7-1997

Water Management Study: Upper Rio Grande Basin. Final Report. Report to the Western Water Policy Review Advisory Commission

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Policy Review Advisory Commission

July 1997

Executive Summary

In September, 1996, the Western Water Policy Review Advisory Commission contracted with ECONorthwest to study the major problems associated with the growing competition for scarce water and related resources in the Upper Rio Grande Basin, and to make recommendations for appropriate federal policies and actions for addressing the problems. This is our final report. The study covers the area from the headwaters, in Colorado, to Ft. Quitman, Texas (see map).

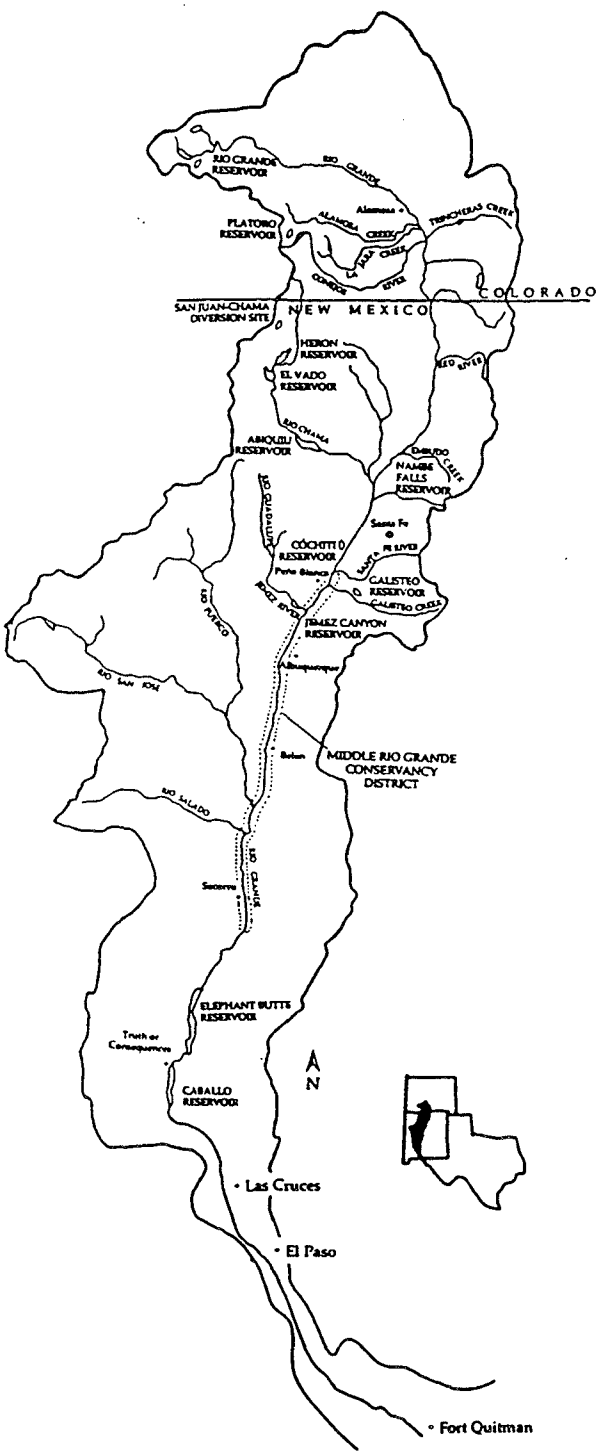
An Important Message For The Reader

In this report we identify problems and make recommendations associated with the growing competition for scarce water and related resources in the Upper Rio Grande Basin. Our definition of problems has a specific meaning. A problem exists if the Basin's water and related resources are not used in the optimal manner that meets the three economic criteria described in the text. In identifying the problems we are not making any evaluation, positive or negative, of any individuals, laws, institutions, or activities, associated with the problems. Our recommendations apply solely to federal policies, agencies, and activities. We make no recommendations whatsoever regarding the Rio Grande Compact, state and local laws, the responsibilities and rights of resource owners, the substantive merits of disputants' claims to resources, or changes in specific resource uses.

A. Background

Precipitation in the Basin is limited and highly variable. Most of the Basin receives 7-15 inches annually, on average. Half of the precipitation occurs as snowfall in the high mountains of Colorado and New Mexico and the other half as intense, summer thunderstorms. The Colorado portion of the Basin produces about 975,000 acre-feet (af) of water annually, but, because of agricultural production and transportation "losses" from evaporation and seepage, only 325,000 af reach the Colorado-New Mexico border.[1] Streamflows in New Mexico add another 650,000 af and about 100,000 af are imported from the San Juan Basin, a part of the Colorado River Basin. About two-thirds (on average, 700,000 af/yr) of the water entering the Middle Rio Grande Valley surrounding Albuquerque reaches Elephant Butte

[1] An acre-foot of water is the amount of water that would cover one acre of land one foot deep. It is equivalent to 326,000 gallons and 43,560 cubic feet of water.



Map of the Upper Rio Grande Basin.
Source: Finch and Tainter (1995).

The U.S. must deliver 60,000 af of this to Mexico. Heavy agricultural use in southern New Mexico and western Texas, together with growing municipal consumption in the El Paso–Ciudad Juarez area, deplete the river so that it generally goes dry before reaching Ft. Quitman.

Agriculture accounts for about 89 percent of the major water uses (typically associated with withdrawals or diversions) in the Basin. The remainder goes to municipal and industrial use, primarily in the Middle Rio Grande Valley and in the El Paso area. The Basin's cities have relied on groundwater but El Paso (population about 650,000) and her Mexican neighbor, Ciudad Juarez (more than 1.5 million), as well as Albuquerque (about 650,000) recently recognized they cannot long continue mining groundwater at historical rates. El Paso has begun using surface water from the Rio Grande and Albuquerque is examining similar options.

Sediment levels in the river are high for most of its length. Intense agricultural use in the southern parts of the Basin increase the water's salinity and add nutrients and agricultural chemicals. The shallow aquifers near urban centers, which provide water for many low-income households, exhibit pollution from septic systems and hazardous-chemical spills. Effluent from municipal wastewater-treatment plants frequently fails to meet water-quality standards and surface water near urban centers is not potable and often not suitable for human contact. Water from the deep aquifers under Albuquerque and El Paso-Ciudad Juarez often includes elevated levels of dissolved solids, such as arsenic.

Human settlements in the Basin have diverted water from the river for centuries, and competition for water has long been intense. Friction among the states led to the 1938 Rio Grande Compact, which stipulates the fractions of available water that Colorado must deliver to New Mexico, and New Mexico to Texas. The allocations in the Compact reflect the agrarian economy and the distribution of agricultural activity that existed at the end of the 1920s, not today's highly urbanized economy. Much of the agricultural development reflected in the Compact occurred in the upper end of the Basin, but most of today's economic growth is occurring farther south, in El Paso-Ciudad Juarez and Albuquerque.

Diversions of water from the river, construction of dams and other structures in the river bed, manipulation of the hydrograph, modification of the channel, and control of vegetation have extensively modified the riverine-riparian ecosystem. The reach below Elephant Butte Dam is largely a

network of canals and 71 percent of the native fish species no longer can be found in this area. Only one portion of the Basin's ecosystem, the riparian cottonwood forest known as the bosque in the Middle Rio Grande Valley, has been examined extensively. The forest no longer is dispersed throughout the historical floodplain, much of it is disconnected hydrologically from the river, and significant changes in ecological structure and function are expected to occur if current management regimes continue. In 1994, the U.S. Fish & Wildlife Service listed the Rio Grande silvery minnow as an endangered species.

The prior-appropriation doctrine underlies most water movement in the Basin, but it does not apply uniformly to all resources or in all areas. Also important is the influence of aboriginal rules and custom, Spanish and Mexican laws antedating the 1848 Treaty of Guadalupe Hidalgo that ceded much of the Basin to the U.S., international treaties, the Rio Grande Compact, the federal government's trust responsibilities for Pueblo tribes and as stewards of many resources, and the unique laws and institutions of the three states.

Water-management issues are especially complex in New Mexico. The state does not recognize instream flows as a beneficial use and, hence, it does not protect instream flows. Furthermore, it has not adjudicated most water rights in the Basin and there is little infrastructure for measuring flows and diversions. Particularly disturbing to many is the lack of adjudication for Pueblo water rights which, at some places and times of the year, probably would embrace all surface flows.

Competition for the Basin's water and related resources is far more intense and complex than in the past. Decades ago, demand came primarily from agriculture, but it now competes with demands reflecting the spiritual value Indians and others place on the river, the contributions the river makes to the Basin's quality of life, and the myriad uses of water in a modern metropolitan city. Some of the competition manifests itself through market mechanisms, but most does not. Powerful economic forces are changing the character of the competition for resources by reducing the ability of traditional resource-intensive industries, such as agriculture, and increasing the ability of non-consumptive and passive uses, such as recreation, to generate new jobs and higher incomes. Increasingly, the economic prospects of communities are determined by their ability to produce, attract, and keep a highly qualified workforce and, as both firms and households become more footloose, communities that offer a high quality of life outperform those that

do not. Water-related recreational opportunities and aesthetics are important elements of the quality of life in the Basin, where economic activity is concentrated near the narrow ribbon of water flowing through the desert.

Throughout the report, we use the term "value" to mean more than just price. We take a broad view of the term, employing it to refer not just to goods and services associated with the Basin's water and related resources that are measured in monetary terms, such as bales of hay produced from irrigated fields, but also to those that are not measured in monetary terms, such as recreational opportunities, protection of endangered species, and maintenance of cultural traditions. Consistent with this approach, we also employ the term "use" to refer both to conventional uses associated with physical manipulation of the Basin's water and related resources, such as withdrawing water from a stream for irrigation, and to more passive or nonquantifiable uses, such as dilution of pollutants or maintaining riparian habitat. We recognize that individuals have multiple perspectives on the "values" and "uses" associated with the Basin's resources. These multiple perspectives give support to a central message of the report—the competition for the resources is complex.

Much of the water in the Basin is not being used in the manner that would generate the bundle of goods and services with the greatest value or the highest levels of jobs, incomes, and standards of living. The prices of water and related resources generally do not reflect these resources' scarcity and, hence, resources often are put to a low-value use while other uses with a higher value go unsatisfied. Much of the water used at the economic margin for irrigation yields crops whose value is less than the cost of growing them. The fundamental legal and institutional structure overseeing water uses tends to favor agricultural and other diversionary uses, however, and does not facilitate voluntary transactions that would release resources from low-value uses and direct them toward high-value ones.

Much of the emphasis on diversionary uses stems from traditions that see irrigation not in economic terms but as a necessary support for human life and an essential element of local cultures. These traditions are being challenged, especially near metropolitan centers, where many farmers see the inevitability, if not the economic advantage, of transferring water to municipal-industrial users.

Issues related to perceptions of the fairness of different resource uses and competing demands abound in this Basin. Many farmers and advocates of irrigation believe those who would restrict irrigation in favor of instream flows and other environmental amenities are latecomers with no right to interfere with the activities of those with a prior claim to water. Many instream advocates counter by arguing that diversionary uses impose environmental damages on all of society and the institutional-legal framework unfairly favors such users. Public officials in Albuquerque and elsewhere are hoping that residents' sense of fairness toward future generations will encourage them to curtail their consumption of finite groundwater resources. Supporters of Indians' rights believe the federal government's failure to defend these rights as it helped finance the development of others' rights is deplorable.

B. Major Problems

The problems affecting the competition for the Basin's water and related resources are so numerous and intertwined that it is impossible to demonstrate cleanly where one stops and another starts. Whatever the approach for describing and evaluating the problems, one first must define the criteria for determining if a problem exists and for measuring its severity. We use three criteria that are standard hallmarks of this nation's economic system to assess the competition for water and related resources in the Basin. These criteria also reflect three major types of arguments raised during controversies over water and other resources. This framework indicates that the outcome from this competition is optimal if: (1) the resources are used in the manner that yields the highest net value for the bundle of goods and services derived from the resources; (2) the resources are used in the manner that yields the highest standard of living; and (3) the resources are used in the manner that is perceived to be fair.

We separate the problems into two sets. We first describe two problems that represent the most serious, fundamental aspects of the past and current failure to meet the three criteria described above. We call these the bottom-line problems. One of them focuses on the resources themselves, and the other on the economies and communities dependent on the resources. We then describe several of the factors that create, exacerbate, or prevent mitigation of the bottom-line problems. We call these the contributory problems.

1. Bottom-Line Problem #1: The Resources are Finite, but the Demands are Not

The Basin's water and related resources are components of, and produced by an ecosystem. This ecosystem, like all others, has limits on how much water and other resources can be extracted from it to support and sustain humans. Within the past decade, the edges of the ecosystem's carrying capacity have become more clear. The designation of the Rio Grande silvery minnow as an endangered species reflects the extreme stress within the ecosystem. The low snowpack during 1995–96 showed that the supply of water can fall far short of current consumption levels, and the prospect of global climate change promises to exacerbate the shortfall. Both the Albuquerque area and the El Paso-Ciudad Juarez area have bumped against the limits of the supply of readily accessible groundwater, and are expecting rapid population growth. Many locations within the Basin have either encountered declines in water quality or recognized that such declines may materialize in the foreseeable future.

2. Bottom-Line Problem #2: The Basin's Water and Related Resources are Persistently Allocated in a Manner That is Less Than Ideal

If the Basin's water and related resources reflected the nation's ideals of competitive markets, they consistently would go to their highest-value uses. As the economy changes over time, some demands for a resource would grow, others would diminish, and the resources would shift accordingly through multiple, voluntary transactions. Reality, however, is far different from this ideal. For most, if not all, of the Basin's water and related resources the prevailing prices do not tell the economic truth about either the overall scarcity of the resources or the strength of one demand relative to another. As a result, the local, regional, and national economies forgo valuable goods and services as well as opportunities for more jobs, larger incomes, and higher standards of living. Some groups, especially the Pueblos, assert that the system is grossly unfair.

Many additional factors contribute to the bottom-line problems. These contributory problems include:

- The Basin's Resources Have Not Been Managed as Elements of an Ecosystem

- Past and Current Practices Have Rendered Water and Related Resources Unsuitable for Some Uses Without Corrective Action
- Resource-Demands that Come From Industrial Activities and Are Measured in Monetary Terms Are Difficult to Reconcile with Those that Are Not
- Many Groups Feel They Are Unable to Participate Effectively in Resource-Management Decisionmaking
- There Is Widespread Uncertainty about the Hydrosystem and Ecosystem of the Upper Rio Grande Basin
- The Relationship Between the Resources and the Economy Is Poorly Understood
- There Is Pervasive Distrust Among Stakeholders

C. Conclusions and Recommendations

We make three major recommendations regarding federal resource-management policies and activities in the Upper Rio Grande Basin. Each embraces several components.

1. Recommendation #1: Federal Policies and Actions Should Reflect the Ecosystem's Complex Role in a Complex Economy

We intend this recommendation to provide fundamental guidance for future federal policies and actions in this Basin. It has two essential features. The first is that federal policies and actions should view the Basin's water and related resources as elements of an ecosystem, not as independent resources separate from the ecosystem. The second is that federal policies and actions should recognize the full set of competing demands for the Basin's water and related resources and, wherever appropriate, strive to optimize these resources' contribution to the economy.

Federal policies and actions should account for the uncertainty surrounding the quantity and availability of the Basin's water and related resources and make an effort not to step beyond the bounds of current knowledge. Federal

agencies should adopt the broad view of the term "use" to ensure that nonquantifiable or passive uses are not ignored in resource-management decisions. In a similar manner, we recommend that federal agencies also adopt the broad view of the term "value" to include not only the goods and services associated with the Basin's water and related resources that are measured in monetary terms, but also those that are not monetized.

We believe four changes in how federal agencies do business will expedite policies and actions with a broader view of the ecosystem and economy. Federal agencies with a significant impact on the Basin's resources should (1) promote institutions that take a broad view of the economy and environment; (2) initiate an integrated scientific assessment of ecological and economic conditions in the Basin; (3) describe tradeoffs more clearly; and (4) communicate ecological and economic issues more clearly. Effecting these changes will require funding, staff, and attention to reducing the confusion generated by various agencies' conflicting policies.

2. Recommendation #2: Strive to Mitigate or Correct Anticompetitive Factors

We recommend federal agencies in the Basin do more to mitigate the constraints to competition that keep water and other resources in low-value uses while high-value demands go unmet. We recognize, however, that the Rio Grande Compact with its preeminent legal position over interstate water decisions in the Basin is an impediment to competition across state boundaries, and will continue to be, absent change by the three signatory states and Congress. Resource managers should work to reduce the transaction costs that restrict the ability of willing "buyers" and "sellers" of resources from consummating mutually beneficial transactions. We believe they can do this by identifying "hotspots" where the discrepancy between the value of resource use and unmet demand are greatest and helping potential "buyers" and "sellers" come together.

Resource managers also should work cooperatively to curtail the externalities of federal resource-management activities. They should continue to work in multi-agency groups, recognizing that the concerns of all must be dealt with jointly. Federal resource-management agencies, acting individually or jointly, periodically should prepare a summary of how their activities affect the value of resource-related goods and services and their impact on jobs, incomes, and other indicators of standard of living. We also

recommend that the Bureau of Reclamation (BuRec), the Army Corps of Engineers (CoE), and other resource-management agencies, working with Congress, broaden the scope of activities authorized for federal dams and other facilities. Congress should specify economic and ecosystem goals for the Basin, identify priorities for how the facilities should contribute to the attainment of these goals, and give the agencies greater leeway to work toward them.

We recommend that federal agencies support institutional innovations to facilitate voluntary transfers of resources from low-value to high-value uses. In particular, we encourage federal resource managers to anticipate proposals, and even develop their own, for the devolution of resource-management responsibility and authority from federal agencies to state and local ones. To participate successfully in a devolution process, federal agencies must be prepared to specify the outcomes they want to see. Then they must have appropriate mechanisms for measuring progress toward individual outcomes, and actions for holding state and local agencies accountable.

3. Recommendation #3: Clarify Federal Interests in the Basin's Water and Related Resources

We recommend that the federal resource-management agencies initiate meaningful steps to clarify the federal interests in the Basin's water and related resources. There are at least five general categories of federal interest in the Basin's resources to be clarified: stewardship, corporate, Pueblo trust responsibilities, economic-welfare, and public-participation. Each of these is affected by risk and uncertainty, to the point that the distribution of risk, itself, constitutes a federal interest in the resources that should be clarified.

We recommend that each agency prepare a statement of its interest in the Basin's resources. This statement should be informed by the results of adopting an ecosystem-management approach, completing the assessment of the Basin's ecological and economic conditions, and setting priorities. It should explicitly address each types of potential federal interest, including those associated with risk and uncertainty. Where necessary, it should identify where the federal interest remains ambiguous and explore mechanisms for resolving the ambiguity.

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Acknowledgments

This report was prepared by Ernie Niemi and Tom McGuckin, with assistance from Michelle Gall, Donna Stumpf, and Sarah Van de Wetering. We gratefully acknowledge the assistance of the many individuals who shared with us their information, insight, and patience. We identify these individuals in the following list (and apologize to any whose name we inadvertently have omitted). Despite the assistance we have received from others, we remain solely responsible for the contents of this report.

Throughout the report we have identified our sources of information and assumptions used in the analysis. Within the limitations imposed by uncertainty and project budget, ECO has endeavored to check the reasonableness of the data and assumptions. As time passes, the results of this report should not be used without accounting for more recent data and relevant assumptions.

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Chapter 1

Major Physical, Legal, and Institutional Characteristics

The Upper Rio Grande Basin stretches for about 1,000 miles, from the headwaters in southern Colorado, through central New Mexico, to Ft. Quitman, 100 miles below El Paso, Texas, on the U.S.-Mexico border. The Basin's climate is semi-arid or arid and its water and related resources have been essential elements of the local and regional economies for hundreds of years. In the next chapter we discuss the nature of the competition for these resources and, in Chapter 3 we discuss the major problems associated with this competition. In this chapter we set the stage for those discussions by describing the Basin's major physical characteristics, providing a short history of human development in the Basin, and describing the major laws and institutions that govern resource use.

A. Major Physical Characteristics

In this section we briefly describe the overall character of the Basin's ecosystem, surface-water flows, and groundwater supplies and uses.

1. Ecosystem

The diversity and complexity in elevations, geology, topography, and precipitation levels across the Basin result in an intricate vegetation pattern. The reach of the river from the headwaters in southern Colorado to the southern end of New Mexico's Middle Rio Grande Valley contains sections of montane grassland, coniferous woodland, and mixed conifer. Spruce-fir (subalpine) forest adjoins these sections at higher elevations. Downstream, the Basin becomes more desert-like, with basin and plains vegetation adjacent to the river's riparian zone.

A comprehensive assessment of ecological conditions in the Basin has not been completed, although some areas have been studied extensively. The sketchy evidence shows that much of the ecosystem has been severely modified, especially since the middle of the last century. Some reaches are commonly labeled as "dead" or "bombed out." These occur in all parts of the Basin. There are highland tributaries, such as the Alamosa River in southern Colorado, that exhibit reduced water quality and loss of natural habitat because of extensive channelization, loss of riparian vegetation, and acid mine drainage. In much of New Mexico, channelization and the operation of dams have altered the river's fundamental bio-physical

character and irrigation withdrawals often leave the river bed dry. Similar changes have occurred in Texas, and in some places the river has been transformed into a concrete-lined ditch.

The most intensive investigations of riverine and riparian ecosystems have occurred in the Middle Rio Grande Valley, and particularly with respect to the cottonwood-dominated riparian forest known as the bosque. The following discussion is drawn from a recent report of the bosque's historical and current ecological conditions (Crawford et al. 1996) illustrating the extent of the ecological changes that have occurred and the associated problems that exist in the Middle Rio Grande Valley. The report concludes that human manipulation of the ecosystem, especially in the past 60 years, is having such a dramatic impact that "in terms of its structure and functioning, [it] will undergo irreversible change in the absence of a new management paradigm." Although one must employ extreme caution before extrapolating from this area to others within the Basin, this general description is indicative of ecosystem conditions, changes, and problems elsewhere in the Basin.

The bosque of the Middle Rio Grande Valley is the longest continuous stretch of cottonwood forest in the American Southwest. Historically, the bosque was distributed throughout a broad floodplain, reflecting the vagaries of climate and the periodic flooding and drought that caused the river to shift channel frequently. Early human settlement by Indians and Spanish settlers had cleared some of the forest and altered the river's hydrology somewhat, but the bosque retained most of its widespread distribution and connection to natural hydrological patterns. Trapping of beaver between 1820 and 1840, however, resulted in the elimination of beaver dams, causing significant increases in runoff intensity and sedimentation. The arrival of the railroads in the 1870s stimulated greater mining, grazing, and other activities that further altered the river's hydrology and changed the Basin's vegetation patterns. With rapid development of irrigated agriculture in the San Luis Valley of Colorado, downstream flows dwindled and the river began to deposit sediment much sooner, causing aggradation (raising) of the river bed. As the river bed rose, so too did the shallow water table in the floodplain and, eventually, some land that otherwise would have been dry became waterlogged. Other areas, however, dried out as the aggradation, plus human intervention, left them inaccessible to the shifting river channel. These hydrological changes, together with continued clearing of land within the Middle Rio Grande Valley, greatly reduced the abundance of the bosque's cottonwoods.

Residents of the valley responded in the 1920s and 1930s, primarily through the establishment of the Middle Rio Grande Conservancy District (MRGCD), to reduce flooding, alleviate waterlogging, and increase irrigated acreage. MRGCD's development of drainage canals quickly eliminated large wetland areas, leaving only narrow strips of aquatic habitats as refugia for water-dependent species. Habitat concentration was exacerbated by the construction of levees and other flood-control structures to force the river to remain in a single channel. The construction of upstream dams to control flooding has further restricted the pulsations of alternating flooding and drought so critical to the bosque. The current stand of dominant cottonwoods traces back to the valley's last big flood, in 1941, when flows up to 25,000 cubic feet per second (cfs) caused widespread inundation and allowed seedlings to germinate and establish themselves. The construction of Cochiti Dam, in 1975, together with development within and restriction of the floodplain has ended the potential for similar flooding and, hence, for regeneration of cottonwoods.

The current bosque ecosystem retains little of its historical character.[1] It exists as a narrow strip along the valley's river bed and canals rather than being distributed throughout the floodplain. Much of it has no hydrological connection to the river and is expected to experience profound change as the current dominant cottonwoods mature and expire faster than replacements materialize. This change will be exacerbated by the spread of exotics, such as saltcedar and Russian olive. Detachment of the forest from the river's influence undoubtedly will have many ecological effects, including an increase of wildfires, but many of these, such as the effects on the abundance and diversity of species, remain unclear.

2. Surface Water

The Basin falls within a transitional climatic zone, receiving precipitation from both the Gulf of Mexico and the Pacific (Bullard and Wells 1992). The climate is semiarid upstream of the Albuquerque area and arid downstream. Most of the surface water in the Basin comes from snowmelt in the San Juan and Sangre de Cristo Mountains of southern Colorado and northern

[1] Evaluations of the wild and scenic character of different stretches of the river provide a rough indicator of the extent to which the ecosystem has been modified. Of the 1,000 miles of river in the Basin, only the first 50 miles of the river in New Mexico have been designated as a federal wild and scenic river and the Bureau of Land Management has identified the last 25 miles in Colorado as suitable for such designation.

New Mexico or from thunderstorms. Average annual precipitation exceeds 25 inches only at the highest elevations; for over two-thirds of the Basin, precipitation is between 7 and 15 inches. Precipitation is highly variable. Snowfall in the high mountains can be as little as 30 percent and as much as 75 percent of the Basin's total. On average, summer precipitation supplies almost half of the Basin's annual moisture in brief, intense thunderstorms. Mountain tops in the Basin reach 12,000 feet. Most of the human population occurs at about 5,300 feet near Albuquerque and 3,800 feet near El Paso.

The Colorado portion of the Basin produces about 975,000 acre-feet (af) of water annually (Daves 1994).[2] Approximately 650,000 af of this total is consumed by agricultural production in the San Luis Valley or "lost" to seepage and evaporation. From the border, the river passes through a steep canyon for about 100 miles, emerging near Santa Fe into a broad valley known as the Middle Rio Grande. The Middle Rio Grande receives about 300,000 af from Colorado, 400,000 af from a major tributary, the Rio Chama, and 250,000 af from tributary streams in the mountains of northern New Mexico. Since 1971, the Middle Rio Grande also receives about 100,000 af imported into the Basin from the San Juan Basin (part of the Colorado Basin) on the other side of the Continental Divide from the transfer of water from Colorado's San-Juan Basin to the Rio Chama (Rio Grande Compact Commission 1991).

Flows on the river receive the greatest attention at two locations. Flows at the gauging station at Otowi Bridge, about 100 miles north of Albuquerque, are used to determine deliveries of surface water to New Mexico from Colorado and flows into Elephant Butte Reservoir, about 120 miles south of Albuquerque, are used to determine deliveries from New Mexico to Texas.

Flows in the Rio Grande vary considerably, as shown in Figure 1.1. It shows the annual flows at Otowi Bridge from 1950 through 1994 and does not include water from the San Juan River. For the time period 1895(1993, average flow at Otowi was 1,060,000 af, with a standard deviation of 525,000 af, indicating that 66 percent of the time the flows of the river varied

[2] An acre-foot of water is the amount of water that would cover one acre of land one foot deep. It is equivalent to 326,000 gallons and 43,560 cubic feet of water.

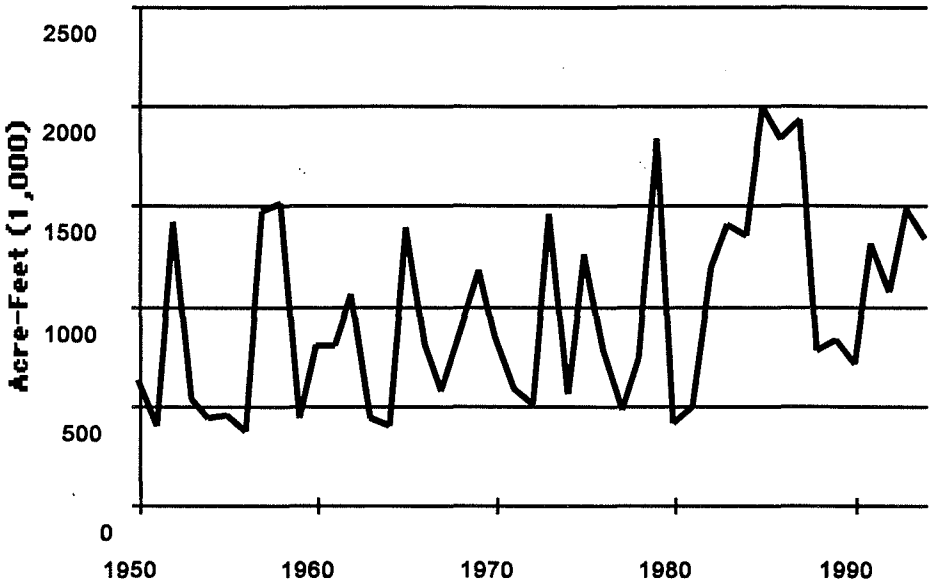

Figure 1.1.—Natural flows of Rio Grande at Otowi Bridge in New Mexico (index supply). Source: ECONorthwest with data from the Rio Grande Compact Commission (1939-94).

between 1,587,000 and 536,000 af (Hydrosphere Inc. 1993). The lower end of this scale, 536,000 af, demarcates a low-flow year in this reach of the Rio Grande. Records for 1950(1993 indicate that low flows occurred in 1950, 1951, 1953(56, 1959, 1963, 1964, 1972, 1974, 1977, 1980, and 1981. Barring unforeseen events, 1996 also will prove to be a low-flow year.

About two-thirds (on average, 700,000 af/yr) of the water entering the Middle Rio Grande reaches Elephant Butte Reservoir, which serves as the measuring point for determining the amount of Rio Grande water New Mexico delivers to Texas (Rio Grande Compact Commission 1991).[3] The balance, approximately 350,000 af/yr, is consumed by agriculture and municipal users or "lost" through seepage and evaporation as the river water moves through the Middle Rio Grande area. Agricultural users account for about half of the water used or "lost", and municipal users and transportation each account for about one-quarter. In 1990, agricultural users in the Middle Rio Grande, on average, diverted 404,000 af and consumed 181,600 af (Wilson 1992). The area's municipal users diverted 155,000 af and consumed 82,200 af (Wilson 1992). Transportation and evaporative losses accounted

[3] The Rio Grande Compact defines the minimum fraction of the water passing Otowi Bridge that must reach Elephant Butte Reservoir. See the discussion of the Compact that follows.

for the remainder. These figures are general calculations based on gross inflows and outflows, reflecting the absence, until recently, of instrumentation to measure diversions and returns.

About 10 percent of the water reaching Elephant Butte Reservoir is "lost" so that, on average, more than 600,000 af is released from the dam. Water is released for three primary users: Mexico as stipulated in the U.S.-Mexican Water Treaty, the Elephant Butte Irrigation District (EBID) in southern New Mexico, and the El Paso County Water Improvement District (EPCWID). Mexico receives 60,000 af/yr under the terms of the 1906 treaty. The remainder of the water is allocated, 57 percent to EBID and 43 percent to EPCWID.

In the past, the water released from Elephant Butte was used almost exclusively for agricultural irrigation. Continued urban growth in southern New Mexico and west Texas, however, has increased urban demand. Whatever water is in the river below El Paso and Ciudad Juarez generally includes return flow from municipal waste water and irrigators. The quality and reliability of this water is low and is used for agricultural production through the Hudspeth Irrigation District on a first-come, first-served basis.

About 100 miles below El Paso at Ft. Quitman, the Rio Grande essentially goes dry. It resurfaces as other tributaries, especially the Pecos from the north and the Rio Conchos from the south, enter near Big Bend, Texas.

3. Groundwater

Most municipal-industrial uses of water in the Basin rely on groundwater. Groundwater supplies are not spread evenly in the Basin, but are most plentiful where the Rio Grande and its prehistoric predecessors filled-in geologic depressions with both sediment and water. Groundwater is pumped most extensively in the San Luis Valley in Colorado, the Middle Rio Grande Valley in New Mexico, in southern New Mexico south of Elephant Butte Dam, and near El Paso and Ciudad Juarez.

Albuquerque derives its water from the Albuquerque Basin, which, in some places has water-bearing deposits extending to a depth of about 15,000 feet and, for a long period residents in the major cities believed that most of this water was readily available (Bureau of Reclamation, Middle Rio Grande Assessment Preliminary Discussion Draft). A common sentiment was that

Albuquerque sat atop an aquifer holding water roughly equivalent to one of the Great Lakes. Events have proven otherwise, however, as water tables and even the land surface have dropped dramatically in some locations. Subsequent scientific investigation (Kernodle et al. 1995; Thorn et al. 1993) has found that the deposits are not layers of coarse sand from which water is easily extracted. Instead, layers of fine-grained material hold less water and do not relinquish it easily. Geologic faults and other features interfere with lateral movement of water. Thus, although there still is a lot of groundwater in the Basin, it will be increasingly costly to extract.

Some parts of the aquifer are hydrologically connected to the river and are recharged through percolation. In some places, recharge can occur over a large landscape, but in others it occurs in small, isolated points. Some parts of the aquifer are hydrologically isolated from the river and experience no recharge.

Since the middle 1950s, the State has required groundwater and surface water in the Albuquerque Basin to be managed as though they were fully connected hydrologically. Thus, one could increase groundwater pumping only by bringing new water to the Basin or by retiring an equivalent amount of surface-water rights. In the 1970s, the City of Albuquerque responded to this requirement by purchasing rights to 48,200 af of water the Bureau of Reclamation (BuRec) was importing to the Upper Rio Grande Basin from the headwaters of the San Juan River. In recent years, the City has pumped about 140,000 af and delivered 60,000 af back to the river through its wastewater treatment plant. Thus, the City was believed to be depleting the river of about 80,000 af a year and it offset this by allowing the surface water it owns (San Juan water plus water native to the Rio Grande) to flow through the valley and percolate into the aquifer. Until recently, it was thought that recharge from its surface water was roughly equal to the amount of surface water it allowed to percolate into the aquifer. The hydrogeologic system was presumed to be in balance, and the City could have increased groundwater use further only by retiring an equal amount of surface-water use.

More recently, scientific studies (Kernodle et al. 1995; Thorn et al. 1993) indicate that only 50,000 af of the City's surface water recharges the aquifer and, hence, the City has been pumping water out of the aquifer faster than the recharge. Instead of being in balance, the aquifer has been drawn down, with some of the draw down being consumed and some being delivered to the river. The City has embarked on a program to decrease water consumption

per household, ensure that water consumption comes from surface sources, and increasingly rely on the aquifer as a source of water during droughts or other emergencies.

El Paso's story is similar. By 1910, when the City of El Paso took over the El Paso Water Company, the entire municipal water supply came from wells. For nearly half a century El Paso relied exclusively on groundwater from the Hueco Bolson, which it shares with Ciudad Juarez. Since around 1917, withdrawals have exceeded recharge. In 1941 El Paso began contracting with the EPCWID to obtain surface water rights from the Rio Grande Project and divert water from agricultural use. It also began withdrawing water from the Mesilla Bolson, an aquifer primarily located in New Mexico. In 1992, El Paso obtained 60 percent of its supplies from the Hueco Bolson, 15 percent from the Mesilla Bolson, and the remainder from surface water. It recently increased its use of surface water to more than 40 percent, with the completion of a new treatment plant.

Groundwater plays an important role in the agricultural sector throughout the Basin. Many farmers, especially in the northern Basin, begin irrigating with groundwater early in the growing season, then switch to surface water as mountain snow melts, and switch back to groundwater as surface flows taper off. Many farmers use the aquifer as an underground reservoir, drawing from it when surface flows are low and recharging it when they are high. In the northern part of Colorado's San Luis Valley farmers currently rely heavily on a large underground reservoir created by seepage from past flood irrigation that used water from the Rio Grande. Here and elsewhere, though, ensuring that the reservoir is not depleted over time remains a considerable technical (gauging) and managerial challenge. Many observers look at the historical tendency to deplete aquifers in the Basin and fear that, especially when the mechanics of an aquifer are poorly understood, this tendency will manifest itself again. Responses to this fear generally take the form of broad prohibitions of actions that might threaten the aquifer. Farmers in the San Luis Valley, for example, are trying to prohibit further expansion of irrigated acreage. The desire to protect water tables sometimes can have complex origins, as in this valley, where many farmers want to protect their future access to groundwater for irrigation, but also want to maintain water tables at high enough levels so they support wetlands providing valuable wildlife habitat.

B. A Brief History of Human Development in the Basin[4]

The Rio Grande first provided for crop irrigation by the Pueblo Indians, who settled along the main river and its tributaries. The Pueblos of New Mexico and Arizona are the surviving remnants of the once considerable population that in ancient time distributed over the valleys of the southwestern U.S. The Pueblos of New Mexico currently use some of the same ancient irrigation ditches that their ancestors used centuries ago. There is no documented history of how long these ditches were used, but some estimates suggest that they existed as far back as 1000 A.D. The Follett Report of 1896 (see below), listed 52 ancient irrigation ditches that, in normal-flow years, could have irrigated over 34,500 acres. During the time of Coronado, much like today, the Pueblo Tribes cultivated maize, beans, gourds, and tobacco.

Spanish exploration and colonization centered around Santa Fe for about 75 years after Coronado first reached the Basin, then were stalled by the Pueblo Revolt of 1680 and the 12-year retirement of the Spaniards to El Paso del Norte. In 1692 the revolt was quashed and the Spanish returned to Santa Fe and all parts of the Rio Grande Valley. Spanish colonization, from present-day Ft. Quitman, Texas, to Espanola, New Mexico, continued into the 1800s and was accompanied by the expansion of irrigation development.

After the Mexican Independence of 1821, the U.S. took portions of Mexico, resulting in the Treaty of Guadalupe-Hidalgo and the subsequent Gadsden Purchase, in which New Mexico and Colorado—as well as most of the present day southwestern U.S.—became territory of the U.S. In the middle 1800s the San Luis Valley of Colorado—above which lie the headwaters of the Rio Grande—experienced a population boom as new settlers arrived from the south and east. Large areas of the fertile valley floor were plowed and miles of irrigation ditches were constructed. By the late 1800s, extensive irrigation development in the San Luis Valley of Colorado—along with new water users in New Mexico and Texas—resulted in water shortages in the Mesilla and El Paso Valleys of southern New Mexico, west Texas, and northern Mexico. Complaints by the citizens around Juarez led the Mexican government to file a claim for damages against the U.S. As a result, the U.S. Department of State instituted an investigation through its International Boundary and Water Commission (IBWC).

[4] A more detailed history is available in (Clark 1987; Horgan 1954a; Horgan 1954b).

The investigation's final report—known as the Follett Report—covered in detail the stream flow, irrigated areas, canal systems, and diversions for every section of the basin from the San Luis Valley to El Paso. The Report's findings that demand exceeded the supply of water led to the so-called embargo of 1896. This embargo was actually an order by the Secretary of the Interior, who suspended all applications for rights-of-way across public lands for use of the Rio Grande's water. This suspension prevented further irrigation development of any magnitude in Colorado and New Mexico. With some modification in 1907, this embargo remained in effect until May, 1925.

In 1898 the New Mexico Territorial Supreme Court said that the public interest, custom, and legislative and judicial decisions dictated that the doctrine of prior appropriation was—and always had been—the settled water law of the territory. This doctrine states that rights to use diverted water are chronological in nature; i.e., someone who can document that he first diverted water for a "productive use" at date X has priority claim—in perpetuity—to use that water over others whose documented first diversion came after date X. Colorado's water law, which dates from 1872, also embraces the prior-appropriation doctrine. The Texas Code, originated in 1913, does not embrace the appropriation doctrine to the extent that the Colorado and New Mexico Codes do.

In 1902 Congress enacted the Reclamation Act. This legislation provided for the construction of public irrigation works for the reclamation of arid lands. The Reclamation Act also provides for the funding of these projects through a pool of monies received from the sale of public lands in 16 western states. Subsequently, Texas became the seventeenth state. Under the provisions of the Reclamation Act, the BuRec constructed Elephant Butte Dam at present-day Truth-or-Consequences, New Mexico. The dam was completed in 1916 with a New Mexico water right, initiated by the Secretary of the Interior, carrying a priority date of 1906. The multi-purpose functions of Elephant Butte Reservoir include the delivery of water to meet an annual 60,000 af treaty requirement between the U.S. and Mexico, another outgrowth of the 1896 Follett Report.[5]

[5] The 1906 treaty formalizing the U.S. obligation to deliver 60,000 af of water to Mexico annually is generally believed to fix Mexican claims on surface water in the Basin for the foreseeable future, insofar as expanding the claims could be accomplished only through extremely difficult negotiations. There is, however, no treaty governing groundwater in aquifers shared by both countries (Utton 1993).

By the turn of the century, surface waters of the San Luis Valley were fully appropriated and shortages were frequently experienced toward the end of the irrigation season. Farmers in the area wished to build reservoirs for storing spring runoff to accommodate late season needs and to carry over storage from wet years into times of drought. Local organizations in Colorado secured permission, through a 1907 modification in the "embargo of 1896", to build nine reservoirs on the Rio Grande and its tributaries. Unlike elsewhere in the Upper Rio Grande Basin, development of water in the San Luis Basin occurred with minimal federal funds until the latter half of this century.

By the 1920s virtually all the water in the Upper Rio Grande Basin was fully appropriated, as agricultural development occurred throughout the Basin, especially in New Mexico's Middle Rio Grande Valley. By the early 1920s increasing competition for use of the river among users from Colorado to Texas generated an attempt to negotiate an interstate compact to apportion the river's flows among the three states. In 1923 Congress formed the Rio Grande Compact Commission, with representatives from Colorado, New Mexico, Texas, and the federal government. Outgrowths of the commission included: (1) the 1929 Rio Grande Compact which established a moratorium on development of the river until a permanent compact could be negotiated; and (2) a fully-ratified Rio Grande Compact that became effective in 1939 and has continued in effect until today. (We describe the Compact further in the discussion of the Basin's laws and institutions.)

Following the construction of Elephant Butte Dam, sediment progressively diminished the downstream river channel's ability to carry flood flows. As a result, in 1933 the BuRec and the U.S. Section of the International Boundary and Water Commission (IBWC) developed and implemented plans that led to the construction of Caballo Dam and numerous diversion dams and extensive canalization, as well as to the construction of the American Diversion Dam and Canal to deliver water to the El Paso Valley. Caballo Dam was completed in 1938 with 100,000 of its total 331,000 af of capacity reserved for control of floods originating downstream from Elephant Butte Dam.

From 1935 to present, several other major facilities were built in the Upper Rio Grande Basin. These include eight major dams: Jemez Canyon, Abiquiu, Cochiti, Platoro, Heron, El Vado, and Nambe Falls. Heron Reservoir, completed in 1970, is used solely to store and regulate the imported San Juan-Chama Project water. The San Juan-Chama Project, completed in 1971, includes three intermountain tunnels (Blanco, Oso, and

Azotea) that are used to divert water from the San Juan Basin, west of the Continental Divide, to the Upper Rio Grande Basin (east of the Continental Divide). In the 1950s, the BuRec built the low-flow conveyance channel (LFCC), a 75-mile structure extending upstream from Elephant Butte Reservoir intended to reduce seepage and evaporation "losses". We describe these facilities in greater detail in appendix A.

C. Laws and Institutions Governing the Basin's Water and Related Resources

The legal and institutional structure governing the resources of the Upper Rio Grande Basin exhibits many characteristics found elsewhere in the West, but it also has some important, unique features. In the following discussion we highlight some of the most salient features of this structure, focusing on the Rio Grande Compact and other elements providing the greatest insight into the competition for the Basin's scarce resources. The discussion is not intended as a comprehensive discourse on the laws and institutions governing the Basin. Recognizing brevity's benefits for both writer and reader, we necessarily make generalizations and focus our attention. The result unavoidably excludes countless elements of the Basin's laws and institutions, many of which are keenly important to the resource users, managers, and attorneys who work with them daily.

We focus on the laws and institutions governing the movement of water. Perhaps their most essential feature is this: in the whole, they are so tangled, so cloaked in technical and legal jargon, that they have become a "Gordian knot (surrounded by an aura of unapproachability" (Bates et al. 1993). They reflect the influence of aboriginal rules and custom, Spanish and Mexican laws antedating the 1848 Treaty of Guadalupe Hidalgo, international treaties, an interstate compact, the federal government's trust responsibilities for Indian tribes and its public-interest trust responsibilities as stewards of the nation's resources, and the unique laws and institutions of three states. The prior-appropriation doctrine underlies—or at least influences—most of the laws and institutions applying to water movement, but it does not apply uniformly to all resources or in all areas. Each state has its own laws and institutions.

To explore the central features of the Basin's water laws and institutions, we first describe the laws and institutions of the three states separately.

1. Laws and Institutions of Each State

Colorado. The administration and regulation of water rights in Colorado rest primarily on two foundation stones. The oldest of these is the Colorado Doctrine, the state's version of the prior-appropriation doctrine, that evolved through custom and practice. The Water Right Determination and Administration Act of 1969 puts the doctrine into current practice. It divides Colorado into seven water divisions, conforming roughly to the state's major drainage systems. The State Engineer, with approval of the executive director of the Department of Natural Resources, appoints one Division Engineer to each of the seven divisions. Division Engineers are required to assist in the performance of the State Engineer's duties including all functions specified by statute and judicial law. In general, the State Engineer is responsible for "the administration and distribution of the state's waters, the promulgation of rules and regulations to assist in such administration, the collection and study of data on water supplies, the compliance with compact commitments and administration between states, and the enforcement of laws imposed by statute and the courts" (Grantham 1991). Division field offices are created and staffed by Water Commissioners that serve the districts within each division. Whereas the Division Engineer is responsible for the daily administration of waters within a division, Water Commissioners oversee the administration of water rights and the collection and recording of field data. Each division also has an appointed water judge who is responsible for the resolution of disputes regarding water rights.

The appropriation of water in Colorado consists of two acts: the diversion of water from the natural stream and the application of that water to beneficial use (Farmers' High Line Canal & Reservoir Co. v. Southworth, 13 Colo. 111, 21 P. 1028 (1889)). The statutes define appropriation as the application of a specified portion of the waters of the state to beneficial use (37-92-103 (3) (a) C.R.S. 1990) (Jennifer Gimbel and Gale Norton, comment on draft report).

Beneficial use is described in the 1969 legislation as "that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the appropriation is lawfully made and includes the impoundment of water for recreational purposes, including fishery and wildlife" (37-92-103 (7) C.R.S.). For about the past 20 years Colorado's water law has recognized instream flows necessary for the preservation of natural environments as a beneficial use. The Colorado Water Conservation Board (CWCB) is the sole entity allowed under law to

possess an instream flow water right (37-92-102 (3) C.R.S. 1990). The CWCB, however, is required to request recommendations from state agencies, the Division of Wildlife and the Division of Parks and Recreation, and federal agencies, the Department of Interior and the Department of Agriculture, before appropriating instream flow rights (Jennifer Gimbel and Gale Norton, comment on draft report). Within the existing structure, many instream appropriations are quite junior to appropriations tied to out-of-stream use and, in years when flows are low, those with senior rights may divert all the water.[6]

Colorado requires the adjudication of most surface water rights and establishes a process for defining, administering, and regulating water rights. The adjudication process is a formal court proceeding resulting in the granting of a decree which recognizes an individual's appropriative date, and thus, their placement in the distribution of water supplies. A decree, however, is not required for a valid water right, but instead confirms the water right (People ex rel. Hal Simpson, et al. v. Highland Canal, et al., 917 P.2d 1252 (Colo. 1996)). The adjudication process defines the amount of water to be diverted, the diversion point at which the diversion will occur, and the intended beneficial use of every water claim. The first adjudication in the Rio Grande Basin was completed in 1896 and since then there have been several general adjudication processes. Each decree awarded by the court for a new water right is considered to be part of an on-going general adjudication. Streams within the Basin are fully (or over-) appropriated and most of the administrators' attention goes to ensuring that each user complies with the terms of her water right. The administrators know where the water right should be delivered, the amount to be delivered, and the use and place of use of the rights (Jennifer Gimbel and Gale Norton, comment on draft report).

Groundwater in Colorado is either designated or non-designated. Non-designated groundwater falls in one of two categories: tributary or nontributary.

Designated groundwater is water that: (1) in its natural course would not be available to and required for the fulfillment of decreed surface rights; and

[6] Under the law of prior appropriation, a decree for an instream flow right protects a stream from further decreases in flow, and if those with senior water rights chose to change their rights in any way, the instream flow right cannot be injured. The law also allows for transfers, sales, and donations of senior water rights for instream flow purposes (Jennifer Gimbel and Gale Norton, comment on draft report).

(2) is in areas not adjacent to continuously flowing natural streams, wherein groundwater withdrawals have constituted the principal water usage for at least 15 years prior to the date of the first hearing on the proposed designation of the basin (37-90-103 (6) (a), C.R.S.).

Designated groundwater basins are fundamentally legal-political boundaries and are not necessarily coincident with hydrologic boundaries. The Ground Water Commission (GWC) is responsible for the initiation, protection, and transfer of groundwater rights. The Rules and Regulations for Management and Control of Designated Ground Water (CCR 410-1, May 1, 1992) adopted by the GWC, govern the administration of groundwater rights.

Ground water in Colorado is presumed to be tributary to natural streams. Litigation has established that the aquifers in the San Luis Valley are, in fact, tributary (American Water Development, Inc. v. City of Alamosa, et al., 874 P2d 352 (Colo. 1994)), and there has been no other determination by Colorado courts or officials that there is any water within the Colorado portion of the Rio Grande Basin that would be administered under any legal mechanism other than the constitutional doctrine of prior appropriation. Since the passage of the Water Determination and Administration Act of 1969, the waters of surface streams and all tributary ground water have been administered by decree and priority date as an integrated system (David W. Robbins, comment on draft report).

The Water Right Determination and Administration Act of 1969 allows the creation of augmentation plans, defined as "A detailed program to increase the supply of water available for beneficial use ... by the development of new or alternative means or points of diversion, by a pooling of water resources, by water exchange projects, by providing substitute supplies of water, by the development of new sources of water, or by any other appropriate means." The basic intent of the plans is to assure the preservation of senior water rights as further rights are granted for developments. Augmentation plans introduce the depletion replacement concept, by devising schemes that obtain other waters and deliver them to the river at the time and place that the injury, or lack of water, otherwise would be felt.

Augmentation becomes important insofar as Article XVI, Section 15, of the Colorado Constitution establishes the right of Colorado citizens to appropriate unappropriated water and, in effect, establishes water rights as vested property rights subject to the same protection as other interests in real property. Because senior water rights have a vested property interest in

the continuation of their acres to water supply, if a new use deprives the senior water right of the use of its appropriated supply, the senior could initiate action, pursuant to state law, to stop the injury. If an alternative source of water is provided through augmentation to fulfill the senior's demand for water, no injury would occur and the new use could continue (David W. Robbins, comment on draft report).

Augmentation can be important because the basic rules of prior appropriation, and specifically the rule that prohibits changes of use that affect junior downstream appropriators, do not apply to the foreign (imported) water. Thus, once foreign water is brought to the designated place at the designated time, it can be re-used or used in a different way without jumping through all the hoops that otherwise would apply.

New Mexico. The State Engineer's Office (SEO) governs surface water rights in New Mexico, operating under the following constitutional and statutory principles:

1. The unappropriated water of every natural stream, perennial or torrential, within the state of New Mexico, belongs to the public and is subject to appropriation for beneficial use in accordance with the laws of the state.

2. Beneficial use shall be the basis, the measure, and the limit of the right to the use of water.

3. Priority of appropriation shall give the better right.

4. New appropriations shall not impair any existing water right.

5. Appropriation should not be detrimental to the public welfare or contrary to conservation of water.

In New Mexico, beneficial use means, in essence, that the water must be taken from the main channel, for domestic, agricultural, industrial, commercial, or any other purpose defined as beneficial by the SEO. Beneficial use also means that a claimant must use his diversion responsibly and use only the amount of water necessary to accomplish the purpose for which the appropriation was made (308 P.2d 983, 987 N.M.1957). New Mexico's water rights are generally fixed with respect to the time, location, and rate of diversion from the channel. New Mexico does not recognize

instream water rights, i.e., it does not consider water left instream to be a beneficial use that the SEO will protect and enforce. Water in a stream may be withdrawn and used for a recognized beneficial use, subject to the recognition and protection of other users' rights. In the state of New Mexico, all beneficial uses are considered equal, regardless of the economic value produced by the use. Someone upstream with a junior water right, for example, may withdraw water from the stream and use it, but must ensure that streamflows remain sufficient for satisfaction of downstream users with senior rights. The 1907 Water Code confirmed the priority of water rights established prior to this date. Such water rights are classified as vested and have priority over senior water rights, just as senior water rights have priority over junior water rights.

The SEO also governs groundwater rights in New Mexico. Legislation passed by the state in 1927 and 1931 essentially extended the state's prior-appropriation doctrine for surface water to groundwater (N.M. Stat. 75-11-1 to 75-11-10). Thus, all unappropriated groundwater belongs to the state and is subject to appropriation under the criteria described above. No well may be drilled within a declared underground water basin without a permit and drilling may only be performed by a well driller licensed by the SEO. Outside declared groundwater basins, the State Engineer has no jurisdiction other than to prevent waste.

When the State Engineer has determined that waters of underground stream channels, artesian basins, reservoirs, or lakes have reasonably ascertainable boundaries, he assumes jurisdiction over the appropriation and use of such water by 'declaring" the administrative boundaries of the basin. Surface and groundwater in declared basins are conjunctively managed, and the appropriation of rights to the latter may require the retirement of the former to avoid impairment of existing water rights and overdraft of underlying water resources. The difficulties in managing a conjunctive system, however, are illustrated by the recent change in understanding of the connectivity of the Rio Grande and the aquifer used by Albuquerque—with the conclusion that the city has been converting large amounts of groundwater into the river, rather than the reverse. Guidelines for groundwater outside declared basins are less stringent, and do not require permits from the SEO (N.M. Stat. 75-11-13 and 75-11-21; McBee vs. Reynolds, 399 P.2d 110 1965).

Both surface and groundwater rights are transferable in New Mexico, subject to the restriction that the transfer of ownership cannot result in impairment of other claims (N.M. Stat. 75-5-23 and 75-11-7 Supp. 1975). There is much

yet to be learned about how transfers can affect other claims, however, and the regulation of transfers is likely to evolve. In practice, few transfers have occurred and fewer still have the potential to effect major changes in water uses. The City of Albuquerque, for example, has been a major purchaser of water rights but has purchased rights to take only about 4,300 af/yr of water from the river that otherwise would have been used for irrigation (City of Albuquerque Public Works Department 1996). When El Paso sought to acquire groundwater from southern New Mexico, the state initially restricted the export of groundwater out of the state, but then agreed to relax the restriction in response to litigation that claimed it was an unconstitutional restraint of interstate commerce insofar as it treated interstate and intrastate transfers differently.

Texas. Texas applies the prior-appropriation doctrine in a manner similar to Colorado and New Mexico, but it does not apply it as comprehensively as those states do. The state's appropriative process applies to surface water as well as to streams that flow under or alongside a surface stream. Texas defines beneficial use as "the use of water that is economically necessary for a purpose authorized when reasonable intelligence and reasonable diligence are used in applying the water to that purpose" (Folk-Williams et al. 1985). Texas Water Code, Chapter 11, Section 11.134 stipulates the following requirements be met:

1. The unappropriated water of every ordinary flow, underflow, and tides of every flowing river, natural stream, and lake; and of every bay or arm of the Gulf of Mexico; and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed within the state of Texas are the property of the state, to be held in trust for benefit of the people and is subject to appropriation for beneficial use in accordance with the laws of the state.

2. Beneficial use defines the limit, measure, and extent of water rights.

3. New appropriations shall not impair existing water rights or vested riparian water rights.

4. Appropriations shall not impair the public welfare.

5. Evidence that reasonable diligence will be used to avoid waste and achieve water conservation shall be provided by the applicant.

Texas authorizes the use of state water through a permitting system administered by the Texas Natural Resource Conservation Commission (TNRCC) or by the adjudication of claims by state court under the Texas Water Rights Adjudication Act. Texas Water Code, Chapter 11, Section 11.301 states that water uses requiring a permit and specific guidelines are to be administered by the TNRCC. Beyond surface water, Texas also governs percolating groundwater and underground streams. Groundwater is subject to capture and use by the overlying landowner as long as the use is beneficial and does not waste the water. Groundwater withdrawal and use may be subject to local regulation by an underground water conservation district created under Chapter 52 of the Texas Water Code or by special districts or authorities created by the Texas Legislature. Water that is below the surface of the land, is subject to capture and ownership by the overlying landowner, unless and until, it is established that such water is in an underground stream or is the underflow of a surface stream. Water determined to be flowing in an underground stream is governed by surface water law and is subject to state ownership and control.

Texas has several exceptions to the basic prior appropriation system: (1) priority of water rights granted on the main stem of the Rio Grande below the Amistad Reservoir in the Lower Rio Grande Valley were assigned based on use, rather than filing date; (2) in the reach of the river below Amistad Reservoir, domestic, municipal, and industrial rights prevail over irrigation, mining, and other uses of water during low-flow conditions; (3) under the "futile call" doctrine, the TNRCC may allow upstream junior rights to divert water, if the water reaching a downstream senior right would be insufficient for beneficial use even in the instance when no diversions were permitted to the former; (4) the Wagstaff Act provides that any appropriation after May 17, 1931, other than on the Rio Grande and for any purpose other than domestic or municipal use, is subject to the right of any city or town to make further appropriations for the water for domestic or municipal use without compensation; and (5) riparian rights provided for domestic or livestock uses, dating back to 1840, are superior to appropriative rights.

The Water Rights Adjudication Act devised the watermaster program, allowing all water rights to be effectively administered by the TNRCC. Watermasters are appointed to adjudicated divisions in the state by the executive director of the TNRCC. With some limitations, the watermaster has the authority to regulate the controlling works of reservoirs and diversion facilities in order to protect water rights during low-flow stream conditions. Disputes outside an established watermaster area are handled

conditions. Disputes outside an established watermaster area are handled though the TNRCC's complaint system. As of June 1995, the Upper Rio Grande above Ft. Quitman is the only river segment that remains unadjudicated. In the summer of 1994, however, adjudication procedures began in this area.

2. Beyond the States: Indian Rights, Federal Rights, International Treaty, and Interstate Institutions

Water in the Upper Rio Grande Basin is governed by more than just the laws of the individual states. Of particular importance are the Basin's Indian tribes, the U.S.-Mexico Treaty of 1906, the Rio Grande Compact, the Middle Rio Grande Conservancy District (MRGCD), and the New Mexico/Texas Water Commission. Also important are almost countless federal laws and many federal agencies. For the most part, these play roles in the Basin that are not unlike their counterparts in other western basins, but there are some distinctive differences. We discuss each of these features of the broader legal and institutional landscape individually.

Indian Water Rights and Laws. The Reserved Rights Doctrine, first announced in *Winters v. United States, 207 U.S. 564 (1908),* generally says that, when the federal government set aside lands for Indians, it also reserved for the Indians the water, then unappropriated, that was appurtenant to the lands and to the extent necessary to accomplish the purpose of the Indian reservation. The Doctrine also recognizes an Indian tribe's inherent authority to reserve rights not divested by Congress. The sovereignty of the Pueblos differs somewhat from that of tribes elsewhere in the U.S., however, insofar as they had existed in their current location for centuries and their sovereignty was acknowledged by the Spanish and Mexican governments before the Basin was incorporated into the U.S. Thus, some Pueblo Indian water rights predate the reservation date.

Indian water rights are property rights subject to federal and tribal laws, not state laws except insofar as state courts quantify, award, and administer those rights. Consequently the "use it or lose it" stipulation of state water laws does not apply to Indian water rights and Indian water rights may fluctuate as to the time, location, and amount of water diverted. The tribes can exercise their rights, however, only insofar as the federal government has secured their adjudication by acting as the trustee for the tribes. Hence, the full extent of reserved tribal water rights remains unknown, but many

at some locations and times. Currently, the recognized rights of pueblos in the Middle Rio Grande Valley total 18,579 af of consumptive use, or about 6 percent of the Valley's total. (Middle Rio Grande Conservancy District 1993).

Non-Indian Federal Water Rights. The federal government has some rights to water through its role as steward of natural resources, its ownership of lands in the territories prior to and following statehood, and its ownership of rights to water created by the construction of dams and related facilities. Many of these rights have not been clearly defined although federal water rights have been or are in the process of being adjudicated. There is some ambiguity, for example, about the federal government's rights to water in the Rio Grande Project. The BuRec holds that all of the water in the Rio Grande from Elephant Butte Dam to Fort Quitman is appropriated for use of the Rio Grande Project and it disposes of this water through contracts with the Elephant Butte Irrigation District (EBID), the El Paso County Water Improvement District (EPCWID), and other entities. New Mexico, however, has not fully adjudicated water rights in the Basin and those who put water to a beneficial use prior to 1907 are not required to have a water-use permit. It is possible, therefore, that a court could determine that many of the pre-1907 claims have priority over the BuRec's rights.

Matters are made more complicated because the Texas Natural Resources Conservation Commission has not accepted the BuRec's position that it owns all waters to Ft. Quitman. Instead, it asserts that, once the water passes into Texas, all authority over the water passes to the state (U.S. Department of the Interior 1995a).

U.S.-Mexican Water Treaty of 1906. In the 1880s water shortages near El Paso began to materialize, largely because of extensive irrigation development in Colorado and, to a lesser extent, New Mexico. Mexicans living near Ciudad Juarez complained to their government that the upstream developments were violating their long-established and prior rights to the river's water. The Mexican government subsequently filed a claim for damages with the U.S. government and, in 1906, the two nations signed a treaty, under which the U.S. guarantees to provide Mexico with 60,000 af of water annually at the International Dam at Ciudad Juarez, except during periods of extreme drought. The BuRec subsequently built Elephant Butte Dam, largely to help ensure the nation's ability to meet this obligation.

The Rio Grande Compact. Texans joined their Mexican neighbors in complaining about the water shortages that materialized at the end of the nineteenth century. Following much disagreement and negotiation, in 1938 Colorado, New Mexico, and Texas entered into the Rio Grande Compact. The Compact was intended to safeguard and perpetuate the allocation of the Rio Grande's surface water among the states, as it existed in 1929. By this time, development in the Colorado portion of the Basin was consuming about 600,000 af of water annually, about two-thirds of the average annual flow that otherwise would pass into New Mexico (Daves 1994).

The Compact stipulates the amount of flows allocated to each participant of the agreement. State laws are of little significance relative to the Compact, in matters of interstate water allocation. Each state's share is a stipulated percentage of actual flows, and thus, fluctuates based on the amount of annual runoff. Colorado must deliver about 20 percent of the gauged flows to New Mexico during dry years, about one-third in an average year, and more than 50 percent in a wet year. New Mexico, similarly must deliver 57 percent of the gauged flows to Elephant Butte Reservoir in dry years and up to almost 90 percent in extremely wet years. (New Mexico's performance relative to its obligations is measured at Elephant Butte, which lies about 100 miles upriver from the Texas border.) Table 1.1 shows the apportionment among the states for a typical year, as estimated by Daves (1994).

Table 1.1.—Apportionment of water among the states under the Rio Grande Compact during a typical year[1]

	Total flow	Delivery requirement	Available for depletion[2]
Colorado	975,000	308,480	666,100
New Mexico[3]	1,194,000	887,000	307,000
Texas[4]	887,000	NA	707,000

Source: Daves (1994).

[1] All numbers in acre-feet (af).

[2] After evaporation.

[3] The Middle Rio Grande Valley, from Cochiti to Elephant Butte Reservoir.

[4] Includes New Mexico, below Elephant Butte Dam, and Mexico.

The Compact is constitutional in nature and an agreement between or among sovereign states on a matter of common or equal jurisdiction. It had to be mutually agreed to by each state and ratified by their respective legislatures. In addition, it is a federal law and became effective only when congressional approval was obtained. The Compact has three signatories, the three states. The U.S. is not a signatory, but is a participant according to the Compact's terms and by the constitutional mechanism of congressional ratification. The Compact has permanent status as the law governing water allocation within the Basin absent any change by the signatory states and the Congress. Its terms will be enforced by the Supreme Court according to the terms of the Compact without modification, despite the intervening actions or activities of the signatory states. (*See* Texas v. New Mexico, 462 U.S. 554 (1983), and Oklahoma v. New Mexico, 501 U.S. 221 (1991)) (David W. Robbins, comment on draft report).

The Compact allows the states some leeway for meeting their obligations: Colorado can accumulate debits of 100,000 af and New Mexico debits of 200,000 af. In 21 of the first 28 years of the Compact, however, Colorado underdelivered or exceeded its limit, with its total debit climbing to 944,000 af. In response to litigation brought by the downstream states, Colorado agreed in 1967 to strictly meet its annual delivery obligations and, with a minor exception in 1979, has done so. New Mexico failed to meet its obligations in 16 of the first 28 years and its cumulative debit exceeded the limit from 1948 through 1968. As a result, it also has been the subject of litigation from downstream. Its cumulative debit has not exceeded the limit since 1968, although it has failed to meet its annual delivery obligation during 9 of the ensuing years, largely because it has a limited ability to meter and regulate diversions (Daves 1994).

New Mexico/Texas Water Commission. In 1991 litigation over the disposition of water supplies below Elephant Butte Dam was resolved with the formation of the Joint Settlement Commission, comprising, from Texas, the El Paso County Water Improvement District (EPCWID) and the El Paso Water Utilities Public Service Board, and, from New Mexico, the Elephant Butte Irrigation District (EBID), New Mexico State University, City of Las Cruces, and Dona Ana County. It later changed its name to the New Mexico/Texas Water Commission. The members of the commission have agreed to work together, identify, and address common concerns regarding the area's water and especially to maximize waters available from the

BuRec's Rio Grande Project. The Commission covers the area from Elephant Butte Reservoir to Ft. Quitman. The Commission has not yet cemented its role in the overall management of resources in the lower end of the Basin.

3. Within the States: Local Districts

Many of the decisions regarding the management and use of the Basin's water and related resources are made at the local level, through irrigation and conservation districts. The following discussion of eight districts highlights the roles they play in the Basin.

Rio Grande Water Conservation District. This district covers the San Luis Valley in Colorado to address the research and legal needs of water users. It was formed in 1967 primarily to help water users obtain and administer funds to respond to litigation from Texas over Colorado's accumulation of water-delivery debits in excess of limits set in the Compact. Since then it has successfully funded opposition to a proposal to export water from the valley to Denver and served as the local sponsor of the San Luis Closed Basin Project which is intended to deliver groundwater to the Rio Grande to help Colorado meet its water-delivery obligation under the Compact. The district does not, however, deliver water to anyone. It has initiated research projects, such as investigations of water quality and the development of wells to monitor groundwater levels. Members of the district's board are drawn from the five counties in the valley and generally represent both water users and the districts that administer the water-delivery system.

Trinchera Irrigation Company. This irrigation company, comprised of 47 stockholders, manages the use of water for irrigation in the northern half of Costilla County, Colorado. The company is responsible for the maintenance of Mountain Home Reservoir and Smith Reservoir and the delivery of irrigation water to approximately 15,000 acres. The number of irrigated acres served by the company has remained relatively stable over the years. Stockholders in the company primarily produce potatoes, alfalfa, and moravian barley. Canola, oats, and spinach are produced in smaller quantities. The five members of the company's board of directors are stockholders and agricultural landowners.

Conejos Water Conservancy District. This district covers 100,000 acres within Conejos County, Colorado. It was formed in 1949 to help sponsor

Platoro Reservoir and to begin repayment of the construction costs allocated to irrigation. In 1991, the district paid off the federal government with a loan from the Colorado Conservation Board and assumed full responsibility for the operation of Platoro Reservoir from the BuRec. Operation of Platoro Dam reverts to the U.S. Army Corps of Engineers (CoE) during flood control operations. The district serves about 86,000 irrigable acres. Primary crop production consists of native hay and alfalfa. Barley, oats, wheat, and potatoes are produced in smaller quantities. In 1996, the average value per irrigated acre for all crops in the district was $149 (Conejos Water Conservancy District 1996). District board members are appointed for a four year term and represent farmers and property owners in the district.

San Luis Valley Irrigation District. This district, comprised of 58,525 irrigated acres, covers portions of Rio Grande, Alamosa, and Saguache Counties in Colorado. It was formed in 1904 as a reorganization of the Farmers Union. The district owns the Rio Grande Reservoir and is responsible for maintaining and delivering water to district members. Primary crop production consists of potatoes, carrots, and moravian barley. District members elect five board members for a three year term. Membership on the district board is limited to farmers who own land under the district.

Middle Rio Grande Conservancy District (MRGCD). The MRGCD, by controlling most of the consumptive use of surface water in the Middle Rio Grande Valley, plays a central role in the management of the Basin's water and related resources. It was formed in 1925 to decrease flooding in the Middle Rio Grande area, drain water from wet areas, increase the storage of water, and establish a water-distribution and river-control system appropriate for the goals of the mostly agricultural landowners within the district (Middle Rio Grande Conservancy District 1993). The conservancy district is a political subdivision of the state of New Mexico, and it has authority to levy property taxes to support its activities. The district originally hoped that the increased value of lands reclaimed by its activities would yield sufficient tax revenue to perpetuate its activities, but this did not materialize. After building El Vado Dam to store water, digging 475 miles of irrigation canals, assuming control of 214 miles of existing canals, constructing diversion dams at Cochiti, Angostura, Isleta, and San Acacia to

divert water into the canals, and completing numerous related tasks, the district's financial support was inadequate to achieve its objectives. Hence, in the 1940s and 1950s, the district asked the federal government for help.

The BuRec responded by providing financial assistance to the district and by constructing, operating, and maintaining facilities above, within, and below the District's boundaries. In 1951 the BuRec acquired all the district's existing debt and received in return, as a security interest, the district's property rights to its works. The BuRec rehabilitated El Vado Dam; repaired the diversion dams at Cochiti, Angostura, Isleta, and San Acacia; conducted extensive work on the district's canals; and channeled 127 miles of the river (Middle Rio Grande Conservancy District 1993). The total cost of the project was $35 million, of which MRGCD was to reimburse $16 million from irrigation revenues.

The district resumed control over many operational and maintenance functions in 1965. The BuRec continues to operate El Vado Dam, however, and to conduct about $3–5 million of annual channel-maintenance activities within the district's boundaries (ECONorthwest 1996).

The MRGCD claims water rights to irrigate 123,267 acres at a rate 2.1 af of consumptive use per acre (Middle Rio Grande Conservancy District 1993). Hence, it claims consumptive rights to 258,861 af/yr and diverts water from the river at this rate, or even higher. In practice, however, the MRGCD irrigates considerably less acreage, about 54,000 acres per year over the past decade. Wilson (1992) estimated that the consumptive use of water on this land in 1990 was 131,000 af.

Elephant Butte Irrigation District (EBID). This irrigation district manages the irrigation use of water in Sierra and Dona Ana Counties of New Mexico. The district is responsible for managing the operation and maintenance of three diversion dams, 300 miles of drains, and 400 miles of canals/laterals (Esslinger 1995). Both the acreage irrigated and the level of water consumption have declined over the past several decades (U.S. Department of the Interior 1995a). Between 1950 and 1990 irrigated acreage fell from more than 85,000 to less than 80,000 acres, and the irrigation consumptive use from almost 280,000 af to less than 225,000 af. Deliveries to farmers in 1995 totaled 254,849 af, averaging 3.3 af per acre to the 1,489 full-time and 1,151 part-time farms. EBID's primary crop production

consists of pecans, alfalfa, cotton, onions, and peppers. Silage or ensilage, oats, wheat, and lettuce are produced in smaller quantities. In 1995, the gross value per acre for all crops within the District was $249.38 (Elephant Butte Irrigation District 1995).

El Paso County Water Improvement District (EPCWID). This district formed in 1917 as a reorganization of the El Paso Valley Water Users Association. It comprises 69,000 irrigable acres in Texas' El Paso Valley. Over the past four decades the irrigated acreage has fallen from more than 67,000 acres to about 45,000 acres, and total consumptive use from more than 210,000 af to less than 125,000 af (U.S. Department of the Interior 1995a). EPCWID's primary crop production consists of cotton and pecans. Alfalfa, hay, peppers, cereals, and onions are produced in smaller quantities. In 1990, the gross value per irrigated acre for all crops within the District was $1,001.40 (El Paso County Water Improvement District 1990).

The El Paso Valley Water Users Association and EBID contracted with the BuRec for the construction of a diversion dam and canal in 1906. In 1920, EBID and EPCWID expanded the contract to include not just costs of the irrigation system but also a proportionate share of the construction cost of Elephant Butte Dam and Reservoir. Over time EPCWID acreage has been purchased by the El Paso Water Utility (EPWU). As of 1995, EPWU had acquired 2,300 acres within EPCWID. EPWU also leases land from farmers in the district. EPWU and EPCWID farmers have entered into 75 year contracts where the utility pays a per acre fee, irrigation taxes, and provides irrigation ditch maintenance and, in return, EPCWID farmers relinquish 11,500 af of water to the utility. EPWU also receives 26,400 af annually from other contracts with farmers and non-farmers in EPCWID.

Hudspeth County Conservation and Reclamation District (HCCRD). This district lies downstream of El Paso and diverts water to more than 18,000 acres from the Rio Grande below El Paso. In 1990 the district provided water to 14,942 acres on 28 full-time and 12 part-time farms. The district collects primarily drainage and waste water. HCCRD's primary crop production consists of cotton, with alfalfa hay, wheat and peppers produced in smaller quantities. In 1990, the gross value per acre for all crops within the district was $647.65 (Hudspeth County Conservation and Reclamation District 1990).

4. Federal Agencies

Three federal agencies have a predominant role in the Basin's management of water and related resources.[7] The International Boundary and Water Commission (IBWC), or its predecessor, has existed since 1890 and, among other things, ensures the delivery of water to Mexico pursuant to the Treaty of 1906. The Army Corps of Engineers (CoE) has primary responsibility for flood control, operates several dams, and maintains levees in the Middle Rio Grande Valley. The Bureau of Reclamation (BuRec) has been involved in the Basin since soon after passage of the Reclamation Act of 1902 and has four major projects in the Basin. The Rio Grande Project extends from Ft. Quitman north to Elephant Butte Reservoir. The Middle Rio Grande Project is concentrated in the reach from Elephant Butte Reservoir north to Cochiti Dam, but it also includes some activities and facilities further north. The San Juan-Chama Project includes facilities that divert water from the San Juan River, transport it to the Chama River Basin, and store it in Heron Reservoir. The Closed Basin Project consists of wells and a canal to collect groundwater from the Closed Basin aquifer and deliver it to the Rio Grande. Table 1.2 lists each agency's major activities, projects, and facilities. More information is provided in appendix A.

D. Focus on Instream-Flow Issues

Much of the concern over resource management in the Basin manifests itself as a debate over instream flows. Immediate concern often focuses on the Endangered Species Act and its repercussions on instream flows or the provision of recreational opportunities for urban residents. The more fundamental, underlying concern centers on protecting the ecological health of watersheds and aquatic ecosystems that are crucial to the sustainable use

[7] We focus on water-management agencies. Other agencies whose programs affect water and related resources in the Basin include: the Environmental Protection Agency (which administers the Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, Superfund, and National Environmental Policy Act); the Department of Housing and Urban Development (Community Development Block Grants); U.S. Geological Survey (earth science data collection and interpretive studies); Federal Emergency Management Agency (emergency response and flood insurance); Natural Resources Conservation Service; Agricultural Stabilization and Conservation Service (Conservation Reserve Program and Agricultural Conservation Programs); Farmers Home Administration; U.S. Fish & Wildlife Service (Endangered Species Act and National Wildlife Refuges); and National Park Service (Big Bend National Park and Rio Grande Wild and Scenic River).

Table 1.2.—Federal water-management agencies and facilities in the Upper Rio Grande Basin

Agency	Primary activities	Major projects and facilities
Army Corps of Engineers (CoE)	Operation and maintenance of dams and reservoirs, levee construction, and protection	Cochiti, Jemez, Galisteo, Nambe, and Abiquiu Dams in New Mexico, Middle Rio Grande Flood Protection Project
Bureau of Reclamation (BuRec)	Operation and maintenance of dams and reservoirs, and channelization	Rio Grande Project: Elephant Butte Dam, Caballo Dam, five diversion dams Middle Rio Grande Project: Low-Flow Conveyance Channel San Juan-Chama Project: diversion dams and tunnels, Heron Dam Closed Basin Project
International Boundary and Water Commission (IBWC)	Provision of water to Mexico, channelization	American Diversion Dam, Rio Grande Canalization Project

of resources and thus, the survival of communities and economies.[8] Both types of concerns are surrounded with much uncertainty about the ecology, hydrology, and economy of the Basin. This lack of knowledge makes is difficult to assess the impacts of specific activities on the use of resources in the Basin and the ecosystem as a whole.

The institutions regulating water use in the Basin evolved in the context, and for the support, of diversionary uses, such as agriculture and municipal-industrial (hydroelectric generation in the Basin is negligible). These institutions do not adjust easily to the demands for instream flows that are emerging as commodities become a smaller component of the economy, urban residents extend their interest in the management of rural resources, natural-resource amenities exert a greater influence on local standards of living, and scientists better understand the interconnected

[8] See, for example, *Aquatic Ecosystems Symposium: A Report to the Western Water Policy Review Advisory Commission* (Minckley, ed. 1997).

functions of the river-riparian ecosystem. In this section we briefly describe the salient characteristics of instream-flow issues and the institutions governing them.

With the headwaters of many rivers, Colorado has striven to protect the ability of its citizens to obtain the greatest possible use of water before it left the state (many Coloradans have viewed water flowing across the state line as a wasted opportunity) (Sims 1993). In 1973, however, the state's legislature enacted a program to protect instream flows. As it has evolved, this program allows the Colorado Water Conservation Board (CWCB), which has responsibility for appropriating and protecting water rights, to appropriate water to instream flows.

The water rights created by such appropriations are similar in nature to those created by out-of-stream appropriations, although they differ in some important ways. In general, instream rights are at least 70 years junior to the most senior out-of-stream rights and, hence, they offer little meaningful protection for instream flows during dry years in the Basin, where all water has long been fully appropriated for agricultural uses. The legislature has given CWCB exclusive authority to apply for, appropriate, and protect instream flows and, in general, such flows are limited to the minimum needed to sustain the related natural environment (Meyer 1993; Sims 1993). In appropriate circumstances, however, other parties can protect instream water rights by first diverting water from a natural stream and then returning the water to the stream bed (Sims 1993). The CWCB must consult with the U.S. Departments of Agriculture and Interior before appropriating instream flows.

Colorado statute authorizes the state to obtain existing water rights by purchase or other means (except condemnation) and devote them to instream flows (Tarlock 1993). As with all water-rights transfers, the CWCB must review such a change in water use to determine if it would have a significant adverse effect on others. Subject to the CWCB's review, the state also can obtain water rights donated to it for instream uses (Meyer 1993). This review must consider the potential for adverse effects on (1) existing water rights and water exchanges, (2) conditional water rights for which facilities have been or are being constructed, and (3) the potential for Coloradans to make future beneficial use of water in a cost-effective and responsible manner (Sims 1993).

The New Mexico Constitution requires that the state regulate the application of water to beneficial use, but neither it nor the state's water statutes enumerate beneficial uses. Hence, in theory, instream flow could be deemed a beneficial use and subject to appropriation and protection by the State Engineer. So far, though, theory has not materialized in practice (DeYoung 1993). Efforts to formalize protection for instream flows in New Mexico have foundered repeatedly. Many factors underlie this record, but among the most salient are these three: weak efforts to promote resource conservation; institutional inertia; and limited financial wherewithal to undertake resource-conservation initiatives.

1. Weak Resource-Conservation Groups

Resource-conservation groups in the Basin generally are viewed as ineffective, especially with respect to river-related issues in the Rio Grande Basin. This weakness reflects both the notable strength of organizations opposed to the protection of instream flows and the underlying weakness of the state's environmental organizations, which are widely considered to be among the least powerful in the western states. There is no Basin-wide coalition of resource-conservation groups focused on river-related issues and local groups, which often are concerned with a narrow set of issues, generally have limited financial, organizational, and technical resources. Many parts of the Basin have no active resource-conservation group at all.

By contrast, long-standing groups supportive of consumptive uses of water and related resources exist throughout the Basin and are well-organized. Effective opposition to instream-flow proposals has come from both grassroots groups, such as acequia associations, and professionally organized groups, such as irrigation and conservancy districts (DeYoung 1993). The political power of these groups is sufficiently strong that they have defeated most proposals to advance instream flows. In New Mexico, for example, they have defeated proposals to establish instream-flow protection in almost every legislative session since the mid-1970s.

A perennial complaint from many conservationists is that they have had little, if any, meaningful access to many of the decision processes affecting the Basin's resource management (Clark 1987). Over 80 percent of water use in the Basin is associated with agricultural activities and immediately linked to acequia associations, irrigation districts, and conservancy districts, the governing bodies of which generally include only those who benefit from

the diversion of water from the river. For example, the Colorado Water Conservation Board (CWCB), which has responsibility for appropriating and protecting instream rights in Colorado, has a statutory mandate to promote development of out-of-stream water uses. Statute reinforces this mandate by requiring that members of the Board must be fully familiar with such uses and the development of projects to support them (Sims 1993), familiarity available almost exclusively through involvement in water-development projects that remove water from the stream.

Resource managers often respond to the complaints from conservationists by observing that the latter frequently fail to avail themselves of opportunities to participate in decision-making processes and, when they do try to participate are not well-informed regarding the technical, environmental, and legal intricacies of the water system. With these perceptions, there understandably is a high level of frustration with what many see to be unqualified newcomers sticking their noses where they don't belong.

Many resource managers, advocates of consumptive use, and conservationists expect instream issues will require additional attention in the future, acknowledge that the different interest groups often poorly understand the others' concerns, and see that education can play an important role in facilitating a cooperative response to specific problems. The past couple of years have seen several important efforts to improve the mutual understanding among the various groups. These include the Fish & Wildlife Service's expansion of the process for developing a recovery plan for the endangered Rio Grande silvery minnow to include a broad spectrum of interest groups. Also, the Albuquerque office of the BuRec has been expanding its outreach efforts to provide information about its programs to groups that traditionally have not been fully involved in reviewing the agency's activities.

2. Institutional Inertia

If proponents of instream flows are to be successful in their endeavors, they first must overcome the considerable inertia of the state's legal and institutional system for regulating water resources. This system has its roots firmly planted in the centuries-old tradition of withdrawing water from the river as the necessary precursor for human existence in the valley. It is supported further by a widespread belief that water should be private property and government's regulatory responsibilities should apply to

ensuring the orderliness of water withdrawals—relying on the prior-appropriation doctrine—but not to favoring one type of use over others. Against this backdrop, many have observed that there exists political, and perhaps even cultural, preference to maintain the status quo (Clark 1987; DeYoung 1993). To some, this inertia is a challenge to be overcome, but to others it provides considerable security regarding how resources will be managed in the future.

The institutional inertia favoring the status quo is reinforced insofar as the system has created broad incentives for landowners to file claims for rights to remove water from the river. The failure to adjudicate water rights or to gauge water flows and uses in New Mexico has created uncertainty about the specific dimensions of past claims and encouraged the filing of new claims against the hope that, within this chaotic context, they will become meaningful assets. Surface water in the Rio Grande is generally understood to be not just fully appropriated but markedly over-appropriated. Against this backdrop, the number of persons and parties with an immediate incentive to oppose instream rights is greater than it otherwise would be. This incentive is illustrated by the Colorado portion of the Basin, where meeting all the existing claims to surface water would require consistent flows of 7,000 cubic feet per second (cfs), whereas actual flows typically drop to about 100 cfs in summer months (Ralph Curtis, General Manager, Rio Grande Water Conservation District, personal communication). Over-appropriation to this degree means that, even if there were actions to reduce irrigation water diversions through conservation practices, any water left in the stream by a senior user probably would be removed from the river by a junior appropriator who currently has an unfilled claim.[9]

Opposition to instream rights sometimes is heightened because the establishment of such rights raises troublesome technical issues. There is widespread agreement, for example, that any flow supported by an instream right would have to be carefully gauged (DeYoung 1993). This requirement raises fears among instream advocates that they will have to bear gauging costs incommensurate with those borne by out-of-stream water users. Perhaps more important, it raises fears among the out-of-stream water users that carefully gauged instream flows might obtain some *de facto* preference

[9] In the San Luis Valley, for example, water conservation by senior users typically would allow junior appropriators to expand yields of hay and alfalfa by allowing them to irrigate lands that otherwise would be dry or to increase the level of irrigation and obtain a second cutting.

over rights that are less precisely gauged. Thus, establishment of instream flows might trigger demand for widespread investment in a technical upgrade in the gauging system. Particularly in New Mexico, where many flows and diversions are not immediately gauged, the extent of this investment can become a significant hurdle to instream flows. The height of the hurdle may diminish in the Middle Rio Grande Valley, insofar as the BuRec is using drought-relief funds to install additional gauges and transferring title to the Middle Rio Grande Conservancy District (MRGCD) under an agreement requiring the latter to monitor and maintain them.

As we observe throughout this report, the existence of considerable inertia in the private and public institutions governing resource-management decisions does not mean these institutions are stationary. Indeed, the past several years have seen some substantial initiatives that already have had bearing on instream issues. The most widely known of these is the listing of the Rio Grande silvery minnow as an endangered species, which has attracted the attention, if not altered the behavior, of water managers throughout the Basin. Other significant events include efforts by Albuquerque and El Paso to increase urban water conservation; cooperative efforts during the summer months of 1996 by the BuRec, Rio Grande Water Conservancy District, and State of Colorado to increase flows and produce environmental benefits in the lower reaches of the Rio Grande in Colorado; and efforts by New Mexico's State Engineer to investigate the feasibility of alternative approaches to adjudicating water rights in the Basin. Some of the significant pending events that might have an impact on instream issues are the environmental-impact reviews of major federal programs and projects. These include a programmatic environmental review by the BuRec and the CoE of river operations above Elephant Butte (scheduled to be complete in the next five years), the on-going review of the International Boundary and Water Commission's (IBWC) river-management activities, and the anticipated review of El Paso's request for funds from the Environmental Protection Agency to support the City's increased use of surface water.

3. Limited Fiscal Resources

The states and communities of the Upper Rio Grande Basin have limited fiscal ability to address instream issues. The New Mexico and El Paso portions of the Basin in particular face daunting fiscal challenges. New Mexico had the highest poverty rate among the states in 1995. Average household money incomes are about 15 percent below the national average

and the percent of persons below the poverty level in recent years has often exceeded 20 percent, whereas the national rate has generally remained below 15 percent (U.S. Department of Commerce 1995). In general, the Basin's metropolitan areas fare better than other areas but, even so, poverty remains a problem. A large segment of the population in the El Paso area has low income levels. Furthermore, the southern Basin is coping with high immigration rates that stress both physical and social infrastructure. Furthermore, low education levels and other characteristics indicate the region will have difficulty raising incomes for much of the labor force in the foreseeable future.

As we explain elsewhere in this report, income, alone, does not tell the whole story about how the standard of living in the Basin compares with elsewhere, in particular because it overlooks differences in quality of life and the cost of living. Nonetheless, these and other data indicate that low incomes in the Basin limit residents' ability to cope with evolving natural-resource issues, such as the protection of instream flows. This ability has been constrained further insofar as the allocation of state and local financial resources to river-related issues has been drained by large water-related lawsuits.

The state's history of low incomes and slow economic growth also affects the pattern of competing demands for the Basin's water and related resources. All else being equal, the higher a community's level of income and the more robust the growth in jobs and incomes, the greater the demand for natural-resource amenities (Clark and Murphy 1996). Thus, the historically low incomes of many groups in the Basin probably have suppressed the demand for clean water, high-integrity riparian zones, and similar amenities below what would have existed if incomes had been close to national averages. This is especially true in the El Paso area, where average earnings are about 20 percent below the national average, and in nonmetropolitan areas (see the discussion in Chapter 2). We expect that incomes in the El Paso area will remain suppressed for the foreseeable future, largely because the workforce is young and has low education levels. Hence, a substantial portion of the local population will express a lower demand for natural-resource amenities than they would if they had education and income levels typical of the rest of the nation.

Things are somewhat different in the Albuquerque area. Although wages in this area have lagged behind the national average (but less so than in El Paso), educational levels resemble the national average and the gap between local and national wage levels is narrowing. Furthermore, the area

is rapidly attracting highly educated in-migrants who probably will obtain above-average incomes in the future. Both these trends indicate it is reasonable to expect that this area's demand for natural-resource amenities will grow faster than elsewhere in the Basin or in the nation as a whole.

Chapter 2

The Economic Setting

In this chapter we describe the economy of the Upper Rio Grande Basin and how it influences, and is influenced by, the competition for the Basin's water and related resources. The economy is complex, and so is the competition for these resources. This was not always the case. Not too long ago the economy was mostly agrarian and outside the mainstream of the nation's economic growth. The demand for water and related resources came from Pueblos, farmers, and small communities. In the past half-century, however, the fundamental forces shaping the economy have changed—indeed, the very pace of economic change has, itself, changed dramatically. While the agricultural and subsistence sectors of the economy have remained stagnant, or even declined, other sectors have expanded vigorously.

The changes in the economy are mirrored in the competition for the Basin's resources. Total demand for the resources has grown along with the economy, and the nature of the demand has also changed. Particularly important is the growth in the demands for resource-based services, such as recreational opportunities and resource-related amenities. This growth means that historical patterns of resource use, developed when the economy derived benefits from the resources primarily by consuming them and converting them into commodities, increasingly are at odds with the evolving patterns of demand. This imbalance creates powerful economic forces for change.

This chapter has four parts. In the first, we describe a framework for assessing and understanding the complex nature of the competition for water and related resources. This description includes a list of the physical resources that are the focus of competitive pressures, as well as the economic goods and services derived from these resources. In the second part we discuss some of the powerful forces that are shaping the evolution of the Basin's economy and, hence, the competition for resources in the Basin. In part three we describe some aspects of the economic imbalance between historical patterns of resource uses and the rapid changes in resource competition. We summarize this chapter in part four.

Before proceeding, we believe it is important to describe what we mean by the term "value." We employ the term "value" in a broad sense to refer not just to preferences for goods and services measured in monetary terms, such as bales of hay produced from irrigated fields, but also those that are not monetized, such as recreational opportunities and the maintenance of

cultural traditions. Because the concept of "value" is at the heart of our analysis of the growing competition for water and related resources in the Upper Rio Grande Basin, we repeat the definition of the term in this chapter and subsequent chapters.

A. A Framework for Assessing the Competition for Water and Related Resources

In the past, it was easy to conclude that economic demand for water and related resources in the Upper Rio Grande Basin came only from the extractive consumption of water removed from streams and the development of in-stream facilities, such as dams and channels. To many, this conclusion was obvious. Irrigation, municipal-industrial development, and flood control created jobs, provided income, and increased property values, and there were no apparent competing demands. But things have changed dramatically. Municipal and industrial demands for water are outstripping conventional supplies and creating economic pressures to transfer water from agricultural to urban uses. There is growing recognition that extensive manipulation of the river can have adverse impacts on other sectors of the economy, as when the dams and irrigation withdrawals interfere with the production of fish and depress recreational fishing industries. Furthermore, many residents of the Upper Rio Grande Basin now demand cleaner water and other goods and services from the environment and they are concerned about issues of biodiversity and sustainability. Underlying all these factors is widespread uncertainty about who has what rights and responsibilities regarding the management of groundwater, surface water, and ecosystem resources.

In this section we describe the competition for the Basin's water and related resources taking these changes into account. There are countless ways to represent this competition, but the structure shown in Figure 2.1 offers a conceptual framework that is particularly useful.

Box 1 in the figure represents those who are competing for the water-related resources of the Upper Rio Grande Basin because they derive economic benefits from intensive use of the resources. The most common intensive uses in Box 1 are urban development and the extractive industries:

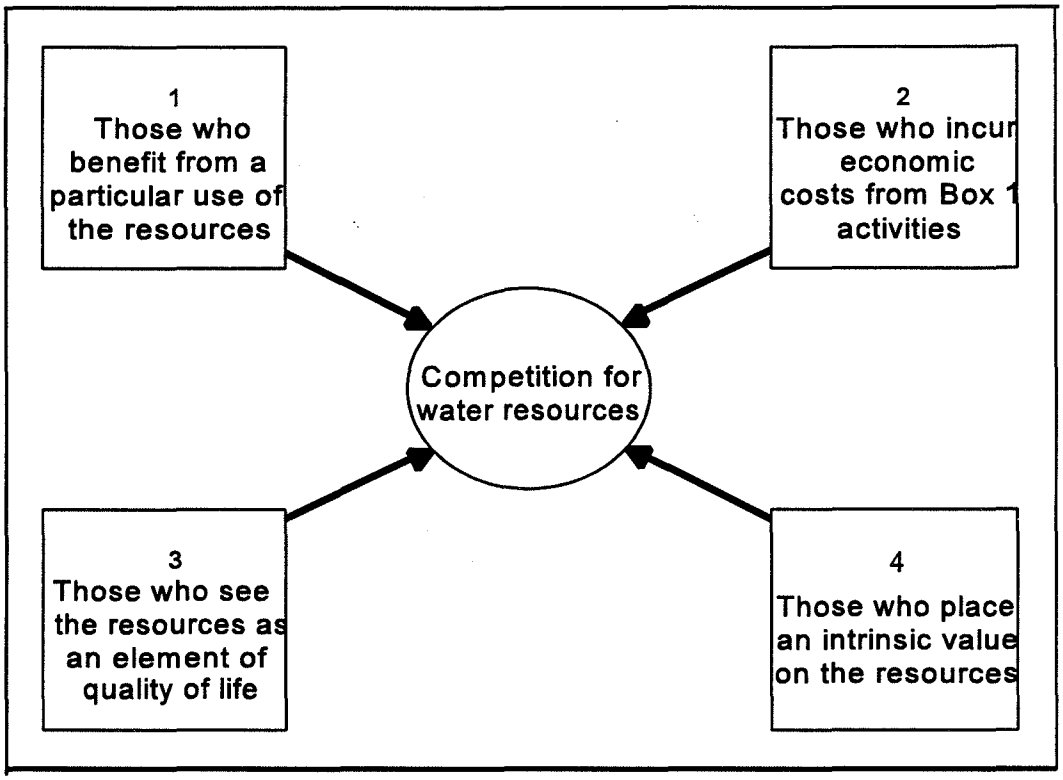

Figure 2.1.—The competing demands for water and related resources of the Upper Rio Grande Basin.

irrigation, timber, mining, road-building, hydropower, and grazing. In some situations, however, Box 1 also might include other activities, such as recreation, that entail resource-intensive activities competing for water and related resources with those represented by Boxes 2–4, even though they typically are not viewed as resource-intensive industries. Box 1 represents, not just those firms and workers directly engaged in a particular intensive use, but also the firms, workers, households, and communities that derive sales, profits, wages, incomes, and tax revenues from this use.

Box 2 represents those who compete for the resources because they incur spillover costs from the Box 1 activities. These spillover costs can assume any number of forms. In many cases, the activities of those in the Box 1 industry have impacts on direct market competitors, such as when the development of one water-related resort reduces sales at another nearby. In addition, there may be spillover costs on other industries, for example, when

the runoff from mining carries toxic or noxious materials into a stream, forcing a downstream food processor to incur additional costs to make the streamwater usable or to obtain water from another source. Or, the spillover costs may accrue directly to households and communities, as when flood torrents from urban impervious surfaces during a storm damage homes, municipal water systems, and roads. In addition to those directly incurring a particular spillover cost, Box 2 also includes the firms, workers, households, and communities whose sales, profits, wages, incomes, and tax revenues are affected directly or indirectly.

Box 3 represents those who compete for the water and related resources affected by the activities in Box 1 because they see these resources as an element of the region's quality of life. Quality of life generally refers to the benefits one derives from being proximate to the natural-resource, social, and cultural amenities of a place.[1] By living in a place, residents have access to its set of amenities and can take advantage of them more frequently and at less cost than if they lived elsewhere. The benefits they realize from these amenities, minus the cost (if any) of accessing them, produce consumer surplus for local residents. In effect, this consumer surplus represents a "second paycheck" that local residents receive from living in this place, so that the total welfare of local residents is the sum of this "second paycheck" plus whatever they can earn through a "first paycheck" through wages from work, deferred earnings received from a pension, or transfer payments. The size of the "second paycheck" derived from water and related resources can be affected by Box 1 activities, thus increasing or decreasing the overall welfare of local residents. The "second paycheck" also can influence migration patterns and the structure of regional economies.

Box 4 represents those who compete for the water and related resources affected by Box 1 activities because they place an intrinsic value on these resources. Intrinsic values do not entail an explicit use of the resource but arise whenever individuals place a value on the sheer existence of a species, scenic waterfall, or other resource, or on the prospect that the resource will

[1] Quality of life also incorporates the costs (negative benefits) one incurs from the disamenities of a place. To facilitate the discussion, though, we focus on the positive benefits of amenities.

be useful, for example, to future generations.[2] In effect, they view these resources as wealth, similar to jewels in a bank's vault. Actions that increase the robustness of the resources, for example, by ensuring the flow of a waterfall, increase the value of this wealth and, conversely, actions that degrade the resources decrease the value.

As illustrated in Figure 2.1, the competition for water and related resources in the Upper Rio Grande Basin goes beyond simply extracting water from the river. The competition involves a complex set of interrelated physical resources including not just the water itself but also its quality, the fish and other resources in the stream, the flora and fauna that exist in the riparian zone adjacent to the stream, and the upland resources that influence the stream. The competition for these resources is driven by the demand for goods and services derived from them, including:

- **Irrigation**. Crops supported by irrigation are important both for subsistence use and for sale within the market-based agricultural sector.

- **Municipal-Industrial Water Uses**. These uses occur primarily in the large metropolitan areas, but also are important in smaller towns and even rural areas.

- **Flood Control**. The risk of flood damage is especially high in the large urban developments along the river.

- **Pollution Disposal**. Residential, industrial, mining, and agricultural sectors use the Rio Grande for the disposal of pollutants.

- **Hydropower**. The hydroelectric generators in this Basin are small relative to those in the Colorado Basin and elsewhere.

[2] We use the term, intrinsic value, because it is more accessible to a layperson than the equivalent terms, such as passive nonuse value, that economists commonly employ. It refers to value separate from the current or expected use of a resource, including both consumptive and nonconsumptive use. Economists have devised several regimes for separating the intrinsic value of a resource into component parts. A common approach (Cicchetti and Wilde 1992) is to distinguish between option value and existence value. Option value is the value one derives from knowing that the resource will be available for one's use in the future. Existence value can be either the inherent value one places on the existence of the resource, itself, or the vicarious value of knowing that the resource is or will be available for others to use. The vicarious value of knowing that the resource will be available for future generations is commonly called bequest value. For the purposes of this discussion it is not necessary to examine these components separately.

- **Grazing and Logging**. The upland areas support logging and grazing activities that may affect both the quantity and the quality of water runoff as well as the character of the instream and riparian resources.

- **Development of Riparian and Upland Areas**. Nearly all urban development in the Basin occurs in the riparian zone or in adjacent uplands.

- **Recreation**. The Basin's water and related resources provide many of the most important recreational opportunities in a Basin that is mostly arid or semiarid.

- **Aesthetics**. Both rural and urban residents value the natural and historical amenities associated with the river.

- **Intrinsic Value**. Residents of the Basin, as well as many who live elsewhere, place a value on the environmental and spiritual aspects of the river's water and related resources.

Some of the competition represented by Figure 2.1 manifests itself through market mechanisms, but much—perhaps most—does not. Market mechanisms are most common where resources are privately owned or where prices can readily be used to govern transactions involving the goods or services derived from the resources. Thus, markets shape the competition for water-related commodities, such as beef, chiles, and alfalfa. Market mechanisms are totally absent, however, where the water-related goods or services, such as the visual aesthetics of natural-appearing riparian areas, lack characteristics that easily lend themselves to transactions and prices. Between these two extremes are situations where markets regulate some, but not all, of the links in the chain of events that connect resources to consumers' consumption of related goods or services. Markets generally apply, for example, to the equipment, food, and travel associated with a recreationist's trip to go fishing, but not to the fishing sites, themselves.

Because so many of the goods and services derived from water and related resources are not regulated by markets, all groups competing for these resources employ both market and non-market currencies to express their demands. In addition to participating in the direct buying and selling of timber, mineral rights, water rights, river-view property, conservancy areas, and grazing permits, they also exert pressure on the political processes and administrative proceedings in an attempt to influence the allocation of water

and related resources to their benefit. Those who believe they have been injured by the allocation of resources to others, or by the actions of those who have been allocated the resources, seek redress through the courts. Many groups seek to increase their share of resources through marketing campaigns aimed at swaying public opinion, and some invest in scientific research believing that the results will buttress their demands.

With no single clearinghouse for expressing and responding to all the competing demands for water and related resources, there is no single method for measuring their absolute and relative strength. Some groups emphasize the economic values of allocating resources to a particular use, while others enumerate the impacts on jobs, incomes, and communities. Most express the opinion that allocating resources to their respective causes is the right thing to do, and anything else is unfair. In such a setting, employing any single method to describe the competition, such as looking solely at water withdrawals, necessarily will favor some groups over others and, if actually used to allocate resources, elicit outrage from those who are disadvantaged.

Given the diverse mechanisms groups use to compete for water and related resources, and the absence of a comprehensive method for measuring competition, one has no choice when describing the competition but to take an eclectic approach, using whatever information is relevant for describing the specific demands represented by each of the four boxes in Figure 2.1 and trying to reconcile the findings. In general, different groups express their demands by focusing on three types of competitive arguments: (1) economic values; (2) economic impacts; and (3) perceptions of fairness.

One way to measure the relative strength of the competing demands for water and related resources is to compare the economic values society ascribes to the different bundles of goods and services derived under alternative resource-management programs. In general, the value an individual places on a specific use is the amount she is willing to pay for it, if she does not already possess the right to use the resource in this manner, or, if she does possess this right, the amount she is willing to accept to relinquish the right and forgo this use.

Much of the public's concern over the management of water and related resources is associated with how different management alternatives affect the economic opportunities available to workers, families, and investors, and

the structures of the local, regional, and national economies. These effects are commonly called the economic *impacts* of an alternative and are different from the effects on economic *values*.

Where there is competition for water and related resources, any resource-allocation decision necessarily creates both economic winners and economic losers. The characteristics of these two groups and the nature of the distribution of the wins and losses influence perceptions about the fairness of the decision. Hence, a comprehensive assessment of the competition for water and related resources generally must examine the comparative impacts of resource-management alternatives on perceptions of fairness. In particular, the assessment should examine issues associated with property ownership, subsidies, and groups of special concern.

B. Economic Forces Shaping the Competition for Water and Related Resources

Many of the changes shaping the competition for the Basin's resources stem from powerful economic forces at play across the international, national, and regional landscapes. In this section we discuss some of these forces. We focus particularly on a study area within the Basin, the area between Santa Fe, New Mexico and El Paso, Texas. This area embraces the bulk of the Basin's population, most of its current economic activity, and nearly all of the anticipated growth in both population and economic activity. The metropolitan areas and counties that comprise the study area are listed in Table 2.1.

The study area includes four metropolitan areas: Santa Fe, Albuquerque, Las Cruces, and El Paso. Albuquerque and El Paso, each with a population of about 650,000, are considerably larger than the others, but even they are too small to provide all of the functions normally associated with a major, regional node (Hoover and Giarratani 1984). Hence, it is important to recognize that the economy of the study area does not function in isolation from such nodes. The study area is somewhat peculiar in that it is heavily influenced by, not one, but three major regional nodes: Dallas, Denver, and Phoenix. Most, if not all, of the following discussion regarding the study area generally applies to these regional nodes and, hence, to promote

Table 2.1.—Counties in the study area and their population, 1994

County	Population, 1994
Santa Fe MSA[1]	**130,758**
Los Alamos	18,520
Santa Fe	112,238
Albuquerque MSA[1]	**645,525**
Sandoval	76,147
Bernalillo	515,570
Valencia	53,808
Las Cruces MSA[1]	**155,466**
Dona Ana	155,466
El Paso MSA[1]	**664,800**
El Paso	664,800
Nonmetropolitan area	**26,209**
Socorro	15,676
Sierra	10,533

Source: ECONorthwest with data from the Bureau of Business and Economic Research (1995).

[1] MSA = Metropolitan Statistical Area, as defined by the Census Bureau.

brevity we do not discuss them directly. We encourage the reader, however, to bear in mind the importance of the relationships between the study area and these nodes.

1. Employment in Resource-Intensive Industries is Stagnant or Declining

The study area generally exhibits national trends regarding employment in resource-intensive industries. The data in Table 2.2 show that total, private-sector employment in the agricultural industry in 1993 was 14,078, or about two percent of total employment in the study area. Agricultural employment is a higher percentage of total employment in the two nonmetropolitan counties than in the metropolitan areas, and a higher percentage in the Las Cruces metropolitan area than in the other

Table 2.2.—Agricultural and total employment in the study area

	Employment in 1993			Employment growth, 1982–93 (percent)	
	Total	Agriculture[1]	Agriculture % of total	Total (%)	Agriculture[1] (%)
Santa Fe MSA[2]	88,369	1,000	1.13	62.39	40.65
Albuquerque MSA[2]	369,912	4,292	1.16	50.60	28.31
Socorro County	6,462	630	9.75	28.37	18.42
Sierra County	3,654	421	11.52	36.34	-2.32
Las Cruces MSA[2]	62,426	5,212	8.35	49.43	38.21
El Paso MSA[2]	288,807	2,523	0.87	30.07	34.70
Total study area	819,630	14,078	1.72	43.40	32.03

Source: ECONorthwest with data from the U.S. Department of Commerce, Bureau of Economic Analysis (1994a).

[1] Agricultural employment includes farm employment and employment in the agricultural services industry.

[2] MSA = Metropolitan Statistical Area, as defined by the Census Bureau.

metropolitan areas.[3] For the study area as a whole, growth in agricultural employment during the past decade did not keep pace with total employment.

The data on income, shown in Table 2.3, follow a similar pattern, but with some important differences. In 1993, proprietors and employees in the study area's agricultural industry earned income of about $269 million, or one percent of total income. Agricultural incomes have grown more rapidly than incomes in other sectors during the past decade, largely because farm incomes were depressed throughout the nation in the early 1980s. Nonetheless, average earnings per employee in the agricultural industry are approximately two-thirds of the overall average.

These data indicate that the agricultural industry, the resource-intensive industry primarily associated with the Upper Rio Grande Basin, generally

[3] Agriculture also is a larger component of the economy in the area north of the Santa Fe MSA.

reflects the national trends for resource-intensive industries. In particular, the data indicate that this industry is a small component of the overall economy and it is not growing as rapidly as other sectors of the economy. Hence, it is reasonable to conclude that the agricultural industry in the study area is unlikely to yield substantial opportunities for additional jobs and/or higher incomes in the foreseeable future.

Table 2.3.—Agricultural and total income in the study area

	Income ($000) in 1993			Income growth, 1982–93 (percent)	
	Total	Agriculture[1]	Agriculture % of total	Total (%)	Agriculture[1] (%)
Santa Fe MSA[2]	2,827,101	9,481	0.34	59.64	58.25
Albuquerque MSA[2]	11,906,635	63,841	0.54	44.13	33.04
Socorro County	190,214	9,857	5.18	40.51	321.06
Sierra County	146,789	3,091	2.11	25.41	13.84
Las Cruces MSA[2]	2,007,844	138,837	6.91	57.18	150.77
El Paso MSA[2]	8,273,573	43,747	0.53	34.05	353.02
Total study area	25,352,156	268,854	1.06	42.96	116.72

Source: ECONorthwest with data from the U.S. Department of Commerce, Bureau of Economic Analysis (1994a).

[1] Agricultural income includes farm income and earnings in the agricultural services industry.

[2] MSA = Metropolitan Statistical Area, as defined by the Census Bureau.

This is not to say that the agricultural sector is unimportant or that it will disappear. To emphasize this point, we repeat it: we fully expect the agricultural sector will remain an important part of the Basin's economy. The evidence indicates, however, that this sector will not play a major role in the overall future economic *growth* in the study area. Insofar as residents and political leaders of the area want to promote growth in jobs and higher incomes, they necessarily will have to turn to alternative sectors and sources of growth. As they do so, and as other sectors grow relative to agriculture, the structure of the competition for water and related resources will change. A major challenge facing the Basin is how to accommodate this change in an

efficient and fair manner. In the remainder of this chapter we discuss some of the factors that will influence the constraints and opportunities for responding to this challenge.

2. Education Is Increasingly Important as a Determinant of Wages

Throughout the U.S., structural changes in the economy are affecting the earnings of individual workers and the economic outlook for communities and regions. Foremost among these is the increasing importance of education as a determinant of earnings, relative to other historically important factors, such as proximity to resource-based and heavy manufacturing industries. In the past, many unskilled workers could count on these industries for jobs offering middle-class earnings, but many of these jobs have disappeared over the past two decades, at the same time as the demand for high-skilled workers has outpaced supply throughout the economy (Bound and Johnson 1995; Ilg 1996). Education is similarly important in the study area. In this section we examine this relationship in the context of the study area, reviewing data for El Paso, New Mexico as a whole, and Albuquerque.

El Paso's economy is among the fastest-growing in the nation. Historically, it has had three major elements: the city's historic role as a trading center for a large, surrounding area; the development of copper and natural gas industries; and the U.S. Army's nearby Ft. Bliss. A recent assessment of El Paso's economy by Brian McDonald, the director of the University of New Mexico's Bureau of Business and Economic Research concludes, however, that for the past three decades, the major source of economic growth has been the expansion of private sector activity, primarily in manufacturing, services, and trade (McDonald 1995). Another source of economic growth is the area's rapid population growth: El Paso and nearby counties in Texas are expected to grow by almost 27 percent during the decade, more than twice as fast as the national average (Sharp 1995).

Although manufacturing often is regarded as a high-wage sector, this generally is not the case in El Paso, where manufacturing is characterized by maquiladora operations. Maquiladora operations typically involve twin plants, primarily in a manufacturing industry, open on either side of the U.S.-Mexico border. Historically, the actual manufacturing activities took place on the Mexican side of the border, in El Paso's twin city, Ciudad Juarez, and the warehousing, administrative, and other support services

occurred in El Paso. Recently, however, the manufacturing activities themselves have located in El Paso, and are concentrated in low-wage industries. Average manufacturing earnings per employee in El Paso are about 59 percent of the national average.

Expansion in El Paso's services and trade sectors also seems to be occurring in the low-wage component of these sectors. For El Paso's economy as a whole, average earnings are about 79 percent of the U.S. average.

There are, of course, multiple reasons for the below-average earnings in El Paso, but one of the strongest is the large supply of low-skill workers, given the relatively low level of educational attainment of El Paso's residents. The 1990 census found, for example, that 34.2 percent of persons 18 years and over in El Paso had not completed high school, versus the national average of 21.6 percent and a Texas average of 28.2 percent (City of El Paso 1995). Furthermore, the percentage of the area's adult population that has not completed the ninth grade is more than double the national average (Sharp 1995). At the other end of the educational spectrum, 14 percent of El Paso's residents 18 years and over had a bachelor's or higher degree, below the comparable national and statewide figures, 19.5 percent and 18.1 percent, respectively. The impact on earnings of the low level of educational attainment of El Paso's workforce is reinforced by its relative youth; in 1990, the median age in El Paso was 28 years, nearly five years below the national average of 32.9 years. The low level of educational attainment in El Paso, relative to other areas of the U.S., essentially dictates that earnings in El Paso will continue to be below the national average.

New Mexico and Albuquerque exhibit a somewhat different pattern of educational attainment and economic development. The workforce is substantially better educated and, although there are some potentially dark clouds on the horizon, a relatively high percentage of the workforce enjoys the prospect of benefiting from national trends toward higher returns to education. For New Mexico as a whole, 24.9 percent of persons 25 years or over did not complete high school, and 20.4 percent have a bachelor's or higher degree (U.S. Department of Commerce 1994). In both cases, the statistic for New Mexico is nearly identical to the national average. In general, one should expect that educational attainment in Albuquerque resembles the statewide average.

Information regarding migration patterns indicates that, in recent years, more highly-educated persons have moved into New Mexico than have moved

out. Indeed, between 1985 and 1990, the state experienced a net increase in the population of persons with a bachelor's or higher degree and a net decrease in the number of persons with less than a college-level education (Ferguson 1995). New Mexico was unique in this regard relative to nearby states—Colorado, Kansas, Missouri, Nebraska, Oklahoma and Wyoming—each of which experienced a net outflow of highly-educated persons. New Mexico's gain in highly-educated persons consisted almost entirely of professionals in the retail trade and business services sectors.

McDonald (1995) notes that Albuquerque's manufacturing sector has grown more rapidly than the national average since 1972 and that much of the *growth* in this sector has occurred in jobs paying wages above the national average. Nonetheless, for the sector as a whole, wages remain 15 percent below the national average. Similarly in other sectors, overall earnings remain below the national average, although the gap is narrowing. In the state's services sector, for example, the number of jobs has grown more than 4.5 percent per year since 1989 and total earnings have grown about twice as fast (McDonald 1995; Smith 1994). Much of the growth in services has occurred in health services and in engineering and management services, which reflects growth in the state's research and testing laboratories.

The ability of Albuquerque and New Mexico to continue to attract highly-educated persons appears to be strong and widespread, although this strength may be weakened somewhat if federal budget cuts markedly reduce federal expenditures in the state. Federal expenditures in New Mexico during fiscal year 1994 totaled more than $11 billion. On a per capita basis, the $6,816 of federal funds spent in New Mexico was higher than the amount spent in any state in the Rocky Mountains or Southwest geographic regions and 36 percent higher than the national average (Bureau of Business and Economic Research 1995).

3. Amenities are Increasingly Important in the Locational Decisions of Workers, Households, and Firms

The subregional economies of the study area, and especially its metropolitan areas, have been growing rapidly for several decades and the area's social, cultural, and natural-resource amenities undoubtedly contribute to this

growth in important ways.[4] Estimating the value of the area's amenities is a difficult task that lies beyond the scope of this study, but other studies provide some important insights regarding these values.

One study (Greenwood et al. 1991) examined the patterns of migration across the fifty states and attempted to determine the relative strength of two primary motives workers and households have for moving: to earn a higher wage (adjusted for differences among the states in the cost of living); and to have access to the particular amenities of the individual states. Workers tend to move from places with lower wages to places with higher wages, all else being equal, and from places with lower levels of amenities to places with higher levels. Hence, to attract and maintain a comparably productive workforce, employers in places with lower levels of amenities generally have to pay higher wages than firms in places with higher levels of amenities. In general, the differential in wages between two states provides an indirect measure of the differential in the value of the states' respective amenities.

Based on migration patterns for 1971–87, Greenwood et al. estimate the amenity-related differential in wages for each state, relative to a national average. They find that, on average, the amenity-related differential for New Mexico is about 8–13 percent. In other words, the amenities of New Mexico are sufficiently attractive to those who work in the state that, on average, these workers would not relocate elsewhere in the U.S. unless they received an increase in wages of more than 8–13 percent. In 1994 total wage-and-salary earnings in the state exceeded $16 billion, and 8–13 percent of this amount, approximately $1.3–2.1 billion, represents the annual value that workers in the state place on those amenities that distinguish New

[4] Amenities also play an increasingly important role in determining the economic fortunes of rural areas. A recent study of nonmetropolitan counties between the Mississippi River and the Rockies, from Canada to Oklahoma found that those experiencing growth in jobs typically are widely perceived to have above-average natural-resource amenities, whereas those experiencing job declines typically had a high concentration in extractive industries (Drabenstott and Smith 1996). These and numerous other findings support more general observations, such as this one (Galston 1992):

"Absent heroic assumptions about the future location of manufacturing plants, there is no possibility that routine production jobs can soak up excess rural workers in the 1990s as they did to some extent in the 1970s.... During the 1980s,... [t]he kinds of natural characteristics regarded as 'amenity values' by retirees, vacationers, and certain businesses have emerged as the chief new source of rural comparative advantage. (We may speculate that this relative advantage has been widened by declining amenities in many urban areas.) Rural places with substantial locational assets have commanded the lion's share of nonmetro population and employment gains."

Mexico from the rest of the nation. This amount does not include the value that others—retirees and other nonworkers in New Mexico and residents of other states—place on these amenities.[5]

It is impossible, given currently available data and analytical techniques, to discern the value of New Mexico's individual amenities, including those that are associated with the resources of the Upper Rio Grande Basin. Surveys of in-state and out-of-state travelers (see, e.g., Thompson and Cordova 1995) generally confirm that these amenities include the state's historical sites and museums; its opportunities for fishing, hunting, and hiking; and its national and state parks. Assessments by the Middle Rio Grande Conservancy District, state agencies, federal agencies, and the general public (see, e.g., Crawford et al. 1993 and Middle Rio Grande Conservancy District 1993) have identified a wide range of amenities associated with the Upper Rio Grande Basin, including these broad categories:

- The rare, if not unique, ecosystem, known as the Rio Grande bosque, that embraces the river, its riparian forest dominated by cottonwoods, and the dependent communities of plants and animals.

- The visual aesthetics associated with the river itself, as well as the associated vegetation, both uncultivated, e.g., the bosque, and cultivated, e.g., irrigated lawns and fields.

- River-related recreational opportunities, including those associated with the network of open space, riverbanks, trails, and roadways where city dwellers can find refuge from traffic and noise.

- The river's role as a component of traditional cultures and lifestyles, including Native Americans' use of the river for ceremonial purposes, farmers' use of water for irrigation, and city-dwellers' use of the river as the central focus for urban development in an otherwise desert environment.

[5] Retirees are footloose consumers who often base their locational decisions on the availability of natural-resource and other amenities, and on the cost of living. Their expenditures, derived from pension and other non-wage sources of income, have a marked impact on the structure of local economies throughout the West (Power 1996).

4. The Economies of Nonmetropolitan and Metropolitan Areas Are Becoming Increasingly Integrated

Viewing the Upper Rio Grande Basin in the context of the interactions among the nearby metropolitan and nonmetropolitan areas is important because, as Peirce (1993) and others have observed, the ability of the nation to compete effectively in the global economy will be determined largely by the ability of its different economic regions to be competitive. Peirce uses the term *citistate* to refer to a region centered on a major metropolitan area, and observes that a citistate is important because it is the unit of economic organization where many of the most essential economic decisions are made:

> *The inescapable oneness of each citistate covers a breathtaking range. Environmental protection, economic promotion, workforce preparedness, health care, social services, advanced scientific research and development, philanthropy—success or failure on any one of those fronts ricochets among all the communities of a metropolitan region. No man, woman, family, or neighborhood is an island. There are compelling reasons why center cities, for example, need and depend on their suburbs, and equally compelling reasons why the suburbs need a healthy center city.*

This argument, which is consistent with conventional regional economics (see, e.g., Hoover and Giarratani 1984), extends not just from center city to suburbs, but also from a metropolitan center to the surrounding non-metropolitan areas, and from a relatively small metropolitan center to the adjacent larger ones (Galston 1992). Decisions regarding the management of nonmetropolitan resources, such as the Upper Rio Grande Basin, will affect, not just the economic well-being of the residents of adjacent nonmetropolitan towns, such as Socorro, but also the well-being of the residents of nearby metropolitan centers, such as Albuquerque, and the well-being of distant regional centers, such as Phoenix. Insofar as the management of the Basin reinforces (undermines) the fundamental economic strength of the metropolitan centers, it will brighten (cloud) the overall economic outlook for all residents of the region.

The economy of the study area is highly concentrated in the area's four metropolitan centers: Santa Fe, Albuquerque, Las Cruces, and El Paso. Nearly all of the households, jobs, and economic activity in the study area occur within these four areas: the data in Table 2.1, for example, show that approximately 98 percent of the population in the study area resides in the counties that constitute the area's four metropolitan statistical areas

(MSAs). This percentage somewhat overstates the portion of the area's population that actually has a metropolitan residence, because these are large counties and each one contains both urban and nonurban residents, but nonetheless, it is clear that economic activity in the area is highly concentrated.

Furthermore, the level of concentration is increasing. During the period, 1990–94, for example, population growth in the four MSAs was markedly greater than in the remainder of New Mexico (see Table 2.4). Planners and economists generally anticipate that the Middle Rio Grande area will continue to grow faster than the remainder of the state (Bureau of Business and Economic Research 1994; Middle Rio Grande Council of Governments 1991).

Table 2.4.—Change in the study area's population, 1990–94

Area	Percent change in population
Santa Fe MSA[1]	11.7
Albuquerque MSA[1]	9.6
Las Cruces MSA[1]	14.7
Remainder of New Mexico	7.2
El Paso MSA[1]	12.4

Source: ECONorthwest with data from the Bureau of Business and Economic Research (1995).

[1] MSA = Metropolitan Statistical Area, as defined by the Census Bureau.

By concluding that the study area's metropolitan centers contain most of the area's economic activity and generate most of the growth in population and jobs, we are not saying that the nonmetropolitan areas are unimportant. Instead, we are saying that, although from a *geographic* perspective the Upper Rio Grande Basin is predominantly nonmetropolitan, from an *economic* perspective it is predominantly metropolitan. Metropolitan areas contain nearly all of the investment, labor, infrastructure, and other elements that constitute the area's economy. Furthermore, nearly all of the future *growth* in the economy is likely to occur in the metropolitan areas.

The Albuquerque metropolitan center plays such a dominant role in the economy of the Middle Rio Grande area that most, if not all, of the economic adjustment that might be triggered by changes in the quantity, quality, and use of resources associated with the Upper Rio Grande Basin would occur in it. The metropolitan areas of El Paso and Las Cruces contain most of the economic activities that would have to adjust if a management decision concerning the Basin were to affect water flows downstream of Elephant Butte. Industrial activity occurring outside the metropolitan cities—primarily agricultural activity in Socorro County and Sierra County and in the nonurban sections of the counties in the Albuquerque and Las Cruces MSA—are a small element of the study area's overall economy.[6] And, more important, this agricultural activity does not exist in isolation from the metropolitan centers that provide most of the transportation, financial, warehousing, and other services that support agriculture.

C. Economic Values Associated With the Basin's Water and Related Resources

If the Basin's resources were allocated in a manner consistent with competitive markets, then market forces would ensure that the resources would be allocated to those who place the highest value on them. As the economy changed over time, some demands for a particular resource would grow, others would diminish, and the allocation of resources would shift accordingly through a dynamic process involving multiple, voluntary transactions and exchanges. The forces of demand and supply would reach a dynamic equilibrium, in which the market price for each resource reflected both the cost to sellers of increasing the supply by a small amount and the value that buyers place on increasing their demand by a similarly small amount.

Reality, however, is far different from this ideal. There are few transactions allowing resources to move from a low-value use to one with a higher value. Some demands that reflect a relatively low value for a resource are satisfied while others that reflect a relatively higher value do not. Few resource users pay a price that reflects either the value they place on the resource or the value others place on it. As a result of the disparities between ideal and

[6] Expanding the analysis to include the nonmetropolitan areas north of Santa Fe would not alter the conclusion that most of the Basin's economic activity occurs outside the agricultural sector.

actual conditions, there is no equilibrium between the forces of demand and supply for the river's resources. We illustrate the disequilibrium by describing some of the values associated with alternative water-related activities in the Middle Rio Grande area. We use the term "value" to refer to both the goods and services associated with the water and related resources of the Middle Rio Grande area that are measured in monetary terms, and to those that are not monetized.

Agricultural Values. Without water, very little agricultural production would occur in the Middle Rio Grande area. It would be a mistake, however, to attribute the entire value of the crops produced in the area solely to the water, because many other factors of production, such as labor and capital, are employed to produce these crops. A conventional way to allocate a crop's value among the various factors of production entails taking the total revenues from the crop, subtracting the readily quantifiable production costs, such as the cost of tractors, fuel, and labor, and attributing the residual to a set of factors that reflect farm earnings, namely, the return to the farm business' management, land, and assumption of risk.

The data in Table 2.5 show the results of such a calculation for major crops in the Middle Rio Grande area.[7] Specifically, the data show the amount of water applied to each crop, the yield, and the farm earnings for a typical farm in 1995, under two scenarios: one assumes full-water conditions when the Middle Rio Grande Conservancy District (MRGCD) does not have to restrict the availability of water because of short supplies, and the other assumes the amount of water applied per acre is reduced by one acre-foot (af). The final column in Table 2.5 shows the incremental change per af in yield and farm earnings associated with the reduction of 1 af of water applied to the field. The data show that alfalfa is being produced on 30,837 acres in 1995, 4 af of water are diverted and applied to each acre, on average, and each acre can be expected to produce 4.4 tons and net earnings of $195 per af/ac. With a reduction of one af/ac, yield can be expected to drop to 3.3 tons and farm earnings to $70 per af/ac. Hence, the net earnings attributable to a reduction of 1 af/ac in the supply of water available for irrigation is ($195-$70=) $125 per af/ac.

Similar calculations indicate that the net earnings attributable to a reduction of 1 af/ac in the supply of water available for irrigation is $19 per

[7] Data for agricultural estimates come from the New Mexico Cooperative Extension Service (1995) and the U.S. Department of Interior, Bureau of Reclamation (1980-1994).

af/ac for pasture, $134 per af/ac for corn silage, and $459 per af/ac for green chile. The calculation for pasture requires some additional explanation. Note that the net earnings for pasturage is negative, i.e., the farm business incurs a net loss, even under full-water conditions. This finding does not mean that every owner of pasture incurs a net loss, but that farm businesses, on average, do so. Reducing the supply of water by one af/ac reduces the net loss, on average, by $19 per af/ac. The overall average net earnings attributable to a reduction of 1 af/ac in the supply of water available for irrigation for the major crops grown within the boundaries of MRGCD in 1995 is $105 per af/ac.

The data in Table 2.5 have important implications for any assessment of the economic consequences of altering the allocation of water in the Middle Rio Grande area, because they indicate that, at the margin, the value of water used for irrigation is no greater than zero. That is, increasing the supply of water for the lowest-value irrigated crop, pasture, does not yield an increase in output that is more valuable than the costs of capital, labor, and other factors of production.

This conclusion is not unique to the Middle Rio Grande Valley. A 1990 analysis published by the Economic Research Service of the U.S. Department of Agriculture examined the entire Basin from the headwaters through El Paso County and concluded that, at the margin, the value is zero for water diverted from the Rio Grande and used for irrigation (Hansen and Hallam 1990).

Another factor reinforces the conclusion that the marginal value of water used for irrigation is zero. Most irrigators in the Basin use water made available through extensive federal expenditures on dams, channel maintenance, and other items. The irrigators do not incur the full costs of obtaining, storing, and delivering water to their fields and, hence, the federal expenditures, in effect, subsidize use of the water.[8]

[8] Some observers, especially those who benefit from federal expenditures, object to calling these benefits subsidies. The objections take several forms, but typically involve one or both of these two arguments: (1) food and water are essential to human life and, hence, promoting agricultural and urban water development is not a subsidy but an essential expenditure of public funds; and (2) because Congress has approved water-development projects, they reflect societal preferences rather than subsidies. We intend no offense through our use of the term, which reflects the standard economic treatment of public expenditures that extract fiscal resources from the general economy to benefit a particular sector or group. With respect to the economic consequences of resource-management policy, the terminology is far less important than the fact that, whenever resource users do not incur the full cost of their activities, they have powerful economic incentives to use more than they otherwise would. This incentive potentially applies to all resource users: irrigators, urban households, industries, recreationists, and resource conservationists.

Table 2.5.—Estimated value of water diverted for major crops in the MRGCD

Crop (acres irrigated in 1993)	Production characteristics[1]		
	Under full-water conditions	With 1 af less per acre	Incremental product per 1 af of field applied water[2]
Alfalfa (30,837)			
Irrigation water applied (af/ac)	4	3	--
Yield per acre (tons)	4.4	3.3	1.1
Net earnings[3]	$195	$70	$125
Pasture (15,848)			
Irrigation water applied (af/ac)	3	2	--
Yield per acre (AUM)[4]	4	2.7	1.3
Net earnings[3]	-$80	-$99	$19
Corn silage (3,621)			
Irrigation water applied (af/ac)	3	2	--
Yield per acre (tons)	20	14.7	6.3
Net earnings[3]	$18	-$116	$134
Green chile (896)			
Irrigation water applied (af/ac)	4	3	--
Yield per acre (sacks)	275	206	69
Net earnings[3]	$385	-$74	$459

Source: ECONorthwest.

[1] Production characteristics for a typical farm enterprise, as estimated by the New Mexico Cooperative Extension (1995) and reported by the U.S. Department of Interior, Bureau of Reclamation (1980-1994).

[2] Since there is approximately a 50 percent return flow of water that is applied to irrigation fields, the value per consumptive use is double the amount in the table.

[3] Net earnings equal the return to management, land, and risk.

[4] AUM = animal-unit month of forage, e.g., the amount of forage consumed by a cow-calf pair per month.

Tracing the subsidies for individual federal water projects is tedious and has not been completed for any project in the Basin. Irrigators participating in a federal water project can receive financial assistance through (1) federal subsidization of the project's construction cost; (2) shifting some of irrigators' repayment obligation to others because the obligation exceeds irrigators' ability to pay; and (3) relieving irrigators of part of their repayment

obligation in special circumstances, such as drought or economic hardship (U.S. General Accounting Office 1996). Each of these elements, especially the first one, is difficult to estimate. Tables 2.6 and 2.7 report some financial information for projects in the Basin, showing the allocation of initial costs among irrigation and other purposes, and then summarizing the repayment status of the portion allocated to irrigation.

Table 2.6.—Allocation of costs for Federal projects in the basin, September 1994 ($000)

Project	Irrigation	M&I[1]	Power	Flood control	Recrea-tion	Fish and wildlife	Other[2]
Middle Rio Grande	15,974	0	0	0	202	0	22,615
Rio Grande	25,661	0	13,301	1,574	608	0	1,000
San Juan-Chama	34,614	39,332	0	0	901	7,960	0
San Luis Valley	2,332	0	0	1,643	0	0	0

Source: U.S. General Accounting Office (1996).

[1] Municipal and industrial water supply.

[2] Other nonreimbursable costs, such as water quality, investigations, and the Settlement Land Program.

Although exact amounts of the subsidies are not known, one summary estimate of the average subsidy—greater than $50 per af—to all irrigators using water from all the Bureau of Reclamation's (BuRec's) projects provides some context (Secretary of the Interior 1994). If this estimate applies to irrigation in the Basin, then each of the values attributed to water in Table 2.5 would be reduced by $50 per af/ac. Making this adjustment would lower the overall net earnings in 1995 per af of water from $105 to $55 per af/ac. The adjusted net earnings for pasture would become negative, -$31 per af/ac, indicating that the total cost—to the farm business plus federal taxpayers—would exceed the value of the forage produced.

Table 2.7.—Repayment status of costs allocated to irrigation, September 1994 ($000)

Project	Repayment to date		Future repayment		Irrigation assistance and charge-offs	Discount loans
	By irrigators	By others[1]	By irrigators	By others[1]		
Middle Rio Grande	13,745	9	2,244	0	9	0
Rio Grande[2]	14,504	1,052	0	5,535	7,150	4,110
San Juan-Chama	743	346	2,947	30,154	30,924	0
San Luis Valley	475	7	0	0	1,863	0

Source: U.S. General Accounting Office (1996).

[1] Irrigation assistance payments made with revenues from power or a project's other sources, such as miscellaneous water sales and land-use leases, because the amounts allocated to irrigators have been determined to exceed their ability to pay.

[2] The Rio Grande Project has repaid its entire construction obligation to the federal government and has received title to all of its distribution and drainage facilities (Esslinger 1997).

Municipal Values. As with agriculture, a modern city would not exist without extensive water services. But this does not mean that one reasonably can attribute to the water the full value of the city's economy. Indeed, in a complex urban setting there are many different ways to look at the value of water. The value urban consumers place on water at the margin, i.e., for a small change in consumption, probably is substantially less than the value of big changes. Values may change over the long run, as a city implements new pricing structures, consumers' tastes and preferences change, and the economy's industrial structure evolves. Especially in a desert environment, stored water also acquires an option value, giving consumers security that they will not run dry during a drought period.

There are two recent studies of municipal values in the Albuquerque area. One employed a model of the demand for water by the city's single-family residences, given the prices they faced in 1992 (McGuckin 1994). This model estimated the reduction in consumers' economic welfare that would occur if single-family residential use in Albuquerque were curtailed by 4,000 af per year (this is 2,000 af of consumptive use), from 53,000 af to 49,000 af. The result indicates that the value of water to residential consumers in Albuquerque is approximately $326 per af of water available at the tap, or $652 per af on a consumptive-use basis.

The other study took a more comprehensive look at the different ways to consider the value of water in the area (Brown et al. 1996). It estimated that the marginal value of water to households is probably $7-33 per acre foot, but could rise to more than $400 under a scenario of pricing, regulatory, and other measures to curtail average consumption by about one-half. Given the city's determination that it must curtail consumption patterns, future marginal values will be higher than today's, although they might not rise to the upper bound estimated by Brown et al. This conclusion is reinforced by the data in Figure 2.2, which shows the current consumption rate in Albuquerque is considerably higher than those in other Southwestern cities. The difference stems primarily from differences in prices and economic structure. Although consumption in each city is a function of many variables, including water price, climate, and economic structure, Figure 2.2 indicates that Albuquerque probably has considerable leeway to reduce consumption— and increase the marginal value of water—and still retain the character of a modern metropolitan economy.

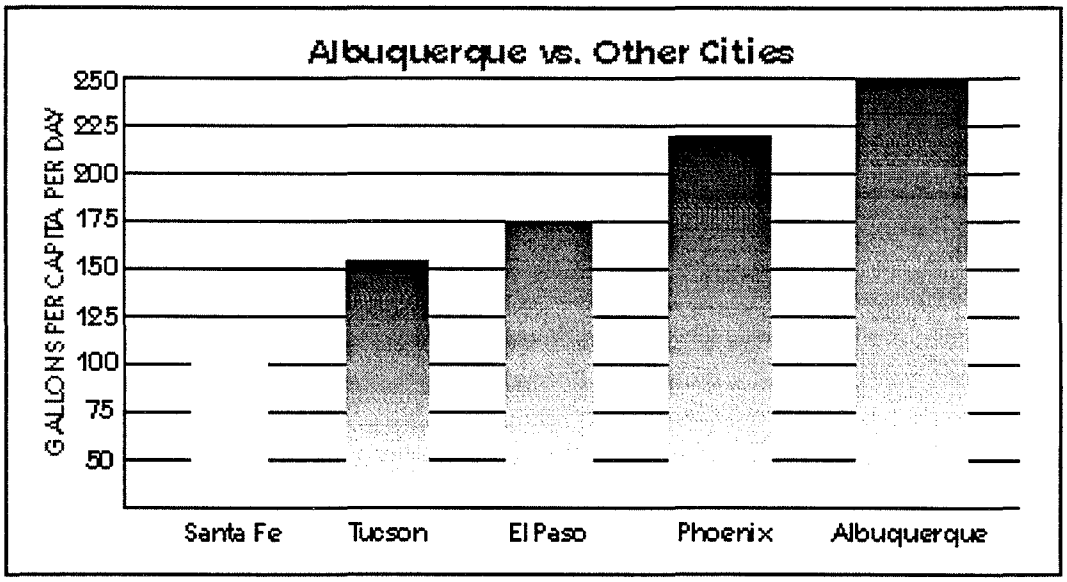

Figure 2.2.—Per capita water consumption for Albuquerque, Phoenix, El Paso, Tucson, and Santa Fe.
Source: City of Albuquerque, Water Conservation Office (1996).

Recreational Values. There is no comprehensive assessment of the value society places on water-dependent recreation in the Basin, but several studies provide some useful insights. Using a conservative estimate of the value that anglers place on water used for fishing for the area that embraces the Rio Grande Valley from the Colorado-New Mexico border to below

El Paso, Hansen and Hallum (1990) conclude that the marginal value of water used for fishing is about $100 per af, measured in today's dollars. This estimate does not include other types of recreational use that might benefit from increasing the amount of water supporting the river's fishery. In a summary of other relevant literature, Bonnie Colby (1993) reports that increasing stream flows in the Rio Chama during low-flow periods generates recreational values of $16–27 per af, findings generally consistent with similar research in the Rocky Mountains. In her own research, Colby has found that, because the demand for whitewater rafting in the Wild & Scenic portion of the river, near Taos, often is thwarted by low summer flows, "agreements that would decrease agricultural diversions and leave more water in the river during July and August for recreational and environmental purposes would generate net benefits and stimulate economic activity in some of the poorest areas of the Southwest."

Water-Quality Values. Changes in water quality can affect several types of economic benefits derived from the Basin's water and related resources, including the productivity of water used by agriculture and industry, its suitability for human consumption and recreation, its cultural and religious contributions, and the passive benefits to nonusers (Crutchfield et al. 1995). No analysis specific to the Basin has been completed of how past changes in water quality have affected these benefits or of how they might be affected by future changes. Thus, one must rely on a more general literature to provide the general parameters of the water-quality values applicable to the Basin.

One study, based on a detailed national survey, found that households indicate a willingness to pay of about $240 per year, on average, to improve surface water quality from "nonboatable" to "swimmable" (Carson and Mitchell 1993). Survey research specific to New Mexico found households indicating a willingness to pay $30 per year for five years to protect the minimum instream flows needed to prevent extinction of the Rio Grande silvery minnow, and $79 to provide minimum streamflows in all the state's major rivers (Berrens et al. 1995). Research conducted for the U.S. Department of Agriculture found that sediment generated by agricultural practices on highly erodible land in the Mountain Region, which includes Colorado and New Mexico, causes off-site damages of $1.12 per ton (1986 dollars).

Crutchfield et al. (1995) provide a summary of research on the benefits associated with changes in groundwater quality. Some of the literature indicates that households are willing to pay between about $35 and $80 per

year to prevent contamination of groundwater by pesticides, nitrates, toxic chemical, and petroleum spills. Other studies show that households place a far higher value—as high as $1,500 per year—on protecting groundwater.

Water-Conservation Values. Water can be conserved in multiple ways. For example, urban residents and governments can change landscaping practices and increase the use of plants that require less water, or farm businesses can install water-saving irrigation systems for their crops. The cost per af of water conserved by such practices can vary, from nearly zero to several hundred dollars. An illustration of the potential for water conservation comes from Intel Corporation. According to company records, the company's water-conservation programs have successfully reduced Intel's daily water consumption by 2.131 million gallons per day (mgd), or about 6.5 af per day. To accomplish these savings, Intel has made capital expenditures totaling $3 million (Intel intends to expand the program to $4.77 million). Amortization of these expenditures translates them to an annual cost of $488,236, indicating that the annual cost of increasing the supply of water available to other users is $207 per af.

Albuquerque initiated a city-wide conservation campaign in June of 1994. Since that time, numerous steps have been taken to educate the public on wise water usage. In 1996, the City implemented a low-flush toilet rebate program. A residential water audit was planned to begin in late 1996. The cost and effectiveness of these efforts remain to be determined.

Market Distortions from Federal Programs. All of the values described in the preceding paragraphs are heavily influenced by federal investments, especially those of the BuRec and the Corps of Engineers (CoE); regulatory actions, such as those of the Environmental Protection Agency and Fish & Wildlife Service, and the numerous programs that affect human activities in the Basin. In effect, these federal expenditures have altered the prices that all consumers pay for the Basin's water-related goods and services. In some instances, the price distortions occur through deliberate action, such as reducing the costs of federal projects allocated to irrigators. In others, they occur because a federal project, regulation, or program affects a bundle of goods and services, many of which have free-rider characteristics. A dam built to provide water for irrigation, for example, also can affect the risk of flooding for homeowners in the floodplain, the availability of recreational opportunities, and the integrity of the ecosystem. Furthermore, flood protection for one parcel in the floodplain also is available to its neighbors, and society as a whole generally shares access to the recreational

opportunities and the benefits of ecosystem integrity. With such a web of unintended consequences, federal policies and actions have pervasive and, in many cases, unavoidable impacts on prices.

The most apparent and immediate market distortions affect diversionary uses of water and related resources. In the absence of federal expenditures for water-development and flood control, local water users and property owners, not federal taxpayers, would bear the full financial burden and, hence, pay a higher price whenever they divert water from the river, or develop in the floodplain.

Economic theory, as well as empirical evidence, strongly suggest that, if water users had to pay the full costs of the federal facilities and programs, they would curtail their water use in response to the higher prices. Most of the curtailment would occur in irrigation, which accounts for more than 80 percent of water use in the Basin. The estimates discussed above indicate that farm businesses pay a small portion, perhaps less than 20 percent, of the cost of water derived from BuRec projects and they consequently use the water on lands with relatively low productivity and crops with relatively low value. If these farm businesses had to pay the full cost, much of this land would be withdrawn from production and the land remaining in production would be dedicated to higher-value crops.

Similar reasoning applies to urban residents and businesses: if they had to pay fully for the benefits they derive from federal facilities and programs, they too would ration their water use more tightly. Because of federal expenditures, municipal and industrial water users do not see the full cost of the water they use for drinking, watering lawns, industrial processes, or countless other uses. For users who rely on groundwater and bear the associated drilling and pumping costs, the impacts of federal expenditures on water consumption probably are less pronounced than for users who rely more heavily on surface water. Federal expenditures on flood protection encourage urban development in the floodplain that probably would not occur if the local communities had to bear these costs fully.

Farmers and urban water consumers are not the only ones affected by the market distortions of federal policy. Anglers and other recreationists have incentives to seek a greater supply of recreational opportunities and to avail themselves of these opportunities more frequently when they do not have to pay the full cost of producing them. Residents and visitors who prize the scenery and other amenities of a river/riparian ecosystem or of irrigated

green pastures in the desert would demand less of them if they bore the full cost, as would advocates of protecting the intrinsic value of river-related resources.

When there is competition for resources, of course, a federal policy or action that creates incentives for one competitor generally creates an offsetting disincentive for another. In particular, as these policies and actions traditionally have encouraged irrigators and urban consumers to use more water, they have reduced the water available for those with a preference for the goods and services derived from instream flows and a natural ecosystem. More recently, as federal policies and actions increase the likelihood that those preferring protection for endangered species and the ecosystem will have their preferences satisfied, they often do so at the expense of consumptive users, especially farmers, who account for most water consumption in the Basin. Given the complex set of goods and services derived from the Basin's natural resources, the growing competition for them, and the pervasive federal influence on the competition, *any* decision regarding these resources affects the composition of incentives and disincentives affecting the different competitors.

The market distortions from federal policies and actions trigger all sorts of responses by competitors for the Basin's water and related resources: understandably, those who benefit from a particular policy or action try to protect it, while those who don't benefit try to have it reversed or to strike a deal with the beneficiaries. In theory, it is possible for the different groups to compete among themselves and find ways for resources to move from low-value uses to high-value ones. To some extent, such maneuvering occurs. This past year, for example, saw extraordinary efforts to avoid potential environmental disasters by increasing instream flows in southern Colorado and the Middle Rio Grande Valley with water that otherwise would have been used or reserved for consumptive use. By and large, however, the existing economic, legal, and resource-management institutions are sluggish and considerable resources remain in low-value uses.

D. Summary

The Upper Rio Grande Basin is home to a complex set of interrelated physical resources. Powerful economic forces drive the competition for these resources. Traditional or early economic forces imposed limited and simple competitive pressures on the resources: water was extracted for agricultural production and the needs of small settlements. Over time, however, the

economic forces at play in the Upper Rio Grande Basin, as elsewhere, changed and developed. As the economy changed some demands for particular goods and services grew, and others diminished. Currently, the traditional sector remains relatively steady, but the urban sector has grown tremendously. With this growth comes demand to use more resources for industrial and residential consumption. The growing demand for the Basin's resources from urban residents conflicts with the traditional demands from Pueblos, acequia communities, and those in the agricultural sector. Traditional interests want to secure their historical rights, urban interests want to secure rights to meet their increasing municipal and industrial needs, and environmentalists want to secure uses created by the river's natural flows.

The rigid legal and institutional framework that guides current water policy in the Basin was designed and set in place when the resources faced limited and simple competition. This framework cannot adequately address the current competitive pressures. As a result, water and related resources in the Basin are allocated suboptimally and, from an economic perspective, this misallocation leads to economic distortions that create powerful economic forces for change.

No comprehensive study of the dislocations stemming from federal policies and actions has been undertaken. This chapter's discussion of the competition for resources and the relative economic values of different resource uses indicates that the most severe economic dislocations occur when federal policies and actions (as well as other factors) create incentives for water to be used to produce agricultural products whose value is less than the full cost of producing them. In the urban sector, similar distortions favoring water consumption are apparent primarily in the two major metropolitan areas, Albuquerque and El Paso, which have a history of consuming water at rates that deplete aquifers and do not reflect the full costs of securing replacement surface water. The extent of the distortion probably is greater in Albuquerque, insofar as its pricing structure has given less attention to water's true scarcity and per capita water consumption exceeds El Paso's by more than 40 percent.

On the flip side of the coin, the strongest evidence of market distortions disfavoring competitors occurs regarding the benefits of instream flows. The studies showing marginal values for instream water exceeding marginal consumptive values and households' significant willingness to pay for the benefits of somewhat higher instream flows in some areas support the conclusion that, but for the absence of appropriate institutional mechanisms,

greater amounts of water would be devoted to instream flows. The greatest forgone benefits occur where the demands for ecosystem integrity, recreation, and amenities are highest: near population centers and transportation corridors, and in locations with generally high recreational and amenity attractions.

There are strong reasons to believe that the distortions will increase in the absence of significant institutional change to allow resources to shift from low-value to high-value uses that may or may not be measured in monetary terms. Among these are warnings of marked disruption of ecological functions, projections of rapid population growth—especially in metropolitan centers—and forecasts of accelerating change in the Basin's economy as traditionally important sectors stagnate or decline and new sectors expand.

Chapter 3

An Overview of the Basin's Resource-Management Problems

In this chapter we summarize the major problems associated with the growing competition for water and related resources in the Upper Rio Grande Basin. The biggest challenge in this endeavor arises because there are so many problems, all deeply intertwined, that it becomes impossible to demonstrate cleanly where one stops and another starts. We sort through this confusion in a manner that we believe is conducive to the evaluation of alternative policies and actions for resolving the problems. We recognize, however, that our definition of individual problems and our depiction of how they relate to one another are necessarily somewhat arbitrary, and recommend that the reader consider our discussion of individual problems not in isolation but only in the larger context.

Whatever the approach for describing and evaluating the problems, one first must define the criteria for determining if a problem exists and for measuring its severity. We use criteria derived from the principles of economics and our analytical framework, described in Chapter 2, for assessing the competition for water and related resources in the Basin. The outcome from this competition will be optimal if:

Criterion #1: The resources are used in the manner that yields the highest net value for the bundle of goods and services derived from the resources.

One must look not just at the value of goods and services directly derived from a particular use but also at the concomitant effects on the competing demands for each resource. We describe this comprehensive scope in the discussion of Boxes 1-4 in Figure 2.1. In the optimal case, allocation and management decisions yield the highest sum of the net value of the goods and services produced currently plus the net present discounted value of the future goods and services whose production is determined by current decisions.

The preceding paragraph illustrates a difficulty inherent in this study: one cannot discuss the competition for scarce resources in this Basin without using concepts and words that are ambiguous and controversial. As we explain below, the competition for these resources is intense and rests on a history that often has been bitter. In this setting, the groups vying for the resources often adopt words, such as resource "use," "value," "allocation," and "management," as code words meaning one thing to one group and quite a

different thing to another. We use these and other potentially hot-button terms not because we are siding with any group but because we must. They are mainstays of economic discourse on the competition for scarce natural resources and we use them strictly within this analytical context.

We employ the term, "use", to refer not just to conventional uses associated with physical manipulation of the resource, such as withdrawing water from the stream for irrigation, but also to more passive uses, such as recreation or maintaining riparian habitat, that entail leaving water in the stream. Consistent with this approach, we also take a broad view of the term, "value", employing it to refer not just to preferences for goods and services measured in monetary terms, such as bales of hay produced from irrigated fields, but also to those that are not monetized, such as recreational opportunities and spiritual fulfillment derived from some streams. We also use the terms, "allocation" and "management" in a broad sense, referring to all aspects of private and public decisions that inevitably have allocative and managerial consequences for the use of the Basin's resources.

Criterion #2: The resources are used in the manner that yields the highest standard of living.

Although many factors contribute to the standard of living, the impact of alternative resource uses on standard of living typically is estimated by looking at three factors: the number of jobs, level of income, and quality of life. In the optimal case, the impact on all factors would coincide so that the best alternative would yield the most jobs, highest income, and best quality of life. In reality, one alternative might dominate for one or more factors but not for all. Hence, applying this criterion entails making judgments weighing each alternative's aggregate impact on the standard of living.

Criterion #3: The resources are used in the manner that is perceived to be fair.

The assessment of fairness is a complex task that generally entails making a subjective comparison of the benefits and costs individuals or groups are entitled to receive from a given resource use against the benefits and costs they actually receive. Issues of fairness embrace the allocation of benefits and costs among groups within the current population as well as between the current population and future generations. In the optimal case, there would be agreement about the fairness of the allocation and management of the

Basin's water and related resources. In reality, there is widespread disagreement about who is entitled to what and, hence, about the fairness of the actual distribution of benefits and costs among different parties.

Where these criteria are not met a problem exists with the total amount of economic benefit derived from the Basin's water and related resources, the distribution of these benefits, or both. Where the deviation from the criteria is severe, so is the problem.

These criteria are useful insofar as they focus directly on the outcomes of the competition for the resources, have a solid foundation in the concepts of economics, and, where sufficient information exists, lend themselves to measurement. They are less than ideal, however, insofar as the conclusions one draws from applying them to the Basin can vary, depending on one's perspective. If the beneficiaries of a resource-management practice take a narrow perspective, they probably will conclude that, for them, it yields the greatest value, produces the highest standard of living, and is fair. Those who do not share the benefits, but instead incur costs, probably will reach the opposite conclusion. Those taking a broad, societal perspective, probably will reach a conclusion that lies somewhere between these two extremes.

The different perspectives of benefits and costs are inseparably linked to the political feasibility of resource-management decisions. Someone who will suffer immediate and direct short-run costs from a decision is likely to oppose it vociferously, while someone else seeing less tangible benefits materializing over a longer period is less likely to feel compelled to offer strong support. In other words, without a conscious corrective effort, there can be a strong tendency for resource-management decisions to be influenced most by short-run concerns, with the result that the decisions lead to less than ideal outcomes.

Commensurate with our charge from the Commission, we take a broad perspective and apply the criteria from a federal, or national, perspective. That is, we evaluate the outcomes from the competition for water and related resources in the Basin in terms of the value of the goods and services available to all Americans, the standard of living for all Americans, and the fairness to all Americans.

We separate the problems into two sets. We first describe two problems that represent the most serious, fundamental aspects of the past and current failure to meet the three criteria described above. We call these the

bottom-line problems. One of them focuses on the resources themselves, and the other on the economies and communities dependent on the resources. We then describe several of the factors that create, exacerbate, or prevent mitigation of the bottom-line problems. We call these the contributory problems.

A. Bottom-Line Problems

There are two bottom-line problems associated with the management of water and related resources in the Upper Rio Grande Basin. One arises because, although the ecosystem embracing these resources has a finite ability to produce goods and services for human consumption, the demand for these goods and services does not fully recognize these limits. As a result, some of the resources of the Basin are being exploited and degraded at unsustainable rates. The second arises because the economies and communities of the Basin every day forgo opportunities to use the water and related resources to create higher levels of economic benefits and to distribute these benefits in a manner that many would consider fair. Both of these problems represent less than ideal outcomes for the national economy.

A.1. Bottom-Line Problem #1: The Resources are Finite, but the Demands are Not

The Basin's water and related resources are components of, and produced by an ecosystem.[1] This ecosystem, like all others, has limits on how much water and other resources can be extracted from it at any particular place and, hence, the ecosystem's ability to support and sustain humans is limited. Biophysical scientists sometimes refer to these limits as the ecosystem's carrying capacity. This carrying capacity can change over time in response to three factors: changes in the ecosystem, such as those that occur when species become extinct; changes in human behavior, such as the adoption of resource-conservation technologies; and changes in the larger global climate, such as an increase in temperature and aridity.

[1] An ecosystem is the community of organisms and their physical environment that interact as an ecological unit (Salwasser et al. 1993). The ecosystem of the Upper Rio Grande Basin comprises numerous smaller ecosystems. To facilitate the discussion, we generally do not enumerate the smaller ecosystems, but speak of the Basin's overall ecosystem or of large subsets, such as the riverine-riparian ecosystem.

Within the past decade or so, at least some of the edges of the ecosystem's carrying capacity have become more clear. For example:

a. The Risk of Drought.—The Basin experienced an extremely low snowpack in the upper elevations during the 1995-96 winter. This caused widespread consternation throughout the Basin and reminded residents that there always is a substantial risk that the Basin will experience drought. Detailed weather records from the past several decades as well as the general historical record from the mid-seventeenth century indicate that the area experiences a major drought every 20 to 25 years (Finch and Tainter 1995a). The Basin previously had not seen drought conditions for about 15 years, and it has not seen a prolonged period with consecutive years of drought since the 1950s. Given the high rate of immigration, a substantial portion of the current population has no memory of earlier droughts in the area.

b. Unsustainable Use of Groundwater.—Nearly all urban uses of water rely on groundwater. The Basin's two major metropolitan areas, the Albuquerque area (population about 650,000) and the El Paso-Ciudad Juarez area (more than 2 million), have bumped against the limits of the supply of readily accessible, potable groundwater. Residents of each area once believed they sat atop an aquifer holding an amount of water roughly equal to one of the Great Lakes. Accordingly, each area pumped water, built houses, and grew an economy as though, despite living in a desert, water was not scarce. In the past decade, however, each area has realized that the amount of readily available, potable groundwater is much smaller than previously expected and that it has been overdrafting the aquifer for decades. For some of Albuquerque's wells the water table dropped more than 150 feet during the past 30 years. If mining of the groundwater continues at recent rates, the supplies of water available with low pumping and treatment costs would be exhausted within a few decades.

Although Albuquerque and Ciudad Juarez continue to obtain water solely from the aquifer, El Paso now draws about 40 percent of its water from the aquifer. El Paso and Albuquerque have embarked on campaigns to encourage water conservation and are developing plans that include substituting surface water for groundwater (City of Albuquerque Public Works Department 1996; Rebuck 1993). El Paso also has initiated desalination projects to derive drinking water from groundwater with a high salt content.

c. Ecosystem Degradation.—Parts of the Basin's ecosystem are under extreme stress. The river below Elephant Butte Dam has been extensively canalized and exhibits little of the habitat characteristics that existed prior to the development of industrial agriculture in the area (Pittenger 1992). The closure of dams in this reach, dewatering of the river bed, degradation of water quality, and channel-maintenance activities, such as vegetation removal and mowing, have severely compromised the biological integrity of the plant and animal communities that historically occurred in this reach. The loss of 71 percent of the native fish species in this area indicates the severity of the impact.

In 1994 the U.S. Fish & Wildlife Service listed the Rio Grande silvery minnow as an endangered species, observing that the species, once prevalent throughout the Rio Grande, now can be found only in some places in the Middle Rio Grande (U.S. Fish and Wildlife Service 1994). The minnow is the sole survivor of a guild of five similar species that once inhabited the Rio Grande. In the Middle Rio Grande half of the original fish fauna have disappeared. Between 1918 and the 1980s this area has experienced the elimination of all the saltgrass meadow (48,603 acres), and nearly half (17,498 acres) of the timber and brush dominated by cottonwoods, and seen 17,833 acres become dominated by exotic species (Crawford et al. 1993b). Much of the riparian cottonwood forest, known as the bosque, is now functionally detached from the river and will experience marked change under current resource-management practices (Crawford et al. 1996).

d. Global Climate Change.—The prospect of global climate change promises to exacerbate the demands for water and related resources in the Upper Rio Grande Basin. Models of global climate predict that the accumulation of carbon dioxide and other greenhouse gases will produce global warming and other climatic changes over the next century. There is no single way to show the potential effects of these changes, but one study highlights the potential impact. Drawing on a large body of past research showing that the price of agricultural land is related to the net earnings farmers expect to derive from the land in the foreseeable future, Robert Mendelsohn and two co-authors estimated the potential impact global warming would have on the farmers' net earnings and, hence, on the price of agricultural land (Mendelsohn et al. 1994). They determined that a warming of 7^0 F, even with an 8 percent increase in precipitation, would cause farm land prices to decline by $200–450, and perhaps by as much as $1000 per acre (1992 prices) throughout most of the Upper Rio Grande Basin.

e. Human Population Growth.—The Basin is expecting rapid population growth. Projections from the Census Bureau for New Mexico indicate the state's population is expected to grow by about 1 million people (55 percent) between 1995 and 2025. Most of this increase is expected to occur in the Rio Grande valley and primarily in the Middle Rio Grande area (Parker 1996). The City of Albuquerque anticipates that its demand for water will grow from the current 125,000 acre-feet per year (af/yr) to almost 300,000 by 2060 unless the City can reduce per-capita usage by 30 percent (City of Albuquerque Public Works Department 1996). Even if it meets this target, demand will exceed 200,000 af/yr.

f. Declining Water Quality.—Many locations within the Upper Rio Grande Basin have either encountered declines in the quality of the readily available water supplies or recognized the threat that such declines may materialize in the foreseeable future. Analysis of water quality data by the Clean Rivers Program of the Texas Natural Resource Conservation Commission identified fecal coliform and salinity as a "concern" in portions of the Upper Rio Grande Basin (Texas Natural Resource Conservation Commission). Past spills of trichloroethylene (TCE) and other toxic substances have polluted some of the groundwater in the Albuquerque area, causing the City to shut down some of its wells (City of Albuquerque Public Works Department 1996). Septic systems in much of the most heavily populated areas of the Middle Rio Grande area have polluted the shallow aquifer and in some places the pollution has the potential to migrate into the deep aquifer. Similar septic problems occur elsewhere in the Basin, including in the unincorporated communities, known as colonias, near
El Paso (Borja 1996).[2] Naturally occurring arsenic in water from some of Albuquerque's wells would fail to meet the new drinking water standards for arsenic being considered by the Environmental Protection Agency. Water users near Taos fear that discharges from mining sites contain toxic materials, and Indians in northern and middle New Mexico fear that the degraded quality of water in the river interferes with important cultural practices requiring clean water.

There is considerable concern that surface water and groundwater south of Elephant Butte are subject to contamination by agricultural nutrients or pesticides and by untreated sewage. Flows in the El Paso-Ciudad Juarez

[2] Colonias are rural communities that lack basic infrastructure including water, electricity, and waste services. Although colonias have existed for more than 100 years, they now number almost 1,500 communities with 360,000 residents in Texas. New Mexico has about 32,000 people living in colonias (Borja 1996).

area are dominated by municipal wastewater effluent during low-flow periods and may pose a threat to human health (U.S. International Boundary and Water Commission et al. 1994). They also increase treatment and other costs for downstream water users. El Paso is seeking to construct a pipeline and take other actions that would enable it to obtain water with fewer pollution problems from farther upriver and to prevent relatively clean water from being polluted by irrigation return flows. The El Paso County Water Improvement District (EPCWID) diverts more water from the Rio Grande than its contract with the BuRec allows in an effort to dilute the dissolved salts in its return flows (U.S. Department of the Interior 1995a). A water quality study conducted by U.S. and Mexican state and federal agencies identified the area downstream of El Paso-Ciudad Juarez as having high potential for toxic chemical impacts on aquatic health (U.S. International Boundary and Water Commission et al. 1994).

A.2. Bottom-Line Problem #2: The Basin's Water and Related Resources are Persistently Allocated in a Manner That is Less Than Ideal

If the water and related resources of the Upper Rio Grande Basin were allocated in a manner consistent with the ideals of competitive markets, then market forces would ensure that these resources would be allocated to those who place the highest value on them. As the economy changes over time, some demands for a particular resource would grow, others would diminish, and the allocation of resources would shift accordingly and quickly through multiple transactions and exchanges. Reality, however, is far different from this ideal. The values of many goods and services derived from the resources are not easily expressed in monetary terms or traded in market-like transactions. Some demands that reflect a relatively low value for a resource have legal preference over others that reflect a relatively high value, and these preferences are enforced—some more rigorously than others—by a complex web of treaties, laws, contracts, and institutions. As a result, the local, regional, and national economies forgo valuable goods and services as well as incremental increases in the standard of living. Many assert that the system is grossly unfair.

The evidence for these conclusions is broad, but mostly indirect. One must rely on indirect evidence both because the relationship between the economy and the resources is complex and because there are few data for directly

measuring the current resource-management and allocation system against alternatives. Some of the major elements of the relevant evidence include:

a. Prevailing Prices Don't Tell the Economic Truth.—Under the ideal, competitive-market conditions that generally serve as the basis for the American economy, prices play a special role. The prevailing prices for a resource signal the degree of scarcity for the resource and encourage its efficient allocation. A scarce resource is used efficiently when it is used in the manner that yields the highest-value bundle of goods and services for society. If it is used for one use rather than for higher-value alternatives, then the outcome is inefficient and the overall economic well-being of society is lower than it could be. If the prevailing prices for the Basin's water and related resources resembled the competitive-market ideal any owner of a resource readily could determine if a would-be buyer values the resource more highly than she does and, if so, relinquish ownership in exchange for compensation. Numerous arm's-length transactions would yield an equilibrium market price and ensure that, at the margin, this price equals both the amount potential buyers are willing to pay to acquire the resource and the amount potential sellers are willing to accept as compensation to be deprived of the resource.

For most, if not all, of the water and related resources of the Upper Rio Grande Basin, the market does not work at all efficiently and prevailing prices do not tell the economic truth about either the overall scarcity of the resources or the strength of one demand relative to another. There are few arm's-length transactions. Resource users generally do not pay compensation to those who are deprived of its use, and many water users pay nothing for the resource, per se.[3] That is, the price they pay to use the resource is independent of the degree of scarcity. In some cases they have free access to the resource, as when a rancher allows cattle to drink water from a stream that passes through his property, a city resident strolls along a stream

[3] The initial appropriators of water paid nothing for the water, per se, and the holder of a water right similarly pays nothing when the value of that right increases. When someone purchases water rights, however, we reasonably can conclude that he has paid something for his use of the resource, as when a farmer pays more to buy land with appurtenant water rights than for similar land without, or a rancher pays more to rent a pasture that has stream water than for one that does not. Also, city water users pay something for the water when a city purchases a water right from a farmer and folds this cost into municipal water rates. One should not, however, read too much into these examples. If pricing mechanisms were functioning in the Basin, one would see evidence of higher prices during dry years, when water is more scarce, and lower during wet years.

bank, or a rafter floats down a river. More common, users pay nothing for the resource but only for the cost of conveying the water from one place to another, as when irrigators pay levies to cover the cost of building and maintaining ditches, landowners pay taxes to cover the costs of flood protection, or city dwellers pay rates that cover the costs of wells and pipes.

In most instances, the pricing of conveyance costs distorts things even further. Although most of the water used for irrigation by farmers in New Mexico and Texas is available to them only because of the upstream federal dams, they pay far less than full market value for those portions of the dams' costs that are allocated to irrigation, and nothing for those portions allocated to non-irrigation purposes, such as flood-control. Farmers in Colorado and New Mexico use large amounts of water that would not be available to them if the federal government did not help each state meet its Compact obligations, and yet the farmers pay a fraction of the federal government's costs. The disparity between the price a farmer pays for water and the cost of delivering the water is especially important because irrigation accounts for about 80 percent of the major water uses (typically associated with withdrawals and diversions) in the Basin (Ellis et al. 1993). The size of the disparity has not been estimated for the Basin, but some estimates derived from data for all Bureau of Reclamation (BuRec) projects provide a frame of reference. A recent summary of studies reported that a 1975 study found the disparity was 82 cents of every dollar of BuRec costs, and a 1982 study found that the disparity was about $50 per acre foot (in 1996 dollars) delivered from a BuRec project (Secretary of the Interior 1994).

Farmers are not the only ones paying less than the full costs of water-management facilities. Urban water consumers who derive benefits from projects, such as the one that diverts water from San Juan Basin into the Upper Rio Grande, pay far less than the projects' actual costs. Recreationists using the Basin's reservoirs pay little or nothing to cover the cost of establishing and maintaining them. Landowners in the flood zone pay little, if anything, for the costs of the flood-control structures and maintenance activities. Advocates of resource conservation similarly are not confronted with the full costs of satisfying their desires.

In the absence of prices—or some appropriate substitute for prices—that reflect the true degree of scarcity for the Basin's water and related resources, these resources are not used efficiently. Instead, those who have access to the resource have a strong incentive to use more of it than they would under competitive-market conditions and some potential users who place a higher

value on the resource see their demands go unmet. Although those who enjoy the use of resources at prices less than the true costs associated with the use undoubtedly also enjoy a standard of living higher than they would if this disparity were erased, the nation's overall standard of living is diminished.

b. Water and Related Resources Are Not Just Private Goods, But Also Public Goods.—Many factors underlie the absence of competitive- market conditions for the water and related resources of the Upper Rio Grande. One is that the resources are not strictly private goods, subject to full control and disposition by the owner, but have a strong public-good character.[4] The water rights for water flowing down the river bed or canal may be the property of a private landowner, for example, but this flow might generate economic benefits or costs for others in the general public by increasing the risk of flooding, opportunity for fishing, or aesthetic quality of nearby residences. Economists call these benefits or costs public goods (if positive, or public bads, if negative).

America's economic and legal systems have not yet devised a good mechanism that allows the public to express their demands for public goods in a market setting. Owners of rights to use resources often make decisions about the use of the resource as part of their attempt to maximize their earnings from the resource, overlooking the public-good consequences. In some instances, decisions to maximize private earnings can yield results that are optimal from the public-good perspective, but this is not necessarily the case. In most instances, the outcome is suboptimal, or less than ideal, and society is deprived of goods and services that are more valuable and of contributions to a standard of living that is higher than those derived from the current uses of the resources.

The legal and economic systems are not, however, unaware of the tension between the private-good and public-good aspects of water and related resources. Water rights, for example, embody this tension insofar as they are limited property rights that give the holder rights to use water within functional and geographic boundaries and subject to supervision by the state, and the state exercises its authority based, in part, on its obligation to protect the public interest. Historically, there was little tension between the state's public-interest obligations and the prior-appropriation doctrine that is

[4] Public goods are also known as free-access goods or free-rider goods. All these terms refer to goods—and services—where the consumer cannot obtain them through a transaction that allows her to exclude others from consuming them.

the general basis for water law in the Basin. Under its early application, the prior-appropriation doctrine allowed that a water right generally existed only insofar as the holder diverted water from the river and put it to beneficial uses. Over time, however, the tension has mounted as society has acquired greater understanding of the environmental and economic consequences of actions taken under the prior-appropriation doctrine and placed increasing value on the public goods derived from water, such as clean water, fisheries, recreation, and environmental quality (Bates et al. 1993; Ingram and Oggins 1992). Water-rights holders, environmental advocates, water-management institutions, public leaders, and courts are searching for ways to relieve the tension, but the economic forces we describe throughout this report indicate that the tension will continue to increase and the only meaningful option is to find reasonable, workable ways to manage it.

Given the emphasis on promoting competitive markets in the American economy, there often is a temptation to conclude that things traded in markets are more important than those that are not. This temptation should be resisted as it applies to the Basin's water and related resources. Although there is no comprehensive assessment of the value society places on the public-good aspects of the Basin's water and related resources relative to the private-good aspects, several recent studies indicate there is good reason to believe that, in some places and times, public-good values are equal to or exceed the private-good values. Three recent studies provide some useful insights.

The first study, a 1990 analysis published by the Economic Research Service of the U.S. Department of Agriculture, compared the economic values of different water uses in the Upper Rio Grande, from the river's headwaters through El Paso County (Hansen and Hallam 1990). In particular, the authors conducted a marginal analysis, i.e., they focused on what would happen to the net value of the bundle of goods and services derived from water if a small, additional amount of water were used for irrigation or, alternatively, for recreational fishing. They found that the marginal value of increasing the supply of water for irrigation is zero, but the marginal value of increasing the supply for angling is about $100 per acre-foot (af).

The second study, conducted nearby in Colorado, looked at the potential increase in the total value of the bundle of goods and services that occurs when water is shifted from agricultural to urban uses (Booker and Young 1994). The authors specifically compared the consumptive aspects of agricultural and urban uses, which roughly correspond to private goods, with

the nonconsumptive aspects, which roughly correspond to public goods. They concluded that the consumptive and nonconsumptive values were about equal. These findings probably are transferable, more or less, to the Upper Rio Grande Basin. They certainly support the conclusion that, insofar as decisions regarding the use of water in the Basin are based solely on the private-good aspects of the resource, the value of the bundle of goods and services derived from the water probably is substantially less than what would exist if the decisions were based on both the private- and the public-good aspects of the resource.

The third study reinforces this conclusion further by showing directly that New Mexicans place considerable value on the public-goods associated with instream flows (Berrens et al. 1995). In response to survey questions regarding a hypothetical policy to protect instream flows beneficial to the Rio Grande silvery minnow (RGSM), New Mexicans indicated that, on average, they are willing to pay $30 per year for five years to support the policy.[5] They also indicated a willingness to pay $79 to provide instream flows in all of the state's major rivers. The amount specific to the Middle Rio Grande area, where the last populations of RGSM survive, multiplied by the state's 580,000 households, indicates the total willingness to pay for instream flows is about $17.4 million per year and $87 million over five years. These results do not apply solely to the RGSM, however, because, although the survey informed respondents that, in addition to benefiting the RGSM, instream flows also would support other fish and wildlife, vegetation, and habitat, as well as recreational and viewing opportunities. Higher instream flows also might yield additional economic benefits, including improved water quality, filtration of sediments, and a reduction in the likelihood that other species using the river's habitat will become threatened or endangered

c. Resource-Management Institutions Generally Show a Strong Bias Favoring Commodity Uses.—[6]Most of the laws and institutions governing the management and use of the Basin's water and related resources have their

[5] Residents living outside the state are also likely to place a value on instream flows beneficial to the RGSM, although the magnitude of this value has not been estimated.

[6] Some individuals object to the term, bias, believing that it connotes disreputable intentions. We strongly disavow such connotations and use the term in its strict economic sense, expressing a tendency that has meaningful implications for the value of the goods and services derived from the Basin's water and related resources, the impacts on the standards of living and components of local economies in the Basin, and on the distribution of costs and benefits among different groups. Insofar as there is a tendency toward suboptimal outcomes with respect to one or more of these evaluative criteria, the resource-management institutions yielding these outcomes are said to be biased.

roots in past eras when the economic demands for those resources were very different from those that exist today. And those of today almost certainly are different from those that will materialize in the future. Insofar as the laws and institutions have not adjusted to these changes, they can restrict the ability of resources to shift from old demands to new ones. As a result, while they protect those who benefit from the conventional uses of the resources, they deny other households and firms in the local area, region, and nation of opportunities to have more jobs, larger incomes, and higher standards of living. The net effect can be like a tax imposed on those associated with the new demands for the resources.

The Basin's resources undeniably are the source of important commodities, including water for irrigation and human consumption, forage, and timber. In the distant and not-so distant past it was easy to believe that converting resources into commodities was the best—often the only—way to derive economic benefit from them. Today, though, it is clearly apparent that Americans derive value from these resources in other ways (Power 1996). Important categories of non-commodity values include:

- Spiritual values associated with the resources' contribution to spiritual well-being as often irreplaceable sacred places and their role as religious symbols.

- Quality-of-life values stemming from some people's preference for natural scenery, unpolluted surroundings, and a resource-oriented lifestyle.

- Environmental and recreational values reflecting the importance some people place on having access to high-quality water, hunting and fishing opportunities, and general outdoor activities.

- Ecological values that recognize the role of conserving habitat integrity and protecting threatened and endangered species, if society is to accomplish goals of ecological and economic sustainability.

Analytical paradigms built on a foundation of commodity production and monetary quantitative techniques do not easily lend themselves to the assessment of all these categories of values. The difficulties are perhaps most apparent with respect to groups, such as the Basin's Native Americans and Hispanic populations, who have ways of life that do not place the same emphasis on industrialization and monetization as does the mainstream

American economy. But they also apply to groups who generally are considered part of the mainstream, including ranchers and farmers seeking to maintain a way of life they and their families have pursued for decades, as well as resource-conservationists seeking to arrest and reverse the adverse consequences that way of life imposes on the environment.

Resources will continue to be inefficiently allocated to commodity uses as long as most of the rules, laws, and institutions governing the Basin's water and related resources implicitly or explicitly favor commodity-related demands for these resources over other demands. There are many examples of laws and institutions with commodity biases. Virtually all of the reports from the federal, state, and local agencies responsible for managing the Basin's water focus solely on commodity uses of the water or mention non-commodity uses as an afterthought. The majority of all of the responses by the agencies' staff to our questions about their perceptions of the problems associated with the growing competition for the Basin's scarce water and related resources had a similar character.

The existence of the three agencies that have the greatest control over resources in the Basin—Bureau of Reclamation (BuRec), Army Corps of Engineers (CoE), and Middle Rio Grande Conservancy District (MRGCD)—stems from construction projects oriented toward commodity uses of water and their current activities that are organized around the operation and maintenance of these projects. They continue to operate their major dams and reservoirs according to rules set as far back as 1916 (see Table 3.1), even though ecological conditions have changed dramatically since then (Crawford et al. 1993a). Although there have been important efforts in recent years to the contrary, these agencies' overall operations continue to be highly oriented toward commodity uses and to downplay the non-commodity values described above.

There undoubtedly are many reasons for the fixation with commodity uses, but one of the most important seems to be this: water and food are essential to human life. The agencies' behavior suggests that, to a great extent, they have taken this irrefutable truth and concluded that human consumption and agriculture must have the highest priority for all water in the Basin. The merits of this conclusion are refutable. Without doubt, humans give supreme value to ensuring that their basic needs for water and food are met, but once they are, then the benefits of allocating more water to human

Table 3.1.—Principal functions of water-control facilities in the Upper Rio Grande Basin

Facility	Principal function	Completion date/ownership operation
Elephant Butte Reservoir	Irrigation, water-supply storage, recreation, hydroelectric power	1916/BuRec
El Vado Reservoir	Irrigation, water-supply storage, hydroelectric power	1935/MRGCD
Jemez Canyon Reservoir	Flood and sediment control	1954/CoE
Abiquiu Reservoir	Flood and sediment control, water-supply storage	1963/CoE
Galisteo Reservoir	Flood and sediment control	1970/CoE
Heron Reservoir	Water-supply storage	1971/BuRec
Cochiti Reservoir	Flood and sediment control, fish and wildlife, recreation	1975/CoE

Source: ECONorthwest with Crawford et al. (1993a).

consumption and agriculture fall and the costs rise. There can be no doubt that, for much of the consumptive use in the Basin, the costs now outweigh the benefits. Furthermore, some of the consumptive uses, such as depleting the groundwater, increase the probability that future generations will have difficulty meeting their basic needs.

The depletion, or mining, of groundwater raises concerns about the sustainability of resource uses in the Basin. Pumping groundwater faster than it is replenished is obviously not sustainable in a physical sense. From the perspective of economics, however, one might conclude that the level of economic well-being derived from the groundwater is sustainable if society were using it as part of an investment program to create technology, knowledge, or other forms of capital that could serve as a replacement when the groundwater is gone. Although some of the water undoubtedly has been used in this way, most has not. Instead, water prices markedly beneath the scarcity value of water have stimulated consumptive use of water rather than encouraged entrepreneurial pursuit of conservation technologies and other potential substitutes.

By concluding that the existing laws, rules, and institutions are biased toward commodity-related demands, we do not conclude that the entire system must be thrown out to facilitate shifting resources from low-value to high-value uses. The system can be made more flexible. Much of the effort devoted to the governance of water allocation has focused on guaranteeing certainty regarding allocation and, thus, encouraging private investment in resource-development. Many observers have concluded that the resulting laws and institutions do not necessarily have to result in the production of commodities (Bates et al. 1993). They argue that the legal framework does not require that water forever be put to original, commodity-oriented uses, but instead guarantees that those who first put the water to a recognized beneficial use can rely on the continuation of stream conditions regardless of who comes to develop water later. Thus, the tendency for resources to become voluntarily stuck in low-value uses when higher-value uses materialize is less the certainty of the law and more the inflexibility of its implementation. If instream flows were fully protected as a beneficial use, for example, conservation groups and recreationists would be able to use the legal framework the same as other water users by acquiring senior water rights, dedicating them to instream uses, and having those uses receive the same protections as others.

Some flexibility is already apparent. Standard practice within the Forest Service and Bureau of Land Management has long favored conventional uses, such as grazing and logging, over new competing uses, such as recreation and ecosystem restoration, but changes are occurring and more is promised (Dombeck 1996). Although each of the three states favors water uses that withdraw water from the stream over instream uses—with New Mexico the extreme case, providing no protection whatsoever for instream uses—officials in each state are seeking ways to afford greater instream protection. The International Boundary and Water Commission (IBWC), which previously held that its actions were considered beyond the reach of the nation's environmental laws, now acknowledges that it must comply with these laws. The CoE and the BuRec have broadened their focus somewhat to incorporate additional environmental concerns into their programs. The MRGCD has developed a *Water Policies* Plan that explicitly recognizes the importance of the public goods derived from its operations.

Much more flexibility is needed, however, if the Basin's legal and institutional structure is to make significant strides toward meeting the

three criteria we define at the beginning of this chapter. As long as actual resource allocations fall far short of these criteria, there will be strong economic pressures for change.

d. Ownership of Some Resources Remains Poorly Defined.—Markets require certainty about who owns the item being bought and sold. In some parts of the Basin, however, there is considerable doubt about who owns what. Numerous Native American claims on water and non-Indian federal reserved water rights, such as those for national parks, wilderness areas, and monuments remain unresolved and create deep and broad uncertainty regarding the claims of others. The probability that Native Americans and federal entities will receive legal substantiation that their claims predate and supersede at least some of the claims of others in at least some places within the Basin, can have a chilling effect on the establishment of markets for water rights. The failure to resolve these claims—especially those of Native Americans—also is regarded by many as grossly unfair.

Evidence of problems stemming, in part, from ambiguity of resource ownership is readily available. Over the past decade the MRGCD, for example, has diverted more water from the river, when it has irrigated less than 60,000 acres, than Congress authorized it to divert as part of the Middle Rio Grande Project in 1948, when it irrigated about 85,000 acres (Miller 1996). MRGCD, rather than leaving water in the river, asserts that it can divert enough water to irrigate almost 125,000 acres and, under some interpretations of New Mexico's water law, it must divert this water to solidify its water rights (DuMars et al. 1993).[7] In the spring of 1996, MRGCD diverted even more water than it had for the same period of time in the past decade (Miller 1996). Some of the diversions took all the water in

[7] MRGCD's diversion of water, despite the reduction in acreage, illustrates the limited nature of water rights and the opportunities for the state to exercise its authority to increase the efficiency of water usage. For a general discussion of these issues, see DeYoung (1993). The incentive for MRGCD to divert the water arises because the holder of a water right does not have absolute, perpetual control over the water, but can lose the water right if it is not continually exercised by withdrawing water from the waterway and applying it to a use legally recognized as a beneficial use. If the state determined that diverting water in excess of the needs of the approximately 54,000 acres being irrigated were not consistent with the public interest, it presumably would have the authority to prohibit excess diversions in the future. Furthermore, if it determined that it would be in the public interest to encourage irrigation technologies that use less water than the flood-irrigation that currently prevails, it presumably could restrict MRGCD's diversions even further.

the river bed, with the result that about 40 percent of the population of the endangered Rio Grande silvery minnow were killed, according to estimates by the Fish & Wildlife Service.

The situation is especially uncertain in the New Mexico and Texas portions of the Basin, where water rights have not been adjudicated. Adjudication processes are underway in New Mexico, below Elephant Butte, and in Texas, from the New Mexico border to Ft. Quitman, but final resolution of these processes is years away. They are made more complicated because of uncertainty about who owns the water made available from the BuRec's Rio Grande Project. BuRec claims it owns and has the authority and obligation to manage the water all the way to Ft. Quitman. The irrigation districts that were the local sponsors of the project claim that, insofar as their repayment obligations have been met or forgiven, they own the project's facilities and can control the water (Esslinger 1997). Texas asserts that, once the water passes into the state, it has absolute jurisdiction (U.S. Department of the Interior 1995a). Adjudication processes have not yet begun elsewhere in New Mexico's portion of the Basin, although the State Engineer currently is investigating the potential feasibility of alternative approaches for clarifying ownership in these reaches.

Without adjudication, or some acceptable substitute, water-right-holders, except those with the most senior rights, cannot fully know where their rights stand relative to the rights of others. In such a setting it becomes almost impossible for market forces to play a significant role in allowing and promoting open, fair, and voluntary transfers of water rights from low-value uses toward high-value ones. The problems associated with the lack of certainty about who owns what are pervasive. The State Engineer, for example, has written, "[U]ntil ownership and quantification are accomplished it is difficult to imagine making significant progress on issues of water quality" (Turney 1996).

Similar uncertainty exists throughout the Basin regarding assets other than water rights. Who, for example, owns the riparian resources of federal lands in the Basin? Although the administrative agencies, relying on legal precedent, conclude that their title to the resources is indisputable, others clearly dispute this claim (U.S. Department of the Interior 1994). Many argue that the owners of ranches that have held grazing permits over the years now have a de facto ownership interest in the resources and argue for making this interest de jure (Nelson 1995).

e. Resource Owners' Rights and Responsibilities Remain Ambiguous.— Owners of natural resources in the Basin have both rights regarding the use and disposition of the resources and responsibilities not to exercise these rights in ways that unreasonably restrict the rights—whether private or public— of others (McElfish 1994). There always has been controversy over the delineation between rights and responsibilities of owners of water and related resources and efforts to implement the Endangered Species Act and other resource-conservation laws in the Basin (and elsewhere) have highlighted the ambiguities underlying this controversy. It is generally acknowledged that, when an upstream property owner exercises her property right to degrade the water quality of a stream, she has a responsibility not to infringe upon downstream owners' property rights to have clean water. Does she also have a right to adversely destroy the water-related habitat needed by an endangered species, or the responsibility not to do so? If her neighbors already have destroyed habitat on their property, thus contributing to the endangerment, do they bear any responsibility for helping her maintain the remaining habitat on her property?[8]

Ambiguity about the rights and responsibilities of resource owners can seriously interfere with efforts to allocate resources efficiently. For example, it might create incentives for owners of resources that contain habitat for a species that might come under the protection of the Endangered Species Act to destroy the habitat deliberately in an attempt to escape the Act's restrictions. Learning more about the extent to which everything is connected to everything else within the ecosystem can decrease ambiguity in some instances, but increase it in others. Additional ambiguity can arise as ecologists develop a better, but still incomplete, understanding of how ecosystems work and develop the ability to show that actions modifying the ecosystem at one location can lead to changes elsewhere. Destroying (creating) some components of riparian habitat, for example, might drive

[8] The issues raised by these questions are not unique to endangered species and environmental protection. Analogous questions arise relative to extractive uses of water and related resources, e.g., under the prior-appropriation doctrine where one's rights do not necessarily relate to one's position on the stream. Instead, the doctrine says that a junior appropriator has a right to assume that stream conditions will remain substantially the same as when he first established his beneficial use. Thus, if a senior appropriator (who is, in every other way, dominant to the junior in exercising rights) wants to change the timing or place of diversion, or the type of use, this will be allowed only if it is determined not to harm any junior appropriator. Making these determinations can be difficult.

(attract) the species dependent on the habitat to relocate to (from) adjoining properties. It might also increase (decrease) the risk of flooding for downstream property owners (Reid 1993).

Our economic, political, and legal systems have not provided clear guidance about the rights and responsibilities in such instances. Nor do they provide market-like solutions for, first, determining the relative importance of public and private goods derived from water and related resources, and then, ensuring the resources are allocated commensurately. Things become complicated further as the evidence regarding the widespread extent of the ecological changes in the Basin seemingly outpaces the legal and institutional framework for managing the ecosystem and one ponders the current generation's rights and responsibilities relative to those of the future. All these factors reinforce the conclusion that persistent, less than ideal allocation of the Basin's water and related resources constitutes a bottom-line problem in the Basin.

B. Contributory Problems

In the preceding section we identify the two bottom-line problems and, in describing them, identify some of the major factors that contribute to them. Other factors also make important contributions to the bottom-line problems and we describe them in this section. Because the contributory problems are too intermingled to separate neatly, our definition of individual problems and our depiction of how they relate to one another is necessarily somewhat arbitrary and, hence, we encourage the reader to consider each of the problems only in the context of the others.

B.1. Contributory Problem #1: The Basin's Resources Have Not Been Managed as Elements of an Ecosystem

Ecosystems are "places where all plants, animals, soils, waters, climate, people, and process of life interact as a whole" (Salwasser et al. 1993). The water and related resources of the Upper Rio Grande Basin have never been managed as elements of an ecosystem, that is, they have not been managed to account fully for the interactions that occur among the "plants, animals, soils, waters, climate, people, and process of life" within the ecosystem. Each group that has moved, stored, and used water has done so without full recognition of the ripple effects on other resources and people who are part of

the ecosystem. The same observation applies to groups who have engaged in other resource-manipulation activities, including but not limited to urbanization, forest management, grazing, and road construction.

Failure to account for the ecosystem effects of individual resource-management activities has important implications for the competition for scarce water and related resources. In particular, it alters the supply of individual resources and increases the scale and scope of the spillover effects from each resource use. An extensive body of research shows that making resource-management decisions focusing on a single resource, such as water flows, can have wide-ranging and persistent effects throughout the ecosystem (Doppelt et al. 1993; Pacific Rivers Council 1996). These effects on the ecosystem can, in time, have feedback impacts on the resource itself, by altering the quantity and quality of the water, for example. They also are likely to impose wide-ranging and persistent costs on specific individuals and groups, and on the local, regional, and national economies.

Diverting a little water from the river for a short period of time might have little effect on the ecosystem and, hence, on the full set of goods and services humans derive from it. Diverting all the water for a long time, however, has had profound impacts on the ecosystem, especially when linked to correlated activities, such as draining of wetlands, altering of the hydrograph, and channelizing of the river bed.

The following statements, taken from the *Bosque Biological Management Plan* for the Middle Rio Grande (Crawford et al. 1993a) illustrate the impacts of past and current management activities on the ecosystem:

- *Hydrology is the primary factor influencing Middle Rio Grande aquatic habitat. ... Historically, the Middle Rio Grande has maintained periods of high, flooding flows and low, dessicating flows. ... Native aquatic species have adapted to survive these conditions until high flows reestablish habitat continuity and availability. Human influence often exacerbates the impacts of natural disturbances. The introduction of a water regulation infrastructure in the Middle Rio Grande has increased the potential for longer and more frequent periods of low flow and habitat fragmentation. The extent of channel dessication due, in part, to water regulation has been identified as a causative factor in the decline and extirpation of several Middle Rio Grande fish species [citations omitted].*

- *Currently there are about 20 species of plants and animals in the management area that, because of the apparent rarity or declining population trend, have state and federal designations such as 'endangered' and 'threatened.' In addition, there are several species which are designated as candidates for federal listing or have been determined by us to need special management considerations."*

- *[P]robably as a result of the construction of Cochiti Dam, the northern reaches ... Cochiti and Albuquerque ... of the Middle Rio Grande are now degrading. Because sediments are trapped at the dam, released waters have high potential for erosion and the channel is deepening. ... Comparison of 1935 to 1989 aerial photos indicates that the riverine, or river channel portion of the Middle Rio Grande, has been reduced by 49%. ... For native riparian plant species, there is little or no recruitment, except for banks and bars adjacent to the main channel of the river that are exposed after high flows. These areas may be scoured by the next high flows and are often subject to mowing to maintain the floodway.*

- *Poor water quality in the Albuquerque Reach may have contributed to low numbers of Rio Grande silvery minnow and to an overall reduction in fish abundance [citation omitted].*

- *If habitat is fragmented into isolated patches, any given patch may not be large enough to support the home range of certain wildlife species. Long distances between patches may preclude an area from supporting viable populations of desired species. ... Compared with riparian habitat downstream of Elephant Butte Reservoir, upstream of Velarde and on other southwestern rivers, the overall riparian zone along the Middle Rio Grande is relatively wide, intact, and unfragmented [but fragmentation] is occurring on the Middle Rio Grande at the plant community level. The anticipated continued decline in Rio Grande cottonwood-willow communities would lead to significant loss and fragmentation of this plant community in the foreseeable future. Fragmentation of the entire riparian ecosystem by private residential development is a concern.*

The authors of the *Bosque Plan*, who represent the University of New Mexico, U.S. Fish and Wildlife Service, BuRec, CoE, and New Mexico State University, also conclude that continuation of recent and current approaches to managing the area's resources would cause substantial,

further damage to the ecosystem. The consequences would include further: constriction of the preferred range of native, warm water fishes; decline and loss of native fish populations; reduction in water quality from the effects of sewage and runoff; reduced populations of a significant variety of vertebrate and invertebrate species; and local, if not actual, extinctions of invertebrate species inhabiting the banks of wetlands.

Arresting and reversing the widespread changes in the Basin's ecosystem will require a fundamental, systematic change in the public and private activities affecting the plants, animals, soils, waters, climate, people, and processes of life that are interacting within the Basin. Some significant corrective actions also will be required. Several recent reports highlight the importance of taking a broad approach to the management of aquatic ecosystems and the water and related resources within such ecosystems (National Research Council 1992; Pacific Rivers Council 1996).

There has been no coherent, sustained effort to initiate and institutionalize an ecosystem approach to resource management in the Basin. Some recent efforts, however, have attempted to address the ecosystem-management issues associated with some locations within the Basin. The largest of these began in 1992, with the pivotal assistance of Senator Pete Domenici, when an interagency team of scientists and a committee of concerned citizens initiated development of the *Bosque Plan* (Crawford et al. 1993a). The plan has no provisions for enforcement, however, and the results from this and other efforts remain limited and their potential impacts on future approaches to resource management remain uncertain (Finch and Tainter 1995; Shaw and Finch 1995).

B.2. Contributory Problem #2: Past and Current Practices Have Rendered Water and Related Resources Unsuitable for Some Uses Without Corrective Action

In most cases, the competing demands for the Basin's water and related resources are not contending over pristine resources. Some resources are naturally not suitable for all possible uses—some storm runoff into the Rio Grande, for example, has naturally high levels of sediment—and virtually all of the resources have been subjected to human manipulation for decades, even centuries. Some of the uses have been so intense that resources have become degraded in their ability to meet the needs of competing demands.

In some cases, restoring the ability of a resource to meet all competing demands is physically impossible; in others, restoration may be possible, but only at considerable economic and political cost.

This is particularly true with impacts on water quality. Water quality is not an absolute concept but a relative one that evaluates the usefulness of water based on its temperature, physical, and biological characteristics. In places where groundwater has been used to accept and dilute the effluent from septic systems or spills of toxic chemicals, for example, it can continue to be useful in this role, but it no longer is acceptable as drinking water. Either the water must be abandoned as a potential source of drinking water or costs must be incurred to render it useful for human consumptive use.

The special requirements of the Basin's tribes offer another example of where corrective action also is needed to render resources suitable for particular uses. The Isleta Pueblo was the first tribe to have water-quality standards certified by the Environmental Protection Agency under the Clean Water Act. These standards relate to the tribe's ceremonial use of river water and require the water to be suitable for personal contact and ingestion. Adoption of these standards, together with rapid population growth within its own city limits, has induced Albuquerque to promise to expand its sewage-treatment facilities and to reduce some pollutants and eliminate others.

Past studies of surface-water pollution in the Rio Grande have found uses impaired in portions of the Middle Rio Grande Area by nutrients, trace metals, radionuclides, biocides, volatile organic compounds, chlorine, pathogens, siltation, reduced riparian vegetation, and streambank destabilization (Fox et al. 1995). Uses also can be impaired in Texas, where there typically are 8-900 parts per million (ppm) of dissolved solids in the river near El Paso, and crop damage can occur when concentrations reach 1,000 ppm (U.S. Department of the Interior 1995b).

The Basin's riparian resources have been heavily altered and degraded in their ability to meet some demands. These resources are covered by the conclusions of a recent report by the Bureau of Reclamation, which observes that, "Extensive field observations in the late 1980s suggested that riparian areas in most of the West were in the worst condition in history ... [and these] areas will not recover on a large scale without changes in policy, regulations, and management ..." (U.S. Department of the Interior 1995b). The report

also identifies the following list of benefits from a properly functioning riparian community and implies that, until corrective action is taken to rehabilitate the riparian areas, society will forgo these benefits:

- Improved water quality
- Filtration of sediments
- Moderated streamflow (reduced flooding)
- Retention of water, thereby extending late-season flow
- Restoration of perennial streamflow
- Recharge of ground water
- Protection from accelerated erosion
- Aggradation or maintenance of high water table
- Increased recreational opportunities
- Optimal habitat for some fish and wildlife
- Increased biological diversity
- Increased forage for wildlife
- Enhanced aesthetics

Similar problems exist in upland areas that are tightly connected to the Basin's riverine-riparian areas ecologically, even though separated spatially, insofar as they affect the dynamics of water flows and the availability of nutrients and energy along the landscape's gradients of slope and vegetation (Finch and Tainter 1995). In their review of the literature, Finch and Tainter provide some sense of the magnitude of the degradation in upland systems when they observe that New Mexico's pinyon-juniper ecosystems constitute 23 million acres and on the National Forests, alone, nearly half of the pinyon-juniper watershed contains degraded soils and vegetation. Degraded soil conditions, which includes soil compaction, and accelerated erosion, together with removal of grass cover is associated with long-run

reductions in the productivity of soils and the quality of water produced in these watersheds. In some cases, activities on upland areas have altered runoff patterns and the soil's ability to retain water so that some streams that once were perennial are now intermittent. Finch and Tainter conclude that, "From an ecosystem perspective, managing the quantity and quality of nutrients and sediments delivered from upland watersheds to the Rio Grande and its tributaries should be a major goal of Basin Management."

Manipulations of water quantity also render some resources unsuitable for some uses. The construction and operation of dams, irrigation canals, and other facilities also sometimes remove all the water from stretches of the river that otherwise would remain wet. More generally, the manipulation of water flows by these facilities alters the hydrograph so that at some times there is more water and other times less than there otherwise would be. These changes can dramatically reduce the water's suitability for some plants and animals. Restrictions of the periodic pulse of floodwater onto the floodplain, for example, have significantly altered the floral composition and spatial distribution of the bosque in the Middle Rio Grande (Crawford et al. 1993b). Changes in the hydrograph, together with changes in water temperature, occasioned when the water released from Cochiti Dam is colder than natural flows, also appear to affect the survival of the endangered Rio Grande silvery minnow. The minnow and other species also are affected by dams and other barriers to movement along the river.

B.3. Contributory Problem #3: Resource-Demands That Come From Industrial Activities and are Measured in Monetary Terms are Difficult to Reconcile With Those That are Not

Both the culture of the modern industrial society and basic human nature sometimes create subtle biases favoring industrialized, monetized demands for natural resources over demands that do not have these characteristics. The language of resource economics often embodies these biases, insofar as it applies terms, such as "wasteful," to activities, such as using water for irrigating crops that have little cash value but play a significant cultural role for some groups within the Basin (El-Ashry and Gibbons 1988). Further biases arise insofar as industrial demands are far more amenable than nonindustrial demands to extensive quantification. Psychological research has found that, all else equal, people place greater weight on arguments accompanied by large volumes of quantitative data than on those that are not (Josephs et al. 1994).

Numerous observers have commented on the difficulties inherent in managing resources and an ecosystem when some of the competing demands have a strong cultural element and others do not (DeBuys 1990; DuMars 1993; Finch and Tainter 1995).[9] The difficulties are not just analytical in nature. City dwellers, rural farmers, newcomers, old timers, Indian Pueblos, Hispanic groups, grassroots interest groups, and large bureaucracies all take different approaches to the management process, itself. They often have a different view of what should matter in the decisionmaking process, use different terminology, and prefer different pathways for making decisions. Finch and Tainter make these useful observations about the connections between cultural differences and the competition for the Basin's water and related resources:

- *Conflicting cultural perceptions and goals in land use underscore an important point: environmental problems are essentially human problems, and solutions to them require more than the traditional bio-physical approaches. Too often, those who work in natural resource management have not foreseen that their work has social and cultural consequences. Especially in places where cultural diversity is high, and where land and resource use differ by cultural group, how people use the land can easily become a part of cultural identity. It can also be part of a strategy to resist assimilation. The issues that arise from threats to traditional land use are more than merely economic. Subsistence practices and other uses of land may be no easier to abandon than any other aspect of cultural identity. These issues are particularly salient in ... the Rio Grande Basin.*

[9] According to National Research Council's 1996 book, *A New Era for Irrigation,* the public views agriculture in two not necessarily consistent ways. The first is that irrigated agriculture is an industry that happens to be essential to human existence. The competing view sees irrigated agriculture as an individual culture that shapes the way people live and determines part of the national identity. How society views irrigated agriculture affects decisions about the management of water resources. If the industry view of irrigated agriculture is chosen, farmers will bear most, if not all, of the costs of production. On the other hand, if society views irrigation as a culture, then society will share in the costs and uncertainties of farming largely through the provision of various subsidies. Although the prevailing view of irrigated agriculture varies from region to region and person to person, trends in recent years indicate that irrigated agriculture in the U.S. is increasingly being viewed as an industry that must compete in the global economy (National Research Council 1996).

- *We understand poorly the basis for cultural identity or the reasons for cultural conflict. ... To an outsider or casual observer it is easy to suppose that conflicts between different cultural groups are conflicts about culture. In fact, [in many conflicts] people struggle not for their culture but for more fundamental economic and political issues that happen to be expressed in cultural terms. ...*

- *If such disputes [over resource management] have an economic or political basis, but are expressed in cultural terms, then to address only the cultural issues is not to resolve the problem. This is not to deny that people often have strong feelings for traditional uses of land. Such uses are often a central part of cultural identity and may be no easier to abandon than religion, language, or community. The point is that if attempts to mediate disputes address only expressed cultural issues, the attempts will fail. The fundamental economic and political disputes must be resolved as well.*

B.4. Contributory Problem #4: Many Groups Feel They are Unable to Participate Effectively in Resource-Management Decisionmaking

There is no neat, clean, simple way to address and resolve all the cultural, economic, and political issues described above. The issues intensify daily insofar as decisions are made allocating the Basin's water and related resources among the competing demands for them and many groups feel they have not had a fair opportunity to participate in the decisionmaking. Those whose demands for the public-goods aspects of the resources have materialized lately conclude that they have little, if any, ability to see their demands met insofar as the rules and rights for using the resources were set decades ago and there is no economic or political marketplace where they can purchase what they want. Even if there were water rights available for sale, if a group wanted to buy water rights and leave the water in the river to benefit riverine-riparian resources in New Mexico, for example, state water law does not recognize instream flows as a beneficial use of water and, hence, would not protect the water from being withdrawn.

Those whose demands have long roots also are frustrated. The Indian Pueblos, with a history of water use extending back centuries, have seen water rights issued to others but have not been able to have their demands

adjudicated and protected.[10] Farmers and ranchers, both those producing for cash markets and those producing for subsistence, believe they have been denied access to resources they have traditionally used by decisions regarding environmental protection and other concerns.

Much of the frustration about being excluded from decisions is directed at local, state, and federal agencies. But not all. Current residents see land developers at work and wonder who will have to give up water and other resources to meet the demands of new industries and residents. Farmers wonder who will incur the costs of maintaining the irrigation dams and ditches when their neighbors sell their water rights and divert water away from the ditches to nearby cities. Farmers become frustrated when others enjoy the greenery and other byproducts of irrigation but are unwilling to share the cost.

The frustration stretches across miles, both within the Basin and outside it. Those who live on one side of Elephant Butte Dam are frustrated insofar as they are excluded from decisions made on the other side. The same applies to each of the state lines the river crosses. Taxpayers living outside the Basin wonder why they do not have more influence on how publicly-owned lands, resources, and facilities are managed.

Much of the frustration is unavoidable. The resources and ecosystem of the Upper Rio Grande Basin are complex and so too are the competing demands placed on them. Every resource-management action and every resource use denies somebody's demand for the resource and has multiple spillover effects on others. Some of the frustration also seems to stem from the current political climate of dissatisfaction and distrust.

Many believe that at least part of the frustration stems from sources that can be mitigated through the development of new institutions or the

[10] The administration of environmental laws, such as the Endangered Species Act (ESA), has increased the frustration of some tribal members, who fear that these laws constitute yet another hurdle they must surmount before they can have their claims to water and related resources validated. Much of this fear has arisen because some beneficiaries of non-Indian development projects have argued that, insofar as the environmental laws prohibit further development and the Indians have not fully developed their use of water, these laws necessarily prohibit the Indian developments but leave the existing development unaffected. The Interior Department's Regional Solicitor counters, however, that the ESA does not elevate other water-resource development over the exercise of Indian water rights (Vollmann 1996). Indians can proceed to press their claims and, once validated as senior rights to those already developed, they can develop these rights, with the immediate burden of the ESA falling more heavily on holders of junior rights.

significant evolution of old ones. In particular, they believe that much of the frustration stems from the Byzantine maze of overlapping entities with overlapping responsibilities for managing the Basin's resources and seek the establishment of one or more forums for broad public review and involvement in resource-management policy and practice. Support for this view comes from several directions. Some supporters believe water resources must be managed at a broad regional level, much as transportation is. Others are consumptive water users who accept the inevitability of additional restrictions on these uses and want a better mechanism for holding the promoters of these restriction more accountable for the local consequences, such as when environmental regulations curtail irrigation and results in lower incomes for some farmers and disruption in some communities. Conversely, some of the advocates of such restrictions want a better mechanism for holding resource users accountable for the inadvertent consequences of their actions, such as when the diversion of water from the river causes general taxpayers to bear the costs of environmental damage.

Others reach the opposite conclusion. They see the multiple, overlapping entities as representative of the multiple, overlapping interests in the Basin's water and related resources and believe there is no better substitute for the tugging and pulling—the competition—among them. While acknowledging the past weaknesses of existing institutions, they believe there is a growing recognition of the economic and environmental imperatives for change and an expanding willingness to work cooperatively to find solutions to pressing problems.

Federal resource-management agencies and personnel are a lightning rod for much frustration and even anger. Animosity toward them is intense and widespread. It has multiple origins and takes many forms. Many feel betrayed—as when Indians see federal dollars used to develop water for newcomers to the Basin, environmental advocates see federal programs accelerate ecological change, or irrigators see federal agencies curtail water deliveries for environmental reasons—and want federal agents to do more to promote their interests. Others, confident they will have better success getting what they want through state and local political channels, want the federal agencies to give resource-management authority to their state and local counterparts and withdraw. Some just see federal agencies as overly bureaucratic or even incompetent. Not everyone sees the federal agencies in these ways, of course. Indeed, many representatives of interest groups

conclude that the federal agencies have accomplished much that is good and are working hard to do better. Most residents of the Basin probably have no strong opinion one way or another.

In sum, there is no consensus in this Basin about steps to take to reduce the level of frustration. Although few disagree with the need for meaningful, affordable public participation that is effective and inclusive, many feel threatened by proposals for institutional innovations. The mere suggestion of a Basin-wide institution with resource-planning or -management responsibilities generally elicits vehement opposition from resource managers. A similar response comes from those who derive economic benefits from current resource policies, see such proposals as unfair attempts to change the rules in the middle of the game, and believe they have nothing to gain and everything to lose by pursuing compromise with others. Those wanting greater influence on resource-management decisions, such as some representatives of Pueblos or environmental organizations, typically are at most lukewarm to the idea, fearing that they have too little political power and technical expertise to participate in such an institution effectively and, hence, they would be disadvantaged even further than they are now.

B.5. Contributory Problem #5: There is Widespread Uncertainty About the Hydrosystem and Ecosystem of the Upper Rio Grande Basin

Much is unknown about the current status of the Basin's water and related resources. Some of this uncertainty stems from the vagaries of nature that continue to lie beyond the grasp of scientific knowledge, despite intense effort. Much of it, however, is the result of deliberate decisions to ignore knowledge that has lain within reach. Moreover, many conclude that resource-management decisions in the Basin have been made without recognition of the limits of knowledge and the consequences for posterity, and thus, constitute a fundamental failure of water management in the West (William deBuys, comment of draft report).

The hydrology of the Basin has been subjected to intense study, but major breakthroughs in understanding have occurred sporadically (Bureau of Reclamation, Middle Rio Grande Assessment Preliminary Discussion Draft). Until recently, the conventional wisdom was that the Albuquerque area rested on a readily-accessible aquifer roughly the size of Lake Superior and that this aquifer was closely connected to and readily recharged by surface flows in the Rio Grande. A reexamination of this hypothesis was prompted

by unexpectedly rapid drops in the water table at some of the city's wells and occasional surface subsidence nearby. Studies completed earlier this decade have revealed that the Rio Grande connects to the aquifer at just a few locations, the rate of pumping has been about double the rate of recharge, there is less water than previously believed in the aquifer, and much of the water in deeper substrates will be difficult to make available for human use. These studies have raised new questions about the area's hydrology.

Similar hydrological uncertainty exists elsewhere in the Basin. The El Paso-Ciudad Juarez metropolitan area has gone through an experience similar to Albuquerque's, first believing that the supply of groundwater was essentially inexhaustible, and then facing the consequences of decades of mining the aquifer at unsustainable rates. At the upper end of the Basin, further research is needed to understand the extent of the groundwater, the connectivity to surface water, and the consequences of different levels of extraction.

Uncertainty also exists regarding the area's ecosystem. The Upper Rio Grande Basin is subject to severe and unpredictable climatic fluctuations that directly affect the quantity and quality of the Basin's water and related resources (Scurlock 1995). The sporadic pattern of rainfall affects not just the amount of water in the Basin at a given place and time but also the rate of soil erosion, diversity and size of wildlife populations, and the density and composition of plant communities. Important temperature variations occur over the historical record, seasonally, along topographical gradients, and latitudinally. Extended periods of cold gripped the area from the mid-fifteenth to early nineteenth centuries, followed by a period of relatively warmer temperatures and more frequent droughts from the 1860s to the 1950s. Recent records indicate the area experiences a major drought every 20–25 years. Models of the effect of greenhouse gases on global climate indicate that this area should expect gradual warming over the next century.

Climatic changes are of particular interest in the central portion of the Basin, which embraces the intersection of three major plant communities, or biomes: Great Plains grassland, Great Basin steppe, and Chihuauan Desert (Gosz 1991). Abrupt changes in vegetation structure occur in this area as the principal species from each biome confront their limits. Some evidence suggests that the boundaries of these three biomes may reflect important constraints that climate imposes on species and, hence, that the area may be especially sensitive to future change in global climate. Human actions can magnify the effects of climate change, and interactions among climate and

the patterns of human use of this area's related resources are likely to have important implications both for the ecosystem and for its ability to respond to the various competing demands for resources.

Resource managers often are relying on institutions and laws based on models of uncertainty that are inconsistent with current scientific knowledge. Water law in the three states is based on a model that assumes the economy does not benefit unless the water is removed from the river.[11] The activities of resource-management agencies generally reflect this view, often with perverse impacts on the local, regional, and national economies. A recent episode provides a good illustration. The Rio Grande Compact requires that a specific percentage of water be delivered each year to Elephant Butte Reservoir, but also stipulates that, if water "spills" over Elephant Butte Dam at any time during a year, New Mexico and Colorado will have no further obligation for the rest of the year to deliver water to Elephant Butte.[12] The statutory rules governing Cochiti Reservoir require the CoE to release water on demand by MRGCD and other parties, but prohibit the CoE from releasing some of the water during the summer months, out of fear that, because New Mexico does not protect instream flows, irrigators in the Middle Rio Grande will consume the water before it reaches Elephant Butte Reservoir.

At the end of summer, 1995, there was about 100,000 af of water that had been held above Cochiti dam. When water managers in New Mexico and Colorado realized that last winter's snowpack would be small, they sought to delay the release of the held-back water even further and to release it in a pulse so that water would "spill" at Elephant Butte Dam early in January, 1996. The potential prize was a big one: if water were to have "spilled in January, water users in New Mexico would have had no further obligation to deliver water to Elephant Butte Reservoir in 1996 and users in Colorado similarly would have been exempted from obligations. Various parties concerned about the potential adverse environmental impact of the proposed

[11] This statement is especially true in New Mexico, where instream flows are not recognized at all as a beneficial use. It also applies elsewhere, insofar as the spillover economic consequences of water diversions (Boxes 2-4 of Figure 2.1) are not factored into resource-use decisions.

[12] Water does not have to physically spill over the dam to trigger this provision. The three states can agree that a spill would have occurred, but for upstream storage of water in facilities developed subsequent to adoption of the Compact or for accelerated releases of water from Elephant Butte reservoir.

pulse[13] were able to get the release spread out over about three months. At the same time, water users below the dam accelerated their withdrawals from Elephant Butte Reservoir to dilute the salinity from agricultural runoff, but with the effect of reducing the probability that a spill would occur. In the end, the three states did not agree that a "spill" occurred. The net result, however, was that, because of the institutional and legal system for managing the river and the parties' attempts to manipulate the system to their respective advantage, abnormally large amounts of water flowed through the system just as it became apparent that runoff in the Basin in 1996 would be at near-record drought levels.

Subsequent events reveal even more about how some of the laws, rules, and institutions governing the management of the Basin's water and related resources are based on yesterday's models of the ecosystem and the economy, and disregard the realities of the competition for these resources. As the severity of the potential drought became more apparent early in 1996, MRGCD accelerated its calls for water to be released from Cochiti and diverted even more water than usual from the river (Miller 1996). In the Socorro Reach, for example, MRGCD's withdrawals from the river in March were about 230 cubic feet per second (cfs), compared with 160 cfs, the district's approximate average for the preceding decade. Thus, with runoff at one of the lowest levels on record and in the face of severe drought, the district's response was not to conserve water, but to use it even more intensely. MRGCD's diversion of all water from the river and the subsequent death of about 40 percent of the population of Rio Grande silvery minnows eventually prompted preliminary legal action seeking to prevent further occurrences.

Other parties responded differently. Recognizing that the drought posed especially severe consequences for the Rio Grande silvery minnow and other environmental resources, the BuRec, U.S. Fish & Wildlife Service, CoE, City of Albuquerque, and others, including MRGCD, worked to locate water that could be spared elsewhere and dedicated their efforts to ensuring that it remained instream. In other words and from an economics perspective, they

[13] The natural hydrograph peaks in the spring and early summer. Hence, the proposed pulse in the winter could have dramatically affected species, such as the endangered Rio Grande silvery minnow, whose life cycles are tied to the normal hydrograph (Jeff Whitney, U.S. Fish & Wildlife Service, personal communication).

recognized that, at the margin, the value of the demand for water relating to the minnow exceeded the demand for water elsewhere and diverted it from the low-value use to the high-value use.

This episode shines light on other aspects of the disparities between today's realities and the historical models that underlie the governance of the Basin's water and related resources. In contrast to Colorado and the Elephant Butte Irrigation District (EBID), where most water uses are carefully metered and monitored to prevent actual use from exceeding authorized use, there is much less metering and monitoring in the Middle Rio Grande Valley. Using data from U.S. Geological Service gauging stations, a recent report by the New Mexico Interstate Stream Commission (Miller 1996) compared actual diversions with those authorized by Congress. The author concludes (p.8) that the actual diversions "are substantially greater (notwithstanding the fact that the actual amount of acreage irrigated in the Middle Rio Grande Project today, which is approximately 60,000 acres, is substantially less than the 85,000 acres authorized by Congress." The reality is that nobody has known the details of who diverted how much water in the Middle Rio Grande Valley, an area where the competing demands for water and related resources are especially complex and the economic costs of diverting water away from non-irrigation uses are especially high. This limitation should, however, change soon. The BuRec has used drought-relief funds to purchase and install additional metering equipment, and is contracting with MRGCD to transfer title, subject to performance requirements.

B.6. Contributory Problem #6: The Relationship Between the Resources and the Economy is Poorly Understood

Uncertainty about the economy exacerbates the hydrological and ecological uncertainties. The Basin's economy is undergoing dramatic change. For the Basin as a whole, the economy is not agrarian, but heavily urban. Although the four major urban areas—El Paso-Ciudad Juarez and Albuquerque and, to a lesser extent, Las Cruces and Santa Fe—occupy only a minor fraction of the *geographic* landscape, they dominate the *economic* landscape, even in places far removed and where farming and ranching are common activities.

The mechanisms of this change, however, are not well-understood. The professional literature on regional and urban economics contains many studies documenting at a national level the declining importance of factors,

such as agricultural and primary manufacturing, that once dictated the economic fortunes throughout the land and the ascending importance of other factors, such as quality of life and the skill level of the workforce. Far less is known about how these changes operate within individual communities and states. Thus, economists can say with certainty that there are tradeoffs between, say, withdrawing water from the river to irrigate crops and leaving the water in the stream to provide recreational opportunities and aesthetic benefits, but they cannot specify those tradeoffs precisely.

Viewing the problems of resource management in terms of stewardship provides some insight into the importance of the economic uncertainties and their interaction with the hydrological and ecological uncertainties. Resource stewardship entails managing resources so as to best fulfill the owners' objectives. In the past there were fewer owners and their slate of objectives was simpler than today's. Today's owners reside not just on farms or in towns near the Basin's rivers and streams, but in major metropolitan areas and, in some respects, throughout the U.S. The objectives of today are not just to increase the supply of water for crops and drinking water, although some strongly have these as their primary aim, but also include maximizing the value, standard of living, and fairness that all Americans derive from the ecosystem.

The growth in interested owners and the changing complexity of their objectives inevitably produce two frequent criticisms of current resource management. Those with new objectives often complain that the private parties and public institutions in charge focus too much on the current generation and on short-term benefits; and those favoring the old objectives often complain that the newcomers are sticking their noses where they have no business and that the institutions are being inappropriately side-tracked from their historical mission. The disagreement among these two viewpoints is real and will persist. The disagreement is made more intense, however, by the absence of a good understanding about who will gain and who will lose under different resource-management scenarios. As long as the tradeoffs remain poorly understood, the different parties contesting for resources will have strong incentives to promote their interests on ideological, not empirical, terms.

B.7. Contributory Problem #7: There is Pervasive Distrust Among Stakeholders

The individuals, groups, and agencies with an economic interest in the Basin's water and related resources generally distrust one another. The three states continue their long history of struggling with one another over the Basin's water.[14] Those who currently control the water and other resources are fearful that the Native Americans' claims will deprive them of the benefits they have enjoyed for decades. The Native Americans are resentful that the federal government and others have expended large amounts of money to make water available for use by groups with a far more tenuous claim to the resource but has not exhibited a similar willingness to resolve their claims to water.[15] Environmental groups in the Basin often observe that the resource-management institutions pay little attention to their concerns about the environment and, although environmental groups in the Basin generally have not been as organized or assertive as in other regions, nonetheless their efforts frequently evoke resentment and suspicion. The agricultural community often expresses a lack of confidence in the science underlying much of the environmental policy, e.g., the Endangered Species Act, implemented by federal agencies.

The stakeholders have little experience working cooperatively, with all the relevant interest groups at the table, to resolve major substantive issues. The consumptive-use stakeholders in Texas and southern New Mexico began working together to take a regional approach to resolving their concerns in the southern part of the Basin only through the settlement of a lawsuit, and nonconsumptive interest groups participate, if at all, from the sidelines. Meaningful cooperation among multiple parties to address the needs of the endangered Rio Grande silvery minnow was slow in coming until the diversion of all water from the river resulted in many deaths and the threat of lawsuit and severe penalties under the Endangered Species Act.

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[14] The Rio Grande Compact came about only after farmers in Colorado and New Mexico diverted water at such a rate that Texas (and Mexico) often received none. The BuRec's original activities in the Basin, construction of Elephant Butte Dam and other aspects of the Rio Grande Project, were an attempt to ensure that water would reach Texas and Mexico. Even with the Compact, Texas was shortchanged by upstream users, and it sought redress through legal action that eventually reached the Supreme Court, which sided with Texas. Other litigation across state lines occurred over El Paso's access to groundwater in southern New Mexico. The parties vying for water and related resources in the Basin seem always to recognize that additional litigation is an ever-present threat.

[15] Efforts to resolve Indian water rights seem lost in a legal nightmare. One adjudication has been underway for almost 40 years. In another, the parties have been waiting seven years for a federal judge to issue an opinion regarding a master's findings.

Considerable effort by New Mexico's senior U.S. senator was required to get federal agencies and other parties to work together to assess the biological needs of the bosque ecosystem in the Middle Rio Grande and develop a plan for managing the ecosystem—the only one of its kind in the Basin. Even so, the plan's recommendations are very broad in nature and, despite constant attention and dialogue among stakeholders, tangible change in operations by the major water agencies has yet to be realized.

It is unrealistic to expect that things will get simpler or easier in the future. Instead, the competition for resources will intensify, and, as it does, the stakeholders will continually face not just the day-to-day problems, such as how to coordinate research or keep water in the river during one summer for the Rio Grande silvery minnow, but also the more fundamental ones, such as:

- Who should have a "place at the table" and, thus, have a say in decisions regarding overall resource-management decisions and decisions regarding specific resources?

- What is the public-welfare interest in these resources, and how should the inevitable conflicts between private and public interests be managed?

- How should the stakeholders accommodate what some see as new demands and other see as the inevitable consequences of old ones? For example, should the weight of conserving species rendered endangered by past resource-management practices fall on those who benefited from these practices in the past, those who want to engage in similar practices in the future, or on society as a whole?

- How should the stakeholders encourage decentralization, innovation, and experimentation?

- How should the stakeholders communicate with the public and manage all the various types of risk and uncertainty regarding the hydrology, ecosystem, and economy?

- How should the stakeholders coordinate with Mexico on the management and use of shared resources?

The current level of distrust among the stakeholders in this Basin creates extraordinary challenges for any attempt to address the problems associated

with the growing competition for the Basin's scarce resources. Some of the stakeholders believe that current institutions are up to the task of addressing these problems and express their resolve to oppose vehemently any attempt to reshape the building blocks, such as the Rio Grande Compact and the contracts and legislation associated with the different projects, that form the legal and institutional foundation for resource management in the Basin. Others just as strongly take the opposite view. Similar polar positions will accompany every proposal to address the Basin's problems. One thing is certain, however: the problems, themselves, will not wait forever. Sooner or later, the stakeholders must address them with far more political will and initiative than they have demonstrated in the past.

Many observers believe that, because everybody stands to lose if the problems worsen while the stakeholders squabble, substantial opportunities exist for finding outcomes that can benefit everybody. We agree. We also observe that there are many, very talented people among the stakeholders, each of whom expresses a desire to move forward but lacks the ability to surmount the barriers of distrust. Thus, we expect there will be little progress toward resolving the Basin's problems until appropriate leadership materializes to lower these barriers.

Chapter 4

Addressing the Basin's Problems

The central theme of the preceding chapters is that the composition of the competing demands for the water and related resources of the Upper Rio Grande Basin is complex and shifting over time, the total level of competition is rising rapidly, and the institutions—both private and public—with responsibility for managing the resources are lagging behind. In short, the current system of resource management is a foot on the brake, retarding the ability of these resources to improve incomes and standards of living in the Basin and for efforts to maintain and restore the Basin's ecosystem. In an ideal world, well-regulated markets would materialize to release the pressure on the brake. Buyers and sellers representing all types of interest in the resources would readily effect transactions, everyone would have full knowledge of the tradeoffs among competing resource uses, and resources continually would move from low-value uses to high-value ones.

The real world is far different. Transactions are rare, and nothing other than very limited, local markets are likely to develop in the foreseeable future.[1] Many of the Basin's resources remain in low-value uses as high-value demands expand. Resource-management institutions are struggling to break free of habits and legislative legacies based on the far-simpler resource-competition of the past. Nobody can seriously contend that current patterns of resource use are sustainable, and many recognize that the longer unsustainable practices continue the greater the ultimate cost of recovery.

In the absence of well-regulated markets, resource managers must employ other ins titutional mechanisms if they are to increase the value of the goods and services derived from the Basin's resources, expand the resources' contribution to jobs, incomes, and standards of living, and address the concerns of those who see resource allocations as unfair. Most of the alternative mechanisms, such as lawsuits and political tussling, retain the winner-take-all competitive spirit of markets, but they are far more

[1] Market mechanisms, such as a water bank, can encourage the voluntary transfer from low- to higher-valued uses. A water bank can be used to facilitate temporary or drought-year water transfers between agriculture and urban users. The water is not transferred permanently between the two sectors, but moves to the more highly valued use when most needed. In the Upper Rio Grande Basin, the Middle Rio Grande Conservation District (MRGCD) is attempting to form a water bank. To date, however, the potential success of the program remains undetermined.

cumbersome. An alternative approach involves different interest groups working cooperatively, searching for innovations and agreements that allow competitors to make mutual progress.

In this chapter we briefly examine some of the conditions that generally must exist for cooperative efforts to succeed. We then describe some of the past efforts to solve the Basin's resource-management problems cooperatively, and we conclude with an outlook for future cooperative efforts.

A. Requirements for Cooperative Resource Management

There is no standard formula for cooperative resource management. The determinants of success vary depending on the type of issues being addressed, the characteristics of the participating parties, and the emotional legacy of past actions. Nonetheless, several factors commonly are believed to be instrumental in increasing the likelihood of success.

One factor is deemed essential. Each party must see that it has something to gain by participating in the effort in good faith. Sometimes this requirement is turned on its head: each party must see that it has something to lose by not participating. This requirement often has not been satisfied in the Upper Rio Grande Basin, as some groups that enjoy the greatest use and control over water have felt they have nothing to gain and much to lose by working with groups seeking to restrict their use and control. This observation applies generally to irrigators, who account for 80 percent of diversionary use in the Basin, and to the agencies representing their interests. It also applies, as a rule, to those who have first access to water and related resources, either because they are located higher in the Basin and have the physical capacity to use surface flows, or because they are first in time and have a superior claim to water and other resources over those who came later and future generations.

Four additional factors can substantially influence the success of a cooperative effort (Rieke et al.). One, the effort must have broad participation embracing all interest groups with a stake in, and ability to alter, the outcome. Two, it must have sufficient technical expertise to yield plausible answers to the "What if?" questions that must arise if the participants are to explore innovative solutions to difficult problems. Three, it must have a process that allows each party to feel it has been treated fairly relative to the others; generally the process entails having a coordinator that

all parties agree is unbiased. Four, it must be supported by sufficient political will so that all parties know their concessions to the process will yield political benefits and, conversely, any actions to undermine the process will result in political, public-relations, or legal sanctions.

B. Cooperative Efforts in the Basin

This basin is more widely known for its disputes over resource management than for cooperative efforts to resolve the disputes. The level of distrust among different interest groups is high and few individuals or institutions are widely perceived as neutral and capable of bringing groups together. Disagreement and contentiousness are deeply institutionalized.

Despite these difficulties, however, there is a long and expanding history of attempts to bring about cooperation in the Basin. Cooperative management of water and other resources typifies the activities of the pueblos and acequia associations, with traditions reaching back centuries. Recent events—notably the listing of the Rio Grande silvery minnow as a federal endangered species, the realization that the largest metropolitan areas are running out of groundwater, and the drought of 1996—have opened new avenues for cooperation. A complete description, even a listing, of cooperative efforts in the Basin is beyond the scope of this study. It is useful, however, to examine some of these efforts, to place them in the context of the problems described in Chapter 3, and use them as a basis for looking to the future.

1. Rio Grande Compact

The Rio Grande Compact lies in the background of all efforts to cooperatively address problems regarding the management of the Basin's water and related resources. Virtually all cooperative activities in the Basin must take the Compact into account. We describe the major features of the Compact elsewhere and here only recount some of the features that bear most heavily on cooperative efforts. Foremost among these is the Compact's overarching focus on protecting the quantitative distribution of surface water among the three states as it existed sixty years ago.

Many express the belief, however, that the Compact has not provided a good forum for addressing issues other than quantities of surface water passing

state lines. As we describe above, the Compact creates incentives for water managers in each state to manipulate water flows to take advantage of the Compact's provisions—by trying to create or prevent "spills" at Elephant Butte—rather than to maximize the net benefits derived from the water. Representatives of Pueblos in the Basin argue that the Compact, being an agreement among states, has no bearing on the sovereignty of Pueblos or the U.S. obligations to them. Resource managers in Texas complain that the Compact so far has not facilitated resolution of their concerns about the degraded quality of water reaching Texas as runoff from agricultural lands in southern New Mexico. Competitors for groundwater observe that the Compact does not provide guidance for management of this resource. Advocates of taking a holistic approach to managing the Basin's ecosystem conclude that the Compact creates barriers by focusing each state's attention on the amount of water flowing across political boundaries that have no ecological meaning.

Despite these beliefs, some observers have concluded that, because the Compact has a ubiquitous presence in resource-management activities that might affect interstate flows, it may be possible—indeed, necessary—to employ the Compact as a tool for addressing a wide array of other issues. By and large, state resource managers and representatives of the irrigators and others who engage in the greatest direct use of water adamantly express opposition to any proposal that might be seen as an attempt to circumvent the Compact and the institutions that have built up around it. Some of the defenders see nothing wrong with the Compact and how these institutions affect management of the Basin's water and related resources. Others, though no less dedicated in their insistence that the Compact play a central role in resource management, interpret the Compact to have greater flexibility and are more sanguine that the Compact-related institutions can take a leading role in addressing environmental and other issues.

2. New Mexico/Texas Water Commission

The New Mexico/Texas Water Commission evolved out of the settlement of litigation between El Paso, New Mexico, and several stakeholders with an interest in water from the Bureau of Reclamation's (BuRec's) Rio Grande Project, which extends from Elephant Butte to Ft. Quitman. The litigation began after El Paso challenged New Mexico's statutory embargo on exporting water out of the state. In 1980, El Paso applied to the New Mexico State Engineer Office (SEO), requesting permission to appropriate and transport

groundwater from southern New Mexico into Texas. The request included drilling 60 wells and appropriating 50,000 acre-feet (af) of water annually in the New Mexico portion of the Hueco Basin,[2] as well as drilling 266 wells and appropriating 246,000 af of water annually in the Lower Rio Grande Basin, south of Elephant Butte. The SEO denied the request because New Mexico water law prohibited out-of-state export of groundwater. El Paso's suit claimed, in part, that the SEO's action was an illegal constraint of interstate commerce.

Eleven years later, on March 6, 1991, the litigation ended with three parties—El Paso, New Mexico State University (NMSU) and Elephant Butte Irrigation District (EBID)—signing a settlement agreement.[3] El Paso withdrew its application for groundwater from New Mexico and agreed to meet its future demand for water, giving preference (in declining order) to: (1) water conservation; (2) surface water; and (3) groundwater. EBID committed to work with El Paso to facilitate the delivery of Texas' portion of Rio Grande Project water.[4] Both parties agreed to study the effects of the Canutillo well field located near the Texas-New Mexico state line on New Mexico water users. All parties involved in the settlement agreed to support year-round delivery of surface water to El Paso, to exchange necessary technical information, and, where warranted by study, to support construction of conveyance facilities to carry Rio Grande Project water to Texas from Caballo or downstream points. New Mexico parties will cooperate with El Paso to obtain federal support through grants, loans, appropriations, and/or federal matching for the conveyance project. All parties promised to strive towards efficient utilization of Rio Grande Project water to meet the groups' long-term needs, and to coordinate their respective water plans.

[2] El Paso and Ciudad Juarez have pumped heavily from the Texas and Mexico portions of the Hueco aquifer for decades.

[3] Motion for Voluntary Dismissal of Appeal in the Court of Appeals for the State of New Mexico. *The City of El Paso vs. Eluid L. Martinez, State Engineer and Elephant Butte Irrigation District, et al.* March 6, 1991. The New Mexico State Engineer, who was defendant, joined and concurred in the motion to end the litigation, but was not a party to the settlement agreement.

[4] Although parties in Texas are entitled to 43 percent of the water from the Rio Grande Project, the water is used extensively by irrigators in the EBID before it reaches Texas, raising complaints about increased salinity and other water-quality problems, and concerns about the timing and reliability of deliveries to Texas.

The agreement also called for the formation of a "Joint Settlement Commission," now called the New Mexico/Texas Water Commission (Commission), to organize and encourage major items of the settlement. Although the Commission was created through the signatures of the three parties (El Paso, EBID and NMSU) to the settlement agreement, it has six voting members, three from each state. Two of New Mexico's members represent EBID and one comes from NMSU. Texas' members include one representative each from the El Paso County Water Improvement District (EPCWID), the El Paso Water Utility Public Service Board, and the University of Texas, El Paso (UTEP). The Commission also has three advisory committees covering management, legal, and environmental issues.[5]

The Commission serves largely as a forum to facilitate regional communication, cooperation, and planning. It has no authority, beyond the background commitment of its individual members, to compel action. The powers of the states and the individual members have not been delegated to the Commission. If a decision by members of the Commission does not require action by anyone else, they proceed to act on it. If, however, it requires the regulatory or enforcement authority of an outside body, such as permission from the New Mexico SEO, the Commission cannot supersede that body's authority. All of the Commission's decisions have been made by consensus. The primary incentive to reach consensus on issues brought before the Commission is the mutual desire to avoid further litigation. This incentive is considerable, as the bitter taste of a 11-year suit costing millions of dollars has not been forgotten.

Since its formation in 1991, the Commission has obtained funds totaling $1.9 million from the Texas Water Development Board, the New Mexico Interstate Stream Commission, UTEP, BuRec, and local contributions from both New Mexico and El Paso. These funds have supported studies examining the possibility of year-round supply of surface water to the Las Cruces-El Paso area.

To date, both an initial and a final feasibility study of the Rio Grande conveyance, storage, and treatment system have been conducted. The two

[5] The Management Advisory Committee has representatives from the City of Las Cruces, Dona Ana County and the International Boundary and Water Commission (IBWC). The Legal Advisory Committee has attorneys and a representative from the SEO. The Environmental Advisory Committee has representatives from the Southwest Environmental Center, New Mexico Game & Fish Department, and the U.S. Fish & Wildlife Service.

studies were conducted jointly by Boyle Engineering Corporation and Parsons Engineering Science, Inc. Phase I of the initial feasibility study, completed in 1993, compared water savings under two alternatives for conveying surface water from Caballo Dam to the City of El Paso: (1) construction of a lined canal paralleling the Rio Grande; or (2) enlarging, lining, and extending EBID's existing canal system. The first alternative estimated a savings of 37.1 billion gallons of water annually. Alternative two estimated a savings of 67.4 billion gallons of water annually. Phases II and III of the initial feasibility study, completed in 1994, explored numerous other options for providing Texas with year-round surface water supplies and enhanced water quality. Additional options included: delivery of water via the river channel; a pipeline that would carry Texas' Rio Grande Project water from Caballo to El Paso; a canal parallel to the river from Las Cruces to El Paso; water treatment plants; aquifer storage and recovery; and the utilization of EBID's canal system. Original cost estimates for each option, in excess of $500 million, were prohibitive and thus caused the Commission to limit Phase I of the project from Mesilla Dam (near Las Cruces) to the American Dam in El Paso and to utilize EBID's existing canal system.

The final feasibility study of the Rio Grande conveyance, storage, and treatment system remains in progress. Efforts from this study are presented in two reports. The first report identifies recorded hydrologic information and the second proposes a measurement program to obtain needed data for a stream simulation model. The study area for both reports includes the stretch of the Rio Grande from Elephant Butte Reservoir to Riverside Dam in El Paso.

In October 1996 a contract was awarded for the inquiry of another facet of the final feasibility study. The focus of this study component is the development of a water accounting or hydrologic model of the Rio Grande from Elephant Butte Reservoir to Riverside Dam. The hydrologic model, BESTSM, developed by Boyle Engineering Corporation will include parameters on Rio Grande flows and water quality. The hydrological model is expected to be completed by August 1997. Other on-going efforts supported by the Commission include the upgrading of the Maddock MODFLOW model of the lower Mesilla basin. The Commission currently focuses almost exclusively on promoting consumptive uses of water. The 1991 settlement agreement stipulates that the parties "agree to work together in a cooperative effort to maximize the utilization of waters provided to New Mexico and Texas through the Rio Grande Project in order to provide reliable and cost-effective water supplies to meet current and

projected long-term agricultural and municipal needs of the region." The Commission's current priorities are consistent with this objective and look only at increasing the quantity of water for irrigation and urban use and at reducing water-quality constraints that restrict these uses.[6] The Commission has not initiated any surveys of the river's environmental condition or any National Environmental Policy Act (NEPA) review process. Although it has an advisory committee on environmental issues, the voting members have a primary interest in promoting agricultural and urban water consumption.

3. Rio Grande Alliance

State and federal officials from Mexico, Texas, New Mexico, and Colorado as well as tribal representatives and non-governmental organizations gathered in El Paso in July, 1996, to provide guidance in the development of the Rio Grande Alliance. The Alliance, according to the mission statement adopted at the El Paso gathering, "exists as an international forum to support collaboration among the diverse groups of the Rio Grande Basin concerned with the protection, improvement, and conservation of natural resources and human health (Rio Grande Alliance 1996).

The Texas Natural Resource Conservation Commission (TNRCC) initiated the Alliance after spending two years discussing the idea of the Alliance with over 250 different federal, state and local agencies, non-governmental organizations, and residents of the Basin. In response to the concerns raised by many of the stakeholders, the Alliance hopes to realize three accomplishments: (1) provide a forum where decisionmakers and agencies can coordinate their work and thus reduce overlap; (2) increase communication between individuals that may not otherwise have the opportunity to speak with one another; and (3) help communities find solutions to their environmental problems by researching and locating resources to fit their needs. The specific goals of the Alliance defined at the coordinating meeting include:

[6] The priorities include: (1) providing year-round surface water supply of suitable quality for both El Paso and the irrigation districts; (2) identifying and analyzing improvements needed in the existing regional conveyance system to remove bottlenecks or reduce "losses"; (3) identifying new conveyance facilities needed to deliver water efficiently; and (4) identifying and analyzing the water treatment facilities and any aquifer storage and recovery facilities that can be planned, constructed, and managed by these agencies (Archuleta 1995).

- Develop mechanisms for cooperative activities.
- Foster community-based decision-making to address local needs.
- Promote action-oriented efforts focusing on sustainable development.
- Develop inter-disciplinary approaches to environmental problems.
- Create opportunities for basinwide exchange of information and technology.
- Develop projects that specifically address human health issues.

At the coordinating meeting, participants pledged to work together to begin building information banks related to environmental data in the Basin. Stakeholders throughout the Basin are currently developing a representative Coordinating Council for the Alliance. Participants of the El Paso meeting and other interested parties have tentatively agreed to gather in Albuquerque in April 1997 for a second meeting of the Alliance. Some observers believe interest in the Alliance diminishes the further one is from Texas and the TNRCC.

4. Regional Water Planning in New Mexico

New Mexico embarked on intrastate, regional water planning following a 1987 federal court decision in the El Paso-New Mexico litigation finding the state's prohibition against out-of-state transfer of groundwater was an unconstitutional violation of the Interstate Commerce Clause of the Constitution. The Supreme Court, in a separate case, ruled that a state could not single out interstate transfers for regulation but identified the conditions a state must meet to justify restrictions on transfers, whether between basins within the state or out of state, to protect public health and welfare. The development of regional plans was seen as a necessary step for determining when and where these conditions would be satisfied.

The legislature directed that regional planning should occur at the initiation of local interests, who define the relevant region through their hydrological and political common interests. At first, the regions took different approaches, to the extent that the different plans were too inconsistent to satisfy the state's legal and planning objectives. Hence, in 1994, the state

published a handbook with assumptions, guidelines, and a template for regional water planning (New Mexico Interstate Stream Commission 1994). The handbook says that New Mexico may decide to use the regional plans as a basis for a statewide water plan to influence litigation, water development, and legislation. It does not take a statewide view of the interests competing for water in each region, however, and instead "strongly encourages regions to negotiate solutions to local water problems. The handbook emphasizes the importance of promoting high levels of water quality, conservation, and broad public participation, but leaves the details to each region's residents.

The fundamental premise underlying regional planning is that future water needs and steps to meet those needs could best be worked out at the regional level. In a November, 1996, account of the process, an advocacy group promoting cooperative approaches, New Mexico Water Dialogue, concludes that its "true worth (is evident in a flourishing respect for cooperation and consensus that today seems at least as prevalent as the old readiness to fight for the right to water" and observes that "stakeholders are evolving a distinctly New Mexican process for 'getting along.'"

There are six planning regions in the Rio Grande Basin, covering the Rio Chama watershed, Taos area, Santa Fe-Los Alamos area, Albuquerque area, the sparsely populated counties north of Elephant Butte, and the area between Elephant Butte and Texas. Funding for the plans is small, and progress is slow. In some areas planning entities have yet to be formed, in others they are trying to amend and flesh-out plans developed before the handbook was published.

5. Rio Grande Silvery Minnow

Following the kill-off of endangered Rio Grande silvery minnows in April 1996, and the subsequent threat of litigation, several agencies tentatively have taken the first steps toward the development of a long-term water-management strategy, known as the "White Paper" for the Middle Rio Grande Valley (Whitney et al. 1996).[7] The plan recognizes the threat that, absent successful cooperative efforts, water-management decisions may be made in the courts. After acknowledging that past success meeting the composite needs of the minnow and water users occurred largely because the

[7] Participants in the development of the strategic plan represent: the City of Albuquerque, Middle Rio Grande Conservancy District, New Mexico Interstate Stream Commission, CoE, BuRec, and U.S. Fish & Wildlife Service.

City of Albuquerque and other entities made some San Juan-Chama water available at no cost to augment instream flows, the plan observes that this water is not expected to be available in the future. After describing the considerable challenges facing them, it expresses the stakeholders' commitment to "share responsibilities in meeting future water needs equitably."

The plan then identifies a set of actions that, in combination, might accomplish the joint goals of securing long-term, dependable amounts of instream water in the valley and accommodating consumptive water users. These actions include:

- Acquiring water from willing sellers and using it to facilitate accomplishment of the goals.

- Managing groundwater and surface water conjunctively so that, for example, surface water during wet years could be stored in aquifers and then pumped to augment surface flows in dry years.

- Altering the management of upstream water-storage facilities to increase the supply of water available for meeting the goals. Some potential actions could be accomplished under existing authorizations, while others would require legislative changes. The plan recognizes the need to prepare an annual operation plan for reservoirs and diversions in consultation with all stakeholders.

- Increasing water-use efficiencies by taking actions, such as lining canals, improving irrigation practices, and improving water management.

- Improving water-rights administration by pursuing adjudication, improving metering, and evaluating water-management options.

The plan recommends that the agencies and entities with a stake in water management in the valley should work cooperatively to investigate the feasibility of these actions and develop a plan of action for meeting the needs of the water users and the Rio Grande silvery minnow. Preparers of the plan conclude by encouraging the leadership of their respective agencies to pursue the goals and actions they have described.

The plan was developed against the backdrop of the Rio Grande silvery minnow Recovery Team. Notable aspects of its activities include: the first

attempt by the U.S. Fish & Wildlife Service to implement the Secretary of Interior's July 1994 policy direction to involve stakeholders in the development of recovery plans; preparation of a draft report for public review by mid summer 1997; and continued cooperation between stakeholders and management agencies.

6. Jemez River Watershed

During the drought of 1996, the Jemez and Zia Pueblos worked with one another and with their neighbors, the New Mexico State Engineer Office, and the Bureau of Indian Affairs, to find a way to share the dwindling supply of water. As federal attorneys were preparing legal action to ensure that upstream users did not deprive the downstream Pueblos of water, all the local stakeholders worked together to negotiate an agreement that acknowledges the Pueblos senior rights but establishes a rotational water-delivery schedule to allow all irrigators to share available supplies. The agreement also includes groundwater in the rotation schedule and provides a dispute-resolution process. The agreement, which was approved by the federal court, "marks the first time (in New Mexico history and perhaps in the nation's) that affected water users in a stream system have delineated a priority call process for themselves" (New Mexico Water Dialogue 1996). Stakeholders hope to build on their success and use the agreement as a model for settling adjudication in the Jemez Valley.

7. Enhanced Streamflows in Colorado

A short-run cooperative effort to enhance streamflows in Colorado was promoted by the drought of 1996. When flows within the Wild and Scenic portion of the river at the Colorado-New Mexico border dropped to 17 cfs in July, Colorado, the Rio Grande Water Conservation District, and the BuRec worked together and with environmental interests to augment flows. Specifically, the groups agreed to pump groundwater from the San Luis Valley Closed Basin Project into the river to benefit the environment within Colorado, but carefully avoided setting a precedent that would substantiate a claim for water to be used to maintain environmental benefits or streamflows in New Mexico.

These examples of cooperative efforts in the Basin represent a broader array of efforts to address the increasing competition for water and related

resources. By citing them and discussing the potential merits of efforts promoting cooperation, we are not saying such efforts necessarily will result in the resolution or avoidance of disputes over the competition for the resources. The best that such efforts can do is to provide a better forum within which to deal with the conflicts that are inherent in the Basin. At their heart, disputes over resources are nothing more or less than the forces of economic competition at work. Efforts to increase cooperative management of the Basin's resources can never be a substitute for competition, but, when successful they help competitive forces work more efficiently.

C. Cooperative Outlook

As new demands for water and related resources have materialized in this Basin, three types of response strategies have dominated. One is the subsidized technological fix, which relies on outside monies to increase the extraction of products from the ecosystem through steps, such as the construction of dams to increase the supply of water in summer months, levees to protect properties in floodplains, and logging roads to extend the reach of sawmills. Another is political domination, with dominant political groups forcing groups with marginal political or economic power, such as Native Americans, to yield. The third is for established resources users to hunker down and hope that the threat of competing demands will evaporate.

There are some notable occasions where each of these strategies was successful. Most attempts at a technological fix involve federal funding. The BuRec's investments in the San Juan-Chama Project brought water from the other side of the Continental Divide to insulate this Basin's water consumers from supply limitations. These investments, together with those in the San Luis Valley Closed Basin Project and low flow conveyance channel (LFCC) have aimed at allowing upstream waters to meet their downstream obligations by using "outside" water or reducing transportation "losses" rather than confronting the political and economic difficulties of curtailing consumption.

The interplay among dominant and vulnerable groups plays out in several ways. Indian water rights remain largely undefined while newcomers' rights are pressed forward. The residents of colonias and other low-income families not connected to urban water systems continue to rely on water from wells that may be contaminated. Residents of agricultural communities wonder

how their communities will hold together if water and other resources are diverted from local control to being controlled by the political and economic might of urban centers.

Virtually all resource managers in the Basin are aware of the need for hunkering-down strategies to cope with short dry spells, such as 1996. The Basin's most notable example of hunkering down occurred when residents of Colorado and New Mexico successfully escaped the full consequences of their states' long failure to meet their Compact obligations. When several wet years in the early 1980s caused water to "spill" at Elephant Butte, provisions in the Compact erased the remaining obligations from the books. Some water users, though not all by any means, have benefited from federal programs that forgave repayment obligations when they were unable to meet them without extreme financial hardship.

Given the past successes, one must expect that future growth in demand for the Basin's resources will be met with similar response strategies, at least to some extent. Indeed, one does not have to look far to see them in action today. El Paso looks to the Environmental Protection Agency for money to construct pipelines to extract water from the river far upriver, land developers continue to build houses and malls without having to demonstrate how their occupants' demands for water will be met, and many conventional water users hope that Congress somehow will make demands for greater instream flows disappear by repealing the Endangered Species Act.

We anticipate, however, that the conventional strategies will be far less successful in the future than in the past and that pressures for cooperative resource management will expand markedly. There are several reasons for this conclusion. Among the most prominent are these:

The Competition for Resources Will Accelerate. Additional competition will come from all corners. Perhaps most important is the expectation that population growth and rising incomes in the Basin will increase the demand for municipal-industrial water and for clean water and other readily accessible amenities. Pueblos are likely to press their demands for water that meets their quality standards.

The Ecosystem Will be Less Forgiving. The aquifers underlying the major urban areas will not sustain current pumping levels for long without apparent effect. The current findings from research on the Middle Rio

Grande's bosque and other areas indicate that significant ecological change will occur in the foreseeable future if current management regimes are extended. Global warming is expected to add more stress to the ecosystem.

Changes in Federal Priorities and Budgets. National political pressures to curtail federal spending undoubtedly will affect the availability of funds to support the management of the Basin's water and related resources. The shrinkage of federal funds (or failure to grow as fast as in the past) will reinforce emphasis on local control and responsibility.

In short, we expect that the pressures for more efficient resource uses and for greater flexibility in the management system will continue to mount. Existing institutions eventually will change to accommodate these pressures, or new institutions will emerge.[8] These changes might occur gradually and piecemeal over the next several decades. Given appropriate conditions, however, they could occur suddenly, and one need not possess much of an imagination to see how this might happen. A prolonged drought might induce major corporations to locate elsewhere, a change in the ecosystem might cause widespread mortality in the bosque, or a pivotal court decision might force the issues of tribal water rights or environmental protection in one way or another.

Against this backdrop, we anticipate that conditions conducive to cooperative management of the Basin's resources will strengthen. In particular, we anticipate that groups who believed they had little to lose by sustaining the status quo increasingly will realize that they have much to lose if they do not aggressively look for innovative solutions to satisfy at least some of the demands of others. The killing of thousands of endangered Rio Grande silvery minnows in 1996, when irrigators diverted all water from the river, induced environmental groups that heretofore had been essentially powerless to raise the threat of lawsuits. This threat induced parties that otherwise would have remained aloof to participate in heretofore-unheard-of cooperative efforts to address the minnow's instream needs.

If competition continues to outpace the ability of resource-management institutions to shift resources from low to high-value uses, the likelihood of

[8] Meaningful institutional changes can occur in innumerable forms and places, and often seemingly prosaic changes hold the greatest potential. In a 1993 conference on resolving water-related conflicts, for example, Charles Dumars (1993) highlighted the importance of simplifying the legal processes governing legal documents regarding claims to water and making these processes more accessible to citizens.

unforeseen crises that can cause abrupt institutional change will increase. Nobody can seriously believe, for example, that the political system will long tolerate using vast amounts of water on low-value crops if drought or other events cause high-value water uses of the metropolitan areas in the middle and southern end of the Basin to go unmet. Conversely, support for instream flows, stronger connections between the river and its floodplain, and a more natural hydrograph is likely to plummet if major flooding occurs. Furthermore, residents of Albuquerque cannot expect much sympathy for the pain they endure while reducing per capita water consumption as long as their consumption exceeds levels in similar communities.

In short, growing competition is likely to destablilize institutions that do not accommodate it. It is impossible to say now just how all this will play out, for much will depend on problematic variables, such as climate and political leadership. Many believe that major challenges and changes will materialize if resource-conservation groups find they have sufficient political muscle and scientific ammunition to significantly delay or modify major construction projects, such as El Paso's planned pipelines. Another test will occur as major federal activities, including the IBWC's operations in the southern Basin and the CoE's and BuRec's programs in the middle Basin are subjected to extensive review of their environmental impacts.

Despite the outlook for growing pressures for stronger cooperation, at this time there is no consensus in the Basin supporting the establishment of a Basin-wide commission for addressing the Basin's problems. Opposition comes from many sides. It is especially strong, for example, among those who currently have the greatest control over the Basin's water and related resources, such as irrigation interests in Colorado's largely rural and agricultural portion of the Basin. Irrigators in Colorado have first access to almost all, and consume about 600,000 af of the approximately 1,060,000 af of surface water generated in Colorado's portion of the Basin in a typical year. Understandably, many residents of Colorado, seeing that most of the new demands for water and related resources come from urban, nonagricultural sources further south, anticipate that a new Basin-wide commission would seek to limit their access and use of water. They typically label water in excess of Compact obligations that passes out of the state as a "waste." They see no advantage in participating in a Basin-wide commission, insofar as they believe that the Rio Grande Compact protects their access to and control over the water.

Opposition to a Basin-wide commission also comes from those who feel they are at a disadvantage, economically and politically. Some representatives of Indian Pueblos, for example, are fearful that they would not have adequate financial resources or legal, political, and other expertise to participate in the commission on equal terms with entities, such as the large cities, irrigation districts, and conservancy districts.

In sum, we anticipate that the pressure for innovative approaches for bringing the demands for and supply of water and other resources into balance will grow, but there is no consensus in the Basin supporting a particular institutional framework—especially a basin-wide commission—for pursuing these innovations. New approaches, whatever their structure, will not eliminate the competition for resources and may do little to dampen the controversy over resource management or the federal role therein, at least in the short run. At this point, however, there seems to be widespread recognition that new approaches are necessary.

Federal agencies can play important roles in facilitating better cooperation, both among themselves and with all interested parties. We discuss, in the next chapter, some of the steps agencies can take toward this end. In general, though, we fall back to the fundamentals described at the beginning of this chapter. Each agency should set a high standard for: (1) embracing all interest groups; (2) providing technical expertise and financial support to help stakeholders answer "What if?" questions; and (3) treating all parties fairly.

Chapter 5

Conclusions and Recommendations

In the preceding chapters we describe the competition for scarce water and related resources in the Upper Rio Grande Basin, identify some of the major problems associated with the competition, and examine the various roles the federal government has played in contributing and responding to these problems. In this chapter we draw on this information to develop recommendations for steps the federal government might take to respond to problems more thoroughly and efficiently in the future. Before proceeding, however, we emphasize the following points to allay fears that this study covers policies and actions outside federal purview. We make no recommendation whatsoever regarding the resource-management policies and actions of non-federal entities. We specifically are NOT making recommendations regarding:

1. The content or administration of the water laws of the individual states.

2. The responsibilities and rights of resource owners, including owners of water rights.

3. The substantive aspects of disputes among federal, state, local, and private entities (although we do make recommendations for steps that might accelerate their resolution).

4. How specific resources should be used.

As in the previous chapters, our discussion cuts through multiple, intertwined issues and, hence, the separation of one recommendation from the others is necessarily somewhat arbitrary. We encourage the reader to consider each recommendation in the context of the others. We also encourage the reader to keep in mind that the term "value" is employed in a broad sense, referring to goods and services associated with the Basin's water and related resources that are measured in monetary terms, such as bales of hay produced from irrigated fields, and those that are not monetized, such as spiritual fulfillment derived from some streams.

A. Federal Policies and Actions Should Reflect the Ecosystem's Complex Role in a Complex Economy

We intend this recommendation to provide fundamental guidance for future federal policies and actions in this Basin. It has two essential features. The

first is that federal policies and actions should view the Basin's water and related resources as elements of an ecosystem, not as independent resources separate from the ecosystem. The history of resource management in this Basin exhibits a strong emphasis on managing water quantity for consumptive uses, with little or no regard for the unintended consequences for water quality or for the impacts on the structure and function of riverine and riparian ecosystems. Both inside and outside the Basin, ecologists have sounded alarms about the potential consequences of continuing in this mode. Ignoring these alarms would be foolhardy. We recommend that federal resource managers strive to understand more fully the potential ecological consequences of resource-management decisions, to help stakeholders and the public share this understanding, and to give these consequences appropriate weight in every relevant decisionmaking process.

The second essential feature of this recommendation is that federal policies and actions should recognize the full set of competing demands for the Basin's water and related resources and, wherever appropriate, strive to optimize these resources' contribution to the economy. In Chapter 3, we identify three economic criteria for defining and evaluating the major problems associated with the growing competition for the Basin's scarce water and related resources. These same criteria also are useful for evaluating the extent to which alternative federal policies and actions contribute to the economic well-being of Basin residents and other Americans. Insofar as possible, federal policies and actions should strive to increase (1) the net value of the bundle of goods and services derived from the Basin's water and other resources; (2) the levels of employment, income, and other indicators of standard of living associated with these resources; and (3) perceptions that the resources are managed fairly.

These two features, ecological and economic, of this recommendation are inextricably linked. Humans and human activity are part of the ecosystem. Insofar as this report is an examination of the competition for scarce resources derived from the ecosystem, we adopt a distinctly anthropocentric view and conclude that human well-being, measured against the three criteria mentioned in the previous paragraph, will be enhanced by taking a broad view of how resource-management policies and actions affect both the ecosystem and the economy.

Why is this an appropriate recommendation for federal policies and agencies? There are two primary reasons. The first is that the scientific evidence strongly supports the conclusion that resource-management

decisions will have repercussions not just locally but throughout the ecosystem and regional economy. Thus, the overall economic benefits the nation derives from the Basin's resources are likely to increase the more managers take these repercussions into account. The second is that nonfederal resource-management institutions in the Basin are not likely to take these repercussions fully into account in the foreseeable future. Groups in the Basin have a long history of taking a parochial view of their interest in water and related resources. A common view is that water not consumed in one's state or local district is "wasted."

In making this recommendation, although we observe that past and current federal policies and actions generally do not correspond with a broad view of the ecological and economic repercussions, we are not saying all resource managers are unaware of the Basin's ecological and economic issues. Indeed, many struggle with these issues daily. The fact remains, however, that each agency's management of water and related resources has been and continues to be focused on a subset of the resources and driven largely by concerns for a subset of the competing demands.

We believe four changes in how federal agencies do business will expedite policies and actions with a broader view of the ecosystem and economy. Federal agencies with a significant impact on the Basin's resources should (1) promote ecosystem-management institutions; (2) initiate an integrated scientific assessment of ecological and economic conditions in the Basin; (3) describe tradeoffs more clearly; and (4) communicate ecological and economic issues more clearly. We discuss each of these in turn.

1. Promote Institutions That Take a Broad View of the Economy and Environment

One analyst of the organizational and legal aspects of ecosystem management recently observed, "As a practical matter ecosystem management is dependent on developing new organizational relationships for managing natural resources" (Meidinger 1997). We agree. At least since the turn of the century, public resources have been managed under the Progressive model, which places great responsibility on agency experts and assumes some separation between their objective, goal-driven planning and the vicissitudes of public opinion. Now, however, with new knowledge of the unpredictability of ecosystems, intensely greater competition for natural resources, and a more-empowered public demanding to be involved, some

agency officials around the country are working under a different model. Generally known as ecosystem management, various observers define it differently, but the basic idea is to try to manage in a more coordinated fashion across jurisdictional boundaries and to incorporate mechanisms for implementing what is learned about management actions (adaptive management). The central features of ecosystem management include (Kohm and Franklin 1997a):

- Working with as many resource owners and managers as possible to coordinate the gathering and analysis of ecological and socio-economic information covering a larger area than under conventional management approaches.

- Coordinating management activities with all relevant resource owners, managers, and regulators, taking into account management objectives with a longer horizon than under conventional management.

- Recognizing the unpredictability of ecological processes and anticipating that surprises in the understanding of these ecological processes can necessitate a rethinking of management approaches.

- Engaging in and supporting dialogue with all stakeholders to elevate understanding of ecological and socio-economic issues, evaluate resource-management alternatives, and elucidate decisions.

Although the discussion in Chapter 4 reveals that some federal agencies recently have taken significant steps consistent with ecosystem management, we recommend that federal agencies in the Basin do more. Especially those agencies most directly involved in resource management—Bureau of Reclamation (BuRec), Army Corps of Engineers (CoE), Fish & Wildlife Service, Environmental Protection Agency, Forest Service, Bureau of Land Management, and Natural Resource Conservation Service—should investigate and pursue opportunities for taking a broader ecological and economic view of their activities. Each agency can and should do more to alter its own operations as well as to coordinate with other federal agencies and to reach out to non-federal entities. We do not believe it is advisable, or even possible, at this time and distance to prescribe the structural, behavioral, and legal arrangements for individual agencies or for sets of agencies. Indeed, the adaptive nature of ecosystem management

requires that the agencies learn as they go. We are recommending only that they begin the journey and have sufficient administrative and political support to stay the course.

2. Initiate an Integrated Scientific Assessment of the Basin's Biological, Physical, and Economic Characteristics

We recommend that federal agencies with an interest in the Basin's resources cooperatively undertake an assessment of the current status of the biological, physical, and economic characteristics of these resources. This assessment would help fill an important gap in the understanding of how resource-management policies and activities affect the ecosystem and economy. The central aim should be to provide resource managers—private and public, nonfederal and federal—with better information to guide their management decisions.

Resource-management activities in this Basin are highly fragmented spatially and institutionally, and there has been no Basin-wide assessment of how this management approach affects ecological conditions, causes problems, and creates opportunities. Only one stretch, the bosque (riparian cottonwood forest) of the Middle Rio Grande Valley, has been examined from a comprehensive, ecosystem-management perspective (Crawford et al. 1993).[1] There similarly has been neither a Basin-wide assessment of the full set of competing demands for water and related resources nor an examination of how alternative resource-management strategies would affect the value of resource-related goods and services, levels of employment and incomes, or perceived fairness of resource allocations. In short, there has been no comprehensive analysis incorporating the management of the Basin's scarcest and most valuable resources into the economic-development strategies for communities, states, or the Basin as a whole.

Why is it appropriate for federal agencies to undertake this assessment? Because nobody else will do so, even though there is substantial evidence of the ecological risks and economic costs of failing to have a better understanding of how resource management, ecosystem function, and economic well-being interact. Management institutions in the Basin currently do not take a broad, integrated view of this interaction and there is entrenched resistance to such a view from various positions within the

[1] The *Bosque Management Plan* did not, however, examine economic issues.

fragmented management structure. Initiation of the *Bosque Management Plan* elicited significant opposition and did not evolve through the normal activities of resource-management agencies, but required extraordinary political intervention and leadership. Many close observers believe there has been a lack of commitment to follow-through on the plan. The past year saw some movement toward an integrated approach, with representatives from multiple agencies developing a draft paper on management issues in the Middle Rio Grande Valley (Whitney et al. 1996), for example, but considerably more must be done to expand these efforts into a comprehensive assessment of ecological and economic conditions.

Given the deep antagonism toward what many in this Basin perceive to be hostile federal efforts to restrict conventional consumptive use of water and other resources, we recommend that the assessment process not be included as part of a larger effort to develop and evaluate management alternatives. Merging the assessment with planning likely would trigger fears that federal agencies were trying to dictate management policies for state, local, and private entities and might elicit enough political opposition to scuttle even the most rudimentary assessment efforts.[2] Hence, the assessment should stand alone as an effort to improve understanding of the consequences of management decisions, the potential for ecosystem changes that would be either irreversible or very costly to reverse, and the potential opportunities for increasing the net economic benefits derived from the ecosystem.[3] The voluntary participation of non-federal entities should be encouraged. It is essential, however, that the participation of others, whether formal or informal, should not distract the agencies from taking a broad view of the ecosystem and its relationship to the economy.

[2] Research, alone, can be controversial in the Basin. Advocates of diversionary use of water often oppose research proposals from agencies interested in investigating instream issues, and instream advocates reciprocate by opposing proposals related to increasing the supply of water for diversionary use. The governor of New Mexico intervened to calm disputes over research agendas in the Middle Rio Grande Valley by appointing a research coordinator generally seen as neutral.

[3] It is important to recognize that water and the water-related ecosystem will be the focus of this assessment. This will distinguish this assessment from others, such as in the interior Columbia River Basin, which focused on federal lands. Water is under state control, with rights of use owned by private entities or local public bodies. Hence, the primary objective of this assessment should not be to set the stage for federal land-management plans, but to provide a body of knowledge potentially useful to all resource owners, managers, and regulators.

Although we express this recommendation (and the others) in terms of tasks to be taken soon, we anticipate that each will require on-going effort for the foreseeable future. It will not be enough to assess ecosystem conditions once and then forget about them, especially in the face of potentially significant ecosystem change in some locations, rapid population growth, and changing economic values. Thus, we recommend that the federal agencies identified above permanently assume primary responsibility for improving understanding of the Basin's ecosystem, its economy, and the relationships between them.

3. Describe Significant Tradeoffs More Clearly and Set Priorities

We anticipate that federal resource-management policy will have two primary thrusts, one ecological and one economic.[4] The ecological goal will aim to prevent ecological degradation and to restore biological diversity and ecological integrity insofar as it is politically, economically, and ecologically feasible to do so. The economic goal will seek to increase the value of resource-related goods and services, standards of living, and perceptions of fairness. Federal managers will not have unlimited budgets for pursuing these goals, however, and will have to concentrate on activities most likely to have meaningful impact within the context of the ecosystem-management approach outlined above. Accordingly, we recommend that the agencies identified in the preceding section describe the ecological and economic tradeoffs associated with different activities more clearly and set priorities.

Why is this recommendation appropriate? Examining tradeoffs and setting priorities is especially important for federal agencies in this Basin, where resource-management long has been equivalent to developing water for consumptive use, consumptive demands, alone, far exceed supplies, and any federal action is viewed with suspicion. The importance will mount if federal agencies move in the direction of ecosystem management, both because doing so will change some of the agencies' priorities and because the broad perspective of ecosystem management mandates that each agency communicate its intentions more clearly. Without clear priorities supported by sound reasoning, the substantive controversy over federal activities will be compounded—as they are now—by frustration over the ambiguity and apparent contradiction in federal policies and actions.

[4] As we explore in previous chapters, the distinction between ecological and economic objectives often is false. Nonetheless, we preserve it to expedite our exposition.

The importance of setting priorities is illustrated by comparing two general approaches to watershed restoration. One emphasizes focusing most intensely on rehabilitating the "worst" areas from an ecological perspective, i.e., those areas in a watershed that have experienced the greatest change in composition and function. The other takes the opposite approach. It prescribes protecting the "best" areas within the watershed, facilitating connectivity among these areas, and allowing them to spawn the regeneration of ecosystem functions elsewhere. Several recent comprehensive reviews of watershed management favor the latter approach.[5] The general goal is not to re-create an ecosystem as it existed prior to human activity, but to maintain the essential elements of an aquatic ecosystem in the most efficient and effective manner, within the constraints of limited budgets.

Setting economic priorities is equally important. As we describe throughout the preceding chapters, the demands for the Basin's water and related resources are expanding, with new groups living in sometimes distant areas desiring a more complex set of goods and services than in the past. These changes cut across the boundaries of water districts, county lines, and state borders, and they do not coincide with conventional views that see the resources as economically useful only if they are put to consumptive uses. Most federal resource-management activities have their roots in the conventional views, however, and, hence, we recommend that they explicitly go through a process of reevaluating the economic tradeoffs associated with their major activities and setting priorities.

As it evaluates tradeoffs and sets priorities, each agency should strive to incorporate the views of all stakeholders. We recommend that federal resource-management agencies in the Basin, acting individually or jointly, establish advisory groups (or broaden existing ones) that include all relevant stakeholder interests. We also encourage them to take other steps to expand their outreach to stakeholders beyond their conventional clients. Involving all stakeholder groups in the evaluation of tradeoffs and development of priorities is expensive, time-consuming, and often frustrating. We believe that doing so is better than the alternatives, and a necessary element of moving toward an ecosystem-management approach.

[5] See, for example, "Section III, Approaches to Management at Larger Spatial Scales," in *Creating a Forestry for the 21st Century: The Science of Ecosystem Management* (Kohm and Franklin 1997b) as well as *Healing the Watershed* (Pacific Rivers Council 1996).

4. Communicate Clearly the Ecological and Economic Implications of Alternative Resource-Management Decisions

We recommend that federal resource-management agencies redouble their efforts to communicate clearly with one another, stakeholders, and the general public. As in any institution with substantive responsibilities, the agencies in this Basin exhibit a tendency to overlook the importance of communicating and coordinating with others. More, rather than less, communication will be required in the future, however, as resource issues become more complex, public demands for information increase, and managers shift away from the Progressive bureaucratic model.

It is especially important that federal agencies communicate clearly on issues that cut across the spatial and substantive boundaries of nonfederal entities. If the agencies adopt an ecosystem-management approach, for example, they should incorporate an outreach program to explain why they do so. This program might include forums on the ecological and economic implications of alternative management policies, discussions of research findings, and work groups to explore the interface between local concerns and the broader perspectives of the ecosystem and regional economy. It is also important that federal agencies communicate on the hydrological, ecological, and economic uncertainties of the Basin.

B. Strive to Mitigate or Correct Anticompetitive Factors

In our discussion of problems (Chapter 3) we identify several factors restricting the competition for water and related resources and inhibiting the voluntary flow of resources from low-value to high-value uses. Some of these factors, such as the public-good character of some goods and services derived from the resources, are intractable. Others, though, can be mitigated, if not corrected. Foremost among these are the high transaction costs associated with efforts to shift resources from one use to another, the existence of externalities from some uses, and the inertia of resource-management institutions. Although we recognize that some agencies have been working on these constraints to competition for some time, and with some notable successes, we recommend that federal agencies in the Basin do more to offset these constraints.

1. Reduce Transaction Costs

The absence of viable markets for water and other resources makes it difficult for an owner of a resource to identify those who might want to acquire it and to effect the transaction. We recommend that federal agencies take steps to increase the likelihood that "buyers" and "sellers" can find one another and voluntarily make deals to their mutual interest.[6] We particularly recommend steps in four areas: increasing the flow of information, helping bring potential trading partners together, providing incentives for trades beneficial to federal interests, and participating more aggressively in trades as either a "buyer" or "seller."

Federal agencies may be able to reduce the costs of information useful to potential traders in several ways. One is to create a road map showing potential "buyers" and "sellers" the federal requirements they must meet before completing a transaction. Another is to use the assessment of ecological and economic conditions in the Basin to identify hotspots, where ecological functions are seriously threatened or the discrepancy between the value of actual and potential resource uses is especially high. These hotspots, in effect, constitute the greatest market opportunities for mutually beneficial trades between "buyers" and "sellers."

In some instances, agencies might help broker deals by bringing together potential "buyers" and "sellers" and, if necessary, by sweetening the pot to cement the deal. Brokerage might be especially useful with respect to instream issues, insofar as instream advocates in the Basin are poorly organized and there has been too little communication between those who want more water in the river and those who might be willing to provide it. We anticipate growing controversy over instream issues in this Basin, especially if, as has occurred elsewhere, instream advocates acquire additional political power and seize opportunities to press their demands through administrative and legal channels. If groups on the different sides of instream issues don't talk with one another, the controversy will fester and everybody will lose except attorneys and others paid to join the battle on behalf of their clients.

[6] We set "buyers" and "sellers" in quotation marks to exploit common concepts and language associated with trades, but recognize that, in many instances, there may not be a transfer of title in the usual sense of buying and selling.

A few organizations in the Basin are attempting to bring different stakeholder groups together and we encourage federal agencies to support them. In some cases, the coming together has been sponsored by one or more agencies, such as the Fish & Wildlife Service's incorporation of stakeholders in the effort to develop a recovery plan for the Rio Grande silvery minnow. This action came in response to a change in administrative rules regarding recovery plans and is consistent with the change in management approach generally associated with ecosystem management. We encourage each agency to search its administrative rules for opportunities to open up administrative processes and bring stakeholder groups together.

Federal agencies can provide incentives for trades between two or more other parties in any number of ways. We recommend they continue to search for more innovative ways, becoming known to both "buyers" and "sellers" as a potential source of catalyst for trades. In effect, federal agencies should attempt to use incentives to entice others to take actions beneficial to federal interests. This approach will certainly require different skills and may require different authority than those associated with past approaches, often viewed as heavy-handed, wherein a federal agency acquired property, imposed regulations, or took actions to control resource uses directly. The assessment of ecological and economic conditions, as well as the priority-setting process described above should contribute to each agency's ability to determine if a proposed trade warrants an incentive and, if so, how much.

The assessment and priorities also should inform the agencies regarding where and how they should participate in trades. For example, the ecological assessment, by identifying the "best" areas of riparian habitat, should help the Fish & Wildlife Service determine not just which areas should have the highest priority for protection but also what characteristics of the site are most important. If federal ownership or comprehensive regulatory control of the site is not required to accomplish ecological objectives, the agency might pursue less intrusive alternatives for ensuring the essential features of the site are protected. For less important areas identified by the assessment, the agency might relinquish ownership or relax regulatory controls.

It is important to repeat here a message from the discussion in Chapter 4 of cooperative efforts to reduce transaction costs. By encouraging greater federal efforts to effect transactions between "buyers" and "sellers," we are not saying such efforts are a substitute for competition or that they will reduce the intensity of the competition for the resources. The best that such

efforts can do is to provide a better forum within which to deal with the conflicts that are inherent in the Basin. At their heart, disputes over resources are nothing more or less than the forces of economic competition at work. Efforts to facilitate transactions can never be a substitute for competition, but they can help competitive forces work more efficiently.

2. Curtail Externalities

We recommend that the federal resource-management agencies work cooperatively to curtail the externalities of federal resource-management activities. In particular, they should continue to work in multi-agency groups to address the concerns of each agency, as they have done in the Middle Rio Grande Valley with respect to the Rio Grande silvery minnow during last year's drought. Prior to this, each of the agencies tended to focus on its own concerns independent of the others'. In other words, each agency considered the impacts of its actions on other agencies to be an external concern. More recently, representatives of the agencies have recognized that the concerns of all the agencies must be dealt with jointly—they have worked to internalize the externalities. We encourage agency heads to support further efforts of this kind.

As part of the effort to reduce externalities, federal resource-management agencies, acting individually or jointly, periodically should prepare a summary of how their activities affect the value of resource-related goods and services and their impact on jobs, incomes, and other indicators of standard of living. These summaries should show, for example, the extent to which the different competing demands for water and related resources depend on, or are constrained by, the operation of federal facilities and the expenditure of federal funds; as well as the extent to which the value of irrigated farmland, residential lots in the floodplain, and other properties are enhanced or diminished by federal activities.

We also recommend that the BuRec, CoE, and other resource-management agencies, working with Congress, broaden the scope of activities authorized for federal dams and other facilities. At one time, statutory authorization directing an agency to operate a facility to meet the demands of one subset of resource competitors may have covered the facility's primary interaction with the economy. Now, however, each facility can significantly affect a much broader range of competitors. Management agencies have worked within the statutory constraints to accommodate this shift. We recommend that the

constraints, themselves, be adjusted so that the management agencies better internalize into their operational decisionmaking all the economic consequences of their operations. This is not to say that Congress should change the statutory authorizations to eliminate all preferences or undermine contractual obligations built on past authorization language. Instead, we recommend that Congress specify economic and ecosystem goals for the Basin, identify priorities for how the facilities should contribute to the attainment of these goals, and give the agencies greater leeway to work toward them.

3. Support Institutional Innovations that Promote Competition

We anticipate there will be many efforts in this Basin over the next few years, and certainly over the next few decades, to develop institutional innovations to facilitate voluntary transfers of resources from low-value to high-value uses. We recommend that federal agencies in the Basin support these efforts insofar as they are likely to effect true progress toward competitive ideals. As a necessary step, agencies must, themselves, become more innovative and gain a better ability to evaluate the likelihood that specific institutional proposals will bear desired fruit.

We believe all the preceding recommendations are consistent with and will facilitate making progress with respect to this one. Eventually, ecological and economic imperatives will prove to all parties, federal or otherwise, the importance of taking an ecosystem-management approach to ensuring that management of the Basin's resources accomplish both environmental and economic goals. To the extent that federal agencies get out ahead of others, they will have opportunities to serve as catalysts for institutional change up and down the valley. The assessment of ecological and economic conditions in the Basin, together with the setting of priorities will help individual agencies evaluate the merits of specific proposals.

One innovation already here is the water bank being proposed by the Middle Rio Grande Conservancy District. Before a federal agency provides material support to this proposal, it should determine the likelihood that the bank will facilitate voluntary transfer of water to highest-value uses. If, however, the agency determines the bank is likely to raise the hurdle "buyers" and

"sellers" must surmount before they can effect such a transfer, the agency should withhold its support. In making this determination, the agency should consider the full set of competing demands for water and related resources. Similar prescriptions apply not just to this proposal but to all institutional innovations.

An entire category of innovations, associated with the so-called devolution of responsibility and authority from federal agencies to state and local ones, lies on the horizon. Devolution generally entails a potentially profound change in intergovernmental relationships so that much of the work of government is passed from larger to more local entities. Some see devolution as an appropriate reversal of earlier centralization of governmental activity that will allow local stakeholders to exercise their discretion and find efficient mechanisms for accomplishing national goals. Others are less sanguine and see it as a potential sacrifice of hard-won standards in federal law. We anticipate that the devolution movement will visit the resource-management agencies in this Basin before long and they will wrestle for the foreseeable future with issues regarding the appropriate federal role versus those of their state and local counterparts.

We generally endorse the concept of devolution when accompanied with appropriate safeguards for federal interests in the Basin's ecosystem, economy, and infrastructure. We strongly recommend that federal agencies in the Basin anticipate devolution proposals—even develop their own—and prepare accordingly.

Many observers believe that, to participate successfully in a devolution process, a federal agency sharing its authority and responsibility must be able to specify the outcomes it wants the receiving agency to accomplish. Then they must have appropriate mechanisms for measuring the receiving agency's performance and holding it accountable. In short, before federal resource managers in the Basin can effectively respond to devolution proposals, they must know what goals they want to accomplish. Our recommendations for taking an ecosystem-management view of the Basin's ecosystem and economy, assessing ecological and economic conditions, and setting priorities aim to help federal agencies be prepared when faced with devolution proposals.

C. Clarify Federal Interests in the Basin's Water and Related Resources

We recommend that the federal resource-management agencies initiate meaningful steps to clarify the federal interests in the Basin's water and related resources. There is widespread uncertainty about what the federal interests are. Many believe that, because these resources, with some notable exceptions, are private property or subject to state regulatory authority, the federal government has no interest whatsoever. Others believe that federal agencies have inappropriately failed to protect interests that inherently belong to all Americans—by not meeting the stewardship responsibilities as managers of federal lands, for example—or to specific groups, such as the Pueblos. Still others have concluded that there is a fundamental disconnect between conventional views of the federal interest in the Basin's resources, on the one hand, and the Basin's ecological and economic realities, on the other. All groups appear frustrated by the ambiguity over federal interests.

Whatever view one takes of the federal interests in the Basin's resources, further clarification of these interests would help federal, state, local, and private resource managers better understand the full complement of competing demands for these resources. As a general matter, there are at least five categories of federal interest in the Basin's resources: stewardship, corporate, Pueblo trust responsibilities, economic-welfare, and public-participation.[7] Stewardship interests arise whenever the federal government acts as agents for citizens regarding the management of resources belonging to all of us. Each agency has a corporate interest in managing its assets (dams, refuges, etc.) for the benefit of citizen shareholders. Pueblo trust responsibilities stem from the federal government's obligations to provide for the welfare of Pueblo members and to manage Pueblo assets, including the claim to water and other resources. The federal government's economic interest in the resources arises from its responsibility to promote the general welfare of all Americans and, hence, to promote the highest-value and most fair resource uses. Federal interest in public participation and open government is associated with the national goal of promoting democracy and a fully representative form of government insofar as they apply to resource-management issues.

[7] Here and elsewhere, our discussion of federal interest comes from the perspective of economic policy analysis. We make no pretense of representing legal or other perspectives of the matter.

Each of these types of federal interest is affected by risk and uncertainty, to the point that the distribution of risk, itself, constitutes a federal interest in the resources. In the past, federal expenditures in the Basin have been prompted by a desire to have federal agencies bear risk and rescue resource users who located in flood plains, undertook overly ambitious water-development schemes, and overappropriated a resource without the means to allocate it in an orderly manner. More recently numerous ecological and economic risks have emerged including species extinction, ecosystem change, and global climate manipulation that arise when one aspect of a resource is exploited, ignoring its interconnections to other species and the overall ecosystem.

Debates over the federal interest in a resource, versus private and state interests, often overlook the distribution of risk. Any effort to insulate one party from risk necessarily increases the burden on others. If a private property owner has the right to manipulate her land and water resources in a manner that may contribute materially to environmental change that imposes costs on the larger society, does the federal government have no interest in preventing these costs and no recourse other than paying the owner not to manipulate the resources? If so, the larger society, acting through the federal government, bears all the risk. But, if the government retains an interest in the property and can coerce the resource owner to take action to prevent or mitigate environmental damage, then the owner bears the risk.

We recommend that each agency prepare a statement of its interest in the Basin's resources. This statement should be informed by the results of adopting an ecosystem-management approach, completing the assessment of the Basin's ecological and economic conditions, and setting priorities. The statement should be revised, as needed, to reflect new information and institutions. It should explicitly address each types of potential federal interest, described above, including those associated with risk and uncertainty. Where necessary, it should identify where the federal interest remains ambiguous and explore mechanisms for resolving the ambiguity, taking into account this observation by one of America's Nobel Laureate economists:

> *Biological activity is an interconnected web, a complex dynamic system, in which attempts to exploit one resource may lead to effects in quite different domains. Hence, the concept of systems resilience comes to the fore. It is*

hard to see that any system of property rights could account for the ultimate effects, which sometimes transcend national boundaries and operate over very long distances.

The traditional economic analysis of production thus fails to be rich enough to encompass the actual links observed in the use of natural living systems as resources. But it is also true that economic analysis is not rich enough in its understanding of alternative social arrangements. When private property fails, economists usually think of state intervention, in the form of regulations or substitutes for prices (taxes and subsidies, for example). But human societies have long faced the problems of free access and frequently have created [other] social institutions that regulate them (Arrow 1996).

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Appendix A

Physical Structures That Control the Upper Rio Grande

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Federal agencies, along with local partners, have invested heavily in controlling the Rio Grande. Since 1905, when Congress authorized the Rio Grande Project to control the river in the Middle Rio Grande area, the river

> *[H]as been converted from an essentially natural stream to a highly modified water storage and conveyance system with extensive flood control structures . . . More recent changes . . . enhance conveyance and irrigation . . . Dams and levees have all but eliminated former seasonal floods that in the past provided nutrients and moisture to the floodplain ecosystem. Former floodplain regions have been converted to productive agricultural lands and, more recently, to urban communities. Irrigation diversions create low-flow conditions, and at times a dry river bed, in much of the reach downstream of Bernalillo* (Bullard and Wells 1992).

Major facilities along the Upper Rio Grande include several dams: Rio Grande, Continental, Santa Maria, Platoro, Cochiti, Elephant Butte, and Caballo. Above Cochiti there are two major dams, Abiquiu and El Vado, on the Rio Chama, a major tributary of the Rio Grande, and the San Juan-Chama transmountain diversion project, which diverts water from the San Juan Basin to the Rio Chama. Below Cochiti there are two dams on tributaries: Jemez, located on the Jemez River, and Galisteo, located on Galisteo Creek. There are numerous diversion dams along the Upper Rio Grande supporting irrigation activities in the three states. Also important is the low-flow conveyance channel (LFCC), a canal originally designed to reduce transportation "losses" by expediting the flow of water from San Acacia to Elephant Butte Reservoir. We briefly describe each facility.

Platoro Reservoir

Authorized under the 1941 Interior Appropriation Act and completed in 1951 by the Bureau of Reclamation (BuRec), the reservoir is near the headwaters of the Conejos River, 80 miles upstream from the confluence of the Conejos and the Rio Grande. Of the 60,000 acre-feet (af) of capacity, 6,000 af is reserved for flood control while the remainder is dedicated for storage. Shortly after the dam's authorization, the Conejos Water Conservancy District formed to sponsor the project and to begin repayment of the costs allocated to irrigation. In 1991, the Conejos Water Conservancy District paid off the federal government with a loan from the Colorado Conservation Board and subsequently took over the operation of the reservoir. Operation of Platoro Dam reverts to the U.S. Army Corps of Engineers (CoE) during flood control operations.

Three other reservoirs are found along the Colorado reach of the Upper Rio Grande. The Rio Grande Reservoir, completed in 1913 by the San Juan Valley Irrigation District (formerly the Farmer's Union), was built to store approximately 51,000 af of water. Captured flows extend water availability throughout the irrigation season for pre-1903 water rights. The Santa Maria Ditch and Reservoir Company built the Continental and the Santa Maria Reservoirs which have capacities of 28,000 af and 45,000 af, respectively. These structures, and other smaller projects, represent the efforts by local groups to capture supplies for irrigation purposes.

Galisteo Reservoir

Authorized under the Flood Control Act of 1960 and completed 10 years later, Galisteo Reservoir is owned and operated by the CoE. It lies twelve miles upstream from the confluence with the Rio Grande, approximately 35 miles upstream of Albuquerque. Of the 89,000 af of storage capacity, 79,000 af are dedicated to flood control, with the remainder reserved for sediment storage. The reservoir holds the flows of Galisteo Creek only during times of floods.

Jemez Reservoir

This facility is owned and operated by the CoE, which began construction of Jemez Canyon Dam shortly after its authorization under the 1948 Flood Control Act. Plans for the reservoir were included in a comprehensive flood-control strategy for the Upper Rio Grande. Construction of the dam was completed in 1954. The dam is found on the Jemez River, two miles upstream from its confluence with the Rio Grande. Most of the reservoir's capacity, 73,000 af of the 106,000 af total, is reserved for flood control. The remainder is reserved for sediment. The CoE coordinates the release of flood waters with Cochiti Reservoir to prevent flooding in the Albuquerque area.

Cochiti Reservoir

Owned and operated by the CoE, Cochiti Reservoir is located 44 miles north of Albuquerque along the Rio Grande. Authorized in 1960 under the Flood Control Act of that year, construction was completed in 1975 producing a storage facility with a capacity of 586,000 af. The primary goal of Cochiti is to prevent downstream flood damage. The operation of the facility is tightly

controlled by the 1960 Flood Control Act, subsequent legislation requiring the maintenance of a permanent pool, and the operating procedures of CoE.

In compliance with the 1960 Flood Control Act:

- To prevent MRGCD irrigators from diverting deliveries in route to Elephant Butte Reservoir, Cochiti may not release waters from July through October, nor can releases be made when the natural flow into Cochiti Reservoir falls below 1,500 cubic feet per second (cfs).

- Of the total capacity, 212,000 af of capacity must remain idle at all times, providing adequate storage for flood water resulting from summer thunderstorms. If inflows fall below 1,500 cfs, releases from Cochiti will still be made to ensure mandatory storage levels are maintained. Thus, the storage requirements outweighs the inflow stipulation regulating releases.

In compliance with the requirement for a permanent pool:

- Adequate amounts of San Juan-Chama water must be retained each year within Cochiti Reservoir to support a permanent pool for recreational purposes as well as supporting fish and wildlife populations. The surface area of the pool shall not be less then 1,200 acres.

In compliance with CoE's operating procedures:

- Releases from Cochiti Reservoir, combined with those from the Jemez Canyon Dam, shall remain below 7,000 cfs so as not to exceed flood capacity of the river's channel.

- Whenever feasible, releases from these two reservoirs, should be adequate to guarantee enough flow so that water entering the low-flow conveyance channel will travel the entire length of the channel and reach the headwaters of Elephant Butte Reservoir.

Elephant Butte Reservoir

Elephant Butte Reservoir was authorized by Congress in 1905 and completed by the BuRec in 1916 as part of the BuRec's Rio Grande Project. The reservoir, with a capacity of 2.1 million af, was designed to secure the annual

delivery of 60,000 af to Mexico under the U.S.-Mexican Water Treaty of 1906 and to assure annual delivery of about 600,000 af/yr for the irrigation of 160,000 acres downstream in the Elephant Butte Irrigation District (EBID) and in El Paso County Water Improvement District No. 1 (EPCWID). Furthermore, Hudspeth County Conservation and Reclamation District (HCCRD), located south of El Paso, purchases excess water and return flows related to the Rio Grande Project through arrangements with the BuRec. Water deliveries to EBID are diverted by Percha, Leasburg, and Mesilla Diversion Dams.

Elephant Butte Dam and its reservoir also support a wide array of recreational activities. Annual visits to Elephant Butte State Park exceed a million persons, with highest visitor days taking place on Memorial and Labor Day Weekends. The reservoir supports fishing, boating, skiing, camping, and swimming activities.

Caballo Reservoir

Caballo Reservoir, located 25 miles downstream of Elephant Butte Dam, was completed in 1938 by the BuRec. Approximately two-thirds (231,000) of the 331,000 af of Caballo's storage is dedicated to capturing water released from Elephant Butte during winter power generation. These flows are released from the reservoir as downstream farmers make water delivery requests during the irrigation season. The remaining 100,000 af of storage are kept idle to guarantee capacity for flood waters.

Caballo Reservoir supports similar recreational activities to those found at Elephant Butte Reservoir. Annual visits to Caballo in 1993 exceeded 300,000 persons, with the highest visitation rates occurring during July and August.

Low-Flow Conveyance Channel

The low-flow conveyance channel (LFCC) was designed and built to minimize seepage and evaporation losses in the main channel of the river below San Acacia diversion dam during low-flow periods (U.S. Department of the Interior 1994). The BuRec built the LFCC in the 1950s, when the river channel was closed in four places by the intrusion of vegetation and a prolonged drought that had left little water in Elephant Butte. The LFCC reduced water losses by speeding the flow of water from San Acacia to

Elephant Butte Reservoir and limiting the amount of vegetation with access to the water. The reductions in losses increased New Mexico's ability to satisfy its Compact obligations to Texas and helped the U.S. to meet its treaty obligations to Mexico, without taking actions to restrict water use upstream.

In 1981, the LFCC went out of operation as Elephant Butte Reservoir filled and inundated the lower reaches of the LFCC. The channel subsequently operated for a short time, but it became disabled in 1985 due to the deposition of sediment in the low-flow channel and the headwaters area of Elephant Butte Reservoir. Currently, the LFCC is operated to empty into the Rio Grande floodway through an outfall constructed at a point about nine miles downstream from the San Acacia diversion dam. Both the BuRec and the CoE have undertaken studies to evaluate the options regarding the future of the LFCC. The BuRec is investigating the feasibility of pumping water from the LFCC into the floodway at a point or points downstream.

San Juan-Chama Transmountain Diversion

In 1962, Congress authorized the diversion of Colorado River Basin water into the Rio Chama, a tributary to the Rio Grande. The project, operated by the BuRec, diverts three streams in the headwaters of the San Juan River through tunnels in the Continental Divide into Heron Reservoir, located on Willow Creek, a tributary to the Rio Chama. Heron Reservoir has a capacity of 400,000 af and it cannot store any water that is native to the Rio Chama. The project is authorized to divert approximately 110,000 af/yr. The yield of the project to water users in the Basin after reservoir evaporation and conveyance losses is 94,000 af/yr. Most of the water is contracted for by cities along or near the Rio Grande, with Albuquerque contracting for approximately 50 percent.

El Vado Reservoir

El Vado Reservoir, constructed by the Middle Rio Grande Conservancy District (MRGCD) without federal funds, was completed in 1935. The BuRec, however, assumed responsibility for operating El Vado and MRGCD's other facilities in 1956, after the district encountered severe financial difficulties.

Between 1956 and 1985 the use of Rio Chama water by MRGCD's irrigators was severely restricted by the Rio Grande Compact, since the state of New Mexico had not met its obligations to deliver to Elephant Butte Reservoir. Each year that New Mexico fails to deliver specified amounts, as outlined in the Compact, a debt is accrued. As set forth in Article VI of the Compact, constraints are placed on natural flowing Rio Chama waters held in El Vado Reservoir when Compact deliveries to Elephant Butte Reservoir fail to be fulfilled. These constraints continue until all debt is repaid. Because the debt accrued by New Mexico during this period far outweighed the storage capacity at El Vado Reservoir, MRGCD's irrigators were forced to look elsewhere to meet their irrigation needs.

In 1985 Elephant Butte Reservoir filled and water "spilled" over the dam, an event that erased all of New Mexico's water-delivery debts under the Compact. Also in 1985, control of El Vado reservoir reverted back to the MRGCD, which subsequently has stored natural Rio Chama flows at the facility. This practice may continue while storage at Elephant Butte Reservoir remains above 400,000 af. As stated in Article VII of the Compact, post-1929 reservoirs in New Mexico cannot store native flows when Elephant Butte Reservoir drops below 400,000 af.

Although control of El Vado Reservoir is held by MRGCD, ownership of the facility remains with the BuRec. Ownership will revert back to the MRGCD after the district has completed repayment of the debt it owes the BuRec. The district currently makes annual interest-free payments of $400,000.00.

Another restriction, determined and enforced by the State Engineer, exists for El Vado Reservoir. When flows from the Rio Chama, measured at Abiquiu Dam, fall below 100 cfs during the irrigation season, El Vado Reservoir can store no water and all flows into the facility must continue downstream. This restriction protects downstream irrigators that heavily rely on Rio Chama water to meet their needs.

Since regaining control, MRGCD's management of El Vado has shifted towards securing San Juan-Chama water, which is not restricted by the Compact. MRGCD has leased storage space at El Vado Reservoir to the City of Albuquerque and other entities with claims to San Juan-Chama flows. This tactic has created additional revenues for the district.

Additionally, an operating criterion for El Vado Reservoir is to deliver water to the six Pueblos it services: Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta. The reservoir is required to store adequate amounts

of water for the irrigation of 8,847 acres of Pueblo lands. Pueblo water is released when Rio Grande flows from other sources cannot sufficiently support irrigable acreage for each of the six pueblos.

MRGCD and the City of Albuquerque, in an effort to support the recreational activities of the state, have recently began to time the releases of their Rio Chama water to coincide with peak seasonal demands of weekend rafters and boaters along the same river.

Abiquiu Reservoir

Located on the Rio Chama, the facility was authorized under the 1948 Flood Control Act. Construction was financed and completed in 1963 by the CoE, which retains primary control of the facility. The dam is used to control high spring flows that potentially cause flood damage along the Rio Chama and further down the Rio Grande. Releases of stored waters are made as soon as possible, taking into account the capacity of downstream channels and the demands of irrigators in the MRGCD. Of the 1.2 million af of storage capacity, 500,000 af are used to store and control flood waters and 500,000 af are designated for "structural protection" and remain idle. In 1981, Congress authorized the remaining 200,000 af to be used as storage for San Juan-Chama waters. The majority of this storage and these waters are used by the City of Albuquerque, with much smaller portions consumed by the Cities of Santa Fe and Taos, as well as the Department of Energy and other San Juan-Chama contractors.