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The effects of future climatic changes on international water resources: the Colorado River, the United States, and Mexico

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Abstract. International water resources have been a source of contention in many parts of the world over the last few decades and such conflicts may grow in frequency and severity as future climatic changes alter the quantity or quality of limited water resources. Indeed, some future climatic changes appear inevitable due to growing atmospheric concentrations of carbon dioxide and other trace gases. Unless mechanisms for incorporating climatic changes into water agreements can be worked out, these changes may provoke further frictions and conflicts. One region with a history of political conflict over shared water resources is the Colorado River Basin in the United States and Mexico. While past disagreements over water have mostly been resolved, future climatic changes that adversely affect the existing hydrologic regime of the basin cannot be discounted. This paper examines the possibility that future long-term climatic changes may exacerbate shortages in the Colorado River. Political conflicts and tensions that arise from reductions in water supply in both the United States and Mexico are evaluated and discussed, together with recommendations for incorporating the issue of climatic change into existing international treaties and agreements.

Variations in climatic conditions that alter agricultural productivity, access to strategic minerals, and the availability and quality of freshwater resources can affect national and international relationships (Budyko 1977, Roberts and Lansford 1979, Gustafson 1981, Wilson 1983, Tickell 1986, Westing 1986, Gleick 1987a). In particular, confrontations and disagreements over shared water resources have occurred in a number of regions around the world (Hundley 1966, Widstrand 1980, Biswas 1983, Cooley 1984, Falkenmark 1986). Unless water is treated in international resource discussions as a resource subject to changing natural conditions, conflicts may increase in frequency and severity as future climatic changes begin to appear. Indeed, some future climatic changes appear inevitable as the atmospheric concentration of carbon dioxide and other trace gases increases.

Water-resource conflicts exist in many international river basins: the Jordan in the Middle East; the Nile in northeast Africa, and the Ganges-Brahmaputra in the south Asian subcontinent, to mention a few. In some cases, international treaties have been worked out to settle disputes. In other cases, water conflicts have not yet been resolved. Nowhere, however, have the complications posed by climatic changes been incorporated into international negotiations or hydrologic agreements. A resolution of the problems raised by climatic change requires a change in perception about how water and climatic variability should be treated, and a broadening of the general principles governing international watercourses to include the problems posed by long-term climatic changes. This paper explores ways of incorporating climatic change into international water agreements in the context of the United States and Mexico and the vital Colorado River.

There is a long history of political conflict between the United States and Mexico over the water resources of the Colorado River. Although past disagreements have mostly been resolved, future climatic changes that adversely affect the existing hydrologic regime of the basin could contribute to tensions between the United States and Mexico. Any persistent shortage to Mexico is certain to cause international problems, even if the shortage is shared according to existing provisions. Given the recent difficulties between the United States and Mexico over drug traffic, immigration laws, Central American politics, and issues such as transborder pollution from copper smelters, a resurgence of problems over water resources would be cause for concern.

The shared water resources of the United States and Mexico

The southwestern United States shares more than a common border and history with Mexico — it also shares limited water resources. Because of the arid nature of this region, these water resources have been the focus of long and sometimes bitter controversies among farmers, among states, and between the United States and Mexico.

The Colorado River flows over 2000 kilometers from its headwaters in the Rocky Mountains to its delta on the Gulf of California in Mexico. Although less than a tenth the average flow of the Columbia River and a thirtieth of the flow of the great Mississippi River, the Colorado is the principal river system in the southwestern United States and northwestern Mexico, moving through regions that are among the driest and hottest in the country. Population growth and the rising demand for irrigation water in the region have led to the nearly total allocation of the waters of the Colorado, and in many years no flow reaches the Gulf of California at all.

The heavily exploited water resources of the Colorado River Basin play a crucial role in the economic and agricultural development of important regions of both the U.S. and Mexico. Two major areas of irrigated agriculture in Mexico use Colorado River water — the Mexicali Valley and the San Luis Valley near the delta. In 1978, the Colorado met the domestic needs of more than half a million Mexicans (Holbert 1978), and demands are growing rapidly. Water from the Colorado is also used to irrigate the important Imperial Valley in California and to supply drinking water for many urban centers in the southwestern U.S.

Controversy between the United States and Mexico over water began in the 1870s, when irrigation development that reduced water supplies and water quality brought open conflict (Hundley 1966). These tensions grew as low-water years and growing upstream diversions further decreased flows. Finally, after a series of diplomatic complaints, legal rulings, and political maneuvers, the United States in 1896 directed the International Boundary Commission to study the problem of equitable distribution of the Colorado.

In February 1944, after nearly a half century of debate and controversy, the United States and Mexico signed a treaty guaranteeing 1.5 million acre-feet of Colorado River water to Mexico annually. The treaty resulted, at least in part, from a desire to resolve a long-standing problem with a close neighbor as an example of the 'Good Neighbor Policy'. President Roosevelt noted, 'I am convinced that the United States would stand to lose much more than it could reasonably hope to gain by any further delay in the negotiation of a water treaty with Mexico' (Roosevelt correspondence, 1944). Similarly, Assistant Secretary of State Dean Acheson testified, 'There is a much larger question involved in this matter than in the interpretation of existing arbitration treaties and legal precedents' — the question of maintaining the Good Neighbor Policy and peaceful relations (U.S. Congress, 1945).

Mexican officials also described access to Colorado River water to be of great national importance — 'It represents a national interest superior to any other' (Secretaria de Relaciones Exteriores, 1947). While this expression of importance may be ascribed partly to the public hyperbole that accompanied the signing of the 1944 United States — Mexican water treaty, it is nevertheless an indication of the political significance of the river.

Opponents to the treaty in the United States used international politics and the issue of national security in an (unsuccessful) effort to prevent ratification of the treaty by the Senate. In particular, the Californians serving on the treaty committee warned that the treaty would 'strike a deadly blow at the country's national security by taking water away from southern California's coastal plain — the nation's front on the Pacific.' 'America's future security demands the strengthening, not the weakening of this area within the United States' (from Hundley 1966). This emphasis, convenient at the time of World War II, was condemned by other Colorado River Basin states as selfish and motivated by the pleading of special interests rather than by real security considerations.

The long and careful negotiations leading to the 1944 treaty failed to resolve two important problems: (1) the quality of the water to be delivered to

Mexico; and (2) the possibility of long-term reductions in water availability. The first problem, water quality, strained United States — Mexican relations starting in the 1960s, when United States irrigation projects caused significant increases in salinity levels near intakes for the Mexican supplies. In 1961, Mexicans were forced to let their allocation flow unused to the Gulf of California, rather than risk damage to their soils by using the highly-saline water. After protests by the Mexican government, water-quality discussions were opened between the two countries. These discussions led eventually to Minute 242 of the International Boundary and Water Commission, which set a limit on the salinity of water delivered to Mexico. This agreement was followed several years later by legislation in the United States to implement measures for the control of salinity in the river. Concern over United States—Mexican relations played a significant part in the budgeting for these acts, which authorize salt-control projects in Nevada, Utah, Colorado, and at Yuma near the border (Miller et al. 1986).

The second problem — a shortfall in water quantity — was addressed in the 1944 treaty in a very limited way. In the event of an 'extraordinary drought' or a 'serious accident' to the irrigation system in the United States, the water allocated to Mexico is to be reduced in the same proportion as con-

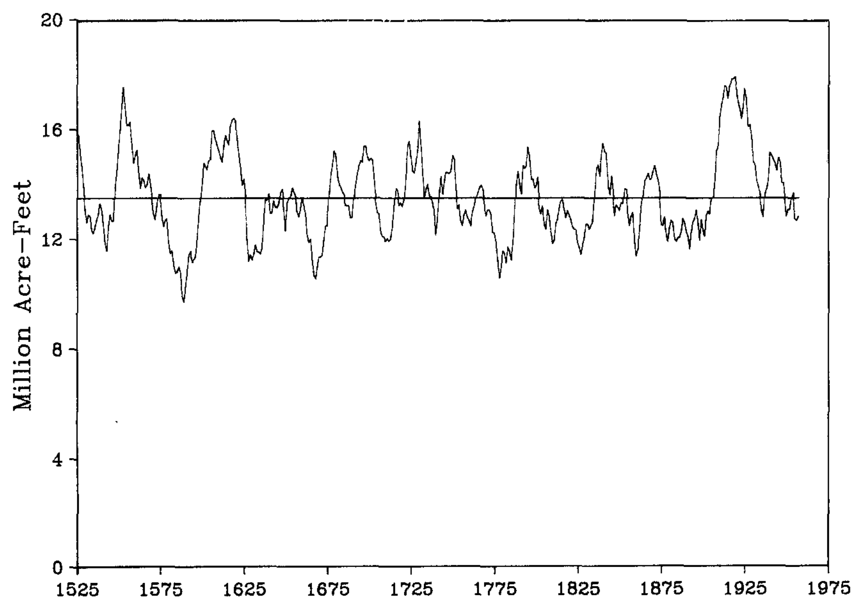

Fig. 1. Long-term (1525—1957) ten-year moving averages of Colorado River runoff, reconstructed from tree rings (Stockton and Jacoby 1976). The long-term mean for the entire period is approximately 13.5 million acre-feet per year. Note the anomolously high runoff during the early 1900s. The average runoff of this period was the basis for the allocations in the 1922 Colorado River Compact.

sumptive uses of water in the United States are reduced. Neither of these terms was defined by the treaty and the negotiating record offers little clarification. Because Mexico has consistently received all the water allocated to it by the 1944 Treaty, this ambiguity has yet to be resolved.

One of the principal assumptions at the time the treaty was signed was that the average Colorado River flow was greater that 16 million acre-feet per year. The best information on the long-term record (see Fig. 1), developed by Stockton and Jacoby (1976), now indicates that the actual average flow in the basin may be as low as 13.5 to 14 million acre-feet per year — an amount far lower than the annual volume of water allocated by the 1922 Compact among the users in the Upper and Lower Colorado Basin.[1] This mistake occurred because the framers of the 1922 compact used a series of anamolously wet years in the early part of the century to estimate the long-term availability of Colorado River water.

Three situations could lead to periodic shortages in the United States and, perhaps, Mexico: (1) the growth of consumptive water demand in both the Upper and Lower Basins to (or beyond) the limits of the present natural supply; (2) a persistent, but temporary drought; or (3) a change in the climatic conditions that reduces the overall availability of water.

A specific example will demonstrate the severity of the problem posed by the growth in demand for water in the Colorado River Basin. The U.S. Bureau of Reclamation estimates that by the year 2000, consumptive uses and reservoir evaporation in the Upper and Lower Basin will total nearly 14.5 million acre-feet annually, with an additional 1.5 million acre-feet per year delivered to Mexico, for a total commitment of nearly 16 million acre-feet (U.S. Bureau of Reclamation, 1982, 1984). Table 1 and Fig. 2 present the predicted consumptive use estimates for the Colorado River from 1985 to 2040. Assuming initially that there will be no draw-down of the reservoirs, runoff to Mexico will equal runoff into the Colorado River less consumptive uses and evaporative losses in the United States.

If the natural flows originating in the Upper Basin average 15 million acre-feet per year and if the consumptive uses reach the levels described above, then the annual delivery of 1.5 million acre-feet of water to Mexico as specified by the treaty would be threatened periodically beginning as early as the mid-1990s. If the presently unquantified water rights of the Navajo Indians are resolved, problems could arise even sooner (Kneese and Bonem 1986). Indian water rights could be as large as several million acre-feet per year.

[1] The depletion estimates include both Upper Basin and Lower Basin allocations, and 1,890,000 acre-feet per year evaporation losses from all the mainstem reservoirs. Annual deliveries to Mexico are an additional 1,500,000 acre-feet. No separate allocation is made here for Indian water rights, which are presently unquantified, but which could be substantial.

Table 1. Colorado River depletion estimates 1985—2040 (1000 acre-feet)[1]

Year	Depletion
1985	11936
1990	13779
1995	13904
2000	14371
2005	14411
2010	14611
2015	14657
2020	14772
2025	14808
2030	14902
2035	14925
2040	15066

Source: compiled from the U.S. Bureau of Reclamation, 1984.

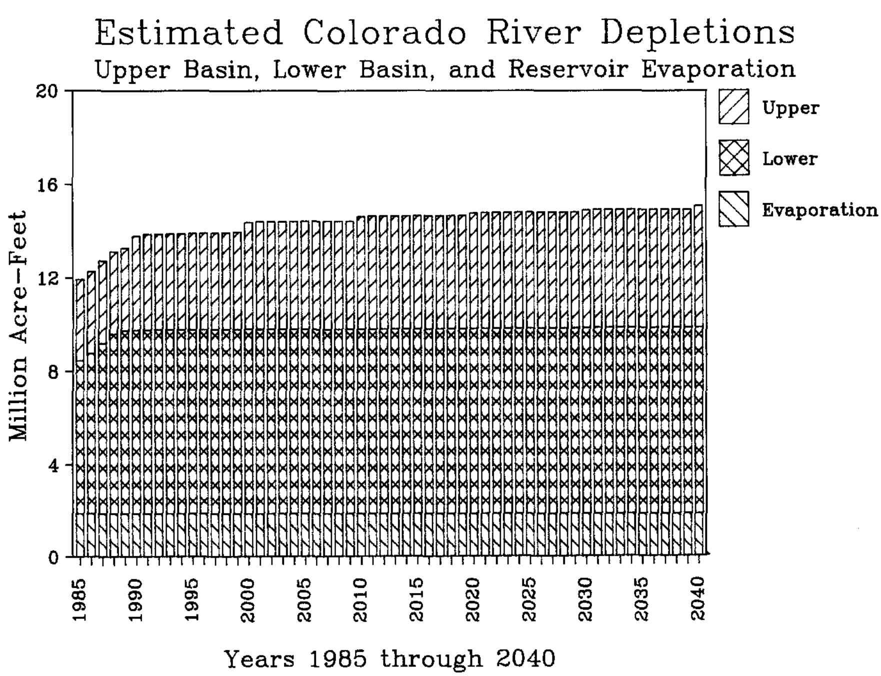

Fig. 2. Estimated consumptive use in the Colorado River 1985—2040 from the U.S. Bureau of Reclamation (1984) for the Upper and Lower Basins, including reservoir evaporative losses. By 2010, estimated depletions will approach 15 million acre-feet per year, not including commitments to Mexico or Indian tribes.

The large storage capacity in the basin is adequate to delay a crisis for several years, but it provides no long-term solution to over-allocation or permanently reduced flows. During the early years of shortage, the large Colorado River reservoirs could, theoretically, contribute enough water to make up the difference and meet the Mexican allocation, but after some reservoir depletion, additional water demand would begin to threaten the generation of hydroelectric power, long-term water supply, and recreational uses. Moreover, if the long-term average runoff in the Upper Basin is actually closer to Stockton and Jacoby's (1976) estimate of 13.5 million acre-feet — 10 percent less than the 15 million acre-feet per year estimated by the Bureau of Reclamation — the assistance provided by even the largest reservoirs eventually disappears.

Long-term drought in the region may also lead to persistent shortfalls. The historical record reconstructed by Stockton and Jacoby (1976) (Fig. 1) shows that 10-year minimum flows as low as 97.1 million acre-feet have been experienced. Table 2 shows some of the historical values for total basin runoff from both the long-term tree-ring record and from measured and reconstructed flows since 1896. In the last 90 years of instrumented measurements, there have been two ten-year periods with average unimpaired flows as low as 116 million acre-feet (or an annual average of 11.6 million acre-feet) (Miller et al. 1986). In the same period, the lowest flow for a single year (1934) was 5.6 million acre-feet.

At the extreme, if a persistent ten-year drought as severe as the one already identified in the long-term record occurs — 97.1 million acre-feet — major

Table 2. Long-term and recent maximum and minimum flows in the Colorado River.

Long-term[1]	Flow MAF/Year	Period
Average	13.5	(1520—1961)
Ten wettest years	17.9	(1914—1923)
Ten driest years	9.7	(1584—1593)
Maximum single year	23.5	(1849)
Minimum single year	3.8	(1532)
Recent[2]	**Flow MAF/Year**	**Period**
Average	14.8	(1896—1983)
Ten wettest years	18.8	(1914—1923)
Ten driest years	11.6	(1954—1963)
Maximum single year	24.0	(1917, 1983)
Minimum single year	5.6	(1934)

[1] From Stockton and Jacoby (1976) tree-ring reconstructions. (MAF/year is million acre-feet per year.)

[2] From measured flows (Miller et al. 1986).

disruptions of standard water-use practices and water deliveries would result and the full deliveries to Mexico would be regularly threatened.

As disconcerting as this picture is, it is important to recognize that the agreements between the United States and Mexico were completed with the implicit assumption that the average availability of water in the Colorado River Basin would continue to be the same in the future as it was in the recent past, i.e. that climate would remain stationary. If this assumption is wrong, the implications for water availability of future changes in global and regional climatic conditions are likely to be even more important than the problems raised by existing climatic variability.

Future climatic change and water availability to Mexico

Anthropogenic climatic changes will alter the availability of water in the Colorado River through changes in either the timing or the magnitude of runoff and water demand. Although water availability in some regions may increase if precipitation increases, there are indications that the Colorado River and other low- and mid-latitude arid and semi-arid regions will not be so lucky (Stockton and Boggess 1979, Manabe et al. 1981, 1986, Revelle and Waggoner 1983, Gleick 1986, 1987b, Flaschka et al. 1987, Rind 1987). Table 3 lists estimates of plausible changes in annual runoff in the Colorado River Basin and similar semi-arid basins that would be caused by future climatic changes. Some of these studies predict that annual runoff will decrease even if precipitation increases (Stockton and Boggess 1979, Revelle and Waggoner 1983), and there is no question that temperature increases accompanied by even slight decreases in precipitation could greatly reduce the availability of water in semi-arid basins (Gleick 1986, 1987b, Flaschka et al. 1987).

There are important domestic political implications of decreased water availability in the Colorado River region. How should the reservoirs be operated under conditions of shortages? How are irrigation priorities and informal transfers of water to be treated? Can conserved water be traded in developing water markets? These issues are already beginning to the addressed as new demands for water slowly consume the remaining unused water resources in the region.

Important international policy questions also arise from climate-induced shortages in the basin. What, for example, are the implications for the treaty obligations of the United States towards Mexico of a reduction in runoff due to climatic changes? Careful thought must also be given to the type of policy responses that should be taken to prevent the worst and most likely consequences of such changes. A reduction in annual runoff in the Colorado of only 10 to 20 percent — well within the range of estimates in Table 3 — would decrease the water available in the basin by 1.5 to 3 million acre-feet per year. Since the small margin of unused water in the basin would not cover a persistent shortfall of this magnitude, prudent planning would explore the implications of such shortfalls. Table 3 suggests that even more extreme decreases in runoff are possible: a permanent 30 to 50 percent reduction in riverflow would be crippling to industries, agriculture, and communities throughout the region, and domestic and international competition for the remaining water would certainly ensue.

Table 3. Effect on runoff of climatic changes in major semi-arid river basins.

Author/Basin[1]	Change in annual runoff (%)
Stockton and Boggess (1979)	
Upper Colorado River Basin	
P − 10%; T + 2C	−35
P + 10%; T + 2C	−33
Lower Colorado River Basin	
P − 10%; T + 2C	−56
P + 10%; T + 2C	−2
Nemec and Schaake (1982)	
Pease River Basin, Texas	
P − 10%; T + 1C (ET + 4%)	−50
P + 10%; T + 1C (ET + 4%)	+50
P − 10%; T + 3C (ET + 12%)	−50
P + 10%; T + 3C (ET + 12%)	+35
Revelle and Waggoner (1983)	
Colorado River Basin	
P − 10%; T + 2C	−40 +/− 7.4
P + 10%; T + 2C	−18
Flaschka et al. (1987)	
Great Basin sub-basins	
P − 10%; T + 2C	−17 to −28
P + 10%; T + 2C	+20 to +35
Gleick (1986, 1987b)	
Sacramento River Basin	
T + 2C; P − 10%	−18
T + 2C; P − 20%	−31
T + 2C; P + 10%	+12
T + 2C; P + 20%	+27
T + 4C; P − 10%	−21
T + 4C; P − 20%	−34
T + 4C; P + 10%	+7
T + 4C; P + 20%	+23

[1] Please refer to individual authors for details on methods and model calculations. T = Temperature (Celsius), P = Precipitation, ET = Evapotranspiration.

A distinction must be made between short-term and long-term shortfalls. Short-term droughts rarely persist longer than a year or two. Long-term water shortages induced by climatic changes would, effectively, have time scales on the order of decades to centuries. Because the climate is assumed to be constant, water-resource systems and institutions are designed to accommodate only short-term fluctuations in water availability. Yet even short-term droughts can have drastic local impacts. The 1976—1977 drought in the western United States resulted in extensive forest damage, shifts in agricultural productivity, livestock losses, and changes in the operation of reservoirs and aqueducts. If this unusual drought had persisted for one more year, the impacts would have been devastating.

Under the 1944 U.S.—Mexico Treaty, only the problem of short-term drought is considered, even though the responses to short-term shortages may be inappropriate for dealing with long-term climatic changes. Because of the difficulty of identifying long-term climatic changes early, the first policy responses to climate-induced shortfalls are likely to be the same as if the shortfalls were due to natural climatic variability. As noted earlier, during severe droughts Mexico's Colorado River allocation can be decreased proportionately 'as consumptive uses in the United States are reduced'. Unfortunately, the interpretation of these provisions of the 1944 Treaty remains open to debate because the treaty negotiators made no attempt to agree on the meaning of 'extraordinary drought' or on how to decide when such a drought was in progress. The ambiguity over these fundamental definitions will almost certainly lead to problems in coming years. These problems and some possible solutions are discussed below.

International implications of climate-induced water shortages

Despite recent advances in the codification of agreements to govern international rivers, there is still no consolidated international water law. Nor are there clear precedents that take into account the problems that will be raised by changing climate. Thus, future alterations in the availability of water due to changes in climate are likely to exacerbate existing tensions over water resources. These tensions will be manifested in both regional and international disputes.

While international water law does not explicitly address the problem of changing climatic conditions, some international legal principles are, at least, beginning to consider climate to be an important factor. For example, the Helsinki Rules on the Uses of the Waters of International Rivers, formulated in 1966 and revised in 1986, speficy that '[E]ach basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin'. The Rules go on to set forth conditions for determining what is 'reasonable and equitable', one of which is the 'climate affecting the basin' (International Law Association 1967, 1986). This provision alone, however, will not resolve the problems posed by climatic changes because of its lack of specificity and because the Helsinki Rules are not universally accepted as a binding guide to international water problems.

Politically and hydrologically, reductions in Colorado River flow will be viewed in two ways, depending on the perspectives and interests of the parties: (1) as a short-term drought; or (2) as a long-term climatic change. The difference between these two views, discussed above, raises an important semantic problem over the difference between the term 'extraordinary drought' from the 1944 Treaty and the concept of 'climatic change'. Consider the following scenario: a climatic change leads to a long-term reduction in average runoff in the basin. Because of the likely incremental nature of such a change and the difficulty of detecting climatic trends, water-resources managers would initially assume that a 'drought' was underway. In such a case, some reduction in flows to Mexico could be justified by the provisions of the treaty. But when the reductions in river flow are perceived to be permanent, Mexican officials would find it advantageous to argue that the new conditions constitute a long-term climatic change rather than a drought and that their entire allocation should be restored.

Both positions have merit. Unfortunately, traditional hydrological sciences and climatology only identify trends in streamflow or climatic variables after a long period of observation. This almost guarantees that a persistent downward trend in runoff will be identified initially as a short-term drought, rather than as a permanent climatic change.

The most crucial policy distinction between long- and short-term changes in streamflow arises from the ability of existing water-resource systems to handle short-term variability without major physical changes to the system and without major disruption of supply to any user. If a shortfall persists, however, low-priority users begin to suffer and the need arises to consider changing the design and operation of the water-storage and transfer facilities.

In the context of the 1944 Treaty, the issue of shortages under conditions of persistent climatic changes should be the subject of U.S.—Mexican discussions, and the question of what constitutes such a persistent change should be answered. Two new treaty components are necessary: (1) clear definitions of 'extraordinary drought' and 'climatic change', and how to identify the onset of such events; and (2) unambiguous allocations of the subsequent shortages. The goal must be to improve the flexibility of the Treaty to account for both short-term droughts and long-term climatic changes. Waiting until serious pressures develop on the water resources of the Colorado River will only increase the difficulty of resolving the issue.

Another issue that must be raised is the possibility that Mexico will ask that negotiations be reopened on the present treaty allocations. This could lead to either a new interpretation of the 1944 treaty or to a treaty revision under the Vienna Convention and Law of Treaties. A precedent for such negotiations can be found in the recent request by Sudan for a revision of the 1959 agreement between Egypt and Sudan on sharing the waters of the Nile Basin (Falkenmark 1986). A reopening of negotiations between the United States and Mexico could result from demands by Mexico for additional water, or from demands to resolve questions arising from changes in supply, including how to allocate climate-induced shortfalls or surpluses. Greater demand in Mexico for water for irrigation or domestic supply in the fast-growing Tijuana region could compel such a request for new negotiations.

A renegotiation of the treaty would most likely opposed by the seven Colorado River states. For the United States government to agree to such a negotiation would therefore require either international political pressure or a desire to resolve other issues of national concern. Among the possible reasons for the United States to agree to renegotiate or reinterpret the treaty could be: (1) a growing dependence by the United States on Mexican oil supplies; (2) concern in the United States financial community over the repayment of Mexico's foreign debt; (3) concern in the United States over changes in the Mexican political environment; or (4) the desire to obtain an agreement on non-water related issues, such as immigration, drug traffic, or Central American politics. Each of these is discussed briefly below:

1. In return for reliable long-term access to the substantial Mexican oil and gas reserves, the United States might bow to a request by Mexico to augment water deliveries from the Colorado at the expense of United States users. In the context of future global pressures on oil supplies, such a request might even be viewed as a favorable alternative to the costly development of synthetic fuels from shales in the Upper Colorado Basin. Shale-oil development in the United States would require tremendous quantities of water from the Colorado, and it might prove to be far less water intensive and ecologically damaging if such water were simply traded directly for energy from Mexico.

2. Mexico's foreign debt presently exceeds $100 billion, the majority of which is owed to United States banks. Concern over Mexico's ability to repay this debt could lead to pressure on the United States to provide a larger allocation of water to Mexico from present users in the United States. This would, for example, permit Mexico to continue to grow and sell agricultural products to the United States from the Mexicali Valley, which produces a sizeable fraction of Mexico's total agricultural trade goods.

3. Concern over the political direction of Mexico and United States—Mexican relations has waxed and waned over the last several decades with

changes in both governments. The fear of an unfriendly government directly south of the United States border, however, could prod the United States into taking various political and economic actions to support moderate elements in the Mexican government. Such concerns over the relationship with Mexico in 1944 helped to resolve the original Colorado River allocation dispute.

4. Finally, in an effort to achieve an agreement on other pressing issues — such as the control of immigration and temporary labor, the 'war' on drugs, or some other item on the political agenda — Mexico or the United States might be tempted to ask for a revision in the present allocation. Coupling water allocations to other regional issues could lead to changes in the overall water available for United States users of the Colorado.

One solution to the problem of water shortages that would permit an increase in the Mexican allotment and yet would not penalize Colorado Basin users would be to somehow augment the supply of water in the river. A provision of the Colorado River Basin Project Act of 1968 makes the supply of water to Mexico an obligation of the federal government and implies that the United States would supply an *additional* quantity of water beyond that already allocated by the Colorado River Compact. The only way of significantly augmenting the flow of the Colorado would be to transfer water into the basin from other regions.

Major interbasin transfers of water will run into major economic and environmental constraints. The costs of building the components of such systems — aqueducts, tunnels, reservoirs, and pumping stations and the energy facilities to power them — are enormous, especially considering the great distances such water would have to come. For example, a proposal similar to what would be required to augment flow in the Colorado was developed and rejected in the 1960s and 1970s to bring water from the Mississippi River region to the Great Plains. The capital costs for the more ambitious transfer plans were estimated at over $20 billion in 1977 dollars; the operating costs would also have been enormous because of the energy needed for pumping. The project would have taken ten to twenty years to complete, and it would have entailed significant adverse environmental impacts (Micklin 1985).

Proposals for interbasin transfers of large amounts of water to the arid west will also cause considerable political conflict (Ingram et al. 1986). Such conflict could result from pressure on the federal government from a coalition of the basin states (who will not voluntarily surrender additional water from the basin) and northeastern states (who may need Mexican oil) to provide and pay for new interbasin transfers to meet the increased Mexican water demands. Such large government projects, which began to fade in attractiveness in the late 1970s, can now only rarely be justified given the budgetary problems of United States government. The shift in attention away from building new, large capital-intensive projects can also be seen in the recent, highly-publicized change in focus of the U.S. Bureau of Reclamation away from project construction toward resource mangement.

Finally, climatic changes will greatly complicate planning large-scale water transfers for two reasons. First, while long-term droughts (or floods) tend to be localized, the climatic changes caused by the greenhouse effect are likely to be widespread and persistent. This could produce shortages in neighboring regions that might otherwise have had surplus water to transfer. Second, uncertainties about details of specific regions climatic changes may take decades to resolve. These uncertainties about available water supply will increase the economic and political costs of large-scale transfers.

Far more palatable than major water transfers — politically, economically, and environmentally — would be a change in the way existing water resources are priced and used. As pressures grow on the existing water resources — due to either growth in population or changes in climate — inefficient users of water should be forced to alter their patterns of use. Such changes in use patterns will come about faster if proper pricing and market mechanisms, now being explored throughout the region, are encouraged and implemented (Blackwelder et al. 1987, Gardner 1986, Ingram et al. 1986). In the long term, if large-scale transfers of water from other regions are not approved, changes in settlement patterns will occur, the limits to the resources of the area will be realized, and those limits met by realistic changes in basin development.

Discussion

Water-resources conflicts in international river basins will be complicated by future human-induced climatic changes. In many regions with shared water resources, unresolved disagreements over water rights and use are already contributing to international frictions. In other regions, such as the Nile in Africa and the Colorado in North America, existing treaties allocate limited water resources and reduce disagreements. Nowhere, however, are the issues of climatic change and climate-induced water shortages explicitly addressed, despite recent advances in international water law.

The early conflicts between the United States and Mexico over the waters of the Colorado River were mostly resolved by the 1944 Treaty, but none of the original treaty provisions confront the possibility of problems caused by climatic changes. Given the existing pressures on the limited resources of the Colorado and the complications of climate-induced shortages, an effort should be made to include the effects of future climatic changes into the U.S.–Mexican treaty. These issues could be raised within the framework of the existing agreements as part of a treaty renegotiation or clarification, just as problems over water quality were treated in the 1960s. Unfortunately, the very act of reopening discussion on the treaty is fraught with intense political, economic, and social difficulties — both international and domestic. Unless these difficulties are resolved before serious pressures develop on water resources in the region, the frictions and conflict are likely to increase.

In the short run, the most appropriate political and economic action to take in the Colorado River Basin is to explore the possibilities for reducing inefficient consumptive uses of water in both the United States and Mexico. Reducing inefficient uses will provide a cushion for both United States users and for meeting treaty obligations to Mexico. Given the uncertainties about future climatic conditions, such short-run actions also permit flexibility in the design of appropriate operating strategies for the existing water system.

In the long run, however, the problem of over-allocation of the waters of the Colorado and the possibility of climate-induced reductions in flows in this and other international river basins will have to be directly addressed. General principles governing international watercourses must be broadened and climatic changes must be explicitly incorporated into long-range water-resource planning. Because of the importance of shared water resources in regions throughout the world, and because of the severity of possible future climatic changes, conflicts and tensions over water will continue to develop unless the problems raised by climatic change can be identified and resolved.

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