WATER, PLANNING, AND ADMINISTRATION IN THE MIDDLE RIO GRANDE BASIN

W. Peter Balleau[76]

ABSTRACT

The Middle Rio Grande Basin is an historical center of water studies for scientific, operational and administrative purposes. The flow through the basin and the volume held in storage both are appreciably larger than required for present or foreseeable uses. The water limitations involve adapting the current pattern of uses to suit future conditions without trespassing on obligations to existing users in the basin and downstream. A flow of value to the old purposes and a flow of water to the new purposes is to be facilitated. Important objectives of the water planning process include an agreed listing of prior water rights that can be transferred to new purposes, and an agreed hydrologic model suitable for illustrating the effects on the basin. Improved science, management and administration in the future will provide water for a larger community with less impact on the environment of the Middle Rio Grande Basin.

INTRODUCTION

The Middle Rio Grande Basin (MRGB) between Cochiti Reservoir and Elephant Butte Reservoir is one of the best-documented hydrogeologic systems in the Earth's crust as reported at a MRGB workshop in February 1998 (U.S. Geological Survey or USGS, 1998). The impetus for the intensive study is wide recognition of the hydrogeologic system's management limitations. Interaction of the basin-fill aquifer with the surface-water system is a major concern. Prominent among the administrative and management concerns are water deliveries to Elephant Butte Reservoir thence to Mexico and Texas, prior water rights in the basin and background environmental conditions. Scientific research and application is producing new information and is confirming and refining the earlier understanding of the basin. The magnitude and variability of the water resource; its uses; the effects of development; and the administrative, planning and economic issues are becoming clear. Research on additional information now can be focused on the critical questions. This paper includes a hydrologic and administrative overview of the MRGB and a projection of a plausible future for the water resource in the Albuquerque Basin.

[76]Balleau Groundwater, Inc., 901 Rio Grande Blvd. NW, Suite F-242, Albuquerque, New Mexico, NET: balleau@usa.net

THE FLOWING RESOURCE

The yield of a water basin is counted in two hydrologic components; a flow component (rate) and a stored component (volume). The ratio of the two is the residence time for the system (volume/rate = time). Groundwater and surface streams have markedly different characteristics in this regard, and are used differently to take advantage of these characteristics. Surface water is of high velocity and relatively low volume with a quick flow-through period. A river flow pulse test in May 1996 traveled from Cochiti to San Acacia in 4.8 days (U.S. Bureau of Reclamation or BOR, 1997). Accordingly, Rio Grande surface water has a short transient time in the system and is highly variable and unreliable. It is used in priority to retain some certainty regarding baseflow supply for the early projects such as Pueblo and Spanish irrigation. Later users, with less certainty of supply, have built storage reservoirs or wellfields (Middle Rio Grande Conservancy District or MRGCD and the City of Albuquerque) to damp out the natural variation in surface supplies.

The historical trends in surface-water supplies are illustrated on Figure 1 showing the record of gaged river flow at San Felipe at the upstream part of the MRGB, and at San Marcial, the station measuring

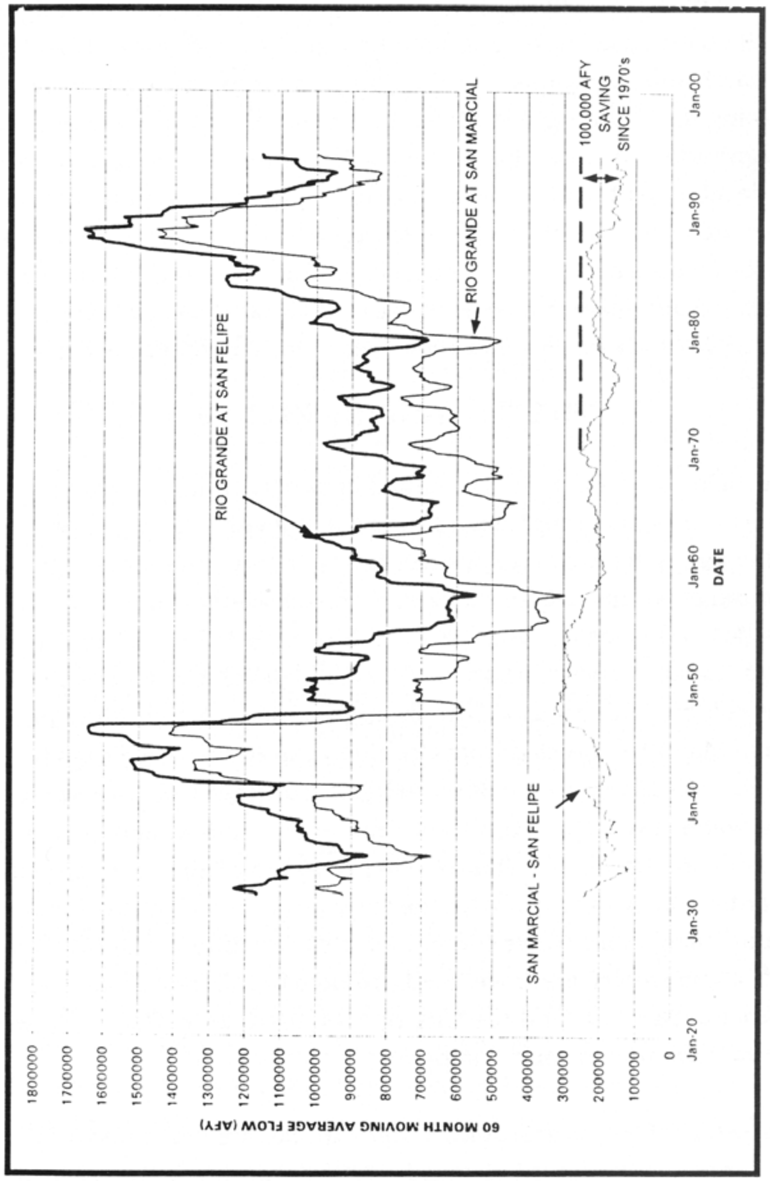

Figure 1. Historical Trends in Surface-Water Supplies

deliveries out of the MRGB. The difference between the two stations shows that the MRGB reach depletes the flow of the river between 320,000 acre feet per year (AFY) in the 1950s to 120,000 AFY in the 1990s. The San Juan-Chama Project has imported 51,500 AFY from 1972 to 1995 (Rio Grande Compact Commission Reports, 1972 to 1995). Municipal return flow adds another 60,000 AFY from basin storage. In recent decades, the net yield of the MRGB has increased by 100,000 AFY. The MRGB in the 1990s relies largely on local sources and uses only 120,000 AFY of the inflow to the basin for managed operations. The Rio Grande through flow is about 1.04 million acre feet per year (MAFY) (Thorn, and others, 1993). Local runoff from the 3,060-square mile MRGB generates about 227,000 AFY (Thorn, and others, 1993).

The groundwater flux is equivalent to natural recharge and discharge in the basin. The USGS has estimated the number as 140,000 AFY (Thorn, and others, 1993). The annual recharge is uncertain, but at any rate is a small percent of stream flow. A distinction is made between natural and induced recharge in the basin water account. The natural recharge rate is pertinent here. The captured discharge and induced recharge to the aquifer due to wellfield development are to be added to the natural rate of aquifer recharge and subtracted from the river baseflow.

THE STORED RESOURCE

The stored volume available in the basin includes the contents of the river channel, the surface-water reservoirs and the groundwater reservoir. Stored water is not static in either case, but is the volume that fills the system and continually is replenished by the flux components discussed above.

I estimate that the Rio Grande channel in the MRGB contains about 50,000 acre feet (AF) on a typical day (0.25 miles x 160 miles x 2 feet storage x 640 acres/square mile = 51,500 AF). The surface reservoirs that are dedicated to the MRGB include El Vado, Heron and some fraction of Abiquiu and Cochiti, with typical storage totaling about 600,000 AFY of MRGB contents (Ortiz and Lange, 1997) (Table 1).

Table 1. Surface-Water Reservoir Capacities

Reservoir	Capacity (AF)	Storage End of Water Year 1996 (AF)
Heron Reservoir	401,300	335,150
El Vado Reservoir	186,250	45,160
Abiquiu Reservoir	1,198,500	145,510
Cochiti Lake	502,330	56,560
Jemez Canyon Reservoir	172,800	18,110
Totals	2,461,180	600,490

The groundwater reservoir is the largest stored resource in the basin. A USGS model (Kernodle, in press) can be used to quantify the stored resource to various levels of drawdown. The surface area and recoverable specific yield of the model water-table zones indicate the volume contained in each foot of aquifer thickness. For the illustrative case of 400 feet of drawdown throughout the basin, the groundwater reservoir holds about 91 million acre feet (MAF) (Table 2) of recoverable water. In this estimate the drawdown is limited by the 400-foot threshold of Santa Fe Group subsidence (Haneberg, 1996), although drilling has shown potable recoverable water to depths below 2,000 feet (Brown, and others, 1996, and Shomaker, and others, 1994).

Table 2. Groundwater Reservoir Contents

	Area (Acres)	Specific Yield	Dewatered Thickness(ft)	Volume of Water (AF)
Albuquerque Basin Model	1,518,080	0.15	400	91,084,800
Bernalillo County	741,760	0.15	400	44,505,600

The productive fresh-water aquifers 400 to 2,000 feet below the water table can be developed by wells, and the drawdown caused by such development will not cause land subsidence until the loading of dewatered sediments exceeds the previous loading in the geologic development of the basin. Pleistocene unloading by sediment erosion in the Rio Grande Valley provides a 400-foot buffer before the loss of sediment buoyancy from dewatering matches or exceeds the pre-consolidation loads on the geologic column. Therefore, the volume of 91 MAF is calculated for the Santa Fe Group aquifer space above that subsidence threshold. The recent alluvium of the Rio Grande floodplain, however, is not protected by pre-consolidation and is subject to rapid subsidence. For interest, the stored aquifer volume to 400-foot depth is about one fourth the volume of Lake Erie (Shiklomanov, 1993). The stored aquifer source is equivalent to about 100 years of average river flow, and is 150 times the total surface-reservoir contents. The physical water resource available to the MRGB is summarized in Table 3.

Table 3. Magnitude of Water Resource in the Middle Rio Grande Basin

	Surface Water	Groundwater	Total
Flowing Resource (AFY)	1.2 million	0.14 million	~ 1.3 million AFY
Stored Resource (AF)	0.6 million	91 million	92 million AF
Residence Period (years)	0.5	650	70

About one MAF of groundwater storage has been depleted through 1992 (Thorn, and others, 1993). Despite reports of a locally diminishing aquifer (City of Albuquerque, 1997), the aquifer storage remains the major source of available water in the MRGB. Four major applications to appropriate 80,000 AFY of groundwater for future needs are pending in early 1998 to serve the City of Albuquerque, suburban cities and the County of Bernalillo.

USERS IN THE MRGB

The water budget of the MRGB includes consumptive use by natural background and by man-made projects. The USGS (Thorn, and others, 1993) values are about 150,000 AFY for background evaporation from riparian vegetation and wetlands, and about 120,000 AFY for man-made beneficial uses, largely from irrigation. Figure 2 shows the water-balance components for the MRGB in the early 1990s. Values are summarized from Thorn and others (1993) and from Kernodle and others (1995). Consumptive use (CU) of water is in two categories, managed and background. Managed uses have water rights administered by the New Mexico Office of the State Engineer (OSE). Background uses are Mother Nature's. Surface-water CU of about 270,000 AFY is a minor part of the overall surface-water and groundwater availability.

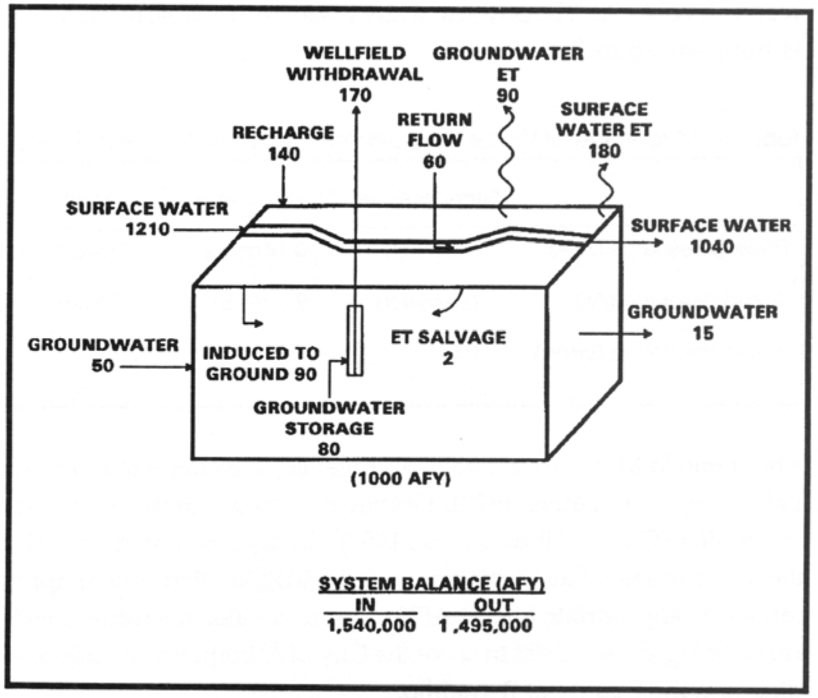

Figure 2. Water Balance of the Middle Rio Grande Basin

Wellfield withdrawals for all purposes were estimated as 170,000 AFY in 1994 (Kernodle, and others, 1995). About 80,000 AFY of the withdrawn amount is derived from the stored groundwater; the remainder is induced recharge from the surface-water system.

Overall physical availability is not a management concern when usage is about one third of the renewable surface-water supply and one thousandth of the stored volume. The limitations lie in the specific effects of development on the local structures and the external administrative requirements for water rights, compacts and treaties. For example, water-table drawdown in the floodplain alluvium on the east side of downtown Albuquerque has exceeded 50 feet and is implicated in foundation subsidence for structures in the valley (Albuquerque Journal, January 7, 1994). Microchip manufacturing, and other new projects, are constrained by accounting for effects on required pass-through deliveries to Elephant Butte.

EFFECTS OF DEVELOPMENT

The response to surface-water development is seen quickly at downstream points in the watercourse on a time scale related to the flow-through period of a few days. The response to groundwater development is retarded by the large storage in the aquifer system. The time scale of response to aquifer stress is related to the hydraulic properties (diffusivity[77] and distance from the stream) and may range from days to millennia. A higher transmissivity or a lower storage coefficient for the aquifer being developed will cause a quicker response in the interrelated stream. Transmissivity, indicating how readily water is transmitted through the aquifer under a unit hydraulic gradient, is measured as the volume of water transmitted per unit of time through a unit width of the aquifer ($L^3/T/L$). Greater transmissivity means greater response at the interrelated stream. Storage coefficient, indicating the fraction of the volume of dewatered aquifer space that

[77]Hydraulic diffusivity is the ratio (transmissivity/storage coefficient) or (hydraulic conductivity/specific storage)with dimensions (L^2/T) that indicate the rate of growth in the area of response.

yielded water, is a dimensionless ratio. Smaller storage coefficient means greater response at the interrelated stream.

The water produced from wells in the MRGB is accounted for by depletion of two components, stored groundwater and interrelated surface water. A growth curve, such as indicated by the USGS model (Kernodle, in press) of the basin, shows the transition from initial aquifer-storage depletion to ultimate induced surface-water depletion. Figure 3 illustrates the curve simulated by the USGS model for two example wellfields located one-mile and six-miles west of the river. After 100 years, about 20 percent of the well water is derived from the stream regardless of distance from the stream. For these illustrative conditions, wells deplete the Rio Grande to a lesser fraction and salvage evapotranspiration to a greater fraction of withdrawals. The surface-water impact consists of direct depletion of river, drains and canals, and on indirect interception of surface water that feeds riparian vegetation or associated evapotranspiration from the shallow water table. The salvage of evapotranspiration losses does not add to the net river depletion. The evapotranspiration salvage affects background environmental conditions, and the Rio Grande depletion affects the water right and compact concerns. Different curves can be simulated for different wellfields operating at different times in the basin. Less water can be salvaged from evapotranspiration in a developed basin than in a waterlogged undeveloped basin.

The shape of these growth curves for effects on the Rio Grande is critical to the administrative planning issues regarding prior rights and downstream delivery. The stress-response curves depend on hydraulic characteristics of the aquifer and the stream alluvium that are necessarily uncertain. Part of the planning question is to decide how well-defined that stress-response curve must be for practical management. The curves on Figure 3 show induced recharge in response to development, which must be distinguished from natural recharge throughout this discussion.

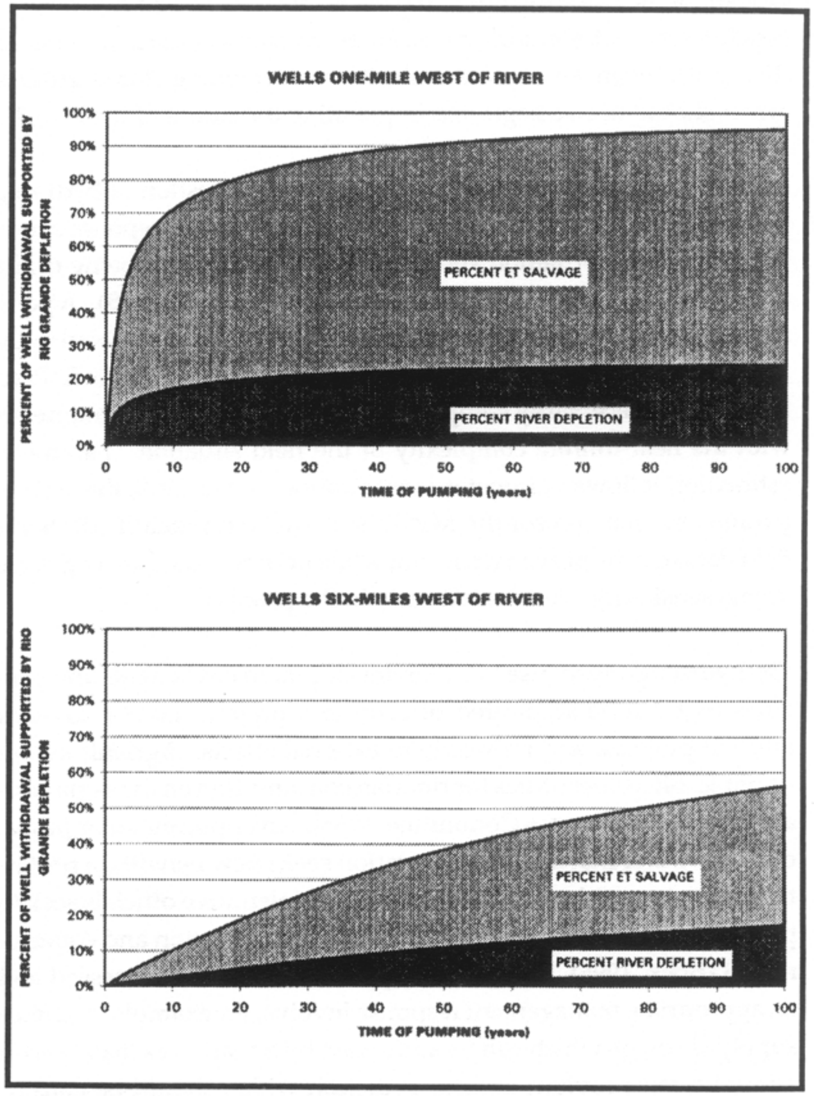

Figure 3. Illustrative Transition Curves from Initial Aquifer Storage Depletion to Induced Surface-Water Depletion.

Induced recharge of river water by well development must be offset to maintain the flow through the MRGB. If wells induce about 20 percent of their production at 100 years, then wells add five times as much to the net yield of the basin as do surface-water diversions. The great benefit to users of water from developing stored groundwater should not be neglected in planning the future of the MRGB.

Much of the current intensive study is on the question of hydraulic characterization (McAda, 1996). The sensitivity of the response curves to additional information and to present uncertainty is being evaluated (Mr. John Stomp, oral communication, February 1998). A pertinent principle of hydrologic modeling is that the level of detail in the model must fit the requirements of the question being studied. Practical models necessarily compromise the identification of parameters with the near-infinite complexity of the field situation. Parameter estimation follows parameter identification. As of 1998, the suite of parameters that control the MRGB still are being identified. Some field data may be proven irrelevant while pertinent data are neglected unless sensitivity is evaluated early in the process.

The hydrologic response to water development has benefits and penalties that can be accounted directly to a project, directly to other affected projects, and indirectly to external effects. Agriculture, for example, often substitutes for riparian consumption on the same acreage (Natural Resources Committee, 1938). An applicant for approval of a new water management operation seeks new benefits, a protestant seeks to avoid new costs and the administrative officials seek to promote public values such as efficiency, conservation and community (Tarlock, 1996). Some of the types of effects to be assessed and an appropriate management response involve, for example, a surface supply shortage which can be addressed by a market exchange with administrative review, aquifer depletion which should be considered a beneficial investment for the future and the hazard from land subsidence which requires all users to manage the local groundwater level by site specific drawdown and recharge operations.

LIMITS OF WATER DEVELOPMENT

Some limits to growth of water consumption in the MRGB, including physical and administrative limits, are listed in Table 4. This listing tends to confirm that the MRGB water use will reach a water rights and compact limit at about 300,000 AFY before it reaches a physical limit.

Table 4. Physical and Administrative Limits on Water Use in the Middle Rio Grande Basin

Irrigation Water Rights	126,300 AFY (OSE, 1983)
Municipal Water Rights	96,000 AFY (Balleau, 1994)
Rio Grande Compact (Average Year)	261,000 AFY (New Mexico Statutes 1978 Annotated, 1997)
San Juan-Chama Project Imports	51,500 AFY (Rio Grande Compact Commission Reports, 1972 to 1995)
Tributary Inflow	227,000 AFY (Thorn, et al, 1993)
Rio Grande Inflow	1,210,000 AFY (Thorn, et al, 1993)
Virgin Flow, Predevelopment	3,060,000 AFY (Natural Resources Committee, 1938)
Aquifer Stored Resource	91,000,000 AF

Today's use of water for the established pattern of agricultural, background and municipal purposes cannot grow to a larger net amount of water without new interstate agreements. Instead of growing, the established patterns are shifting as they have in the past, with increased municipal and industrial uses and reduced agricultural and background use. Transfers of use are the order of the day for surface water. Conversion from natural background uses to managed permitted uses is a major historical trend. Abundant stored groundwater remains to be appropriated where transfers can offset associated surface-water effects. Reliable knowledge of the hydraulic relationships among the sources of water and categories of use is required for the transfers to proceed with a full accounting of the internal and external project effects. Today's merely adequate models are sufficient for today's findings and decisions without waiting for tomorrow's superior models. Applied hydrology has an exceptionally demanding task in the MRGB in defining the relationships in the system.

WATER-RIGHTS ADMINISTRATION

Water-right owners have the mission of creating benefits from their water operations and avoiding costs imposed by other water operations competing for the same water. A regulatory agency has the mission of examining and approving or denying applications for proposed water-management operations based on legal standards. The legal standards include impairment of existing uses, resource conservation and public welfare. In this paper, I distinguished the roles as management and administration. It may be useful to view management as looking after the narrow proprietary account, and administration as looking after the broader public-interest account. Other commentators extend management to include the public policy-setting which is subsequently administered by agency officials (Corker, 1971). However, if management is what owners do to enhance project benefits, then government agencies generally do not "manage the water resource."

Albuquerque, an owner and operator, has developed an Albuquerque Water Resources Management Strategy (City of Albuquerque, 1997) to enhance benefits to the municipal users of water in the basin. The OSE, the administrative agency, has developed a task force draft policy on administrative criteria (OSE, 1994). The Albuquerque Water Management Strategy, for example, will be examined in terms of OSE administrative criteria. The criteria are not yet officially adopted, but generally call for an end to new appropriation in areas where water levels are declining or will decline faster than a rate of 100 feet per 40 years, and require that the induced depletion of the Rio Grande be fully offset. Offset can be by return flow or transfer of rights or imported water. The implied objectives are to extend the lifetime of the stored resource, and to maintain status quo on the Rio Grande flow. The criteria are designed to administer an unadjudicated basin, i.e., the priority of rights is not a consideration.

The priority of water rights is not administered in the MRGB because the rights are unadjudicated. No enforceable Court decree of the priority, diversion points, source, amount, place or purpose of rights has been made. The OSE is not empowered to decide priority, therefore, the OSE cannot administer priority, but treats each application for permit as the junior right with all existing rights as senior but of equal administrative standing. In a transfer application, for example, a valid recent permit is as good administratively as a valid older right originating from Spanish or Pueblo times. The status quo as of 1956, when the Rio Grande underground basin was brought under administration (OSE, 1995), however, does not protect priority by distribution of water in periods of shortage according to seniority of appropriation. A decree of water rights provides the initial condition from which administration can ensure that new uses obtain water with a full accounting of impacts on the issues regulated. The issues specifically, are impairment of other water uses, resource conservation and public welfare.

Many of the issues of MRGB planning would be removed by having a listing of water-rights quantity, location and seniority. The American Society of Civil Engineers (1987) advised that "The major water adjudications within a hydrologic unit can, if properly handled, offer a solution to many organizational and financing problems which are otherwise extremely troublesome."

A central administrative objective is to maintain the baseflow of the Rio Grande at its 1930s Rio Grande Compact condition. Two changes since those times have affected the yield of the basin, the imported San Juan-Chama Project water and the development of groundwater storage. About 120,000 AFY have been added historically to the river from the two supplementary sources (Thorn, and others, 1993 and Rio Grande Compact Commission Report, 1972 to 1995). The aquifer storage has been delivered downstream in excess of requirements partly because of the intentionally conservative calculation in the OSE administration of stream depletion from wells. The San Juan-Chama water is delivered downstream in excess because accounting is made at Otowi, but is not tracked in the MRGB. Figure 4 shows that 2.2 MAF, mostly since 1980, has been spilled from Elephant Butte due to deliveries in excess of requirements. The MRGB is entitled to capture and use that water under the Compact. Overly-conservative administration of the river has reduced the stored water reserves for the MRGB. The State of Texas complains that the spilled water is unmanaged and of little benefit to them (Keyes, 1996). One planning question is whether overstating stream depletion in OSE administration of well permits helps or hurts New Mexico.

WATER COSTS

The cost of water in the MRGB in 1996 is indicated in Table 5. The value of water in the MRGB was thoroughly studied in Brown, and others (1996). Assuming that price reflects value, the current pattern of allocations can be shifted to municipal and commercial use from agriculture with considerable value added to each purpose of use.

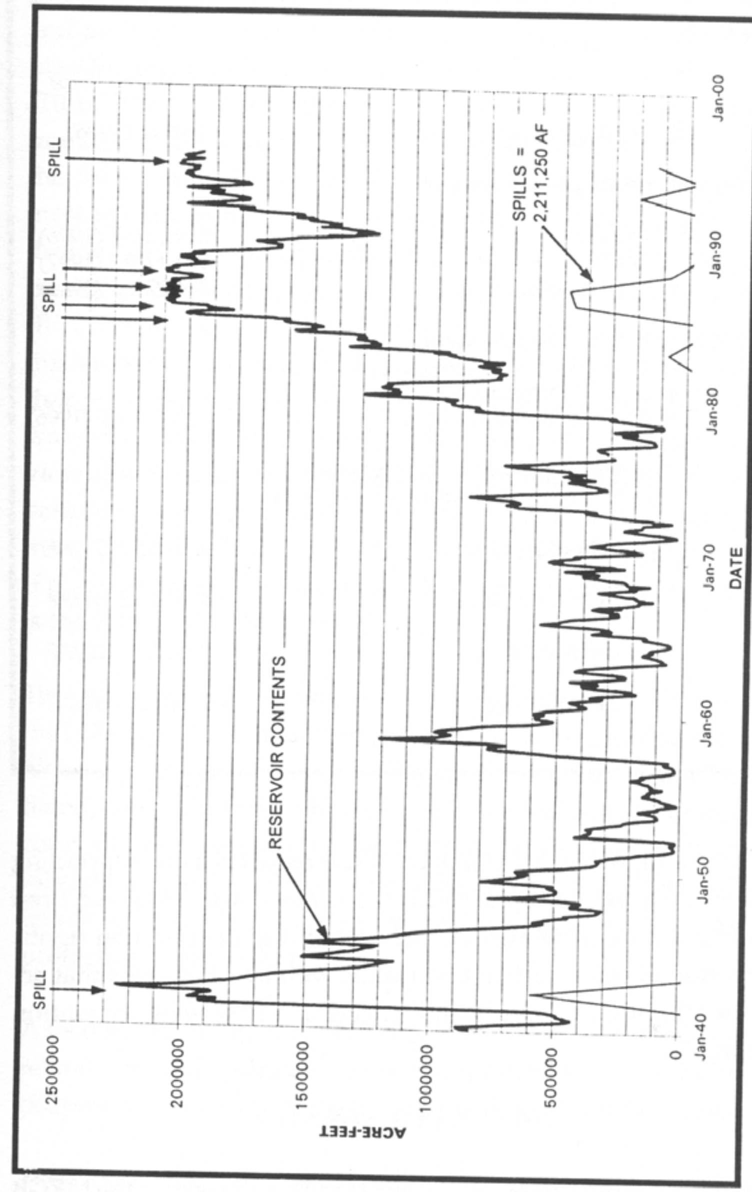

Figure 4. Elephant Butte Reservoir Contents and Spills

Table 5. Cost of Water in the Middle Rio Grande

Agriculture	
MRGCD	$9.33/AF (1996)
City of Albuquerque	$10/AF (1996)
Non-Agricultural (Secondary Lease)	
San Juan-Chama	$39.14/AF (1996) $43.17/AF (1997)
City of Albuquerque	$41.02/AF (1996)
Public Supply (City of Albuquerque)	
Unit Cost (Commodity Charge Plus State Conservation Fee)	$296.21/AF (1996)
Water Users Pay Different Rates Based on Meter Size and Customer Class (1996)	
Residential	$317 to $321/AF
Commercial	$334 to $341/AF
Industrial	$401 to $425/AF
Institutional	$330 to $337/AF

Transfer to a higher value purpose of use requires a corresponding payment to the owner of the former purpose of use. Also required is an administrative examination of accounting of effects on rights, conservation of the resource and public welfare. Transfers that account for all internal and external effects of a new water operation are desirable.

WATER PLANNING

A basin-wide regional water planning effort is underway in the MRGB with participation of an Action Committee of managers, advocates

and experts. The effort intends to meet the guidelines of State regional planning (New Mexico Interstate Stream Commission, 1994), and perhaps to go beyond that and outline a comprehensive water plan for the basin. The role of water planning is widely acclaimed (Titus, 1998), and sometimes disparaged (Ms. Ann Rogers, oral communication, November 8, 1997). Water planning, in fact, cannot usurp the future manager's function of determining how to produce the most benefit from water to a future project account, neither can it decide how a future administrator will evaluate resource conservation or public-welfare interests. The last New Mexico Water Plan (BOR, 1976) forecast uranium mining, power, and oil and gas production as the major growth in state-wide water use. Post-audits show that projections often are wrong about sectors and levels of future water-use activity (Konikow, 1986). Barrow (1998) in a critical review of water plan implementation finds that "Various forms of river basin development planning and management have been applied in many countries. Unfortunately, the results have been disappointing." If planners cannot foresee future demands and valuations, then what is the role of MRGB planning?

Two goals for the planning effort are suggested. One helpful goal of the MRGB regional planning effort would be to agree on the listing of historic priority and amount of rights in the basin. A planned, negotiated, comprehensive adjudication is needed that can be adopted by court decree. Future managers and administrators will appreciate inheriting a decree of rights that allows them to proceed with transfers of valid rights to accommodate development in the basin while protecting those valid rights.

A second helpful goal of planning is an accepted model of the interrelationships of hydraulic stresses and responses in the basin, for the purpose of evaluating changes in terms of effects on the decreed rights.

Today's planners should not attempt to define future water uses or quantities for those uses. They should find agreeable mechanisms for moving water and compensatory value to satisfy changing demands.

INFORMATION NEEDS

Abundant information on the hydrology of the basin is becoming available. The MRGB study workshop February 10-11, 1998, displayed progress on mapping, geology, geophysics, drilling, magnetics, seismic history, geographic information systems, climate, land use, cartography, geochemistry, modeling, dating and tracing groundwater, temperature, field tests, recharge rates, unsaturated zone and mass-balance studies. Hydrologists know that the near-infinite detail in the Earth's crust cannot be characterized fully, therefore, we ask "What do we need to know to satisfy the applied hydrologic objectives?" I suggest that practical objectives and attainable information are along the lines listed in Table 6.

Success in applied hydrology usually comes from using the abundant information available in an observational approach. The increment of new data added from intensive effort each year invariably is less than the accumulated data recorded in the past. The Albuquerque Basin studies should examine the sensitivity, in terms of practical results, to the gain in new information in comparison to the better use of old information.

A HYDROLOGIC PROJECTION

The Rio Grande High School class of 2000 will have its 40th reunion in the year 2040, which is the current planning horizon for State water studies. What will water operations in the MRGB be like in 40 years? My projections include some hopeful speculation.

The three percent annual growth in productivity of the economy (Atack, 1995) will make most goods costs 30 percent of today's real cost. Water works will be less productive (U.S. Economics and Statistics Administration, 1995), but will be provided at 66 percent of today's real cost, that is, twice the relative future cost of other goods. Basin population may double (McDonald, and others, 1989). Water use will shift

Table 6. Information Needs for Practical Objectives

Objective	Information Requirement
1. Delivery obligation to Elephant Butte	•Comparison of Compact index curves to 1990 conditions. •Monthly flow data at river and at diversions. •Annualized system response to managed diversion/operation. •Separation of natural and induced river-depletion response to managed well withdrawal/ re-charge operation. •River stage (stress) versus seepage and aquifer head (response) relationship. •A river boundary stress test for comparison to the aquifer stress tests. •Identify area of influence of aquifer development.
2. Administration of priority for security, ease of transfer and reliability of supplies	•A negotiated Court decree of priority, amount, diversion point, place and purpose of uses. •Hydrographic survey and historical uses inventory.
3. Environmental baseline protection	•Same as 1 above.
4. Maintain community objectives	•Obtain statement of community objectives through basin planning process.
5. Understand effects of alternative wellfield development	•Examine calibrated model results for basin wellfields at alternative sites and rates from Cochiti to Socorro.
6. Understand water-quality and yield patterns in aquifer	•Drill and sample one well per township throughout the basin to the depth of the potable water limit.
7. Model calibration	•Model calibration requires observational history matching of the response to historic development. The best three-dimensional data set in the basin is the Intel daily monitoring data for 15 constructed wells and 15 existing wells since 1995. •Short-term stress and response tests cannot provide the information contained in the 50-year observational history of stress and response. The model that matches long-term history is the best for projecting the long-term future.

from today's approximate thirds for municipal, agricultural and environmental categories to two-thirds municipal, one-sixth each for agricultural and environmental. Conservation will have had an initial, but not a long-term, impact on per capita water use. The benefits of improved water facilities and management will exceed the costs.

The available surface-water supply will be the same. Discussions on adding water leasing provisions between the States will be in progress. Groundwater will have depleted an additional four MAF from the 100 MAF aquifer reserve at the average rate of 100,000 AFY from storage. Wellfield withdrawals will be steady at 200,000 AFY with one half derived from the surface stream. Basin wellfields will be more extensive and further from the river. Less drawdown over a greater area of the basin will avoid a concentrated cone of depression in water levels. The Albuquerque Northeast Heights wellfields still will be operating but with new equipment at deeper pump settings at about the same rates as in the 1990s. Wellfield depletion of the river will be offset by full San Juan-Chama Project imports and by leasing of old irrigation rights. Regional integration of water operations will not succeed. Each County will have an independent water-system operation. Negotiated operating criteria will avoid conflicts.

Albuquerque Metropolitan Area Flood Control Authority and MRGCD drains and canals will be buried and covered for safety, mosquito control, efficient pressurized operation and for recreational use of the rights of way (bicycle, equestrian, walking, etc.). Water will be injected into the floodplain alluvium to maintain the water table at a controlled level and prevent further subsidence in downtown Albuquerque.

The Federal agencies will provide water information in the form of data, interpretation and calibrated model projections on each watercourse, conveyance structure, diversion point, evapotranspiration, habitat and three-dimensional aquifer level. The data are updated in

a real-time system model with on-line public access to diversion, consumption rates and return flow water quality. A public-access database of permits, priority and discharge plans will be available for comparison to actual use. Monitoring is by interested citizens who query networked hydrologic information systems data and rights in their neighborhoods. Federal officials provide information, State agencies administer permits according to court decree and private parties manage their operations for the best value.

The majority of river flow, about one MAFY will continue to be delivered downstream. In doing so, the deliveries are scheduled and controlled to provide valuable services for riparian, environmental, recreational and public welfare benefits from the waters passed through the MRGB. Water rights for the small additional depletions due to those services have been acquired by public agencies and private groups. Elephant Butte no longer spills because the spill water is retained for use in the MRGB.

New water demand is supplied from the list of initial water rights adopted by stipulation among the major interests and decreed by the court. The initial list of rights is continually updated by transfers. Water operations managers routinely evaluate their plans, the capacity to pay value to a previous right owner and the explicit administrative criteria for resource conservation and public welfare that were agreed upon in the court stipulation.

New developments that require water apply at the one-stop OSE where a catalog of decreed water rights and subsequent administrative actions documents the current status of all water-use rights in the State. Any degree of reliability is available for the new development from the pool of identified rights with priority offered in the on-line catalog.

High priority rights are available at a substantial premium. The surface-water reservoirs and the abundant aquifer-storage reserves and integrated operating rules have made water shortage rare. Reservoir releases will be used to offset streamflow induced into the extensive wellfields.

The rare shortage in a multi-year drought will be provided for by leasing of Pueblo reserved and old Spanish historical rights. Annualized payments for intermittent use of old prior rights have eclipsed the revenue from gaming in the valley. The Pueblo and mountain tributaries with enforceable senior priorities have been maintained as required by Court decree. Wastewater will be treated and extensively reused. Permitted discharges maintain background conditions through the Pueblo stream reaches and wildlife refuges. Effluent pipelines have been constructed to by-pass sensitive recreational and environmental reaches of the stream. Some effluent is conveyed to Elephant Butte Reservoir to take advantage of its mixing zones and assimilative capacity.

In the year 2040, New Mexico remains the oldest and happiest center of habitation in North America and a center of advanced hydrologic science renown throughout the world.

CONCLUSIONS

1. The water resource in the MRGB consists of about 1.3 MAF of annually renewable water, and 92 MAF of stored reservoir contents. Both the renewable and the stored resource exceed the current and projected level of use in the basin. The stored resource in the aquifer is large and its continued use is essential for the future of the basin.

2. Surface water consumed and depleted from the MRGB is about 270,000 AFY for artificial and natural background uses. Since the 1970s, the basin has been conveying a larger fraction of inflow to Elephant Butte than in earlier decades.

3. Uses are not limited by the physical supply, but by compact and treaty agreements to deliver most of the physical supply to downstream sites. The working principle for the future involves transfers of value to existing users and corresponding transfers of water to new users.

4. The hydrologic relationships between changes in patterns of use and the responses at other parts of the hydrologic system must be understood for checking whether proposed changes are acceptable to the MRGB community. The general relationships are understood. The degree of site-specific precision required in characterizing the relationships is being studied. It is possible that we know enough in 1998 to manage properly.

5. Managers and owners of water operations must remain able to propose beneficial new project operations that enhance the value of water in the basin. The ability to adapt to new opportunities is aided by clear administrative criteria. The greatest shortcoming in basin administration is the lack of a court decree of water-right priorities and amounts. Without a starting position, water cannot move.

6. Planning should be directed toward:

   a) a negotiated comprehensive agreement on the priority listing of water rights for adoption by court decree, and
   b) an agreement on a serviceable quantitative model of the basin for evaluating the effects of applications for new water permits.

7. Today's planners should not attempt to define future water uses or quantities for those uses. They should find agreeable mechanisms for moving water and compensatory value to satisfy changing demands.

8. Water to serve environmental, recreational and public welfare needs can be scheduled from the one million AFY already passing through the basin. Rights for relatively small additional depletions due to re-scheduling the flows may be acquired from the decreed list of prior rights.

9. Technical studies should be selected in terms of practical advancement of the administrative questions, and should apply the abundant historical data for model calibration.

10. The management, administration, and science of the basin will be better in the future, and will support a larger community of users with less impact on the background environment.

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