1,584	2,974	1,847	-0	-0	-0	-0	-0	-0	-0	741	-0	28	25	4,971	424	-0	-0	-0	A 11
A 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	25	2,431	-0	16	394	162	-0	-0	-0	A 12
A 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	45	112	4,504	22	246	100	-0	-0	-0	A 13
A 14	Canning, Preserving, Freezing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	27	32	9	-0	-0	-0	A 14
A 15	Miscellaneous Agri. Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	300	-0	72	47	1,053	818	-0	-0	-0	A 15
A 16	Chemicals and Fertilizers	36	7	12	1,029	2,462	873	34	149	315	112	521	30	100	88	1,056	2,347	27	147	53	A 16
A 17	Petroleum	6	4	-0	60	93	32	3	11	28	7	2	3	7	1	9	26	6	11	7	A 17
A 18	Fabricated Metals and Machinery	87	5	23	324	312	135	7	34	168	166	13	10	27	2	21	44	6	9,408	5,585	A 18
A 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1	-0	452	18,892	A 19
A 20	Primary Metals	2	-0	1	-0	3	1	-0	-0	-0	-0	-0	-0	-0	7	77	229	-0	6,012	3,079	A 20
A 21	Other Manufacturing	55	26	11	34	95	882	15	59	17	37	292	85	792	75	377	322	9	1,948	1,568	A 21
A 22	Mining	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1	1	-0	1	155	10	15	-0	A 22
A 23	Utilities	812	41	225	165	1,542	402	17	67	115	161	103	363	346	31	327	884	41	898	878	A 23
A 24	Selected Services	314	12	43	35	110	47	4	15	15	17	61	249	385	18	149	287	3	245	29	A 24
A 25	Trace and Transportation	1,775	3	1,385	31	188	50	6	20	24	298	1,023	4,699	3,470	326	3,757	2,511	166	5,262	2,503	A 25
A 26	Unallocated	5,050	117	717	1,986	8,894	1,706	94	360	1,161	876	617	2,169	2,003	193	3,249	2,010	121	5,323	7,046	A 26
A 27	Scrap and By-Products	763	163	28	-0	-0	725	27	73	-0	11	1,548	2,667	-0	-0	-0	12,686	-0	42	10	A 27
A 28	Net Trade with Outside	69,652	-1,978	13	6,074	10,295	7,421	279	1,093	2,691	1,994	2,547	5,732	3,241	757	3,977	7,814	1,888	21,304	7,845	A 28
A 29	Maintenance Construction	500	21	104	189	857	236	12	44	143	49	61	109	216	23	291	109	4	148	201	A 29
A 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	A 30
	Households and Government	33,978	1,490	11,932	16,004	110,578	59,731	1,143	7,251	28,862	29,465	7,479	187	9,128	1,676	25,964	5,968	332	40,302	46,539	
	GROSS OUTLAY	142,829	8,117	25,736	28,161	150,795	73,848	1,701	9,898	34,268	26,891	23,274	51,686	46,142	4,163	50,453	38,956	2,652	98,948	98,589	G.O.

Table 7-36. (Section 4.)

Thousand Dollars

Sector Number	Sector Title	A 20 Primary Metals	A 21 Other Mfg.	A 22 Mining	A 23 Utilities	A 24 Selected Services	A 25 Trade and Trans.	A 26 Unal-located	A 27 Scrap & By-Prod.	A 28 Net Trade to Outside	A 29 Maint. Constr.	A 30 New Constr.	A 31 State & Local Gov.	A 32 Federal Gov.	A 33 Inven-tory Addit'n	A 34 Inven-tory Deplet'n	A 35 Gross Pri. Cap. Form.	A 36 All House-holds	A 37 Total Production	Sector Number
C 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	9,850	-0	-0	-0	-0	708	-0	-0	209	493,911	C 1
C 2	Poultry and Eggs	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	339	-0	-0	16,732	325,015	C 2
C 3	Farm Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	4	-0	-0	11	395,520	C 3
C 4	Food and Feed Grains	-0	-0	-0	-0	-0	-0	-0	-0	766	-0	-0	1	-0	159	-0	-0	3	177,030	C 4
C 5	Cotton	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	300,069	C 5
C 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	-0	72	-0	-0	-0	-0	-0	-0	-0	15	548,150	C 6
C 7	Fruit (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	677	-0	-0	1	-0	-0	-0	-0	1,706	405,600	C 7
C 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	340	-0	-0	-0	-0	-0	-0	-0	97	158,815	C 8
C 9	Forage	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	206,568	C 9
C 10	Miscellaneous Agriculture	-0	17	-0	-0	-0	-0	-0	-0	36	-0	-0	-0	-0	-0	-0	-0	10	342,310	C 10
C 11	Grain Mill Products	-0	-0	-0	-0	1	4	98	41	-0	-0	-0	59	-0	-0	-19	-0	2,335	440,727	C 11
C 12	Meat and Poultry Processing	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1,231,630	C 12
C 13	Dairy Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	769,477	C 13
C 14	Canning, Preserving, Freezing	-0	17	-0	-0	34	153	3,882	-0	-0	-0	-0	289	-0	630	-0	-0	64,687	1,623,104	C 14
C 15	Miscellaneous Agri. Processing	-0	7	-0	-0	12	52	1,354	6	-0	-0	-0	41	-0	23	-0	-0	31,165	1,869,686	C 15
C 16	Chemicals and Fertilizers	226	313	1,459	8	164	41	207	4,347	-0	584	420	164	-0	15	-0	-0	4,139	1,437,278	C 16
C 17	Petroleum	21	29	87	52	43	312	100	2	-0	81	192	60	-0	-0	-10	-0	1,252	3,156,418	C 17
C 18	Fabricated Metals and Machinery	1,376	654	420	725	2,316	538	3,027	475	6,388	3,241	17,750	431	-0	-0	-1,174	7,547	8,303	5,003,122	C 18
C 19	Aircraft and Parts	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	3,569,019	C 19
C 20	Primary Metals	4,520	73	260	22	5	22	124	124	7,237	203	638	-0	-0	98	-0	-0	6	1,222,036	C 20
C 21	Other Manufacturing	171	3,385	513	92	358	344	3,237	38	57	956	6,725	195	-0	22	-0	285	5,074	5,037,396	C 21
C 22	Mining	337	70	1,569	1	-0	-0	1	-0	5,111	23	101	-0	-0	-0	-0	-0	-0	395,021	C 22
C 23	Utilities	67	45	145	316	59	274	272	-0	505	5	25	52	60	-0	-0	17	1,107	2,222,819	C 23
C 24	Selected Services	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	3,811,907	C 24
C 25	Trade and Transportation	892	1,148	1,143	380	1,359	2,140	3,042	-0	2,261	1,146	4,369	297	1,536	-0	-0	1,083	38,728	11,113,313	C 25
C 26	Unallocated	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	11,942,913	C 26
C 27	Scrap and By-Products	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	336,365	C 27
C 28	Net Trade from Outside	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	5,831,423	C 28
C 29	Maintenance Construction	10	31	40	628	207	1,107	5,291	-0	-0	1	5	4,182	460	-0	-0	-0	-0	2,276,253	C 29
C 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	1,931	-0	-0	34,872	-0	6,570,405	C 30
	Households and Government	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	13,840,257	
A 1	Meat Animals and Products	-0	-0	-0	-0	-0	-0	-0	-0	107,956	-0	-0	-0	-0	3,161	-0	-0	2,294	142,824	A 1
A 2	Poultry and Eggs	-0	-0	-0	-0	-0	-0	-0	-0	-76	-0	-0	-0	-0	142	-0	-0	7,016	8,117	A 2
A 3	Farm Dairy Products	-0	-0	-0	-0	-0	-0	-0	2,667	-573	-0	-0	-0	-0	450	-0	-0	1,300	25,735	A 3
A 4	Food and Feed Grains	-0	-0	-0	-0	-0	-0	-0	-0	8,016	-0	-0	10	-0	2,127	-0	-0	44	28,162	A 4
A 5	Cotton	-0	-0	-0	-0	-0	-0	-0	13,098	49,775	-0	-0	49	-0	69,798	-0	-0	-0	150,795	A 5
A 6	Vegetables	-0	-0	-0	-0	-0	-0	-0	-0	58,911	-0	-0	24	-0	-0	-0	-0	12,329	73,841	A 6
A 7	Fruits (Excluding Citrus) & Nuts	-0	-0	-0	-0	-0	-0	-0	-0	452	-0	-0	1	-0	-0	-0	-0	1,138	1,700	A 7
A 8	Citrus	-0	-0	-0	-0	-0	-0	-0	-0	5,171	-0	-0	3	-0	-0	-0	-0	2,165	9,898	A 8
A 9	Forage	-0	-0	-0	-0	-0	-0	-0	-0	1,979	-0	-0	30	-0	-0	-320	-0	-0	34,261	A 9
A 10	Miscellaneous Agriculture	-0	2,182	-0	-0	-0	-0	-0	59	4,125	-0	-0	3	-0	-0	-13	-0	1,253	26,889	A 10
A 11	Grain Mill Products	-0	1	-0	-0	3	16	416	172	-0	-0	-0	251	-0	-0	-82	-0	9,902	23,273	A 11
A 12	Meat and Poultry Processing	-0	29	-0	-0	18	77	2,008	-0	-0	-0	-0	79	-0	109	-0	-0	46,260	51,608	A 12
A 13	Dairy Products	-0	3	-0	-0	16	71	1,826	-0	-0	-0	-0	512	-0	4	-0	-0	38,661	46,142	A 13
A 14	Canning, Preserving, Freezing	-0	1	-0	-0	2	9	228	-0	-0	-0	-0	17	-0	37	-0	-0	3,799	4,161	A 14
A 15	Miscellaneous Agri. Processing	-0	11	-0	-0	17	77	1,997	9	-0	-0	-0	61	-0	34	-0	-0	45,955	50,451	A 15
A 16	Chemicals and Fertilizers	552	762	3,557	19	400	99	504	10,599	-0	1,423	1,025	401	-0	36	-0	-0	10,090	38,953	A 16
A 17	Petroleum	22	31	91	55	45	328	105	2	-0	85	202	63	-0	-0	-10	-0	1,317	2,652	A 17
A 18	Fabricated Metals and Machinery	2,140	1,017	653	1,127	3,602	837	5,952	738	-9,706	5,041	27,616	671	-0	-0	-1,826	11,737	13,037	98,650	A 18
A 19	Aircraft and Parts	4	178	-0	-0	2,042	797	5,694	216	72,002	-0	-0	-0	-0	-0	-2,878	1,031	158	98,589	A 19
A 20	Primary Metals	52,559	848	3,025	257	56	252	1,441	1,438	84,145	2,359	7,416	-0	-0	1,138	-0	-0	73	164,410	A 20
A 21	Other Manufacturing	1,346	26,680	4,047	728	2,824	2,710	25,511	297	449	7,538	53,002	1,536	-0	176	-0	2,249	40,007	175,791	A 21
A 22	Mining	14,676	3,046	68,376	44	1	8	42	-0	221,503	1,018	4,403	2	-0	-0	-0	-0	10	314,519	A 22
A 23	Utilities	4,080	2,743	8,827	19,290	3,622	16,762	16,603	-0	30,840	285	1,500	3,201	3,691	-0	-0	1,066	67,634	187,502	A 23
A 24	Selected Services	258	913	344	295	11,540	10,498	11,198	-0	55,695	174	1,058	841	10,034	-0	-0	-0	104,225	209,831	A 24
A 25	Trade and Transportation	9,060	11,660	11,612	3,862	13,805	21,743	30,911	-0	12,468	11,646	44,391	3,014	15,600	-0	-0	11,006	393,508	632,496	A 25
A 26	Unallocated	4,527	10,359	21,700	25,728	24,224	92,829	140,128	-0	5,438	1,544	24,459	103,271	26,300	-0	-0	3,526	467,446	994,541	A 26
A 27	Scrap and By-Products	1,620	25	55	-0	246	135	55	-0	7,859	22	118	397	-0	-0	-0	-0	20	29,295	A 27
A 28	Net Trade with Outside	14,144	30,126	37,922	13,698	27,534	19,458	30,289	-5,054	-0	11,664	35,739	6,609	30,092	1,578	1,203	-10,834	273,090	666,743	A 28
A 29	Maintenance Construction	104	331	422	6,697	2,211	11,806	56,448	-0	-2,175	9	55	44,613	4,911	-0	-0	-0	-0	130,925	A 29
A 30	New Construction	-0	-0	-0	-0	-0	-0	-0	-0	-6,123	-0	-0	-0	13,114	-0	-0	236,836	-0	249,958	A 30
	Households and Government	51,704	79,056	150,164	113,478	113,065	448,999	641,750	-0	-0	81,876	137,059	141,838	390,248	-0	-0	-0	-0	2,778,258	
	GROSS OUTLAY	164,416	175,791	316,521	187,502	209,831	632,498	994,541	29,296	741,439	130,924	369,076	313,269	497,985	77,204	-5,129	300,421	1,718,392	126,487,635	G.O.

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[a] Each entry shows the value of goods and services produced by California or Arizona sector listed at the left that were purchased by the California or Arizona sector listed at the top.

[b] Some columns and row totals do not add up exactly due to rounding.

Department of Interior, Bureau of Reclamation (February 1972), Colordo River—Great Basin Consortium of Water Centers and Institutes (September 1973), and U.S. Department of Interior, Bureau of Reclamation (February 1974). EPA (1971) has given the sources of salt concentration at Hoover Dam as follows:

Table 7-37. Effects of factors on salt concentrations at Hoover Dam (1942-1961 records).

Factor	Contribution to Concentration (mg/l)	Percent of Total Concentration
Natural Diffuse Sources	275	39
Natural Point Sources	59	8
Irrigation (Salt Additions)	178	26
Irrigation (Consumptive Use)	75	11
Municipal and Industrial	10	1
Exports of Water	20	3
Evaporation and Phreatophytes	80	12
Totals	697	100

The U.S. Bureau of Reclamation has developed a program to deal with important point sources and is in the process of optimizing a program of control with respect to all sources and in light of the damages being imposed (see U.S. Bureau of Reclamation, February 1972, and John T. Maletic in Flack and Howe, 1974). It is clear from the foregoing table that upper basin irrigation contributes substantially to the salt concentration problem, both through its extensive consumptive use of relatively high quality water and through the salt loadings of its return flows. EPA (1971) estimated that the salt pickup from irrigated acreage was approximately as follows:

Average above Hoover Dam	2 tons/acre/year
Grand Valley, Colorado	4 to 8 tons/acre/year
Below Hoover Dam	0.5 to 1.0 tons/acre/year

Skogerboe (Colorado State University) has more recently estimated that some irrigated areas of the Grand Valley contribute as much as 10 tons/acre/year.

When these large externalities are observed and when the marginal economic condition of a significant number of acres of irrigated land in the Upper Basin is noted, a selective reduction in irrigated acreage naturally suggests itself as a potentially efficient way of reducing both salinity loadings and concentration.

On-farm management practices can be expected to form part of an optimum program of salinity control. More careful application of water and the lining of ditches, especially in the areas where return flows pick up such great quantities of salt, are likely to be helpful, as are changing furrow length, recycling drain water from tail water pits, and more extensive use of sprinklers. These aspects of salinity management are being studied by Young and Leathers as part of this project.

Young has suggested to the present authors that the most obvious areas for acreage reduction lie in the Grand Valley and the Uncompaghre Basin. Young indicates that the following acreages constitute the most likely candidates for the phase-out:

Crop	Grand Valley Acres	Uncompaghre Basin Acres
Corn	1,200	1,500
Other Grains	2,000	2,300
Alfalfa	2,300	2,700
Pasture	3,300	3,700
Total	8,800	10,200

Young has indicated that these acreages average (in 1974 dollars) a total output value of about $150/acre/year and yield net incomes to the farmer somewhere in the $30 to $50/acre/year range.

It is these acreage reductions which have been taken for study in this chapter, the objectives being to estimate the impact in the region of losing this amount of agricultural activity and to determine how much water might be saved. Since in any such program the areas should be specifically selected for phase-out on the bases of low direct income production and high salt contributions, we will rely on the EPA estimates that 4 to 8 tons of salt/acre/year are contributed by the selected areas.

Direct and Indirect Economic, Hydrologic, and Salinity Impacts

The main tools of analysis used for this chapter have been the integrated economic and hydrologic models developed by Udis, Howe, and Kreider (July 1973). These models consist of regional input-output models for the Green, Upper Main Stem, and San Juan River Basins, plus (monthly) hydrologic models calibrated to the smaller basins shown on Figure 2. An earlier application of these models to the analysis of an Upper Basin acreage reduction was reported by Howe and Orr (October, 1974 and 1975).

The input-output model of the Upper Main Stem Basin was up-dated to 1970 prices for the present study, and the subbasins of the Upper Main Stem were redefined as:

Colorado Main Stem above Glenwood Springs
Gunnison River to the North Fork
North Fork of the Gunnison
Uncompaghre Basin
Gunnison Main Stem from the North Fork to but not including Grand Junction
Colorado Main Stem below Glenwood Springs including the Dolores and San Miguel Basins

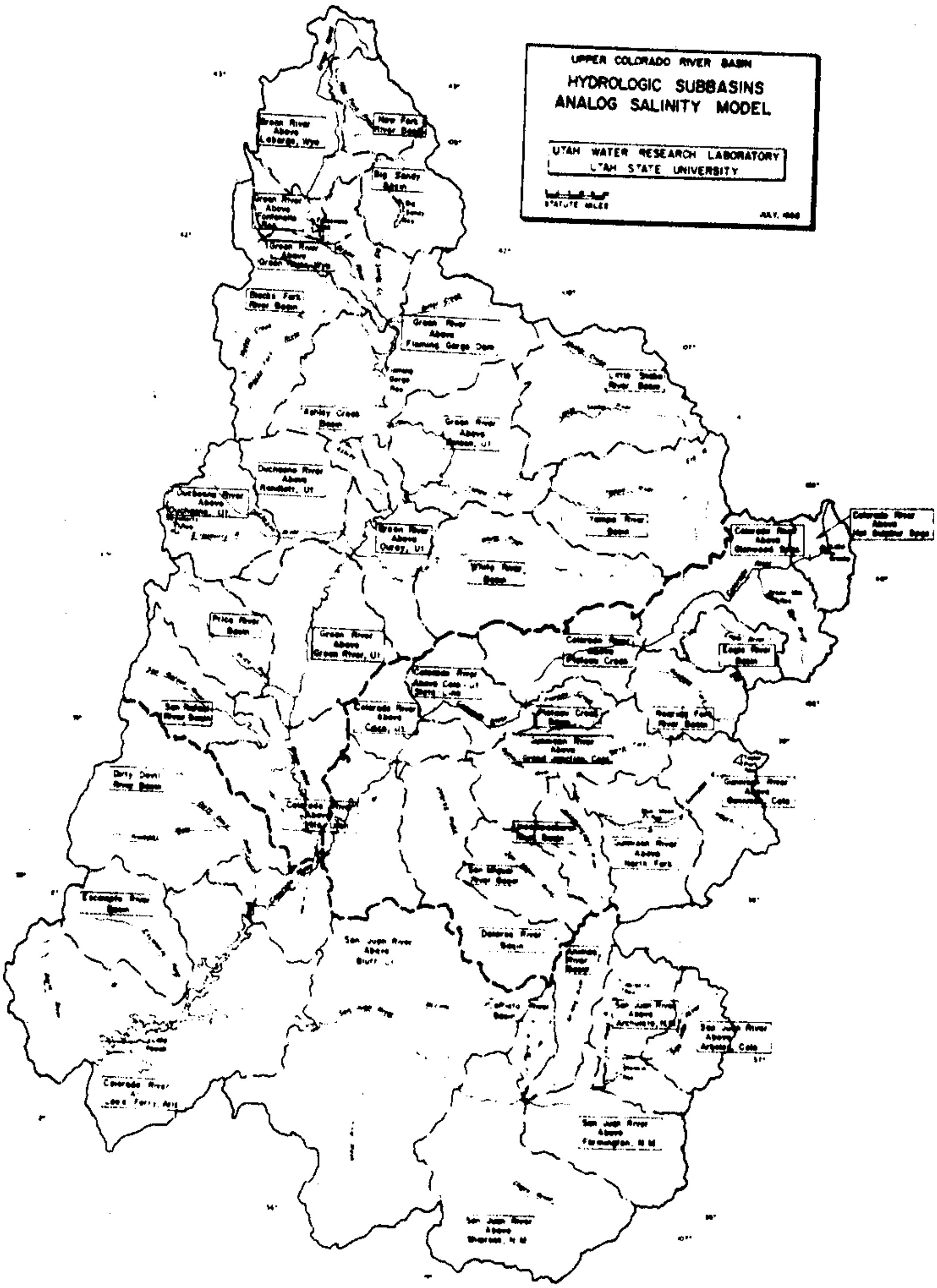

Figure 7-2. Upper Colorado River basin showing main tributary divisions and hydrologic subbasins.

While the hydrologic models were calibrated using hydrologic records of as great a length as possible, the historical record used in deriving the models was 1962-1969, inclusive.

The area containing the subject acreages consists of Mesa, Delta, and Montrose Counties, Colorado, but the integrated economic region of which they are a part also contains Gunnison, Ouray, Hinsdale, and San Miguel Counties. While the input-output model relates to the Upper Main Stem Basin as a whole, the total outputs of each productive sector were allocated to the subbasins listed above. A baseline projection to 1980 of the seven county area is shown in Table 7-38. Also shown are the payments to households (wages, salaries, rents, dividends, and interest) as percentages of the gross value of output. Payments to households were used as an approximation to regional income.

Corresponding to the 1980 economic projections, Table 7-39 exhibits the projected subbasin surface outflows in acre feet, based on the 1962-1969 hydrologic record. Corresponding salt outflows are given in Table 7-40.

Three cases have been treated in the following analyses:

Case I - a direct reduction of 8800 acres of corn, other grains, alfalfa, and pasture in the Grand Valley.

Case II - a direct reduction of 10,200 acres of these crops in the Uncompaghre Basin.

Case III - the combined reductions of Cases I and II.

These reductions have been valued at $101 (in 1970 dollars) gross output per acre and have been treated as reductions in the "range livestock" sector of the input-output model since that sector is defined to contain pasture, alfalfa, and those grains grown on

Table 7-38. Projected 1980 output levels for the affected basins (thousands of 1970 dollars).

	Sector	Uncompaghre Basin	N. Fork of Gunnison	Gunnison[a] Main Stem	Colorado[b] Main Stem	Total 7[c] County Area	% H.P. in T.G.O.[d]
1.	Range Livestock	6,854	1,926	5,794	26,938	41,512	48
2.	Feeder Livestock	1,545	260	955	1,705	4,465	2
3.	Dairy	724	237	639	1,902	3,502	31
4.	Food/Field	2,734	762	898	3,274	7,668	52
5.	Truck Crops	417	159	178	429	1,183	33
6.	Fruit	357	560	735	2,458	4,110	32
7.	Forestry	193	205	213	1,539	2,150	53
8.	Other Agriculture	411	089	213	898	1,611	28
9.	Coal	0	11,218	0	664	11,887	53
10.	Oil and Gas	0	0	0	8,174	8,174	(NA)
11.	Uranium	0	0	0	160,042	160,042	(NA)
12.	Zinc and Lead	1,108	0	0	3,343	4,451	(NA)
13.	Other Mining	1,713	125	248	5,646	7,732	60
14.	Food/Kindred	2,767	529	8,303	17,794	29,393	19
15.	Lumber/Wood	1,848	396	1,531	1,624	5,399	26
16.	Printing/Pub.	345	345	173	3,392	4,255	40
17.	Fabricated Metals	100	0	800	2,900	3,800	30
18.	Stone, Clay, Grass	360	0	480	3,480	4,320	24
19.	Other Manufacturing	1,540	880	2,860	32,254	34,054	19
20.	Wholesale Trade	2,075	907	2,081	27,959	33,022	23
21.	Service Stations	923	199	569	3,146	4,837	68
22.	Other Retail	8,286	1,810	5,172	37,529	52,797	58
23.	Eating/Drinking	3,411	460	1,290	11,472	16,633	31
24.	Agric. Services	814	455	700	2,427	4,396	40
25.	Lodging	761	109	257	9,280	10,407	40
26.	Other Services	3,489	416	1,551	20,176	25,632	47
27.	Transportation	4,747	955	5,172	22,392	33,266	38
28.	Elec. Energy	2,168	161	375	8,082	10,786	26
29.	Other Utilities	3,079	862	1,712	15,766	21,419	42
30.	Contr. Const.	6,177	1,705	3,337	59,801	71,020	27
31.	Rental/Finance	10,213	1,994	5,680	42,542	60,429	73
					Total	684,352	

[a] Gunnison River from North Fork's confluence to but not including Grand Junction.

[b] Colorado River from Glenwood Springs, including basins of the Dolores and San Miguel Rivers.

[c] Mesa, Delta, Gunnison, Montrose, Ouray, Hinsdale, and San Miguel Counties.

[d] Percentage of payments to households in total value of each sector's output.

Table 7-39. Projected 1980 surface outflows based on projected 1980 economic conditions and 1962-1969 hydrology (thousands of acre feet).

	Uncompaghre Basin	N. Fork of Gunnison	Gunnison[a] Main Stem	Colorado[b] Main Stem
January	4.5	2.6	54.9	167.9
February	5.8	4.5	49.6	164.2
March	7.4	8.6	66.1	203.6
April	20.6	22.4	128.4	347.2
May	38.5	84.0	354.2	881.9
June	27.9	72.4	299.5	881.8
July	18.4	24.4	131.7	385.7
August	11.0	6.7	75.1	207.4
September	20.7	7.4	80.7	175.5
October	27.5	9.4	88.0	254.7
November	15.2	8.0	84.5	238.6
December	8.8	3.8	75.9	206.1
Ave. Mon.	17.2	21.2	124.1	342.9
Ann. Total	206.3	254.3	1388.7	4114.6

[a] Gunnison River from N. Fork confluence to but not including Grand Junction.

[b] Colorado River from Glenwood Springs, including basins of the Dolores and San Miguel Rivers.

Table 7-40. Projected 1980 outflows of total dissolved solids based on projected 1980 economic conditions and 1962-1969 hydrology (thousands of tons).

	Uncompaghre Basin	N. Fork of Gunnison	Gunnison[a] Main Stem	Colorado[b] Main Stem
January	16.4	5.6	69.3	247.7
February	17.0	5.8	60.6	234.2
March	17.2	6.7	70.3	253.5
April	52.9	14.1	109.4	331.0
May	96.1	28.9	185.4	603.7
June	59.3	31.1	153.4	497.8
July	44.7	17.7	129.8	345.9
August	37.7	7.7	120.9	293.3
September	55.9	6.2	125.5	269.9
October	67.1	6.5	138.4	323.1
November	32.2	6.5	100.1	295.0
December	21.9	5.9	90.5	278.8
Ave. Mon.	43.2	11.9	112.8	331.2
Ann. Total	518.3	142.8	1,353.6	3,973.8

[a] Gunnison River from N. Fork confluence to but not including Grand Junction.

[b] Colorado River from Glenwood Springs, including basins of the Dolores and San Miguel Rivers.

ranches for winter feed. It has been assumed that the resultant direct reductions in the value of output would take the form of reduced exports from the seven county region. The direct reductions in output are:

Case I:	$892,000 in Grand Valley
Case II:	$1,034,000 in the Uncompaghre Basin
Case III:	$1,926,000 combined

When these reductions in deliveries to final demand are analyzed through the input-output model, the resulting gross output levels are generated and reflect all of the direct and indirect impacts on all sectors of the regional economy. The output levels and the changes from the base 1980 projection are shown in Table 7-41.

The results of analyzing the three cases are given below:

Case I: 8800 acres in the Grand Valley.

gross value of direct crop loss ($1970)	$892,000
total direct and indirect output loss over all sectors	$1,800,000
total direct and indirect reduction in payments to households	$954,000
total direct and indirect reduction in consumptive uses of water (AF)	$14,800
approximate range of reduced salt loading (tons)	35,200 to 70,400

Case II: 10,200 acres in the Uncompaghre Basin.

gross value of direct crop loss ($1970)	$1,034,000
total direct and indirect output loss over all sectors	$2,083,000
total direct and indirect reduction in payments to households	$1,104,000
total direct and indirect reduction in consumptive uses of water (AF)	16,000
approximate range of reduced salt loading (tons)	$40,800 to $81,600

Case III: combined acreage reductions.

gross value of direct corp loss ($1970)	$1,926,000
total direct and indirect output loss over all sectors	$3,882,000
total direct and indirect reduction in payments to households	$2,057,000
total direct and indirect reduction in consumptive uses of water (AF)	30,800
approximate range of reduced loading (tons)	$76,000 to $152,000

Table 7-41. Pattern of gross outputs under Cases I, II, and III[a]*: seven county total*[b] *(in thousands of 1970 dollars).*

	Sector	Case I	Case II	Case III
1.	Range Livestock	40,511	40,352	39,351
2.	Feeder Livestock	4,459	4,459	4,453
3.	Dairy	3,497	3,496	3,491
4.	Food/Field	7,664	7,663	7,659
5.	Truck Crops	1,182	1,182	1,181
6.	Fruit	4,104	4,104	4,098
7.	Forestry	2,149	2,149	2,149
8.	Other Agriculture	1,608	1,608	1,605
9.	Coal	11,882	11,881	11,876
10.	Oil and Gas	8,174	8,174	8,174
11.	Uranium	160,042	160,042	160,042
12.	Zinc and Lead	4,451	4,451	4,451
13.	Other Mining	7,730	7,730	7,728
14.	Food/Kindred	29,347	29,339	29,293
15.	Lumber/Wood	5,397	5,397	5,397
16.	Printing/Publications	4,242	4,240	4,227
17.	Fabricated Materials	3,800	3,800	3,800
18.	Stone, Clay, Glass	4,318	4,317	4,315
19.	Other Manufacturing	34,021	34,016	33,983
20.	Wholesale Trade	32,980	32,973	32,931
21.	Service Stations	4,819	4,817	4,799
22.	Other Retail	52,641	52,616	52,460
23.	Eating/Drinking	16,605	16,601	16,573
24.	Agric. Services	4,368	4,364	4,336
25.	Lodging	10,405	10,405	10,403
26.	Other Services	25,584	25,576	25,528
27.	Transportation	33,206	33,197	33,137
28.	Elec. Energy	10,760	10,756	10,730
29.	Other Utilities	21,382	21,376	21,339
30.	Contr. Constr.	70,965	70,956	70,901
31.	Rental/Finance	60,259	60,232	60,062
	Totals	682,552	682,269	680,470
	Change from 1980 Base Projection	-1,800	-2,083	-3,882
	Change in Payments to Households from 1980 Base Projects	-954	-1,104	-2,057

[a] Case I: reduction of 8800 acres in the Grand Valley; Case II: reduction of 10,200 acres in the Uncompaghre Basin; Case III: combined reductions of Cases I and II.

[b] Mesa, Delta, Gunnison, Montrose, Ouray, Hinsdale, and San Miguel Counties.

INDIRECT IMPACTS OF MUNICIPAL AND INDUSTRIAL SALINITY RELATED LOSSES

Preceding sections dealt with direct and secondary losses related to the use of increasingly saline water in agriculture. Another study in the present joint project (d'Arge et al.) has made estimates of municipal and industrial losses stemming from the presence of a high level of dissolved solids in the water supply. Previous studies (Wesner, 1974; and Tihansky, 1974) have indicated quite substantial detrimental impacts in terms of reduced piping and appliance lives. Tihansky estimated per capita losses in residential applications from $1.15 in South Carolina to $22.50 in Arizona, while Wesner estimated monthly losses per household in Orange County, California to be about $12.

Issues which must be considered when evaluating the municipal and industrial (M&I) impacts of increased Colorado River salinity include: 1) Whether or not the municipalities and industries have opportunities for mixing with purer waters to keep TDS concentrations below highly detrimental levels (e.g. the Municipal Water District of Los Angeles); and 2) the particular constituents presented in the TDS load. It is possible, after all, to have "too good" a water supply in terms of corrosive effects of very pure water.

The sections which follow define the issues which are involved in secondary impacts of M&I losses. The conclusion is that it is likely, on *a priori* grounds, that M&I damages cause changes in patterns of expenditures over time but not in levels of expenditure. Since the resulting expenditure pattern is likely to be similar sector-wise to the original (for households and industry) or is extremely uncertain (for the public sector), secondary effects are expected to be negligible.

Impacts on Households

The major non-health related impact is on the life of water-using appliances and piping. These effects are likely to be relatively long-run in terms of the planning horizons of most families. Plumbing may last 30 years rather than 50, while appliances might last 10 years rather than 12. The present values of the implied differences in cost streams are likely to be very low in view of the high rates of time preference expressed by many households (e.g. see Haveman, 1969). It seems unlikely that many households think clearly in present value terms, but even if they do, differences in costs of far away events become unimportant with a high discount rate. Pertinent examples can be found in Howe and Vaughan (1972).

Unlike the farm output losses which induced no substitute expenditures, greater losses on household appliances and plumbing are most likely to cause the substitution of expenditures on such items for other consumer-type expenditures. While it cannot be known with a high degree of confidence, it seems plausible that increased appliance expenditures will substitute for other types of consumer durables, e.g. if a washing machine is needed earlier, expenditures on lawn equipment or the auto will be deferred or reduced. Thus the sectors of the economy which are likely to experience increased demands from households are highly likely to be the same which experience reduced demands for other consumer durables. This is particularly likely in light of the broad sector definitions used in input-output studies.

It follows from these observations that secondary effects of changes in household expenditure patterns stemming from increased salinity are likely to be negligible and beyond our empirical capabilities of tracing them.

Commercial, Public, and Industrial Secondary Impacts

Commercial and industrial water users utilize water for process and cooling purposes and for boiler feed purposes. The latter use requires such a pure water that complete distillation is often used anyway. The public sector has charge over water supply pipelines and water intake treatment plants, all of which can be affected by water quality.

In these uses, it seems more likely than for households (although far from certain) that increased damage from deteriorating water quality will result in an increased level of expenditures rather than simply a substitution of one type of expenditure for another. However, if increased costs are passed on to consumers in increased prices, the effect on total expenditures depends on unknown price elasticities. Commercial enterprises may thus be faced with having to substitute increased expenditures related to salinity damage for other types of expenditure. This seems highly likely also for local and state governments which have such definite budget constraints.

It is concluded from these considerations that the secondary effects of household and M&I losses are likely to be small, insignificant in welfare terms, and beyond our capabilities of tracing secondary impacts.

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