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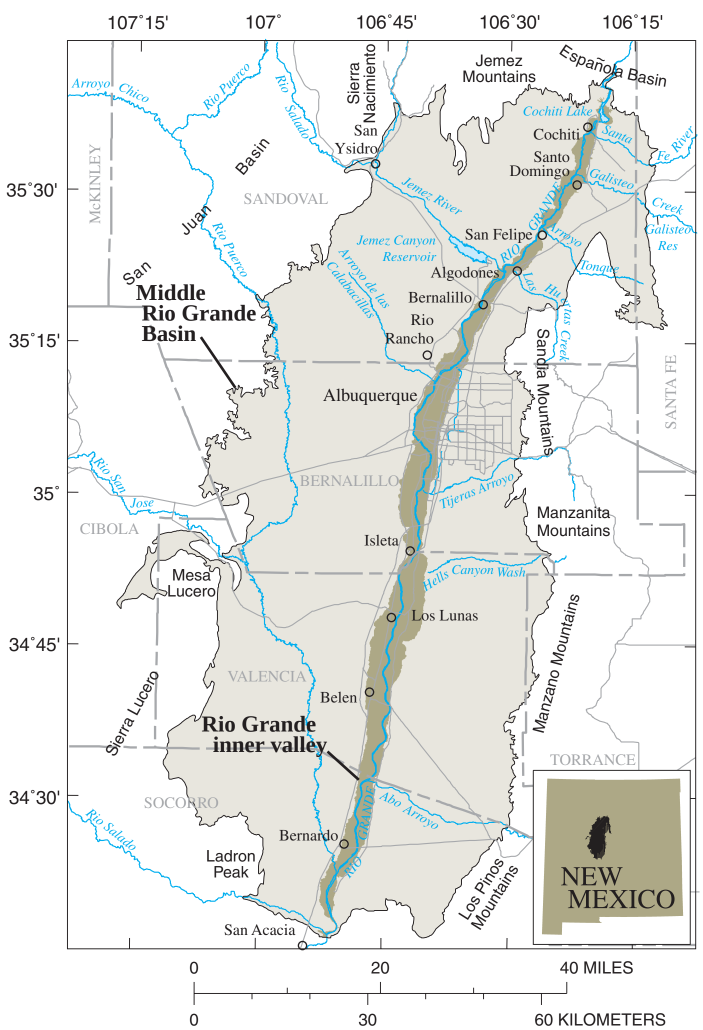
Ground-Water Resources of the Middle Rio Grande Basin



Major physiographic and hydrologic features of the Middle Rio Grande Basin.

What is the Middle Rio Grande Basin?

The Middle Rio Grande Basin, as defined for this study, is the area within the Rio Grande Valley extending from about Cochiti Lake downstream to about San Acacia. It covers approximately 3,060 square miles in central New Mexico, encompassing parts of Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Torrance, and Cibola Counties and includes a ground-water basin composed of the Santa Fe Group aquifer system. (It is equivalent to the Albuquerque Basin referred to by other authors.) The climate over most of the basin is semiarid. In 2000, the population of the Middle Rio Grande Basin was about 690,000 or about 38 percent of the population of New Mexico. Currently (2002), the source of water for municipal and domestic supply is almost exclusively from ground water.

What is the USGS Middle Rio Grande Basin Study?

The U.S. Geological Survey (USGS) Middle Rio Grande Basin Study was a 6-year effort (1995-2001) by the USGS and other agencies to improve the understanding of the hydrology, geology, and land-surface characteristics of the Middle Rio Grande Basin in order to provide the scientific information needed for water-resources management. The Santa Fe Group aquifer system is the main source of municipal water for the region, and the main purpose of the study was to improve the understanding of the water resources of the basin. The New Mexico Office of the State Engineer (NMOSE) administers the appropriation and use of the water resources of New Mexico and has declared the basin a “critical basin”; that is, a ground-water basin faced with rapid economic and population growth where there is less than adequate technical information about the available water supply (New Mexico Office of the State Engineer, written commun., 1995).

In addition to the USGS, many other Federal, State, and local governments and agencies contributed resources to or cooperated in the Middle Rio Grande Basin Study. These governments and agencies include the City of Albuquerque, New Mexico Office of the State Engineer, New Mexico Bureau of Geology and Mineral Resources (NMBGMR), Middle Rio Grande Council of Governments (MRGCOG), and a number of pueblos and other Federal, State, and local agencies.

What is the Santa Fe Group aquifer system?

Most water-bearing units of the Middle Rio Grande Basin are unconsolidated deposits of the Tertiary Santa Fe Group. Post-Santa Fe Group deposits (piedmont fan and valley fill) of Quaternary age formed during the last 1.6 million years. These deposits are present on mountain slopes, in the incised valley of the Rio Grande, and along flood plains of tributaries to the Rio Grande. They are considered part of the Santa Fe Group aquifer system, although these deposits are generally saturated only in flood plains or the inner valley of the Rio Grande. Because the Santa Fe Group and

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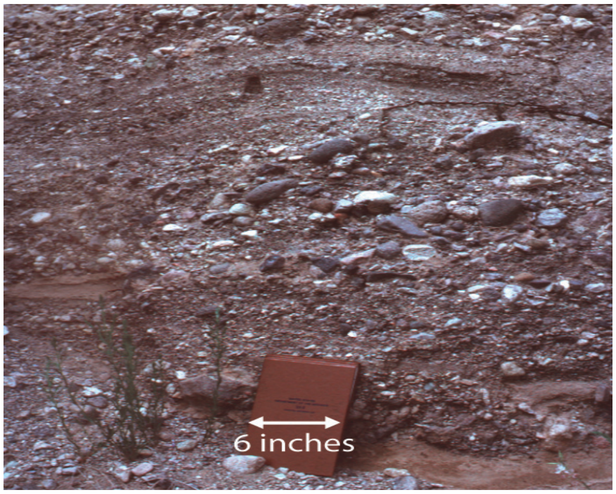
post-Santa Fe Group deposits are hydraulically connected, they are commonly grouped together as the Santa Fe Group aquifer system. Though the aquifer is under confined conditions locally, it is considered to be an unconfined aquifer as a whole.



Santa Fe Group sediments exposed near Bernalillo. Such deposits form some of the most productive zones of the aquifer.

The thickness of the Santa Fe Group in the Middle Rio Grande Basin is highly variable because of complex faulting during sedimentation; total thickness ranges from about 1,400 feet at basin margins to approximately 14,000 feet in localized areas in the center of the basin (Hawley and Haase, 1992; Grauch, Gillespie, and Keller, 1999). The Santa Fe Group is divided into three parts: upper (less than 1,000 to 1,500 feet thick), middle (250 to 9,000 feet thick), and lower (less than 1,000 to 3,500 feet thick). In places, either the upper part or the upper and middle parts have eroded away. Because of the types of sediments in the lower part of the Santa Fe Group, much of it may make a poor aquifer (though most of Rio Rancho's water is withdrawn from very productive areas of the lower Santa Fe Group). For this reason and economic reasons, ground water is thus withdrawn mostly from the sands and gravels of the upper and middle parts; only about the upper 2,000 feet of the aquifer is used for ground-water withdrawal. The depth to water in the aquifer system varies widely, from less than 2 feet near the Rio Grande to as much as 1,180 feet in an area west of Albuquerque.

What kinds of scientific information were collected?

Many scientists from different agencies collected a wide variety of information as part of the Middle Rio Grande Basin Study. Some individual scientific projects had direct application to furthering the understanding of the water resources of the basin, whereas other projects were indirectly related. Though the individual studies are too numerous to list in this publication, some examples are:

- Water samples from 275 wells in the basin were analyzed for environmental tracers and 30 chemical constituents to date ground water, to define zones of differing water quality, and to locate areas of recent recharge. This sampling has made the basin one of the most intensively sampled basins in the world for environmental tracers. Among the tracers used were hydrogen, helium, oxygen, carbon, and sulfur isotopes; dissolved gasses; chlorofluorocarbons; and sulfur hexafluoride. This sampling has defined areas of water along the western edge of the basin to be about 20,000 years old as well as areas of water that have been recharged in the past 50 years, such as in the inner valley of the Rio Grande and along some arroyos and mountain-front areas. These ground-water ages have also provided calibration data for ground-water-flow models of the basin (Plummer and others, 2001).

- Early in the study, non-linear regression methods were applied to a ground-water-flow model of the basin to evaluate six different hypotheses about the hydrogeologic framework of the basin. The resulting information was used to further refine the understanding of the hydrology of the basin. In addition, the resulting model served as a basis for an NMOSE management model of the basin (Tiedeman, Kernodle, and McAda, 1998; Barroll, 2001).

- Geophysical methods were used to interpret different properties of the aquifer system. Gravity techniques were used to estimate the total thickness of the Santa Fe Group deposits, which are less dense than the underlying and surrounding bedrock. High-resolution aeromagnetic surveys delineated faults that offset water-bearing units in the aquifer system and showed the extent of buried igneous rocks, which have different hydraulic properties than the surrounding sedimentary deposits. Airborne time-domain electromagnetic surveys were used to determine changes in the electrical resistivity of the Santa Fe Group related to variations in grain size and hydraulic properties (Grauch, Rodriguez, and Deszcz-Pan, 2002).

- Because of the limitations of ground-water levels measured in or near production wells, the USGS in cooperation with the City of Albuquerque, NMOSE, and Bernalillo County began a program in 1996 to install specialized monitoring wells in the Middle Rio Grande Basin. Most of these wells are groups, or nests, of two or more wells completed at different depths in the aquifer. Currently (2002), 59 such monitoring wells have been installed at 23 sites. Continuous water-level recorders have been installed on nearly all these wells, and all wells have been incorporated into the City of Albuquerque ground-water-level monitoring program.

- To estimate the degree of ground- and surface-water interaction between the Rio Grande and Santa Fe Group aquifer system, studies that use a variety of techniques were applied, including analyses of the distribution of water temperature, electromagnetic surveys, and streamflow losses. These techniques have supplied estimates of the direction and amount of water moving between the river and aquifer system at selected sites (Bartolino, 2002).

- Research on mountain-front recharge applied a variety of techniques, including water-temperature methods, steady-state centrifuge analysis of cores, chloride mass-balance methods, and geochemical analysis of core samples and pore water. These studies have helped confirm that there is substantially less ground-water recharge along mountain fronts in the Middle Rio Grande Basin than previously estimated (Bartolino and Constantz, 2002).

- In the Middle Rio Grande Basin, three methods are being used to check for the onset of land subsidence related to ground-water withdrawals: (1) a high-precision survey network in the Albuquerque area, (2) an extensometer in northern Albuquerque, and (3) Interferometric Synthetic Aperture Radar (InSAR) analysis. The first two methods have not detected land subsidence greater than the detection threshold of 0.5 inch. However, InSAR analysis, in conjunction with water-level data, shows reversible and possibly permanent land subsidence from aquifer-system deformation in parts of the Middle Rio Grande Basin (Heywood, Bartolino, and Galloway, 2002).

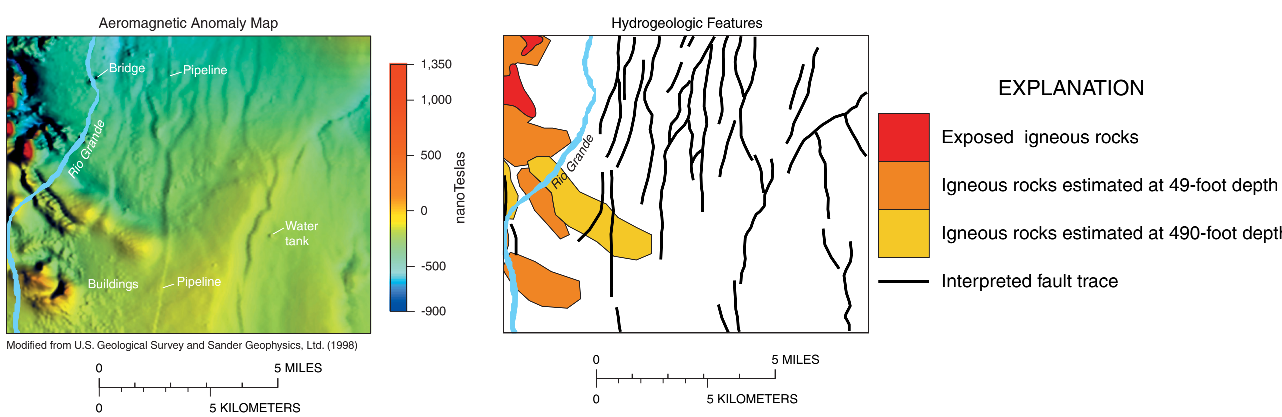
- The conceptual geologic framework of the Middle Rio Grande Basin was revised and updated by mapping the surficial deposits and bedrock outcrops of the Middle Rio Grande Basin and adjoining areas. A number of new maps (1:24,000 scale) are now available in digital form from the Internet (Bauer, 2001).

- The Albuquerque area was modeled using an urban-growth model to project the potential urbanized-area extent in 2050 to help managers form sound policies for guiding sustainable growth. Because the availability of water may ultimately be limited, decisions on growth can be improved by realistic and scientific projections of growth patterns and changes (Hester and Feller, 2002).

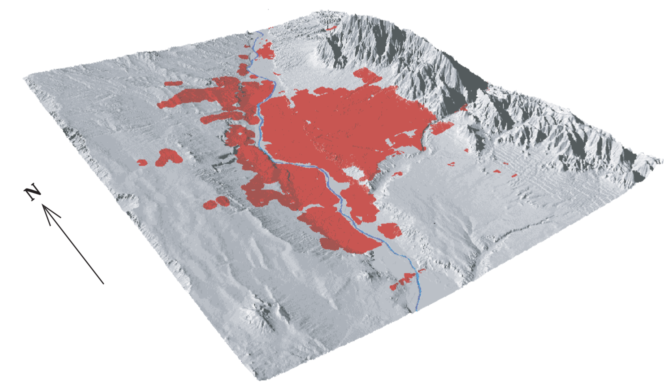
What is the ground-water-flow model of the basin?

Throughout the Middle Rio Grande Basin Study, a revised ground-water-flow model of the basin has been viewed as the culmination of the study. The revised model incorporates new information collected since 1995 into a “state-of-the-art” understanding of the hydrogeology of the basin.

Ground-water-flow models attempt to reproduce, or simulate, the operation of an actual ground-water system with a mathematical counterpart (a mathematical model). The use of such models has provided an opportunity for water managers to quantitatively understand how ground water moves and to estimate the effects of human use of the water (Reilly and McAda, 2002).



Aeromagnetic anomaly map of an area south of Albuquerque and simplified map of important hydrogeologic features. Many geologic features and manmade structures can be seen on the anomaly map, which is displayed in color and shaded as though it were a relief map illuminated from the east. The most important hydrogeologic features expressed in the aeromagnetic map are faults and igneous rocks, depicted on the simplified map. Depths to the buried igneous rocks were estimated by analysis of the aeromagnetic data. Note the shallow, buried igneous rocks near the Rio Grande that probably affect ground-water flow.



Urban area in the vicinity of Albuquerque in 2050 projected using the Slope Land use, Exclusions, Urban, Transportation, and Hillshade (SLEUTH) urban-growth model.

McAda and Barroll (2002) constructed a new ground-water-flow model of the Middle Rio Grande Basin to incorporate the large volume of new hydrogeologic data collected since 1995. This model consists of nine layers, and each layer is divided into a grid of cells containing 156 rows and 80 columns. Each cell is 3,281 feet (1 kilometer) on a side. Thus, the model contains 112,320 cells, 50,449 of which actively simulate ground-water flow. The model encompasses the entire thickness of the Santa Fe Group in order to reproduce probable flow paths in the lower portions of the aquifer. In addition, the orientation of this model grid is north-south (parallel to the dominant trend of faults and the Rio Grande in the main part of the basin) to better align with the principal directions of hydraulic conductivity in the basin.

Among the most important findings and features of this new ground-water-flow model of the basin are:

- Prior to installation of the riverside drains along the Rio Grande, the river was losing flow in most of the basin. This water probably was being evapotranspired and (or) was recharging the Santa Fe Group aquifer system. Currently (2002), the drains intercept much of this flow that would have been lost to evapotranspiration and divert it back into the river.

- In much of the Santa Fe Group aquifer system throughout the basin, water removed from storage is partially replaced, particularly during the nonirrigation season.

- The substantially smaller rates of mountain-front recharge to the aquifer estimated by other studies have been implemented in the model.

The table below shows the annual water budgets simulated by the ground-water-flow model for steady-state conditions and for 1999. Steady state refers to the natural hydrologic conditions before ground-water development and large-scale alteration of the surface-water system.

Though the McAda and Barroll (2002) ground-water-flow model of the Middle Rio Grande Basin does not make any projections of future conditions, it could be modified to do so. The model does provide water-resource managers a more realistic and powerful tool to evaluate the potential effects of management decisions.

Simulated annual water budget for the ground-water-flow model of McAda and Barroll (2002). All values are in acre-feet per year
[--, 0 or not applicable. One acre-foot is the amount of water needed to cover 1 acre 1 foot deep in water or about 325,829 gallons]

Mechanism	Steady-state conditions		1999 conditions	
	Inflow (to aquifer)	**Outflow** (from aquifer)	**Inflow** (to aquifer)	**Outflow** (from aquifer)
Mountain-front recharge	12,000	--	12,000	--
Recharge from intermittent tributaries	9,000	--	9,000	--
Underflow from adjacent basins	31,000	--	31,000	--
Canal seepage	--	--	90,000	--
On-farm irrigation seepage	--	--	35,000	--
Rio Grande main stem and Cochiti Lake	63,000	--	317,000	--
Rio Grande riverside drains	--	--	--	-208,000
Rio Grande interior drains	--	--	--	-134,000
Jemez River and Reservoir	--	--	16,000	--
Ground-water withdrawals	15,000	--	--	-150,000
Septic-field return flow	--	--	4,000	--
Riparian and wetland evapotranspiration	--	-130,000	--	-84,000
Aquifer storage	--	--	110,000	-49,000
Totals:	130,000	-130,000	624,000	-625,000

What are the key points regarding water resources in the basin?

The most prominent hydrologic feature in the largely semiarid Middle Rio Grande Basin is the Rio Grande, whereas the sole source of water for municipal, domestic, and non-agricultural commercial supply is currently (2002) the Santa Fe Group aquifer system. The water resources of the Middle Rio Grande Basin are a combination of the surface- and ground-water systems, which are intimately linked through a series of complex interactions. These interactions often make recognizing the boundary between the two systems difficult, and changes in one system often affect the other. The most important points in our present understanding of the water resources of the Middle Rio Grande Basin are:

- When ground water is pumped from an aquifer system, water is removed from aquifer storage and ground-water levels decline. Ground-water levels have declined with population growth in the Middle Rio Grande Basin. The effects of ground-water pumping are evident when comparing historical (1960-61) and the most recent (1994-95) ground-water-level maps; water-level declines are more than 160 feet in an area beneath eastern Albuquerque.

Riverside drains such as the Bernalillo Riverside Drain at Bernalillo form part of a complex irrigation network that is intimately linked with the Rio Grande and Santa Fe Group aquifer system.

- Years of water-management policy were based on the assumption that the Rio Grande is well connected hydraulically to the Santa Fe Group aquifer system. Recent studies of the interaction between the river and aquifer (including ground-water-flow models) indicate that the hydraulic connection is less than previously thought.

- As Albuquerque grew, most of the new municipal supply wells were completed in highly productive parts of the Santa Fe Group aquifer system. The quantity and quality of the water led to the popular belief that the entire Middle Rio Grande Basin was underlain by a high-quality aquifer; it is now known that such areas of high-quality aquifer are relatively limited and that much less water is available for municipal supply than previously believed.

- Geophysical studies of the Middle Rio Grande Basin, in conjunction with computer modeling of the Santa Fe Group aquifer system, indicate that faults are more numerous than previously thought and that they can affect ground-water movement, particularly when they juxtapose aquifer materials of substantially different hydraulic properties.

- Previous estimates of mountain-front recharge were based on indirect calculations from water budgets and computer modeling of the Santa Fe Group aquifer system. New studies using direct and indirect measurements and ground-water age dating have shown that mountain-front recharge is substantially less than previously believed.

- The bosque assumed its present character in about the past 60 to 70 years, developing in an area that was formerly semibarren flood plain with scattered stands of predominantly cottonwood and willow. The present character was caused by the spread of exotic plant species and the construction of bank stabilization and flood-control structures, including dams and levees. Though estimates vary, a substantial amount of ground and surface water is consumed by evapotranspiration from the bosque.

By increasing the understanding of the water resources of the Middle Rio Grande Basin, water-resource managers and planners will have additional tools to make sound, scientifically based decisions on the future of water in the basin.

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Additional information

This USGS Fact Sheet is a brief summary of USGS Circular 1222—"Ground-water resources of the Middle Rio Grande Basin, New Mexico" by J.R. Bartolino and J.C. Cole, 2002.

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Additional information on the Middle Rio Grande Basin Study can be found at: *http://nm.water.usgs.gov*

To learn more about the USGS and its products call: 1-888-ASK-USGS or go to *http://www.usgs.gov*

An index of geologic maps of the Middle Rio Grande Basin and surrounding area is available on the WWW from the New Mexico Bureau of Geology and Mineral Resources at: *http://geoinfo.nmt.edu/statemap/quads/index/home.html*

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Frequent and consistent measurements of ground-water levels are crucial for understanding the aquifer system and tracking water-level declines.