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Sources of Water to the Rio Grande Upstream from San Marcial, New Mexico

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Introduction

The Rio Grande watershed is a complex hydrologic system that includes numerous tributaries, inflow from transmountain diversions, irrigation diversions, agricultural return flows, reservoirs, and ground-water inflows and outflows. Many people depend on and are affected by the Rio Grande, which is the largest river of the surface-water system draining the Rio Grande watershed. To provide information to further the understanding of the Rio Grande surface-water system, the U.S. Geological Survey, in cooperation with the City of Albuquerque, evaluated streamflow data computed by the U.S. Geological Survey at 60 streamflow-gaging stations. This fact sheet examines the sources of water to the Rio Grande and the "water balance" of the Rio Grande surface-water system upstream from San Marcial, New Mexico, by comparing the mean annual discharge (streamflow) at different stations.

Hydrologic Description of the Rio Grande Watershed

The study area includes the Rio Grande watershed in Colorado and New Mexico upstream from San Marcial, New Mexico, and covers approximately 27,700 square miles (fig. 1). Altitudes in the watershed range from greater than 14,000 feet along the northernmost boundary of the watershed in Colorado to approximately 4,455 feet at San Marcial, New Mexico. Average annual precipitation varies from greater than 50 inches per year along the northwestern mountainous areas to less than 6 inches per year south of Albuquerque, New Mexico (Ellis and others, 1993). In the mountainous areas, the majority of annual precipitation falls as snow during the winter months; at lower altitudes, the majority of annual precipitation falls as rain during late summer and early fall thunderstorms.

Potential evapotranspiration, which is approximated by open-water evaporation, varies from less than 35 inches per year in the mountainous areas to greater than 70 inches per year near San Marcial (Ellis and others, 1993). Actual evapotranspiration (the total water removed from an area by transpiration from plants and evaporation from soil, snow, and water surfaces) is always less than potential evapotranspiration because it is limited by available moisture (Linsley and Franzini, 1972, p. 33).

The numerous tributaries in the Rio Grande watershed can be classified as either perennial or ephemeral. Perennial tributaries flow throughout the year, whereas ephemeral tributaries are dry most of the year and flow only in response to snowmelt or intense rainfall. The Rio Chama, which is the largest tributary to the Rio Grande, enters the Rio Grande upstream from the streamflow-gaging station Rio Grande at Otowi Bridge, near San Ildefonso, New Mexico (fig. 1, reference no. 39). Transmountain diversions (imported water from the Colorado River watershed on the west side of the Continental Divide is transferred to the Rio Grande watershed on the east side of the Continental Divide) affect both the Rio Grande and the Rio Chama.

Effluent discharge from wastewater-treatment plants provides inflow to the Rio Grande surface-water system. The Albuquerque wastewater-treatment plant is the largest in the watershed; daily mean discharge from that plant to the Rio Grande ranged from about 75 to 100 cubic feet per second (ft^3/s) from 1985 to 1998 (U.S. Army Corps of Engineers, 2002).

Reservoirs in the Rio Grande watershed (fig. 1) are generally operated for water storage, sediment removal, flood control, or some combination of these uses. Reservoirs can alter discharge because the impounded water can be "lost" by evaporation or by infiltration (seepage) to the surrounding ground-water system. In addition, changes in reservoir storage can affect mean annual discharge; however, using a longer period of record to calculate mean annual discharge generally minimizes the effects of changes in reservoir storage.

Rio Grande below Goose Creek, Colorado.

Surface-water use is defined as the volume of surface water diverted or withdrawn from a river channel or source (Wilson and Lucero, 1997, p. 71-74). After this water has been used, it may be returned to the river channel (for example, by return flows from agricultural areas) or it may leave the surface-water system (for example, by evapotranspiration from agricultural areas). Water not returned to the river channel is referred to as depletion and results in a decrease in discharge. As used herein, surface-water use does not include evapotranspiration by riparian vegetation or evaporation from open-water surfaces.

Water use is affected by many factors such as population, climate, and legal constraints. The Rio Grande Compact appropriates water use in the Rio Grande watershed. The States of Colorado, New Mexico, and Texas agreed upon the Compact for "the purpose of effecting an equitable apportionment of water in the Rio Grande" (Rio Grande Compact Commission, 2001, p. 18), and surface-water use in those States is restricted by Compact delivery obligations.

An **acre-foot** is the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or 325,851 gallons.

Total surface-water use in 1990 in the Rio Grande watershed upstream from San Marcial was approximately 1,570,000 acre-feet (equivalent to a discharge of 2,163 ft^3/s for 1 year) (Richey and Ellis, 1993). The largest use of surface water was irrigation (99 percent); other categories of surface-water use include public supply, commercial, domestic, industrial, mining, thermoelectric, and livestock.

To evaluate water use in different parts of the watershed and to examine possible causes of variations in discharge throughout the watershed, the watershed was divided into five reaches that were based primarily on locations of gaging stations (fig. 1). Surface-water use in the five reaches is shown in figure 2 as a percentage of total surface-water use in 1990 (1,570,000 acre-feet). Reach 2 had the largest amount of surface-water use. Reaches 1 and 4 had relatively little surface-water use. Water use in the different reaches varies because of allocations that are based on the Rio Grande Compact and locations of irrigable land.

Sources of Water to the Rio Grande

Mean annual discharge (the arithmetic mean of the annual mean discharge for every year in a given period) for 60 gaging stations throughout the Rio Grande watershed upstream from San Marcial is shown in figure 1. To eliminate the comparison of data from periods of varying climatic conditions, water years 1975-98 were chosen as a common period of record (water year is the 12-month period October 1 through September 30 designated by the calendar year in which it ends). Twelve gaging stations did not have data available for the entire period of record; these exceptions are noted in table 1. Mean annual discharge at these gaging stations may represent different climatic conditions than those in 1975-98. Each mean annual discharge has some error associated with it. No attempt has been made to quantify the error associated with the mean annual discharge for each gaging station.

Total surface-water use was 1,570,000 acre-feet per year (Richey and Ellis, 1993).

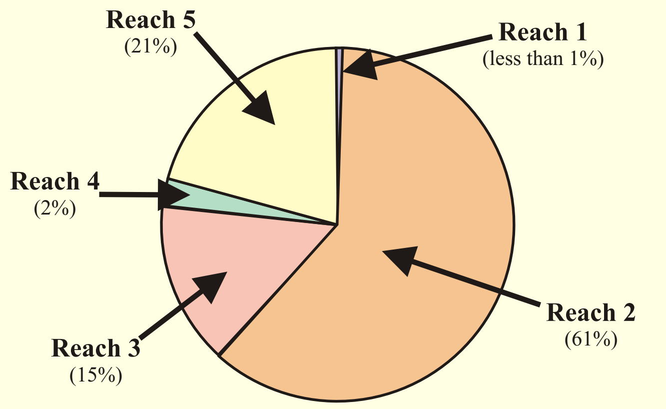

Figure 2. Surface-water use, by reach, as a percentage of total surface-water use in the Rio Grande watershed upstream from San Marcial, New Mexico, 1990. Reach boundaries shown in figure 1.

At some locations in the watershed, particularly in agricultural areas, water moves downstream in the Rio Grande and in other channels adjacent to the Rio Grande such as agricultural canals or drains. At New Mexico gaging stations Rio Chama near Chamita (reference no. 36), Rio Grande at San Felipe (reference no. 45), and Rio Grande at Albuquerque (reference no. 48), discharge is computed only in the Rio Grande; therefore, discharge moving downstream through the surface-water system is greater than that computed in the Rio Grande. At New Mexico gaging stations Rio Grande below Cochiti Dam (reference no. 43), Rio Grande Floodway near Bernardo (reference no. 50), Rio Grande Floodway at San Acacia (reference no. 58), and Rio Grande Floodway at San Marcial (reference no. 60), discharge is computed in the Rio Grande and in other major channels adjacent to the Rio Grande; at these locations, the discharge computed in each channel was summed to represent the total discharge moving downstream through the surface-water system (fig. 1, table 1).

Gaging stations closest to the mouths of tributaries were chosen; for some tributaries, however, the only available data were for a station located some distance upstream from the mouth of the tributary (fig. 1). At such stations, the discharge computed at the gaging station is not necessarily equal to the discharge that enters the Rio Grande (or other receiving river). If inflow enters the tributary between the gaging station and its confluence with the Rio Grande, then discharge computed at the gaging station will be smaller than the actual volume entering the Rio Grande; this is most likely to occur in the uppermost parts of the watershed (for example, at reference nos. 2 and 3). If diversions or seepage losses remove water between the gaging station and its confluence with the Rio Grande, then discharge computed at the gaging station will be larger than the actual volume entering the Rio Grande; this is most likely to occur in agricultural areas (for example, at reference nos. 9, 10, 12, and 20).

Most of the water in the Rio Grande surface-water system comes from tributary inflow that originates in the San Juan or Sangre de Cristo Mountains and enters the watershed upstream from Rio Grande at Otowi Bridge, near San Ildefonso, New Mexico (reference no. 39) (fig. 1). Mean annual discharge at the following gaging stations represents tributary inflow from the San Juan Mountains to the Rio Grande: Rio Grande at Thirtymile Bridge, near Creede, Colorado (reference no. 1; 214 ft^3/s), Willow Creek at Creede, Colorado (reference no. 3; 22 ft^3/s), Goose Creek at Wagon Wheel Gap, Colorado (reference no. 5; 68 ft^3/s), South Fork Rio Grande at South Fork, Colorado (reference no. 6; 226 ft^3/s), and Conejos River near Lasauses, Colorado (reference no. 18; 193 ft^3/s). Mean annual discharge at the following gaging stations represents tributary inflow from the Sangre de Cristo Mountains to the Rio Grande: Red River below Fish Hatchery, near Questa, New Mexico (reference no. 22; 85 ft^3/s), Rio Pueblo de Taos below Los Cordovas, New Mexico (reference no. 24; 81 ft^3/s), and Embudo Creek at Dixon, New Mexico (reference no. 26; 99 ft^3/s).

Most water in the Rio Chama comes from the southern San Juan Mountains. The mean annual discharge at gaging station Rio Chama near Chamita, New Mexico (reference no. 36; 649 ft^3/s), represents tributary inflow from the southern San Juan Mountains and includes transmountain diversions to the Rio Chama, which are measured at gaging station Azotea Tunnel at Outlet, near Chama, New Mexico (reference no. 29; 132 ft^3/s).

Downstream from the confluence with the Rio Chama, very little water enters the Rio Grande (fig. 1). Mean annual discharge at gaging station Jemez River below Jemez Canyon Dam, New Mexico (reference no. 47; 77 ft^3/s), represents tributary inflow from the Jemez Mountains. Other tributary inflow is from small perennial streams that drain the southern Sangre de Cristo Mountains or ephemeral streams that drain the lower altitudes of the watershed.

Many factors in the Rio Grande watershed (see "Hydrologic Description of the Rio Grande Watershed") cause discharge to vary along the Rio Grande. Increases occur when inflows to the surface-water system exceed outflows from the system. Discharge decreases when outflows exceed inflows. Inflows to the surface-water system include tributary inflow, return flows from irrigated areas, inflow from the ground-water system, and effluent discharge from wastewater-treatment plants. Outflows from the surface-water system include irrigation diversions, evapotranspiration by riparian vegetation, evaporation from open-water surfaces, and losses to the ground-water system. Increases and decreases in mean annual discharge may be estimated for any given reach (the area of the watershed between any two gaging stations) of the Rio Grande by comparing all measured inflow (which includes mean annual discharge at the upstream gaging station as well as that of any tributaries) with all measured outflow (the mean annual discharge at the downstream gaging station). In some cases, relatively small increases or decreases may be due to the error associated with the computed mean annual discharge at particular gaging stations.

As shown in figure 1, most increases in discharge along the Rio Grande are caused by tributary inflow. In some cases, increases in mean annual discharge in the Rio Grande or Rio Chama cannot be fully accounted for by the tributary inflow shown in figure 1. This could be due to inflow from ungaged tributaries (tributaries where streamflow is not measured) or to ground-water inflow. For example, between gaging stations Rio Grande at Thirtymile Bridge, near Creede, Colorado (reference no. 1), and Rio Grande at Wagon Wheel Gap, Colorado (reference no. 4), approximately 320 ft^3/s can be attributed to ungaged tributaries and ground-water inflow. The reach between gaging station Rio Grande near Lobatos, Colorado (reference no. 19), and the mouth of Red River receives approximately 90 ft^3/s of ground-water inflow annually (Winograd, 1959).

Discharge decreases by approximately 640 ft^3/s in the reach between the Colorado gaging stations Rio Grande near Del Norte (reference no. 7) and Rio Grande at Alamosa (reference no. 8) and by approximately 170 ft^3/s in the reach between San Acacia, New Mexico (reference nos. 56, 57, and 58), and San Marcial, New Mexico (reference nos. 59 and 60) (fig. 1, table 1).

Discharge appears to decrease by approximately 207 ft^3/s in the reach between gaging stations Rio Grande at San Felipe, New Mexico (reference no. 45), and Rio Grande at Albuquerque, New Mexico (reference no. 48). Actual decreases in mean annual discharge cannot be determined for this reach, however, because of the presence of ungaged streamflow in channels adjacent to the river.

Tributaries draining the mountainous regions in the northern part of the watershed are the largest sources of water to the Rio Grande. Irrigation, the largest category of surface-water use in the Rio Grande watershed, generally results in decreases in mean annual discharge throughout the surface-water system. Mean annual discharge in the Rio Grande generally decreases downstream from the confluence with the Rio Chama.

References

Ellis, S.R., Levings, G.W., Carter, L.F., Richey, S.F., and Radell, M.J., 1993, Rio Grande Valley, Colorado, New Mexico, and Texas: Water Resources Bulletin, v. 29, no. 4, p. 617-645.

Linsley, R.K., and Franzini, J.B., 1972, Water resources engineering: McGraw Hill, 690 p.

Richey, S.F., and Ellis, S.R., 1993, National Water Quality Assessment Program--Water use in the Rio Grande Valley, 1990: U.S. Geological Survey Open-File Report 93-456, p. 1.

Rio Grande Compact Commission, 2001, Report of the Rio Grande Compact Commission 2000, 68 p.

U.S. Army Corps of Engineers, 2002, Upper Rio Grande Water Operations Model: *http://www.spa.usace.army.mil/Urgscripts/getData.pl* (accessed December 2002).

Wilson, B.C., and Lucero, A.A., 1997, Water use by categories in New Mexico counties and river basins, and irrigated acreage in 1995: New Mexico State Engineer Office Technical Report 49, 149 p.

Winograd, I.J., 1959, Ground-water conditions and geology of Sunshine Valley and western Taos County, New Mexico: New Mexico State Engineer Technical Report 12, 70 p.

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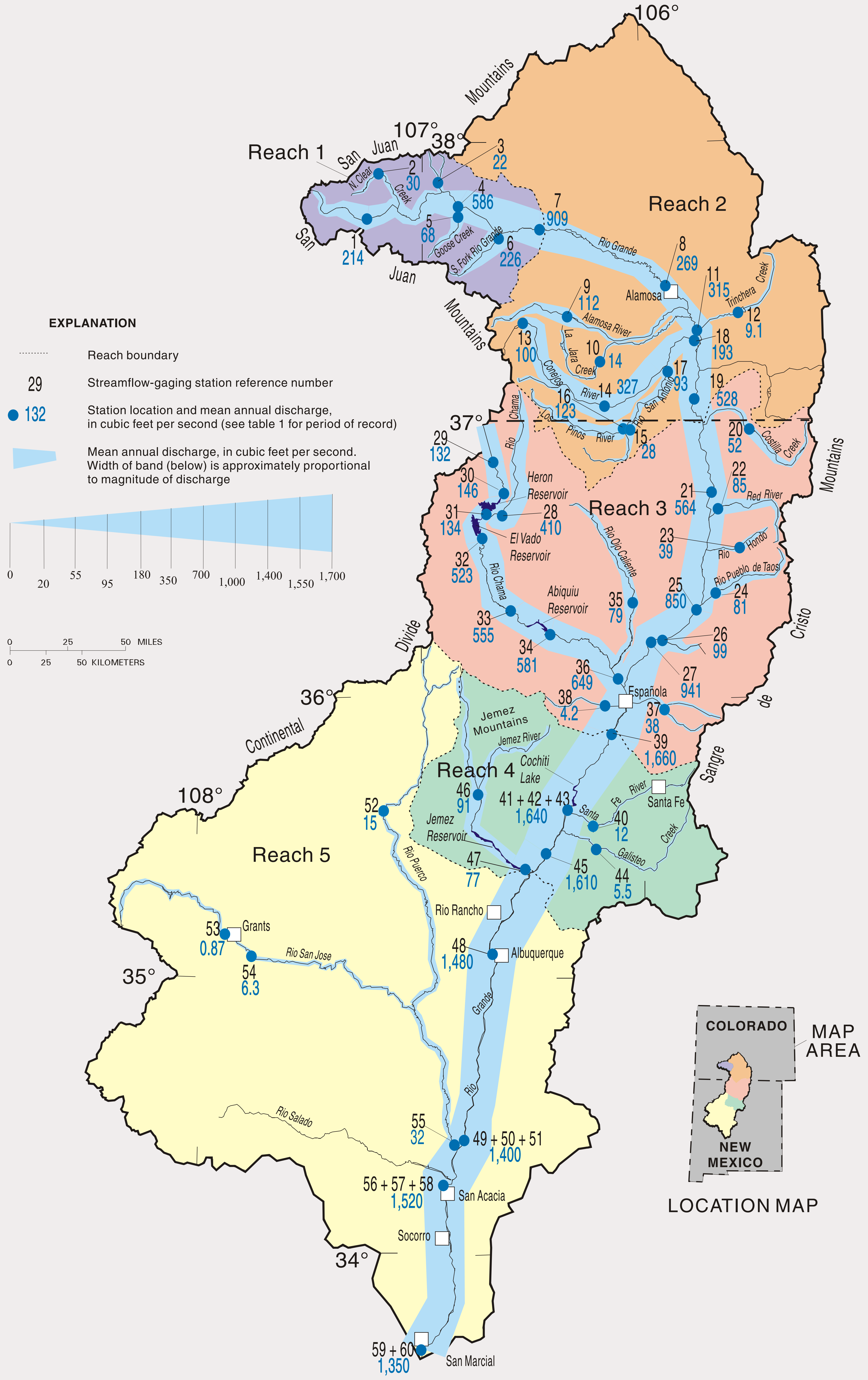

Figure 1. Mean annual discharge at selected streamflow-gaging stations in the Rio Grande watershed upstream from San Marcial, New Mexico. Station names shown in table 1.

Table 1. Mean annual discharge at selected streamflow-gaging stations in the Rio Grande watershed upstream from San Marcial, New Mexico.
[ft^3/s, cubic feet per second]

Reference number (fig. 1)	U. S. Geological Survey Station number	U. S. Geological Survey Station name	Mean annual discharge (ft^3/s)	Period of record used	Reach (fig. 1)
1	08213500	Rio Grande at Thirtymile Bridge, near Creede, Colo.	214	1975-98	1
2	08214500	North Clear Creek below Continental Reservoir, Colo.	30	1975-98	1
3	08216500	Willow Creek at Creede, Colo.[1]	22	1975-82	1
4	08217500	Rio Grande at Wagon Wheel Gap, Colo.	586	1975-98	1
5	08218500	Goose Creek at Wagon Wheel Gap, Colo.[1]	68	1975-91	1
6	08219500	South Fork Rio Grande at South Fork, Colo.[1]	226	1975-95	1
7	08220000	Rio Grande near Del Norte, Colo.	909	1975-98	1
8	08223000	Rio Grande at Alamosa, Colo.[1]	269	1975-95	2
9	08236000	Alamosa River above Terrace Reservoir, Colo.[1]	112	1975-92	2
10	08238000	La Jara Creek at Gallegos Ranch, near Capulin, Colo.[1]	14	1975-82	2
11	08240000	Rio Grande above mouth of Trinchera Creek, near Lasauses, Colo.	315	1975-98	2
12	08243500	Trinchera Creek below Smith Reservoir, near Blanca, Colo.[1]	9.1	1975-82	2
13	08245000	Conejos River below Platoro Reservoir, Colo.	100	1975-98	2
14	08246500	Conejos River near Mogote, Colo.	327	1975-98	2
15	08247500	San Antonio River at Ortiz, Colo.	28	1975-98	2
16	08248000	Los Pinos River near Ortiz, Colo.	123	1975-98	2
17	08248500	San Antonio River at mouth, near Manassa, Colo.[1]	93	1975-82	2
18	08249000	Conejos River near Lasauses, Colo.	193	1975-98	2
19	08251500	Rio Grande near Lobatos, Colo.	528	1975-98	2
20	08255500	Costilla Creek near Costilla, N. Mex.	52	1975-98	3
21	08263500	Rio Grande near Cerro, N. Mex.	564	1975-98	3
22	08266820	Red River below Fish Hatchery, near Questa, N. Mex.[1]	85	1978-98	3
23	08267500	Rio Hondo near Valdez, N. Mex.	39	1975-98	3
24	08276300	Rio Pueblo de Taos below Los Cordovas, N. Mex.	81	1975-98	3
25	08276500	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	850	1975-98	3
26	08279000	Embudo Creek at Dixon, N. Mex.	99	1975-98	3
27	08279500	Rio Grande at Embudo, N. Mex.	941	1975-98	3
28	08284100	Rio Chama near La Puente, N. Mex.	410	1975-98	3
29	08284160	Azotea Tunnel at Outlet, near Chama, N. Mex.	132	1975-98	3
30	08284200	Willow Creek above Heron Reservoir, near Los Ojos, N. Mex.	146	1975-98	3
31	08284520	Willow Creek below Heron Dam, N. Mex.	134	1975-98	3
32	08285500	Rio Chama below El Vado Dam, N. Mex.	523	1975-98	3
33	08286500	Rio Chama above Abiquiu Reservoir, N. Mex.	555	1975-98	3
34	08287000	Rio Chama below Abiquiu Dam, N. Mex.	581	1975-98	3
35	08289000	Rio Ojo Caliente at La Madera, N. Mex.	79	1975-98	3
36	08290000	Rio Chama near Chamita, N. Mex.	649	1975-98	3
37	08291000	Santa Cruz River at Cundiyo, N. Mex.	38	1975-98	3
38	08292000	Santa Clara Creek near Española, N. Mex.[1]	4.2	1985-94	3
39	08313000	Rio Grande at Otowi Bridge, near San Ildefonso, N. Mex.	1,660	1975-98	3
40	08317200	Santa Fe River above Cochiti Lake, N. Mex.	12	1975-98	4
41	08314000	Sili Main Canal (at head) at Cochiti, N. Mex.[1,2,3]	44	1975-98	4
42	08313500	Cochiti Eastside Main Canal at Cochiti, N. Mex.[1,2,3]	80	1975-98	4
43	08317400	Rio Grande below Cochiti Dam, N. Mex.[3]	1,510	1975-98	4
44	08317950	Galisteo Creek below Galisteo Dam, N. Mex.	5.5	1975-98	4
45	08319000	Rio Grande at San Felipe, N. Mex.	1,610	1975-98	4
46	08324000	Jemez River near Jemez, N. Mex.	91	1975-98	4
47	08329000	Jemez River below Jemez Canyon Dam, N. Mex.	77	1975-98	4
48	08330000	Rio Grande at Albuquerque, N. Mex.	1,480	1975-98	5
49	08331990	Rio Grande Conveyance Channel near Bernardo, N. Mex.[4]	9.8	1975-98	5
50	08332010	Rio Grande Floodway near Bernardo, N. Mex.[4]	1,320	1975-98	5
51	08332050	Bernardo Interior Drain near Bernardo, N. Mex.[4]	68	1975-98	5
52	08334000	Rio Puerco above Arroyo Chico, near Guadalupe, N. Mex.	15	1975-98	5
53	08343000	Rio San Jose at Grants, N. Mex.	0.87	1975-98	5
54	08343500	Rio San Jose near Grants, N. Mex.	6.3	1975-98	5
55	08353000	Rio Puerco near Bernardo, N. Mex.	32	1975-98	5
56	08354500	Socorro Main Canal North at San Acacia, N. Mex.[5]	123	1975-98	5
57	08354800	Rio Grande Conveyance Channel at San Acacia, N. Mex.[5]	243	1975-98	5
58	08354900	Rio Grande Floodway at San Acacia, N. Mex.[5]	1,150	1975-98	5
59	08358300	Rio Grande Conveyance Channel at San Marcial, N. Mex.[6]	268	1975-98	5
60	08358400	Rio Grande Floodway at San Marcial, N. Mex.[6]	1,080	1975-98	5

[1] Period of record used is not equal to 1975-98.
[2] Missing data for 1993-94 and 1995.
[3] Total discharge at Cochiti, N. Mex., is 1,630 ft^3/s and includes the Sili Main Canal, Cochiti Eastside Main Canal, and the Rio Grande (conveyance channels not shown on map).
[4] Total discharge near Bernardo, N. Mex., is 1,400 ft^3/s and includes the Rio Grande Conveyance Chanel, Rio Grande Floodway, and Bernardo Interior Drain (conveyance channels not shown on map).
[5] Total discharge at San Acacia, N. Mex., is 1,520 ft^3/s and includes the Socorro Main Canal North, Rio Grande Conveyance Channel, and Rio Grande Floodway (conveyance channels not shown on map).
[6] Total discharge at San Marcial, N. Mex., is 1,350 ft^3/s and includes the Rio Grande Conveyance Channel and Rio Grande Floodway (conveyance channels not shown on map).