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SALINITY ASPECTS OF THE COLORADO RIVER AGREEMENT*

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INTRODUCTION

The 1973 Colorado River agreement[1] between Mexico and the United States is intended to resolve forever one source of conflict between the two countries: the salinity of the Colorado River at the international boundary.

Salinity has been and will continue to be a major threat to the permanence of irrigation agriculture everywhere in the world. The reason is simple: all irrigation waters contain dissolved salts and crop plants are sensitive, in varying degrees, to those salts. If the salinity of the irrigation water is high or if salts accumulate in the soils as the result of inadequate leaching, crop yields decrease and ameliorative measures must be taken to prevent abandonment of the irrigated fields. Amelioration can consist of any of the following actions, singly or in combination: (1) reduce the salinity of the irrigation water, (2) increase the amount of leaching of irrigation water through the soil, (3) grow more salt-tolerant crops, or (4) change irrigation methods.

Irrigation water quality, which is largely a function of the salinity of the water, was not mentioned in the original Colorado River Compact approved by representatives of the Federal Government and the seven concerned states of the United States in 1922.[2] Neither was it mentioned in the 1944 Treaty[3] which allocated 1,500,000 acre-feet of water annually to Mexico. Prior to 1961, the salinity of the water delivered to Mexico to meet treaty obligations was not a major problem. This situation changed abruptly in 1961 when the flow of excess water (above treaty obligations) to Mexico was sharply diminished due to a series of dry years, to the closing of the gates at Glen Canyon Dam in order to begin filling Lake Powell, and to the initiation of a pumping program in the Wellton-Mohawk Irrigation and

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1. Minute 242. Reprinted in this issue at page 2.

2. Colorado River Compact, 70 Cong. Rec. 324 (1928).

3. Treaty with Mexico Respecting Utilization of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944 (with protocol of November 14, 1944), 59 Stat. 1219 (1945), T.S. No. 994.

Drainage District on the Gila River in Arizona for the purpose of lowering the water table. Wellton-Mohawk drainage water was returned to the Colorado River above Morelos Dam, where 1,360,000 acre-feet of the water allocated to Mexico is diverted. The combination of reduced flows in the Colorado River and a large increase in the salinity of the Wellton-Mohawk drainage water resulted in an increase in the salinity of the water at Morelos Dam from about 800 parts per million (ppm) to nearly 1,500 ppm (Table 1). That was when salinity became a matter of paramount concern on the Mexican side of the border. The affected area is the Mexicali Valley in the state of Baja California.

TABLE 1
Colorado River Salinity at Morelos Dam

Year	*Salinity (ppm)*	
1960	800	
1962	1,500	
	*Theoretical**	*Actual+*
1971	1,245	1,160
1972	1,140	1,000

*If Mexico had utilized Wellton-Mohawk drainage water in accordance with 1971 and 1972 agreements.
+Additional Wellton-Mohawk drainage water bypassed, without replacement.
Source: Bureau of Reclamation & Office of Saline Water, U.S. Dep't of the Interior, Colorado River International Salinity Project (Special Rep., Sept. 1973).

RESOLUTION OF THE IMMEDIATE PROBLEM

The first attempt to resolve the salinity problem which resulted from the 1961 events was embodied in Minute 218 of the International Boundary and Water Commission signed in 1965.[4] Minute 218 called for three steps to be taken by the United States to alleviate the problem: (1) construct an extension to the Wellton-Mohawk drainage canal which would permit the drainage water to bypass Morelos Dam or be returned and used above the dam; (2) bypass all Wellton-Mohawk drainage water for at least 90 days each year and repay Mexico for the bypassed water by replacing it with 50,000 acre-feet of mainstream Colorado River water; and (3) do selective pumping of the most saline drainage water at a time when that water could be

4. 4 Int'l Legal Materials 545 (1965), 55 Dep't of State Bull. 555 (1965). *See* Bureau of Reclamation & Office of Saline Water, U.S. Dep't of the Interior, Colorado River International Salinity Project (Special Rep., Sept. 1973).

bypassed and wasted below Morelos Dam, pumping the less saline drainage waters when they could be returned and used above Morelos Dam. Minute 218 was due to expire after five years. It was extended twice, in 1970 and 1971, for one year each time.

After the measures proposed in Minute 218 were in operation, the salinity of the water made available at Morelos Dam had dropped to 1245 ppm. Since the Mexicans believed that the maximum salinity they could utilize for irrigation in the Mexicali Valley was 1230 ppm, Mexico bypassed (without replacement by the United States) the remainder of the Wellton-Mohawk water. This amounted to between 40,000 and 75,000 acre-feet per year. Bypassing all drainage water reduced the salinity at Morelos Dam to 1160 ppm in 1971. This was still considerably above the salinity of Imperial Dam water (about 850 ppm) on the U.S. side of the border.

Protests by farmers of the Mexicali Valley about the adverse effect of Colorado River salt on crop production continued. President Echeverría responded to the protests in 1972 by asking President Nixon to meet with him to find a permanent solution to the problem. The two presidents met in June 1972 and agreed to further reduce the salinity at Morelos Dam by expanding the amount of Wellton-Mohawk drainage water which would be bypassed to 118,000 acre-feet and substituting an equal volume of better quality water from United States supplies. This measure reduced the salt content of water available for delivery at Morelos Dam to about 1140 ppm in 1972 compared to 1245 ppm in 1971. The actual salinity of Morelos Dam water dropped to about 1000 ppm when Mexico again requested that the remainder of the Wellton-Mohawk drainage water (100,000 acre-feet) also be bypassed without replacement from other United States waters. President Nixon also agreed to appoint a special representative to find a "permanent, definitive and just solution" to the salinity problem, to submit the proposed solution to him and, after approval by the United States, to President Echeverría. Herbert Brownell was named the special representative. Provisions of the agreement between the presidents were included in Minute 241 of the International Boundary and Water Commission signed in July 1972.[5]

For Mexico, the principal issue which needed to be resolved was the difference in water quality between that delivered at Imperial Dam (for irrigating the Imperial and Coachella Valleys, the Yuma Mesa, the Indian lands near Yuma, and the Wellton-Mohawk district on the United States side of the border) and that delivered to

5. 67 Dep't State Bull. 198 (1972).

Morelos Dam (for irrigating the Mexicali Valley in Mexico). Mexico contended that the difference of about 290 ppm (850 ppm at Imperial Dam and 1140 ppm for the water made available by the United States at Morelos Dam) was much greater than it should be due to the large amount of salt coming from the Wellton-Mohawk area. All subsequent discussions centered on resolving that issue in a mutually acceptable manner. Minute 241 provided for temporary improvement of the situation while a permanent solution was sought.

In December 1972, the Brownell Task Force presented President Nixon with recommendations for resolution of the salinity problem.[6] The recommendations consisted of two parts: an interim solution and a permanent solution. The interim solution had four aspects: (1) continuing the agreement in Minute 241 to replace 188,000 acre-feet of Wellton-Mohawk drainage water with better quality water from Yuma Mesa Wells and Imperial Dam; (2) relocating and lining a part of the Coachella Canal in order to save 130,000 acre-feet of water lost by seepage; (3) reducing the irrigated acreage in the Wellton-Mohawk Division of the Gila Project to as near 60,000 acres as is practical for the purpose of reducing the amount of salt in the drainage waters; and (4) improving Wellton-Mohawk District on-farm irrigation efficiency to the end that, again, the amount of salt in the drainage water would be reduced.

The permanent solution was to install a desalting plant to reduce the salinity of Wellton-Mohawk drainage water to about 280 ppm and mix this with enough untreated drainage water to keep the salinity of the Morelos Dam water at an acceptable level.

On 30 August 1973, the "final" solution to the salinity problem was agreed upon with the signing of Minute 242 of the International Boundary and Water Commission by Ambassadors Herrera J. (Mexico) and Friedkin (United States).[7] Minute 242 spelled out some of the details of the interim solution. Most importantly, the United States and Mexico agreed that the salinity of the water at Morelos Dam should be 115 ppm ± 30 ppm above that of the salinity at Imperial Dam. What this means in practice is that the farmers in the Mexicali Valley must expect to use waters of about 115 ppm more salt than their neighbors in the Imperial Valley, across the international boundary, but with soils of similar characteristics and with identical climates. The reduction in Morelos Dam salinity was to be accomplished between 1 January and 1 July 1974 by the measures detailed in the interim solution.

6. H. Brownell, Report of the President's Special Representative for Resolution of the Colorado River Salinity Problem with Mexico, December 28, 1972.

7. *See* note 1, *supra,* and accompanying text.

Permanent reduction of the salinity at Morelos Dam to 115 ppm ± 30 ppm above the salinity at Imperial Dam calls for a reverse osmosis desalting plant near Yuma, Arizona and the construction of a canal from the desalting plant to Santa Clara Slough on the Gulf of California in Mexico. The canal is to carry off the brine produced by the desalting plant. All the expense is to be borne by the United States.

Water saved by lining part of the Coachella Canal can be used only temporarily to meet treaty obligations with Mexico because it belongs legally to California. When California needs that water for its own use, it will have to be replaced from other sources. In view of the scarcity of water in the Colorado River Basin, discarding all Wellton-Mohawk drainage water represents a waste that could not be tolerated, hence the decision to construct the desalting plant.

Three additional items are incorporated in Minute 242. One says that the United States will provide nonreimbursable assistance to Mexico for the rehabilitation of the Mexicali Valley relating to the salinity problem. This assistance will include the installation of tile drainage. The second limits the pumping of groundwater within five miles (eight kilometers) of the Arizona-Sonora boundaries to 160,000 acre-feet per year on each side of the border. The pumping limitation is designed to forestall another international dispute about who has rights to groundwater which, apparently, is the result of overirrigation on the United States side of the boundary. The third provision calls for United States support of attempts by Mexico to obtain funds for the improvement and rehabilitation of the Mexicali Valley.

Minute 242 is subject to approval by both governments by exchange of notes. United States costs for implementing the program are subject to authorization by Congress. Costs of installing the desalting plant, constructing the brine-disposal canal to Santa Clara Slough, and building the lined Coachella Canal section are estimated to be $115,000,000.

CONTINUING PROBLEMS

Assuming that the United States Congress appropriates funds necessary to carry out the provisions of Minute 242, the international dispute may be settled, but the salinity problem in the Colorado River Basin—in the United States and Mexico—will not go away. Table 2 shows the change in salinity of Colorado River waters for three points in time and for three points along the river. The salinity of the river increases downstream, as it normally does whether or not water is diverted from the river. Historically, the salinity of the Colo-

TABLE 2
Salinity Changes at Three Stations on the Colorado River

Time	Station *Lee Ferry*	*Hoover Dam*	*Imperial Dam*
Original*	550 ppm	690 ppm	750 ppm
1970	600 ppm	740 ppm	850 ppm
1980	760 ppm	960 ppm	1200 ppm

*1941-1970 average without any salinity control measures.
Source: Bureau of Reclamation, U.S. Dep't of the Interior, Quality of Water: Colorado River Basin (Progress Rep. No. 6, Jan. 1973).

rado River has increased as more dams have been constructed and more areas irrigated. Dams (more properly, their reservoirs) increase salinity by (1) concentrating salt content in the water as the result of evaporation from the reservoir surfaces and (2) by dissolving salts from the soils inundated by reservoir waters. Both factors are important in the Colorado River Basin. Salinity is also increased by evaporation from rivers and canals and by the salt contained in drainage waters which are returned to the river from irrigated areas. Another cause of salt increases in river systems is salt seeping out of salt springs along the rivers or being dissolved out of salt beds traversed by the river. Both of the latter are especially significant sources of salt in the Upper Basin.

Future water development programs in the Upper Basin states will inevitably lead to a further degradation of the water quality in the Colorado River unless measures are taken to alleviate it. Transmountain diversions in the headwaters of the rivers, such as the San Juan-Chama diversions in New Mexico, will remove low-salt water, thereby raising the salinity of the remaining flow. New or expanded irrigation projects will increase the amount of drainage water, which invariably is more saline than the irrigation water due to the loss of water by evapotranspiration and the dissolution of salts from the soil. The Upper Basin presently utilizes only about 3,200,000 acre-feet of the estimated 5,800,000 acre-feet available after allowing for delivery to the Lower Basin states and Mexico of 9,000,000 acre-feet (7,500,000 to the Lower Basin states and 1,500,000 to Mexico).

In the Lower Basin, Arizona has rights to 2,800,000 acre-feet. The Central Arizona Project is designed to utilize the presently unused fraction of that allotment. How much of that water, if any, will return to the Colorado River by way of the Gila River remains to be seen. It may be that very little will be returned since the areas to be irrigated lie primarily in the Phoenix and Tucson areas which are far from the Colorado River.

Unless control measures are instituted between 1974 and 1980, the salinity at Imperial Dam is expected to rise to 1200 ppm and at Morelos Dam to 1315 ± 30 ppm.[8] That degree of salinity will pose problems for both the Imperial and Coachella Valleys as well as the Mexicali Valley. Even with an extensive and closely monitored system of tile drainage, some farmers in the Imperial and Coachella Valleys already are experiencing reductions in crop yields due to excessive salt in the soil. The Mexicali Valley will be in dire straits unless it, too, installs an adequate drainage system and reduces crop acreage to bring it into line with water supplies and the need for leaching. A salinity level of 1200 or 1300 ppm in the irrigation water would not be particularly harmful if the soils were nonsaline naturally and were quite permeable. Unfortunately, neither situation prevails in the Imperial or Mexicali Valleys.

Attitudes toward salinity control measures fluctuate with the amount of irrigation water available. When the flow in the river is above normal, excess water is available for leaching salts and the salinity problem recedes. In dry years, the opposite is true and pressures are generated to reduce irrigation water salinity. At present, water flows are low and salinity control is a high priority item. That situation is likely to continue if, as seems true now, the long-term flow in the Colorado River at Lee Ferry is less than had been estimated when the Colorado River Compact was approved in 1922 and when Mexico was allocated 1,500,000 acre-feet in 1944. Present estimates are that the average may be only 13,000,000 to 14,000,000 acre-feet per year.

SALINITY CONTROL MEASURES

Several salinity control measures are being undertaken or considered to keep the salt content of the Colorado River at acceptable levels and to lessen the impact of irrigation water salinity. These measures are significant for both the United States and Mexico. In the United States, they include attempts to reduce evaporation from reservoir surfaces; sealing off sources of salt, both point sources (salt springs) and diffuse sources (salt seeps along stretches of tributary and mainstream rivers); selective reduction in irrigated acreage in areas where highly saline groundwaters occur; reduction in drainage water by more efficient use of irrigation waters; desalting drainage waters for the irrigation districts at the lower end of the river systems; and improved soil drainage. In the Mexicali Valley, improved

8. Bureau of Reclamation, U.S. Dep't of the Interior, Quality of Water: Colorado River Basin (Progress Rep. No. 6, Jan. 1973).

soil drainage is the number one current requirement. A close second is the need to improve soil and water management practices, such as land levelling and changing from an extensive to an intensive use of water which will permit regular leaching of soils to control salt levels.

Breeding salt-tolerant crops is another possibility; but little has been done to date and the prospects for success in the near future appear to be small, although the long-range potential should be good.

According to accounts appearing in a series of articles published by the newspaper *Excelsior* of Mexico City, in May 1972, the Mexican Government, primarily acting through the Secretaria de Recursos Hidraulicos, began to rehabilitate the Mexicali Valley in 1966. Progressive salinization of Mexicali lands had been occurring for decades due to a variety of reasons. Among the most important was seepage from unlined irrigation canals and an insufficient drainage network. Rehabilitation consisted of lining canals, constructing open drains to lower the water table, levelling land in order to provide more uniform irrigation and better leaching, and improving old wells and drilling new wells to utilize groundwater which—at that time—was of better quality than the Colorado River water. About 20 percent of the planned rehabilitation measures had been completed in 1972. In the future, it seems certain that tile drainage will need to be installed to supplement the open drains, at a large increase in cost. Completion of these control measures should greatly improve conditions in the Mexicali Valley when coupled with the actions to be taken by the United States under Minute 242.

The course of events underway in the Mexicali Valley is similar in general outline to that followed in the Imperial and Coachella Valleys. Farmers in the latter areas are now taking the further step of intensifying the tile drainage network by installing additional drains between the original drain lines. Similar developments can be expected in the Mexicali Valley as the salinity problem becomes more acute. Already farmers there are complaining that the land levelling is not being done properly and that title drains are needed on individual parcels of land. They are also demanding that they be given new land to replace land which has become salted.

The salinity problem at the lower end of the Colorado River system differs significantly in one respect from that which led to land abandonment centuries ago in Mesopotamia (present-day Iraq). On the Colorado River, poor drainage and high water tables were and are problems, as they were in the Middle East, but a different threat is also present in the gradual, long-term increase in the salinity of the river as dams have been constructed and additional water has been

diverted from the river. That was not the case on the Tigris and Euphrates Rivers. The difference means that controlling soil salinity becomes increasingly more difficult even when a drainage system adequate to cope with less saline water has been constructed. It is not hard to see the day coming when on-the-farm ameliorative measures are no longer sufficient. Then we are faced with four alternatives having to do with reduction in the salinity of the river in the Lower Basin: (1) control salt inflow to the river, (2) construct desalting plants for local or imported saline water, (3) develop effective weather modification techniques, or (4) import fresh water from outside the Colorado River basin. A fifth alternative, abandonment of affected lands, is a harsh one for such large areas as are involved here.

Controlling salt inflow to the Colorado River already has been proposed by the U.S. Bureau of Reclamation and investigations have been made to determine what can be done. Desalting Wellton-Mohawk drainage water is proposed as the "permanent" solution to the U.S.–Mexico dispute. Importation of fresh water from outside the basin is many years away, if it is ever done. Controlling salt input is a feasible, albeit costly, solution.

PROBLEMS WITH THE "PERMANENT" SOLUTION

Announcement of the signing of an agreement between Mexico and the United States to find a definitive and permanent solution to the salinity problem on the Colorado River, as stipulated in Minute 242, was not greeted with applause among the Upper and Lower Basin states of the United States. The core of the objection was to having the Federal Government negotiate the agreement without bringing the basin states into the decisionmaking process. In the minds of basin state representatives, commitments were made which may well have far-reaching and, perhaps, troublesome consequences in the future.

There does not appear to have been any doubt among the basin states that the salinity degradation caused by drainage water from the Wellton-Mohawk district could not be tolerated by Mexico and could not be justified by the United States. Something had to be done. What constitutes "something" is, however, a matter of dispute. The troublesome aspects of Minute 242, for the basin states, are:

1. From where will the 118,000 acre-feet of replacement water come? From the Upper Basin, the Lower Basin, or a combination of both? Neither the Upper nor Lower Basin wants to provide the

water—or any part of it—because it would curtail projects in which they have a vested interest, given the now-certain fact that the flow in the Colorado is much less than had been calculated when the original compact was signed.

2. The Upper Basin faces water shortages as it becomes apparent that the average annual flow at Lee Ferry now and in the immediate future is only 13,000,000 to 14,000,000 acre-feet, which falls far short of providing upper states with the 7.5 million acre-feet per year they had expected to have available. The 1922 Compact allocated 7.5 million acre-feet to the Lower Basin states but did not allocate any stated amount to the Upper Basin states.

3. Is the salinity at Imperial Dam to be maintained at 850 ppm? This apparently is expected by Mexico although it is not stated explicitly in Minute 242. If the salinity at Imperial Dam is to be kept at 850 ppm, most of the salinity control will have to be done in the Upper Basin states, where most of the salt originates. Is this equitable?

4. Mexico may now have rights, presumably permanently, to 160,000 acre-feet of groundwater in the San Luis area of Sonora, over and above the 1,500,000 acre-feet to which it is entitled by the 1944 Treaty. The groundwater apparently represents Yuma Mesa water which has percolated through the soils and flows southward underground to Mexico. In the eyes of the basin states, that water is U.S. water which should be available for use on the U.S. side of the border; Mexico should not have a legal entitlement to it.

5. The desalting plant at Yuma will be a perpetual financial drain on the United States of at least $10 million per year for operating costs. Can that cost by justified?

6. For the first time, and without the formality of a treaty, water quality is now accepted by the United States as a factor to be included in the provision of 1,500,000 acre-feet of Colorado River water to Mexico. No explicit mention of water quality was made in the 1944 Treaty.

7. Where will the power come from to operate the desalting plant at Yuma? Lower Basin states contend that power supplies in the area already are fully committed.

8. Why was a minute of the International Boundary and Water Commission used as the instrument to bring about resolution of the dispute rather than the formal mechanism of a treaty, as had been done in 1944? The minute represents an administrative decision of the two governments and does not provide for review by the states involved.

When the United States Congress is called upon to appropriate funds to implement Minute 242, these questions probably will surface and bring into doubt the efficacy of the "permanent" solution.

FUTURE

Assuming that Minute 242 is implemented, the future of irrigation in the Upper Basin states appears reasonably promising due to the large amount of unappropriated water they have and their position on the upper end of the Colorado River system. In the Lower Basin states, the picture is much less promising. Heroic measures must be taken in the United States and Mexico if irrigation in the lower basin is to succeed. Without a doubt, salinity problems in the lower basin will become exacerbated in the next several years. Whether or not they will lead to ultimate abandonment of presently irrigated land will depend upon the wise investment of money and talent. The key decision, for California and Baja California, especially, will be that of the permissible salinity at Imperial Dam. If it is held at about 850 or 900 ppm, irrigation probably can continue. If it is allowed to rise significantly, the future of irrigation is bleak unless the irrigated acreage is reduced, efficient drainage systems are installed, and good soil and water management is practiced.

In conclusion, it should be noted that prophets of doom have long contended that irrigation agriculture cannot be successful permanently. They point to the Euphrates and Tigris Valleys of Iraq as the horrible example of what salinity can and does do. Modern technology, when coupled with adequate planning, appears to be capable of avoiding that destiny, but only if the irrigation water salinity is not allowed to exceed the tolerance level of the crops which are grown. One thing certain is that success will not be achieved easily.