

---

## GLOBALIZATION AND WATER RESOURCES MANAGEMENT: THE CHANGING VALUE OF WATER

AUGUST 6-8 AWRA/IWLRI-UNIVERSITY OF DUNDEE INTERNATIONAL SPECIALTY CONFERENCE 2001

---

### COSTS AND BENEFITS OF INSTREAM FLOWS IN AN INTERNATIONAL BASIN

Frank A. Ward and James F. Booker\*

**ABSTRACT:** Like most western U.S. rivers, the Rio Grande is the region's defining and limiting resource. Even under normal supply conditions basin demands exceed supplies; emerging demands for environmental protection in the form of instream flows further increase competition for scarce water. Preservation and recovery of the endangered Rio Grande Silvery Minnow requires continued streamflows especially in the summer months when the river dries up. This paper identifies costs and benefits associated with proposals for increasing instream flows to meet minnow flow requirements. Impacts are derived from an integrated mathematical model, based on the hydrology, economics, and institutions of the basin, developed for analysis of drought-coping policies. Two policies for instream flow protection and enhancement are examined in detail. The first would enhance instream flows in a critical reach above Elephant Butte Reservoir to provide habitat protection for the minnow through reduced irrigation diversions in the immediate area. The second would enhance instream flows above El Paso and Ciudad Juarez, while providing for future municipal water needs, by allowing market based water transfers from upstream water users. Results show that concentrating all responsibilities for instream flows on New Mexico agriculture costs New Mexico agriculture about \$1 million per year. Introducing a three-way market to share the responsibility between New Mexico agriculture, the City of El Paso, and El Paso area agriculture reduces the total cost of meeting the flows considerably.

### BACKGROUND

The Rio Grande originates in the southern Colorado Rocky Mountains, flows through New Mexico, and forms the border between Texas and Mexico on its way to the Gulf of Mexico. Like most western U.S. rivers, the Rio Grande is the region's defining and limiting resource. Even under normal flow conditions basin demands exceed supplies, and emerging demands for environmental protection in the form of instream flows further increase competition for scarce water. Overlaid on this is explosive population growth, declining groundwater levels, and deteriorating water quality.

The upper Rio Grande from its headwaters to the border cities of El Paso Texas, USA and Ciudad Juarez, Mexico meets the primary water needs of three major metropolitan cities and one million acres of irrigated land in the U.S. and Mexico. In 1906 the U.S.- Mexico water treaty provided that a fixed but small portion of the river's annual flow be delivered to Mexico. In 1938, the Rio Grande Compact was approved by Congress, dividing the annual water flow among the three states. In developing the Compact, the three states considered the likely flow patterns, and the capabilities and limits of storage facilities in order to design an operating agreement for the river which protected water uses existing at that time.

The Rio Grande Compact has proven to be a flexible institution for keeping three states and two nations from going to war over scarce and unpredictable water supplies. Still conditions at that time could not have

\*Respectively, Professor, Department of Agricultural Economics and Agricultural Business, Campus Box 30003, New Mexico State University, Las Cruces, NM 88003; Visiting Fellow, Natural Resources Law Center, and Institute for Behavioral Science, Environment and Behavior Program, University of Colorado; correspondence to Ward: Phone (505) 646-1220, Fax: (505) 646-1563; E-Mail: fward@nmsu.edu.

predicted the growth in the basin's demand for water associated with over a five-fold increase in regional population, (Peach and Williams, 1999) , nor new policies toward fish and wildlife habitat emphasizing endangered species. While municipal and industrial water demands in the major basin cities, Albuquerque, El Paso, and Ciudad Juarez have historically been met by groundwater, such pumping is not sustainable at current withdrawal rates. El Paso is rapidly increasing its use of surface water, Albuquerque has plans to begin direct withdrawals of surface water, and the largest basin municipality, Ciudad Juarez, is projected to deplete its current sole source of water within as little as a decade (Paso del Norte Water Task Force, 2001). In this politically explosive environment we examine possibilities to provide for future water demands, while meeting emerging demands for instream flows. This paper focuses on the issue of agricultural benefits displaced by instream flow requirements for the endangered silvery minnow.

## RIO GRANDE INSTREAM FLOWS

Preservation and recovery of the endangered Rio Grande Silvery Minnow requires continued instream flows (minnow flows), especially in the summer months when the river dries up. For the upper Rio Grande, ecosystem function is largely defined by a self perpetuating wooded riparian corridor, the *bosque*. The cottonwood dominated *bosque* draws shallow groundwater replenished by instream flows. For aquifer regeneration, overland flows are required; such flooding has been largely eliminated due to upstream flood protection efforts. Thus preservation and regeneration of riparian habitat requires flows regimes typically unavailable. Below Elephant Butte Dam the river has been largely channelized, and instream flows occur only as requested by downstream water users. As a matter of course, instream flows are turned on and off in response to irrigation demands.

Finally, instream flows are critical for their dilution value in maintaining acceptable water quality below Elephant Butte Reservoir. Water quality concerns are dominated (though not limited to) by salinity concentrations in river water, shallow groundwater, and nontributary groundwater. In general, as instream flows increase salinity levels decline; conversely, salinity levels can reach critical levels severely impairing crop production and violating water quality standards under very low flow conditions. Further, with increasing levels of good quality instream flow available as far downstream as El Paso/Ciudad Juarez, reliance on nonsustainable groundwater could be reduced through substitution of surface water. Water quality throughout the Basin is poorer in years of drought than in wet years. With a progressive increase in salt concentration of the river water moving downstream, water quality is more critical to the downstream users.

The most sensitive habitat is the 100 river miles upstream from Elephant Butte reservoir, where summer irrigation activity dries the river. This paper considers the impact of the existing Rio Grande Compact, and delivery obligations to Mexico on emerging habitat requirements as defined under the Endangered Species Act. This paper aims identifies the costs and benefits associated with opportunities for increasing instream flows in environmentally sensitive reaches of the upper Rio Grande. Policy options are considered in the context of a previously developed integrated model of the basin (Ward et al, 2001). The model includes essential elements of the basin hydrology, institutions, and economic impacts in order to estimate the system benefits of alternative policy options.

## OPPORTUNITIES AND BARRIERS TO INSTREAM FLOW PROTECTION

Existing Mexican and downstream U.S. water rights provide some protection for these instream flows. Mexico's senior (1906) right is less than 5% of median basin inflows, but it may provide limited benefits for endangered species in providing a senior baseflow. In particular, the junior water rights in Texas and southern New Mexico cannot provide upstream instream flows during low flow conditions. By requiring a baseflow that must be delivered under treaty obligation to Mexico, a small instream flow for the silvery minnow could be maintained at low cost to agriculture or other users.

The presence of Elephant Butte Reservoir downstream of the reach occupied by the silvery minnow allows for significant operational flexibility in the timing of flows reaching Elephant Butte. The situation is complicated by leakage from the main river channel, the importance of local return flows from irrigation, and a hydrologically connected aquifer. As such, it is possible to dry up the Rio Grande mainstem for extended periods without compromising Compact or Treaty obligations. This occurred in 1996, when irrigation withdrawals in the Middle Rio Grande Conservancy District dried up habitat of the silvery minnow (U.S. Fish and Wildlife Service). Based on

historical flows, approximately 30% of years would produce even greater water scarcity at this reach than was observed in 1996. Instream flows in the middle Rio Grande are thus dependent on intra and interstate, and international institutions, as well as on the management actions of federal agencies.

## THE MODEL

An integrated model of the Rio Grande Basin (RGB) was developed to bring the work on hydrology, economics, and institutions within a single framework. The RGB model is used to estimate hydrologic, economic, and ecological impacts of a prolonged basin drought. Proposed alternative water management institutions for reducing economic damages produced by drought are simulated using the RGB model.

The integrated framework provides a flexible environment for representing alternative drought-coping institutions. At the same time, the framework accounts for physical interactions between uses (e.g., agricultural, municipal, instream, and environmental), storage (including groundwater), flows (including diversions, pumping from groundwater, and return flows), and various losses (including field, canal, and conveyance losses). Because of the importance of interstate and international water policy issues, relevant compacts and decrees, uses, storage, and flows must be represented.

The integrated model starts with the basic water supply, which includes all major tributaries, interbasin transfers, and hydrologically connected groundwater. Water demands (current and projected up to 40 years into the future) include agricultural water uses (representing from 86% to 98 % of surface, and 47% to 56% of groundwater use), municipal and industrial demands in Albuquerque and El Paso, recreation at the major basin reservoirs, and environmental demands for instream flow protection. Each component is represented in a yearly time-step over a forty year planning horizon.

Institutions governing water allocation in the basin begin with the Rio Grande Compact and the 1906 Mexican Water Treaty. The Compact establishes schedules relating each states' obligation to the next on the basis of available water inflows to the state. The Mexican Water Treaty establishes an obligation that the U.S. deliver annually 60,000 acre-feet to the Republic of Mexico, except in "extraordinary drought."

### The Rio Grande Compact

While intrastate water rights systems are typically classified as appropriative, riparian, or a hybrid of the two systems, interstate compacts can take many forms (Tarlock). Bennett and Howe provide one approach to classifying compacts by distinguishing between allocations based on fixed versus percentage formulas. In addressing the Upper Rio Grande Basin, it is useful to introduce a complementary approach to classification of the implicit water rights between the three states and Mexico.

For any given water right holder, the actual water delivery over a given period (wet water) is related to the sum of river basin inflows. While the sum of all off-stream deliveries will increase roughly linearly with basin inflows (ignoring return flows and system losses), it is unlikely that a given water right holder will experience constant returns to basin inflows. Rather, the user (e.g. a state or nation) may be allowed decreasing (junior right) or increasing (senior right) marginal returns to basin inflows. The case of constant marginal returns is that of a proportional right. This concept of linking seniority of water right to the nature of the marginal flows reserved with increased total flows offers insights into characterizing water rights implicit in compacts and treaties. This concept is particularly helpful where, as is the case with the Upper Rio Grande Compact, the text of the agreement provides little intuition as to the nature of the respective state water rights.

### Water Allocation under the Compact

Allocations under the Compact and Treaty can be represented using a deterministic model. Central to the Compact are a set of supply indices specifying the proportion of inflows to one sub-basin that are to be passed to the downstream sub-basin. First, Colorado must deliver to New Mexico a minimum water volume based on the headwaters inflows. Let  $\forall_i(Z_i)$  and  $Z_i$  represent the supply indices and the headwaters flows, respectively, for Colorado, and let  $X_{Col}$  represent the implicit consumptive use allocated for Colorado. Then

$$(1) \quad X_{Col} = \mathcal{J}_i (1 - \forall_i(Z_i)) Z_i .$$

Colorado may use from 40% to 80% of the total annual flows. Secondly, New Mexico must deliver annual flows to downstream of Elephant Butte Reservoir for water users in southern New Mexico, Texas, and Mexico. For northern and central New Mexico, consumptive use  $X_{NMI}$  is constrained by the supply index  $\exists(\forall_i(Z_i), Z_i)$  for these deliveries, giving

$$(2) \quad X_{NMI} = (1 - \exists(\forall_i(Z_i), Z_i)) \sum_i \forall_i(Z_i) Z_i + Z_{exempt}$$

where  $Z_{exempt}$  are tributary inflows (and San-Juan Chama imports) that can be fully consumed in northern and central New Mexico. The river reach of greatest concern for the silvery minnow lies downstream of (most of) these uses. The factor  $1-\exists$  ranges from about 20% at high flow levels to a maximum of 43% at low flows. Deliveries to Mexico ( $X_{Mexico}$ ) of up to 60,000 acre-feet must be made from the deliveries below Elephant Butte, giving the allocated use in Texas ( $X_{Texas}$ ) and in southern New Mexico ( $X_{NM2}$ ) as

$$(3a) \quad X_{Texas} = (\exists(\forall_i(Z_i), Z_i) \sum_i \forall_i(Z_i) Z_i - X_{Mexico})$$

$$(3b) \quad X_{NM2} = (1 - \exists(\forall_i(Z_i), Z_i) \sum_i \forall_i(Z_i) Z_i - X_{Mexico})$$

respectively, where  $\approx 43\%$  is independent of flows.

The general pattern of water rights follows both the geography and history of the Basin. Early irrigation in the Basin was concentrated in the upper and middle reaches of the Rio Grande, while most uses downstream of Elephant Butte developed more recently. The Compact is thus consistent with the doctrine of prior appropriation, granting the most senior rights to those regions with the earliest water use. Also consistent with traditional western water law, no protection for continuous instream flows is provided by the Compact.

## RESULTS

Two policies for instream flow protection and enhancement are examined in detail. The first proposed policy would enhance instream flows in a critical reach above Elephant Butte Reservoir to provide habitat protection for the endangered Rio Grande Silvery Minnow. The policy targets reductions in offstream diversions, required under low flow conditions by the Rio Grande Compact, to precisely the river reach most critical to the silvery minnow.

The second policy proposal would enhance instream flows above El Paso and Ciudad Juarez, while providing for future municipal water needs, by allowing market based water transfers from upstream water users. The policy focuses only on water users below Elephant Butte Reservoir, and includes the participation of only U.S. water users. It is thus consistent with both the 1938 Compact and the 1906 U.S. - Mexico Water Treaty.

### Habitat Restoration through Reduced Agricultural Water Use

Table 1 shows the impact of requiring that the largest water shortages be born irrigated agriculture. We use the RGB model to estimate the importance of two opposing impacts. First, the intent of the policy is to increase instream flows by reducing the high level of diversions which bypass the critical river reach. We find that under the lowest quintile flow conditions (the 20% of years with the lowest flows), the savings from reduced diversions contribute to an increase in average river flows of 19%. As an unintended consequence, however, is that aquifer recharge from such diversions is reduced, with a corresponding reduction in groundwater flows to the critical reach. This latter impact could be particularly detrimental in the case of sequential drought years, as groundwater return flows decline just when instream flow levels are already low. Under lowest quintile flows, the effect of reduced flow from groundwater is about 4% of river flows. The net impact of the policy is thus to increase river flows by an average of 15% under lowest quintile flow conditions.

Table 1. Costs and Benefits of Increasing Instream Flow through Reduced Irrigation Diversions

Water Supply	Initial estimated annual flow at San Marcial	Increase in annual streamflow at San Marcial	Water savings from reduced diversions	Water cost from reduced groundwater return flow	Net revenue change near Socorro	Net revenue change above Socorro
	(kaf)	(kaf)	(kaf)	(kaf)	(\$ million)	(\$ million)
normal	575.4	9.6	14.6	5.0	-0.46	0.28
10% normal	83.8	6.9	8.4	1.5	-0.14	0.09
20% normal	131.4	19.4	25.3	5.9	-0.70	0.40
50% normal	266.7	16.7	22.7	6.0	-0.74	0.46

Under lowest decile flow conditions the absolute net increase to flows is only one third the level estimated under the lowest quintile conditions. Under such extreme conditions the policy is thus much less effective in enhancing instream flows. This result arises because of the extreme nature of the lowest decile conditions: there is little diversion to begin with under these very low river flows.

The economic impact of the policy is to decrease farm net revenues for irrigators near the critical reach, but to increase net revenues for upstream irrigators as a result of increased deliveries. Under lowest quintile flow conditions, the net revenue decreases average \$700,000 per year, while net revenue increases average \$400,000 per year. The policy imposes net economic costs because shortfalls in irrigation deliveries are concentrated in a single region. Downstream water users in New Mexico, Texas, and Mexico are unaffected.

A significant obstacle to cooperative approaches is the differing and uncertain nature of water rights and obligations exercised by MRGCD, the Fish and Wildlife Service under the U.S. Endangered Species Act, and Albuquerque water users. Further, while the level of negative impacts under the proposed policy (\$700,000 annually under lowest quintile conditions to irrigators near the critical reach) is modest, there is no clear method of compensation which might create conditions under which these irrigators might support such a policy. One such institution is the development of dry year options (e.g. Michelsen, 1993) to compensate irrigators foregoing water deliveries and use under low flow conditions.

#### Habitat Restoration through Water Market Agreements

Below Elephant Butte Reservoir, major agricultural users include New Mexico's Elephant Butte Irrigation District (EBID), El Paso County Water Improvement District #1 (EPCWID) near El Paso, and Mexican agricultural users near Ciudad Juarez. A policy of market based transfers could include reallocations from upstream to downstream users. Water transfers from upstream users would result in higher annual instream flows which, together with a year-round use for municipal purposes could be a critical component in restoring perennial instream flows, at least upstream of El Paso/Ciudad Juarez.

Table 2 shows the impact on flows and economic benefits of such a policy. Focusing first on lowest quintile flow levels, the policy increases average annual flows near El Paso by about 27%, while allowing the City of El Paso to reduce groundwater pumping by almost 20 kaf per year. The policy would have less impact during more typical conditions. The average impact on flows near El Paso, averaged across all years, is only a 6% increase, while groundwater pumping is reduced by about 7 kaf per year. Net economic impacts are generally small, with the increased benefits to consumptive water users (City of El Paso and EPCWID) only slightly greater than the foregone benefits in EBID. For example, during lowest quintile flows, El Paso region water users enjoy an average annual increase in benefits of about \$7 million, while EBID irrigators suffer reduced net revenues of about \$6 million. Extending water transfers across the state line thus provides little net economic benefit, but does provide substantial increases in instream flows.

Table 2. Costs and Benefits of Increasing Instream Flows through a Three Part Water Market

Water Supply	Initial estimated annual flow at El Paso	Increase in annual streamflow at El Paso	Benefit change for City of El Paso	Net revenue change for EPCWID #1	Decrease in groundwater pumping by El Paso	Net revenue change for EBID
	(kaf)	(kaf)	(million \$)	(million \$)	(kaf)	(million \$)
normal	251.7	15.9	1.59	0.54	6.8	-1.60
10% normal	89.0	57.9	8.19	3.11	28.3	-8.04
20% normal	138.7	37.2	4.98	1.76	19.7	-6.05
50% normal	187.5	19.6	2.54	0.86	10.6	-3.19

One extension of a three party market among U.S. water users is to include Ciudad Juarez area municipal and agricultural water users. While such an approach might offer demonstrable further net economic and sustainability benefits (impacts on instream flows are less clear), the objections to implementing cross-border water transfers makes such an approach impractical at this time. More promising would be an approach to forego a binational market in favor of developing independent markets within each nation. This more limited policy innovation would likely offer similar economic, instream flow, and sustainability benefits while being more acceptable to the range of Rio Grande water users.

#### CONCLUSIONS

Population growth and increasing water demands will result in continued pressure to secure new water supplies, particularly for El Paso and Ciudad Juarez. While the demand growth in El Paso/Juarez could provide an important opportunity to provide instream flow benefits for endangered species important challenges remain. Binational cooperative approaches to providing additional flows of adequate quality to both the City of El Paso and Ciudad Juarez offer a low cost method of increasing instream flows. These might be pursued in conjunction with a demonstrated binational interest in pursuing cooperative solutions to meet municipal water demands. Approaches which capture upstream water for downstream delivery via pipeline or aqueduct increase the cost limit the possibilities for river restoration below Elephant Butte Reservoir, and may constrain lead to an inability to meet the timing requirements of future Mexican water demands. In depth exploration of the alternatives for meeting future binational municipal and instream flow demands for water are ripe for continued inquiry.

#### ACKNOWLEDGMENTS

The following institutions graciously supported this study: Water Resources Research Institutes and Agricultural Experiment Stations of Colorado, New Mexico, and Texas; U.S. Geological Survey. The authors also express their appreciation to those who reviewed this paper and abstract for AWRA.

#### REFERENCES

- Bennett, L. L. and C. W. Howe. "The Interstate River Compact: Incentives for Noncompliance." *Water Resources Research*. 34 (March 1998): 485-497.
- Booker, J.F. and R.A. Young. "Modeling Intrastate and Interstate Markets for Colorado River Water Resources." *J. of Environ. Econ. and Manag.* 26 (January 1994): 66-87.
- Burton, G. "Rio Grande Silvery Minnow." New Mexico Ecological Services State Office, Albuquerque. June 1997
- Frasier, W. M., A.M. Michelsen, R.G. Taylor, J.F. Booker, and R.G. Huffaker. "Economic and Institutional Alternatives for Meeting Interstate ESA Instream Flow Requirements in the Platte River Basin." *Amer. J. Agr. Econ.* 81(December 1999):1257-1261.
- Gillilan, D. M. and T. C. Brown, *Instream Flow Protection*. Washington DC: Island Press, 1997.

- Hamilton, J., G. Green, and D. Holland. "Modeling the Reallocation of Snake River Water for Endangered Salmon." *Amer. J. Agr. Econ.* 81(December 1999): 1252-1256.
- Hibbs, Barry J. "Hydrogeologic and Water Quality Issues Along the El Paso-Juarez Corridor: An International Case Study." *Environ. & Engineering Geoscience* V (Spring 1999) 27-39.
- Hibbs, Barry J. et al. "Transboundary Aquifers and Binational Ground-Water Data Base, City of El Paso/Ciudad Juarez Area." International Boundary and Water Commission and others, 1998.
- Howitt, R. E. and J. R. Lund. "The Economic Impacts of Water based ESA and Environmental Policies in California." *Amer. J. Agr. Econ.* 81(December 1999):1268-1272.
- LeMarquand, David G. *International Rivers: The Politics of Cooperation*. Westwater Research Centre, University of British Columbia, 1977.
- Mumme, Stephen P. "Minute 242 and Beyond: Challenges and Opportunities for Managing Transboundary Groundwater on the Mexico-U.S. Border." *Natural Resources Journal* 40 (Spring 2000): 341-378.
- Ostrom, Elinor. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge Univ Press, 1991.
- Randall, Alan. "Property Entitlements and Pricing Policies for a Maturing Water Economy." *Australian Journal of Agricultural Economics* 25(1981):195-212.
- Tarlock, A. D. *Law of Water Rights and Resources*. New York: Clark Boardman Company, 1991.
- U.S. Bureau of Reclamation and U.S. Corps of Engineers, "1998 Rio Grande Basin Operations Plan," April 17, 1998.
- U.S. Fish and Wildlife Service. "New Mexico Water Managers to Provide Additional Water In Rio Grande for Spawning of Endangered Minnow." Press release, May 16, 1996.
- Ward, F.A., R.A. Young, R. Lacewell, J. P. King, M.Frasier, J. T. McGuckin, C. DuMars, J.F. Booker, J. Ellis, R. Srinivasan. *Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin*. Final report to U.S. Geological Survey. February 2001.
- Wilson, B. C. *Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 1995*. New Mexico State Engineer Office, Technical Report 49, November 1997.
-