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Irrigation as a Solution to Salinity Problems of River Systems

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INTRODUCTION

As one proceeds from the head waters to the mouth of a river system, there is usually increasing salinity. This increase is generally due to the continuous exchange between low salt surface waters and more saline ground waters along the path of flow. As the surface flows become lower, the fraction of water entering the waterway from groundwater sources increases. Hence, during periods of low flow, the salinity in river systems is higher. If diversions are made along the path of flow, this further reduction in flow in the river leads to even higher salinities down stream. Since legislation in the United States requires that no further increase in salinity in river systems will be allowed, methods of diverting the flow of highly saline water from river systems must be found. The strategy to deal with this problem on the Colorado River, as formulated by the Bureau of Reclamation, was to first identify several saline flows into the river. These saline waters were to be diverted from the river. Originally, it was visualized that desalinization projects along the river could effectively remove the salts. However, the energy crisis and a dollar short economy has led many people to believe that desalinization by processes known today are not a viable way of handling the problem. An alternative to desalinization would be the construction of saline irrigation projects close to the mouth of the tributaries with a river system. Using the Colorado river system as an example, consider the quality of the waters to be diverted. Their quantities and salt composition (3) are shown in Table 1. It should be noted at this point that over 95% of the the waters to be diverted from the river have an electrical conductivity of less than 7.2 dSm^{-1}. Arizona far-

Table 1. Saline water sources for the Colorado River

	Units	acre-ft/yr	TDS/ppm	EC dS/m
1.	Big Sandy River	19,000	5,015	7.2
2.	Meeker Dome	1,090	19,300	27.6
3.	Glenwood-Dotsero Springs	25,000	14,200	20.3
4.	Grand Valley	43,500	3,300	4.7
5.	Lower Gunnison	17,200	2,900	4.1
6.	Paradox Valley	568	265,000	278.5
7.	McElmo Creek	32,500	2,700	3.8
8.	Uinta Basin	13,600	4,500	6.4
9.	Price River	24,900	4,000	5.7
10.	San Rafael River	22,200	3,600	5.1
11.	Crystal Geyser	150	14,000	20.0
12.	Dirty Devil River	68,800	1,703	2.4
13.	La Verkin Springs	8,300	10,000	14.3
14.	Lower Virgin	7,200	2,800	4.0
15.	Las Vegas Wash	72,000	2,000	2.8
16.	Palo Verde Irrigation District	253,000	1,700	2.4

mers have long recorded the use of well waters of this conductivity (4) and (8). Although farms using these highly saline waters are severely restricted in choice of crops, their farms none the less form valid economic units.

Over the last two decades, there has been a great deal of research regarding the depressing of yields by saline water. There are now handbooks (1, 5) showing the reduction of yield using waters of various EC. For example, many of the crops grown in Arizona using saline water are shown in Table 2. It should be noted that most of the waters reported in Table 1 could be used to grow these same crops. The data used to develop Table 2 are primarily from small research plots, lysimeters and tank experiments. There has been indeed little data published on yields under actual field conditions (6).

FIELD RESULTS IN ARIZONA

The University of Arizona Safford Experiment Station has been the principle research site in Arizona for studying the use of saline water. At this site soils are high in clay and are saline. Examples of soil analysis from Safford are given in Table 3. The chemical analysis of the well water used for irrigation during the period in which selected yield values were obtained is given in Table 4. It is observed that the concentration of the Safford well water is similar to some of the lower salt waters which are to be diverted from the Colorado River. Yields of cotton, barley, sugarbeets, and safflower are given in Table 5. Of particular interest is that in every case, these yields equal or exceed the statewide average yield for these same crops.

Table 2. Crop Tolerance Table

Yield decrement to be expected for certain crops to salinity of irrigation water when common surface irrigation methods are used.

Crop	EC_w				
	0%	10%	25%	50%	Maximum
	%				
Barley	5.3	6.7	8.7	12	28
Cotton	5.1	6.4	8.4	12	27
Sugarbeet	4.7	5.8	7.5	10	24
Bermuda grass	4.6	5.7	7.2	9.8	22.5
Wheat	4.0	4.9	6.4	8.7	20
Safflower	3.5	4.1	5.0	6.6	14.5
Date Palm	2.7	4.5	7.3	12	32
Sorghum	2.7	3.4	4.8	7.2	18

Table 5. Selected crop yield from the University of Arizona Safford Experiment Station

Crop	Yield	Statewide Average
Cotton (1970)	1258 kg/ha	1120 kg/ha
Barley (1972)	4117 kg/ha	3214 kg/ha
Sorghum (1971)	7820 kg/ha	4892 kg/ha
Sugar beets (1972)	56.0 T/ha	56.7 T/ha

The Red Mountain Farm near Dateland, in southeastern Arizona, reported using irrigation waters from wells ranging in salinity from 4 to 11 dSm^{-1}. The authors chose 4 fields to evaluate during 1982. These fields were numbered 4, 10,

Table 3. Analysis of Soils. Safford Experiment Station 0-30 cm

Series Texture	Paste pH	EC_e dS/m	Soluble Salts ppm	C.E.C. meq/100g	Exchangeable Sodium %
Grabe clay loam *	8.1	4.5	3,150	12.6	----
Grabe clay loam **	8.1	5.1	3,570	26.7	31.8
Pima clay loam *	7.9	5.6	3,920	22.0	----
Guest clay *	7.9	2.0	1,400	33.4	----

* Sampled 1971
** Sampled 1968

Table 4. Analysis of Well Water. Safford Experiment Station

Sample Date	EC ds/m	Sol. Salts ppm	Concentration, ppm							
			pH	Ca	Mg	Na	Cl	SO_4	CO_3	HCO_3
March, 1971	3.06	1991	7.8	80	23	550	560	250	0	468
July, 1971	3.1	2154	7.5	80	26	600	640	350	0	417
August, 1971	3.2	2439	7.5	112	28	665	732	390	0	454
September, 1972	3.5	2474	7.7	128	28	660	740	340	0	527

14 and 29. Fields 4, 10, and 14 are all on a single ditch that is supplied by water from wells ranging in EC from 3.0 to 8.0 dSm^{-1}. The general practice followed by Red Mountain Farms in irrigating these three fields is to germinate their cotton using lower-salt wells and alternate-furrow irrigation. The weighted average of the EC_w for the irrigation water used on these three fields is given in Table 6 and ranges from 4.0 to 6.2 dSm^{-1}. Another field, #29, can only be watered with one well having an EC_w of 11.0 dSm^{-1}. The field is both germinated and irrigated with this water. Soil samples were taken at three depths at four locations in each of the four fields. The electrical conductivities of the saturation extract of each field locations are given in Table 7. It should be noted that soil salinity composition at the different locations varied widely, a common property of saline soils. The average electrical conductivity for saturation extracts, EC_e, for three depths for Fields 14, 10, 4 and 29 are given in Table 8. Also given in Table 8 are the electrical conductivities of the irrigation waters, EC_w, and the calculated electrical conductivity of the saturation extracts, EC_e, which would be expected if there was a 70% irrigation efficiency. It should be noted that these estimated values for the saturation extract are in general agreement with those found between the 30 to 75 cm depth. The estimate of the soil water EC_{sw} moving down toward groundwater at the 60

Table 6. Red Mountain Farms cotton lint yields (kg/ha), 1982.

	Field			
	4	10	14	29
Rep 1	1507	1076	1022	1022
2	1668	1076	807	1130
3	1345	861	807	1130
4	1937	967	700	1076
Total	6457	3980	3336	4358
Average	1614	995	834	1076
Estimated Water EC_w dSm^{-1}	6.2	4.5	4.0	11.1

Table 7. Electrical conductivity of soil saturation paste extracts, Red Mountain Farms, 1982.

Depth	Field 4	10	14	29
	dSm^{-1}			
0-15	2.8	1.4	--	7.3
30-45	13.5	13.8	3.1	20.8
60-75	--	5.5	5.1	15.0
0-15	9.4	1.2	1.1	0.73
30-45	11.5	6.9	3.4	2.3
60-75	13.5	13.5	3.5	4.7
0-15	5.1	1.4	1.6	7.4
30-45	11.7	9.5	7.0	27.1
60-75	--	4.1	5.7	18.6
0-15	2.4	0.95	1.6	12.8
30-45	13.2	2.1	5.9	12.1
60-75	11.6	1.1	6.3	17.5

Table 8. Average electrical conductivity (in ds_m^{-1}) in soil waters, Red Mountain Farms.

	Field 14	10	4	29
EC_e 0-15 cm	1.4	1.2	5.0	7.0
EC_e 30-45 cm	4.8	8.1	12.5	15.6
EC_e 60-75 cm	5.1	6.0	12.6	14.0
EC_w	4.0	4.5	6.2	11.0
EC_e (expected)	6.0	6.8	9.3	16.5
EC_{sw}	10.2	12.0	25.2	28.2

to 75 cm depth ranged from 10.2 to 28.2 dSm^{-1}. These can be compared to the design criteria for the groundwater from the desalinization plant proposed in Yuma (2) which would be approximately 13.5 dSm^{-1}. It will be noted that the soil waters in Fields 4 and 29 greatly exceeds this value. Thus, it may be concluded that irrigation using salt tolerant crops is capable of utilizing diverted or drainage waters between an EC of 4 and 11 and of producing an effluent of higher concentration water than proposed for desalinization plants. The yields for these four fields are given in Table 6. The average yields from these fields ranged from 834 to 1614 kg/ha. These may be compared to the statewide average of 1238 kg/ha. Also given in Table 6 is the EC_w of the waters used for irrigating the fields. It will be noted that the decrement of yield which would be expected from Table 1 is not evident. It must be concluded that other factors such as management, soil type, germination and fertilization can alter the potential reduction in yieldcaused by salinity.

ESTABLISHMENT OF SALINE IRRIGATION PROJECTS

There seems little doubt there would be great resistance from farmers on current irrigation projects if saline waters were to be diverted to them. Their objections would be 1) severe restriction of crops which could be grown, 2) reduction in yields, and 3) changes in management practices to utilize saline waters. There are, however, in the Southwestern United States vast tracks of land which are suitable for irrigation agriculture (7), but which are not currently under irrigation due to the lack of sufficient water supplies. Soils chosen to be irrigated with saline waters should be deep, highly permeable, and capable of being drained by either surface or well-drainage systems. To minimize water storage the area should be capable of producing crops over a 12 month period. In addition, these projects should be located so that the brine created by drainage can be disposed of in either evaporation ponds or to a drain. Irrigation systems used should be of the precision type, that is, dead-level basin or furrows or possibly drip irrigation. If possible, a relatively good quality water should be available for germination. Germination should be accomplished by sprinkler, alternate furrow or drip methods. Special shaping of beds to avoid salt buildup is also helpful.

CONCLUSION

Saline waters diverted from river systems to maintain water quality usually can be used for the production of salt tolerant crops. Irrigation by saline waters has been shown to be economically feasible in Arizona. The establishment of saline irrigation projects with their accompanying drainage systems and brine disposal facilities can economically use most waters being diverted from river systems.

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Use of Saline Waste Water from Electrical Power Plants for Irrigation

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INTRODUCTION

Research on the use of saline water for irrigation has been conducted since 1977 at Huntington, Utah with cooling water from the Utah Power & Light Company Huntington plant. Water is partially "consumed" as it is re-cycled in the evaporation-cooling system of the power plant until the salinity of the water reaches a high level at which time it is disposed of as "waste" water. This waste water is delivered to a holding pond from which it is pumped onto an adjacent farm for irrigation. The waste water is used for irrigation to increase crop production as well as disposing of the waste water. Controlled irrigation use has been found to be the best economic alternative for disposing of the waste water as well as minimizing the decreased crop production caused by use of water for power plant cooling rather than for irrigation.

The process of evaporation during the cooling phase of power plant operation is analogous to the evapotranspiration process under crop production. Irrigation water, with a certain concentration of salts, is subject to evaporation and transpiration by crops. The water lost to the atmosphere is essentially pure water which leaves the salt in the remaining liquid solution in the soil. The salinity of the soil solution increases as the number of evaporation (E) or evapotranspiration (ET) cycles increases. In a river system, water is diverted for irrigation at many points along the way and return flow or drainage from irrigation is returned to the river. Thus the river water generally becomes more saline in a downstream direction.