SURFACE-WATER SUPPLY ASSESSMENT FOR IRRIGATED LANDS SERVED BY PERMANENT IRRIGATION WORKS ON THE ZUNI INDIAN RESERVATION

In the matter of United States and Zuni Indian Tribe vs. State of New Mexico, ex rel. State Engineer, et al.
Case No. 07cv00681-BB

Prepared for:
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INTRODUCTION AND PURPOSE

The Zuni River Basin (Basin) spans the western region of McKinley and Cibola Counties in the State of New Mexico (Figure 1). The Basin is bounded by the Zuni Mountains and the Continental Divide on the east and the New Mexico-Arizona state line on the west. It is part of the Little Colorado River Basin. Towns in the Basin include Zuni, Black Rock, Pescado, Ojo Caliente, and Ramah. The Zuni Indian Reservation, the Ramah Navajo Community and parts of the Navajo Indian Reservation are located within the Zuni River Basin.

Average annual precipitation at the McGaffey, NM station in the Zuni Mountains is 18.7 inches and at the Zuni, NM station is 11.9 inches.[1]

Streams and rivers in the Basin are generally intermittent (flowing in response to snowmelt from the Zuni Mountains) and/or ephemeral (flowing in response to storm events). Major streams in the Basin include Rio Nutria, Cebolla Creek, Rio Pescado, and the Zuni River. Additionally, there are several springs that discharge within the Basin including Nutria Spring, Upper and Lower Pescado Springs, and springs in the Ojo Caliente area. There are several reservoirs in the Basin, including Ramah Reservoir, Nutria Reservoirs No. 2, 3, and 4, Pescado Reservoir, Black Rock Reservoir, Eustace Reservoir, Tekapo Reservoir, and Ojo Caliente Reservoir.

The purpose of this report is to compile and summarize available surface-water data in the Basin and to use that information to consider the surface-water supply that might have been available for several areas of irrigation on the Zuni Indian Reservation. Allen (2008) calculated irrigation diversion requirements for five agricultural units on the Zuni Indian Reservation that have used permanent works: Nutria, Pescado, Zuni, Tekapo, and Ojo Caliente. For areas where surface-water data are available, this report evaluates the supply that would have been available to meet irrigation diversion requirements described by Allen (2008), which are similar to those claimed for the Zuni Indian Tribe in the *United States vs. A&R Productions, et al.* Zuni River Basin Water Rights Adjudication. It is recognized that the Zuni Indian Reservation has several wells which are claimed to be used for irrigation. This report does not estimate the water supply available from aquifers in the Basin.

SOURCES OF INFORMATION

To estimate the surface-water supply in the Basin, several sources of information were used. The primary data sources for stream and spring flow were from the United States Geological Survey (USGS). The USGS has maintained streamflow records for several surface-water gages in the Zuni River Basin, and two of those gages were utilized in this analysis because of their longer period of record and suitable location for evaluation of supply (Figure 1) (Appendix A lists all of the available gages with daily streamflow data in the Zuni River Basin listed on the USGS website (http://waterdata.usgs.gov/nwis/sw),

[1] data from the Western Regional Climate Center New Mexico Climate Summaries, http://www.wrcc.dri.edu/summary/climsmnm.html

including those used in this report). In addition to daily streamflow data on the USGS website, the USGS (1954) published monthly streamflow data for Zuni River at Blackrock, NM and those data were also considered. Additionally, a USGS publication by Orr (1987) was referenced, which is a report that was prepared in cooperation with the Zuni Indian Reservation and describes water resources of the Zuni Tribal Lands.

The report by Allen (2008) was used to obtain acreage and monthly irrigation diversion requirements similar to those claimed for the Zuni Indian Tribe in the *United States vs. A&R Productions, et al.* Zuni River Basin Water Rights Adjudication.[2]

Several additional documents were also reviewed and utilized to provide additional information on such things as spring flow and reservoir capacity.

No new stream or spring flow measurements were collected for this report. If additional information becomes available, the author reserves the right to update the estimates provided in this report.

METHODOLOGY

For the Zuni and Nutria units, both of which have gaged streamflow upstream of their respective areas, streamflow data are presented in figures to illustrate seasonal and annual distribution. For the Nutria, Pescado, and Ojo Caliente units, information describing spring flow is presented.

For the Nutria, Zuni, and Ojo Caliente units, available surface-water data were used to prepare an historical supply analysis. An historical supply analysis estimates the percentage of annual supply available to meet demand based on a monthly assessment of irrigated diversion requirements and surface-water supply. Historical supply analyses were prepared to explore the possible maximum and minimum supply that might have been available in any one year for the Nutria, Zuni, and Ojo Caliente units, and the average historical supply for those units.

In each agricultural unit, the source of monthly supply included stream and/or spring flow and releases from storage in upstream reservoirs. For each agricultural unit, at least two historical supply analyses were conducted: one that did not include additional supply from storage, and another that did consider reservoir storage.

For the analysis that did not consider reservoir storage, the historical supply analysis utilized the monthly irrigation diversion requirements from Allen (2008) and available stream and spring flow data to determine if there were any monthly shortages in supply. If the supply exceeded the demand, the shortage was equal to zero. Then, for each year, the monthly demand was summed and the monthly

[2] Allen (2008) provides monthly and annual unit diversion requirements that are similar to the claimed irrigation water rights for the Zuni Indian Reservation. He does not include in his report the monthly unit diversion requirements for the claimed total irrigation diversion requirements.

shortages were summed, and the difference between the summed annual demand and shortages was divided by the demand and multiplied by 100 to determine the percent of the supply for that year.

To evaluate the historical supply that includes possible releases from reservoir storage, the approach is the same as described above, except that monthly reservoir storage was estimated and considered as part of the supply, in addition to monthly stream and spring flow. The reservoir storage at the start of the irrigation season was estimated based on stream and/or spring flow in the previous non-irrigation months, plus any additional storage remaining at the end of the previous irrigation season (except for the first year), and was limited to the maximum capacity of the reservoir. For each month during the irrigation season, the surface-water supply available for irrigation was based on the monthly stream and/or spring flow data plus the estimated amount of reservoir storage. If the total supply exceeded the monthly demand, then the surplus water remained in the reservoir to be available for use in the next month. The historical supply analysis that included reservoir storage did not consider evaporation or seepage.

The historical supply analysis is a useful approach to exploring whether the monthly supply might have been sufficient to meet monthly demand. For this report, at least two estimates were prepared. The estimate that did not consider the additional supply from reservoir storage probably underestimates the historical supply. The estimate that does consider the additional supply from reservoir storage may overestimate the historical supply because evaporation and seepage from the reservoir were not considered, and optimal reservoir operation was assumed. The two analyses provide a range in the possible historical supply that may have been available for these agricultural units.

For the Zuni and Ojo Caliente units, multiple historical supply analyses were prepared for either different time periods or for different estimates in surface-water supply.

SURFACE-WATER SUPPLY AVAILABLE TO AGRICULTURAL UNITS ON THE ZUNI INDIAN RESERVATION

Nutria Unit

Surface water

The headwaters of the Rio Nutria are in the Zuni Mountains. Streamflow above the Nutria unit has been measured at the USGS gage Rio Nutria near Ramah, NM (USGS ID 09386900), which the USGS reports to be 0.9 miles upstream from the Nutria Diversion Dam (Byrd et al., 2002). The primary reservoir storage for irrigation in the Nutria area is at the Nutria Diversion Reservoir. Orr (1987) reported that in 1969 it had a capacity of 15 acre-feet (ac-ft) (Orr, 1987), and the US. Army Corps of Engineers (1993) reported that it had a capacity of 120 ac-ft at the spillway crest elevation. In Table 2 of the United States Subproceeding Complaint, the volume of Nutria Diversion Reservoir is reported to be 150 ac-ft (it is uncertain the time period that this volume represents).

Figure 2 shows average and median monthly streamflow at the USGS gage Rio Nutria near Ramah, NM. This chart shows that, between water years 1970 and 2008, the highest flow occurs in the late winter and spring months of March and April.

Figure 3 shows annual streamflow measured at USGS gage Rio Nutria near Ramah, NM from water year 1970 to water year 2008. Table 1 summarizes the annual flow that would be equaled or exceeded 20, 50, and 80 percent of the time for this gage, as well as the maximum, minimum and average annual flow for the period of record.

Table 1. Streamflow at Rio Nutria near Ramah, NM (water years 1970 to 2008)

Percent Exceedance	Streamflow, acre-feet per year (ac-ft/yr)
Maximum	16,260
20%	9,920
50% (median)	1,530
80%	310
Minimum	100
Average	4,170

The available data at the USGS gage, Rio Nutria near Ramah, NM, indicate that streamflow is variable both intra- and inter-annually.

Nutria Spring is located downstream of the USGS gage, Rio Nutria near Ramah, NM, but upstream of the Nutria Diversion Dam. Nutria Spring flow has been measured a few times. Orr (1987) reports that Nutria spring flow was 50 gallons per minute (gpm) on December 14, 1950. Drakos and Riesterer (2009) reported that discharge from Nutria Spring ranged from 50 to 90 gpm on November 7, 2007. In a document titled "Zuni Indian Reservation Engineering Studies of Land and Water Resources," flow in September 1956 at Nutria above the diversion dam was 0.32 cubic feet per second (cfs) (144 gpm) (there is a comment included in the document that spring flow measured at this time might have been low based on other hydrologic data).[3]

Allen (2008) reported that the irrigated area served by permanent works in the Nutria unit is 976.6 acres and that the annual irrigation diversion requirement for the Nutria Unit is 4,401.7 ac-ft. Appendix B summarizes irrigated acreage and irrigation diversion requirement and stream and spring flow data for the agricultural units on the Zuni Indian Reservation. Although annual flow above the Nutria Unit is estimated to have reached 16,410 ac-ft, the amount available to meet the irrigation

[3] Arizona State Library, Archives and Public Records, History and Archives Division, Record Group 95, Arizona v. California, Records Pertaining to the Supreme Court Case, 1890-1967, Box 34, Folder 466: US Exhibits, Zuni Pueblo and Reservation, Exhibits 147 [, 159-163], Special Master's Exhibit No. 13 (contains US Exhibit Nos. 159-162), Zuni Indian Reservation, Engineering Studies of Land and Water Resources [by Ernest C. Fortier, Irrigation Engineer and Director of Irrigation for BIA, 1930-46] (Temp. Exhibit No. 36)

requirement for the Nutria Unit depends on how much of the flow occurred during each of the irrigation months, and how much of the flow could be stored in an upstream reservoir.

Historical supply analysis

Two historical supply analyses were prepared to explore the supply that might have been available for the Nutria unit with and without reservoir storage.

Based on acreage reported by Allen (2008), the monthly irrigation diversion requirements for the Nutria unit as described in Table 4-3 from Allen (2008), and monthly streamflow recorded at the USGS gage Rio Nutria near Ramah, NM from 1970 to 2007, plus spring flow from Nutria Spring (estimated to be 90 gpm for this analysis), the average historical supply for the Nutria unit based on the period of record was 11 percent, the maximum historical supply was 34 percent and the minimum historical supply was 3 percent.[4] The results of the historical supply analysis are shown in Appendix C. This analysis assumes that none of the surplus water (in situations where the monthly supply exceeded the monthly demand) could have been stored and used when needed. With reservoir storage, the historical supply may have been greater.

If storage in the Nutria Diversion Reservoir is considered in the aforementioned analysis (based on a maximum capacity of 120 ac-ft), the average historical supply for the Nutria unit based on the period of record was 13 percent, the maximum historical supply was 38 percent and the minimum historical supply was 5 percent. This estimate does not include evaporation or seepage from the reservoir, and may overestimate historical supply.

Allen (2008) reported that several small impoundments serve some irrigated lands in the Nutria unit. The additional supply that might have been available due to storage in these impoundments was not considered in the Nutria historical supply analyses.

Pescado Unit

Surface water

Irrigated lands in the Pescado area may be supplied by water from the Pescado Reservoir, which is on Cebolla Creek, the Rio Pescado, and by springs in the Pescado area.

In the Pescado area there are two large springs, Upper Pescado Springs and Lower Pescado Springs. Orr (1987) provides information concerning spring flow measurements made in the Pescado area. He reports:

> A series of periodic discharge measurements have been made at Pescado Springs since 1978 in order to determine the volume and the variability of flow … Measurements…. represent the flow from both springs. Measured discharges ranged from 0.87 cubic foot per second on December 4,

[4] Year 2008 was not included because monthly streamflow for October and November of 2008 were unavailable at the time the data were downloaded from the USGS website.

> 1979, to 1.6 cubic foot per second on February 25, 1980. The average discharge for this period was approximately 1.1 cubic foot per second, or 500 gallons per minute, for a total annual flow of approximately 800 ac-ft. Irrigation return flow and overflow from the diversion on the Rio Pescado infiltrate to the channel alluvium or are lost to evaporation. Some variability in discharge throughout the year is due to change in water levels within the spring reservoirs. Fluctuations may be attributed, in part, to runoff across the recharge area. Changes in storage in nearby Pescado Reservoir also may have some effect on spring discharge. (Orr, 1987, p. 34)

There have been a few additional measurements of Upper and Lower Pescado Springs. Drakos and Riesterer (2009) reported that Upper Pescado Spring flow was 185 gpm (299 ac-ft/yr) and Lower Pescado Spring flow was 120 gpm (194 ac-ft/yr). In a document titled "Zuni Indian Reservation Engineering Studies of Land and Water Resources,"[5] the combined measured spring flow at the two springs in the Pescado area in September 1956 was reported to be 0.83 cfs (600 ac-ft/yr) (there is a comment included in the document that spring flow measured at this time might have been low based on other hydrologic data).

Based on the few reported measurements, combined flow from Upper and Lower Pescado Springs has varied.

In addition to the Pescado springs, there would likely be additional surface-water supply from Cebolla Creek, which flows into Pescado Reservoir, and the Rio Pescado. Orr (1987) describes flow in the Rio Pescado as intermittent. The U.S. Army Corps of Engineers (1993) indicated that the capacity of Pescado Reservoir at the spillway crest elevation was 720 ac-ft. In Table 2 of the United States Subproceeding Complaint, the volume of Pescado Reservoir is reported to be 720 ac-ft (it is uncertain the time period that this volume represents). No daily or monthly streamflow measurements on Cebolla Creek or the Rio Pescado have been found.

Upstream of the Pescado unit, water is diverted from Cebolla Creek and the Ramah Reservoir for irrigation in the Ramah area. There are 981.7 acres of irrigated lands in the Ramah area (NRCE, 2007). If diversions were reduced upstream, there might be additional water available in the Pescado area. Orr (1987) reported that the capacity of Ramah Reservoir in 1969 was 13,000 ac-ft. Information from the U.S. Army Corps of Engineers (1993) report indicates that the capacity of Ramah Reservoir at the spillway crest elevation was 3,240 ac-ft.

Allen (2008) reported that the irrigated area served by permanent works in the Pescado unit is 1,317.9 acres and that the annual irrigation diversion requirement for the Pescado unit is 5,096.9 ac-ft. Appendix B summarizes irrigated acreage and irrigation diversion requirement and annual stream and spring flow for the agricultural units on the Zuni Indian Reservation.

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[5] Arizona State Library, Archives and Public Records, History and Archives Division, Record Group 95, Arizona v. California, Records Pertaining to the Supreme Court Case, 1890-1967, Box 34, Folder 466: US Exhibits, Zuni Pueblo and Reservation, Exhibits 147 [, 159-163], Special Master's Exhibit No. 13 (contains US Exhibit Nos. 159-162), Zuni Indian Reservation, Engineering Studies of Land and Water Resources [by Ernest C. Fortier, Irrigation Engineer and Director of Irrigation for BIA, 1930-46] (Temp. Exhibit No. 36)

Historical supply analysis

An historical supply analysis was not conducted for the Pescado unit because no streamflow data were found for Cebolla Creek and Rio Pescado.

Zuni Unit

Surface water

Surface-water supply for the irrigated lands in the Zuni area may be supplied by surface water in the Zuni River and Black Rock Reservoir. The storage capacity of Black Rock Reservoir has changed greatly since its completion. In Table 2 of the United States Subproceeding Complaint, the volume of Black Rock Reservoir is reported to be 15,000 ac-ft. USGS (1954) indicates that the initial storage capacity of Black Rock Reservoir was 15,800 ac-ft when storage began in 1908, but by 1944 the capacity had been reduced to about 2,600 ac-ft due to flood damage and sedimentation. For the 1970 to 2007 period, reservoir capacity does not appear to have changed as much. Orr (1987) reported the storage capacity of Black Rock Reservoir to be 2600 ac-ft in 1969, and the U.S Army Corps of Engineers (1993) reported that the capacity was 2230 ac-ft at the spillway crest elevation.

Streamflow above the Zuni unit has been measured or estimated in two locations for two different time periods:

- USGS gage, Zuni River above Black Rock Reservoir, NM (USGS ID 09386950) from water year 1970 to present, and
- Zuni River at Black Rock, NM from water years 1911 to 1930 (USGS, 1954).

The USGS (1954) reported adjusted streamflow data for water years 1911 to 1930 by adding or subtracting flow based on changes in reservoir storage. These records approximate the amount and timing of streamflow that would have occurred without reservoir operations, but the records were not corrected for evaporation or seepage from the reservoir.

Figure 4 shows average and median monthly streamflow at the USGS gage, Zuni River above Black Rock Reservoir, NM, and Figure 5 shows average and median monthly streamflow data for the estimated monthly streamflow at Zuni River at Black Rock, NM published by USGS (1954). Figure 4 shows that, on average, months with the highest streamflow are March and April, but the median monthly flow in March and April is not much higher than flow in other months. Figure 5 also shows high flow in March and April, but the late summer and early fall months also show higher flow.

Table 2 summarizes the annual streamflow that would be equaled or exceeded 20, 50, and 80 percent of the time for the USGS gage Zuni River above Black Rock Reservoir, NM for water years 1970 to 2008, as well as the maximum, minimum and average annual streamflow for the period of record. Table 3 summarizes the annual streamflow that would be equaled or exceeded 20, 50, and 80 percent of the time for the estimated annual streamflow at Zuni River at Black Rock, NM for water years 1911 to 1930 published by the USGS (1954) , as well as the maximum, minimum and average annual flow for the period of record. Figure 6 shows annual streamflow estimated at Zuni River at Black Rock, NM for water years 1911 to 1930 published by the USGS (1954) and measured at the USGS gage Zuni River above Black Rock Reservoir, NM from water years 1970 to 2008.

Estimated streamflow on the Zuni River at Black Rock during water years 1911 to 1930 is higher than during water years 1970 to 2008. Orr (1987) suggested the cause was partly due to the construction of upstream reservoirs, which increased the capacity for storage and for losses due to evaporation and seepage. Orr (1987) (who compared the water years 1911 to 1930 with water years 1970 to 1979) suggested that decreases in precipitation or changes in the seasonal distribution of precipitation probably had less of an effect that increased evaporation losses due to storage.

Table 2. Streamflow at Zuni River above Black Rock Reservoir, NM (water years 1970 to 2008)

Percent Exceedance	Streamflow, ac-ft/yr
maximum	33,950
20%	4,940
50% (median)	1,300
80%	400
minimum	60
average	5,980

Table 3. Estimated Streamflow at Zuni River at Black Rock Reservoir, NM (water years 1911 to 1930)

Percent Exceedance	Streamflow, ac-ft/yr
maximum	55,770
20%	39,340
50% (median)	13,675
80%	5,060
minimum	2,330
average	19,218

There are several areas upstream of Black Rock Reservoir, such as Nutria, Pescado, and Ramah, where streamflow can be diverted. If diversions were reduced upstream, there might be additional water available in the Black Rock area. It is uncertain what the losses or gains to streamflow would be between those upstream areas and the Zuni River above Black Rock Reservoir, NM gage.

Some of the streamflow measured at Rio Nutria near Ramah, NM, may not have been diverted, but instead may have continued to flow to the Zuni River and past the gage Zuni River above Black Rock Reservoir, NM. Thus, some of the streamflow measured at the Rio Nutria near Ramah, NM gage may also be recorded at Zuni River above Black Rock Reservoir, NM.

Allen (2008) reported that the irrigated area served by permanent works in the Zuni unit is 3,629.8 acres and that the annual irrigation diversion requirement for the Zuni unit is 17,901.4 ac-ft. Appendix B summarizes irrigated acreage and irrigation diversion requirement and stream and spring flow data for the agricultural units on the Zuni Indian Reservation. Although annual flow above the Zuni Unit is estimated to have reached 55,770 ac-ft, the amount available to meet the irrigation requirement for the Zuni unit depends on how much of the flow occurred during each of the irrigation months, and how much of the flow could be stored in an upstream reservoir.

Historical Supply Analysis

Several historical supply analyses were conducted to explore the supply that might have been available for the Zuni unit with and without reservoir storage. Separate analyses were performed based on monthly data collected between 1970 and 2007 at the USGS gage Zuni River above Black Rock, NM and monthly data reported in the publication by the USGS (1954) for Zuni River at Black Rock.[6]

A historical supply estimate for 1970-2007 was based on the total claimed irrigated area under permanent works (3,629.8 acres) for the Zuni unit as reported in Allen (2008), the monthly diversion requirements for the Zuni unit as described in Table 4-3 from Allen (2008), the streamflow record at the USGS gage Zuni River above Black Rock Reservoir, NM (USGS ID 09386950), and assuming no reservoir storage in Black Rock Reservoir. From 1970 to 2007, the average historical supply for the Zuni unit would have been 7 percent, the maximum historical supply would have been 31 percent, and the minimum historical supply would have been less than 1 percent. This may underestimate supply because reservoir storage was not considered. If releases of stored water in Black Rock Reservoir (maximum capacity assumed to be 2,230 ac-ft based on the U.S. Army Corps of Engineers (1993)) are considered in the aforementioned analysis, the average historical supply for the Zuni unit based on the period of record would have been 12 percent, the maximum historical supply would have been 44 percent and the minimum historical supply would have been less than 1 percent. This estimate does not include evaporation or seepage from the reservoir, and may overestimate historical supply.

Utilizing the estimated monthly streamflow for the 1911-1929 period at the Zuni River at Black Rock, NM, the total claimed irrigated area and monthly diversion requirements for the Zuni unit from Allen (2008), and assuming no reservoir storage, the average historical supply would have been 27 percent, the maximum historical supply would have been 50 percent and the minimum historical supply would have been 10 percent. With reservoir storage, the historical supply may have been greater.

Robinson (1918) estimated the storage capacity of Black Rock Reservoir in 1906, 1910, 1912, 1914, and 1918. If reservoir storage is considered in the historical supply analysis (based on the estimated storage capacity from Robinson (1918)) along with the estimated monthly streamflow at Zuni River at Black Rock, NM from 1911 to 1918, the average historical supply would have been 60 percent, the maximum historical supply would have been 96 percent (in years 1911 and 1914), and the minimum

[6] Year 2008 was not included because monthly streamflow for October and November of 2008 were unavailable at the time the data were downloaded from the USGS website.

historical supply would have been 30 percent (in year 1918). This estimate does not include evaporation or seepage from the reservoir, and may overestimate historical supply.[7]

The results of these historical supply analyses are shown in Appendix C.

Allen (2008) reported that several small impoundments serve some irrigated lands in the Zuni unit, but additional supply that might be available due to storage in these impoundments was not considered in these historical supply analyses.

Tekapo Unit

Surface water

In the Tekapo unit, downstream from the Zuni unit, Allen (2008) reported that there are 320.6 acres of land irrigated from Tekapo Reservoir and the Zuni River and that the annual irrigation diversion requirement for the Tekapo unit was 1,383.0 ac-ft. No data have been found that describe the surface-water supply available directly above the Tekapo unit.

Historical Supply Analysis

An historical supply analysis was not conducted for the Tekapo unit because there is insufficient surface-water supply data.

Ojo Caliente Unit

Surface water

Irrigated lands in the Ojo Caliente area are supplied by water from Ojo Caliente Reservoir and by springs in the Ojo Caliente area.

In Table 2 of the United States Subproceeding Complaint, the volume of Ojo Caliente Reservoir is reported to be 250 ac-ft. It is uncertain the time period that this volume represents. Orr (1987) also reports the capacity of Ojo Caliente is 250 ac-ft in 1972. In a document titled "Zuni Pueblo and Reservation 1. Descriptive History of Irrigation 2. Description of Storage and Diversion Works," the report states that Ojo Caliente Reservoir had its capacity increased to 273 ac-ft in 1937 and to 325 ac-ft in 1954.[8]

[7] The original streamflow estimates from USGS (1954, p. 532) were "based on change in contents of Blackrock Reservoir, taking into account the quantity of water released from reservoir, but not taking into account seepage and evaporation." The original streamflow estimates probably underestimate streamflow.

[8] Arizona State Library, Archives and Public Records, History and Archives Division, Record Group 95, Arizona v. California, Records Pertaining to the Supreme Court Case, 1890-1967, Box 34, Folder 465, US Exhibits, Zuni Pueblo and Reservation, Exhibits 101-146, Exhibit [124], Zuni Pueblo and Reservation: 1. Descriptive History of Irrigation; 2. Description of Storage and Diversion Works (Temp. Exhibit No. 16)

Orr (1987) described multiple spring flow measurements made in the Ojo Caliente area. He reported:

> Periodic discharge measurements at the springs indicate that the average combined discharge from the springs is approximately 1 cubic foot per second or 450 gallons per minute with a total annual discharge of 720 acre-feet. Discharge during the period of measurements ranged from 670 gallons per minute on May 31, 1979, to 315 gallons per minute on August 22, 1979. This decrease may be caused by increased phreatophyte water consumption at the springs during the summer months and by irrigation management of water levels in the springs. Discharges from 54 to 67 gallons per minute have been measured flowing into Plumasano Arroyo for an additional 87 to 109 acre-feet per year. (Orr, 1987, p. 12)

Information was found in two documents that also reported spring flow in the Ojo Caliente area. In document titled "Zuni Indian Reservation Engineering Studies of Land and Water Resources"[9], measured spring flow at Ojo Caliente in September 1956 was reported to be 1.76 cfs and an additional flow was estimated to be 0.24 cfs for a total flow at Ojo Caliente of 2.00 cfs (there is a comment included in the document that spring flow measured at this time might have been low based on other hydrologic data). Based on another historical document describing the history of project works on the Zuni Pueblo,[10] after improvements were made to Ojo Caliente springs in 1934, the developed flow measured 2.5 cfs.

Spring flow in the Ojo Caliente area was recently measured and reported by Drakos and Riesterer (2009), and based on that report, the combined spring flow in the Ojo Caliente area (not including Plumasano Wash) was up to 365 gpm (589 ac-ft/yr), and the spring flow in Plumasano Wash was 55 gpm (89 ac-ft/yr).

Based on above-described documents and reports and Orr (1987), spring flow appears to have varied over time.

Allen (2008) reported that the irrigated area served by permanent works in the Ojo Caliente unit is 773.7 acres and that the annual irrigation diversion requirement for the Ojo Caliente unit was 2,967.9 ac-ft. Appendix B summarizes irrigated acreage and irrigation diversion requirement and stream and spring flow data for the agricultural units on the Zuni Indian Reservation. Although the combined annual

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[9] Arizona State Library, Archives and Public Records, History and Archives Division, Record Group 95, Arizona v. California, Records Pertaining to the Supreme Court Case, 1890-1967, Box 34, Folder 466: US Exhibits, Zuni Pueblo and Reservation, Exhibits 147 [, 159-163], Special Master's Exhibit No. 13 (contains US Exhibit Nos. 159-162), Zuni Indian Reservation, Engineering Studies of Land and Water Resources [by Ernest C. Fortier, Irrigation Engineer and Director of Irrigation for BIA, 1930-46] (Temp. Exhibit No. 36)

[10] Arizona State Library, Archives and Public Records, History and Archives Division, Record Group 95, Arizona v. California, Records Pertaining to the Supreme Court Case, 1890-1967, Box 34, folder 465: US Exhibits, Zuni Pueblo and Reservation, Exhibits 101-146, Exhibit 144 United States Department of the Interior, Office of Indian Affairs, Assistant Director of Irrigation, Los Angeles, Calif., Compilation of Irrigation Data, July 25, 1939 (Temp. Exhibit 32).

spring flow might have reached 1,810 ac-ft, the amount available to meet the irrigation requirement for the Ojo Caliente unit depends on how much of the flow occurred during each of the irrigation months, and how much of the flow could be stored in an upstream reservoir.

Historical Supply Analysis

Several historical supply analyses were conducted to explore the supply that might have been available for the Ojo Caliente unit with and without reservoir storage and for different estimates of spring flow.

Two historical supply estimates for Ojo Caliente were based on the total area irrigated by permanent works (773.7 acres) for the Ojo Caliente unit as reported in Allen (2008), the monthly diversion requirements for the Ojo Caliente unit as described in Table 4-3 from Allen (2008), annual spring flow ranging from 1 to 2.5 cfs, and an assumption of no reservoir storage. Assuming a flow of 1 cfs, the historical supply for the Ojo Caliente unit would be 15 percent. If the spring flow was 2.5 cfs, then the historical supply would be 35 percent. This analysis may underestimate the supply because an additional amount may have been available by storing water in Ojo Caliente reservoir and releasing it as needed during the irrigation season.

If reservoir storage in Ojo Caliente Reservoir is considered (based on a capacity of 250 ac-ft) along with spring flow of 1 cfs for springs in the Ojo Caliente area and the aforementioned irrigated acreage and diversion requirements, the historical supply for the Ojo Caliente unit would be 23 percent. Assuming spring flow of 2.5 cfs and reservoir storage, the historical supply would be 44 percent.

The results of the historical supply analyses are shown in Appendix C.

Allen (2008) reported that several small impoundments serve some irrigated lands in the Ojo Caliente unit, and the additional supply that might be available due to storage in these impoundments was not considered in the Ojo Caliente historical supply analyses.

DISCUSSION

A historical supply analysis is used here to explore the supply that might have been available for irrigation in the Nutria, Zuni, and Ojo Caliente units. The estimated range in supply under various conditions to meet the irrigation diversion requirements by Allen (2008) for each of those agricultural units is summarized in Table 4.

The following are some comments concerning the limitations of the historical supply analysis:

- Because stream and spring flow data are only available for certain time periods, there may have been years with greater stream and spring flow that were not included in the historical supply analysis because there was no record of them. Thus, the maximum historical supply reported may not represent the actual maximum, just the maximum based on the period of record.

- The purpose of this analysis was to explore the supply that might have been available to meet the irrigation diversion requirements as described in Allen (2008). The historical supply analysis determines the percentage of the supply available to meet the irrigation demand on a monthly basis. If the monthly irrigation demand is higher or lower, the historical supply percentage would change.
- Although a certain supply might have been theoretically sufficient for a given month or year (based on the Allen (2008) irrigation diversion requirements), it may not have been the amount that was actually diverted.
- An attempt was made to explore what the historical supply might have been when considering monthly flow estimates and monthly flow estimates plus reservoir storage. The estimates that did not consider reservoir storage may underestimate the historical supply that may have been available to meet the irrigation requirements. The analyses that included reservoir storage may overestimate the supply that may have been available to meet the irrigation requirements.

Table 4. Summary of the historical supply analyses for the Nutria, Zuni, and Ojo Caliente units

Unit	Description	Historical Supply		
		Minimum	Maximum	Average
Nutria	1970-2007, no storage	3%	34%	11%
Nutria	1970-2007, with storage	5%	38%	13%
Zuni	1970-2007, no storage	<1%	31%	7%
Zuni	1970-2007, with storage	<1%	44%	12%
Zuni	1911-1929, no storage	10%	50%	27%
Zuni	1911-1918, no storage	10%	50%	31%
Zuni	1911-1918, with storage	30%	96%	60%
Ojo Caliente	Assuming 1 cfs of spring flow, no storage	--	--	15%
Ojo Caliente	Assuming 1 cfs of spring flow, with storage	--	--	23%
Ojo Caliente	Assuming 2.5 cfs of spring flow, no storage	--	--	35%
Ojo Caliente	Assuming 2.5 cfs of spring flow, with storage	--	--	44%

SUMMARY

Historical supply analyses were prepared to explore the possible maximum and minimum supply that might have been available in any one year for the Nutria, Zuni, and Ojo Caliente units, and the average historical supply for those units. The historical supply analyses estimated the percentage of supply able to meet the irrigation demand for each year (or flow estimate) with available data, based on a monthly assessment of irrigation diversion requirements from Allen (2008) and surface-water supply. In sum, the available data suggest the following:

- For the Nutria unit, the maximum historical supply might have been between 34 and 38 percent of the Allen (2008) irrigation diversion requirement. The minimum historical supply might have been between 3 and 5 percent. The average historical supply might have been between 11 and 13 percent.

- The Zuni unit might have achieved a maximum historical supply of between 50 and 96 percent of the Allen (2008) irrigation diversion requirement shortly after Black Rock Reservoir was built. The minimum historical supply might have been less than 1 percent based on the 1970 to 2007 period. The average historical supply varied depending on the period of record and whether reservoir storage was considered.

- For the Ojo Caliente unit, with a spring flow of 2.5 cfs, the historical supply might have been between 35 and 44 percent of the Allen (2008) irrigation diversion requirement and with a spring flow of 1 cfs, the historical supply might have been between 15 and 23 percent of the Allen (2008) irrigation diversion requirement.

It is uncertain what the historical supply for the Pescado and Tekapo units would have been due to insufficient data.

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FIGURES

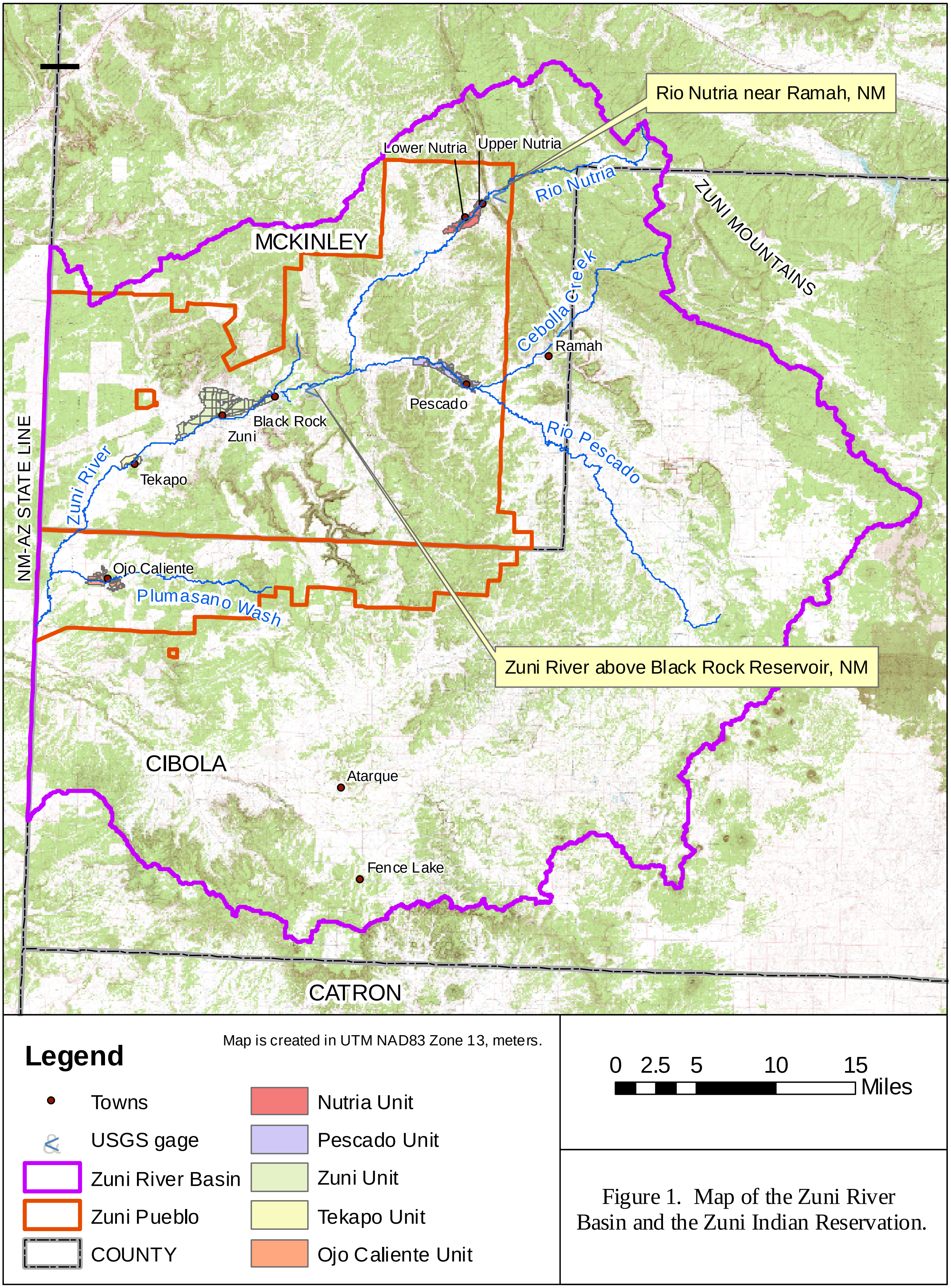

Figure 1. Map of the Zuni River Basin and the Zuni Indian Reservation.

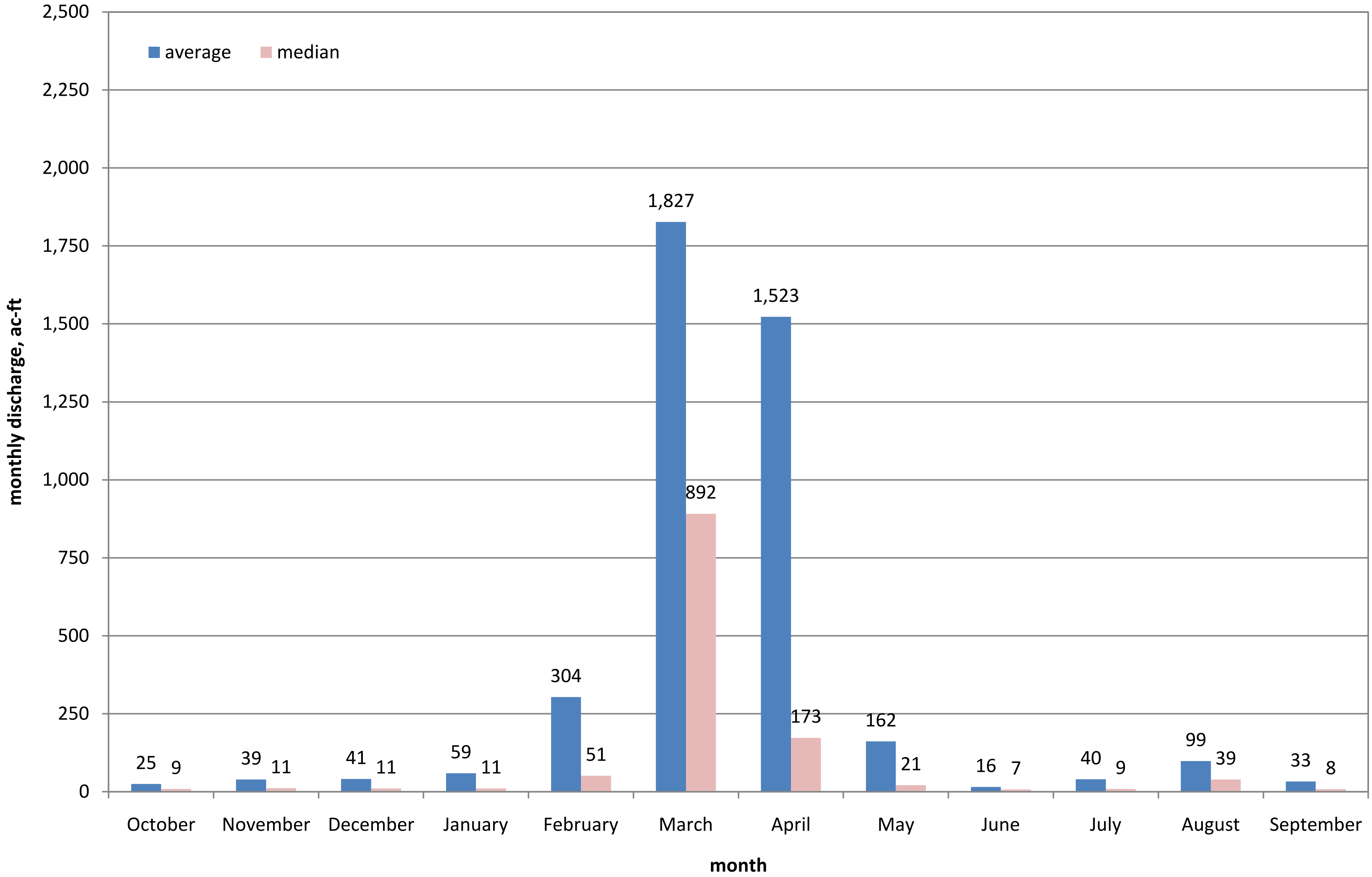

Figure 2. Monthly discharge at the USGS gage Rio Nutria near Ramah, NM (Water Years 1970 to 2008).

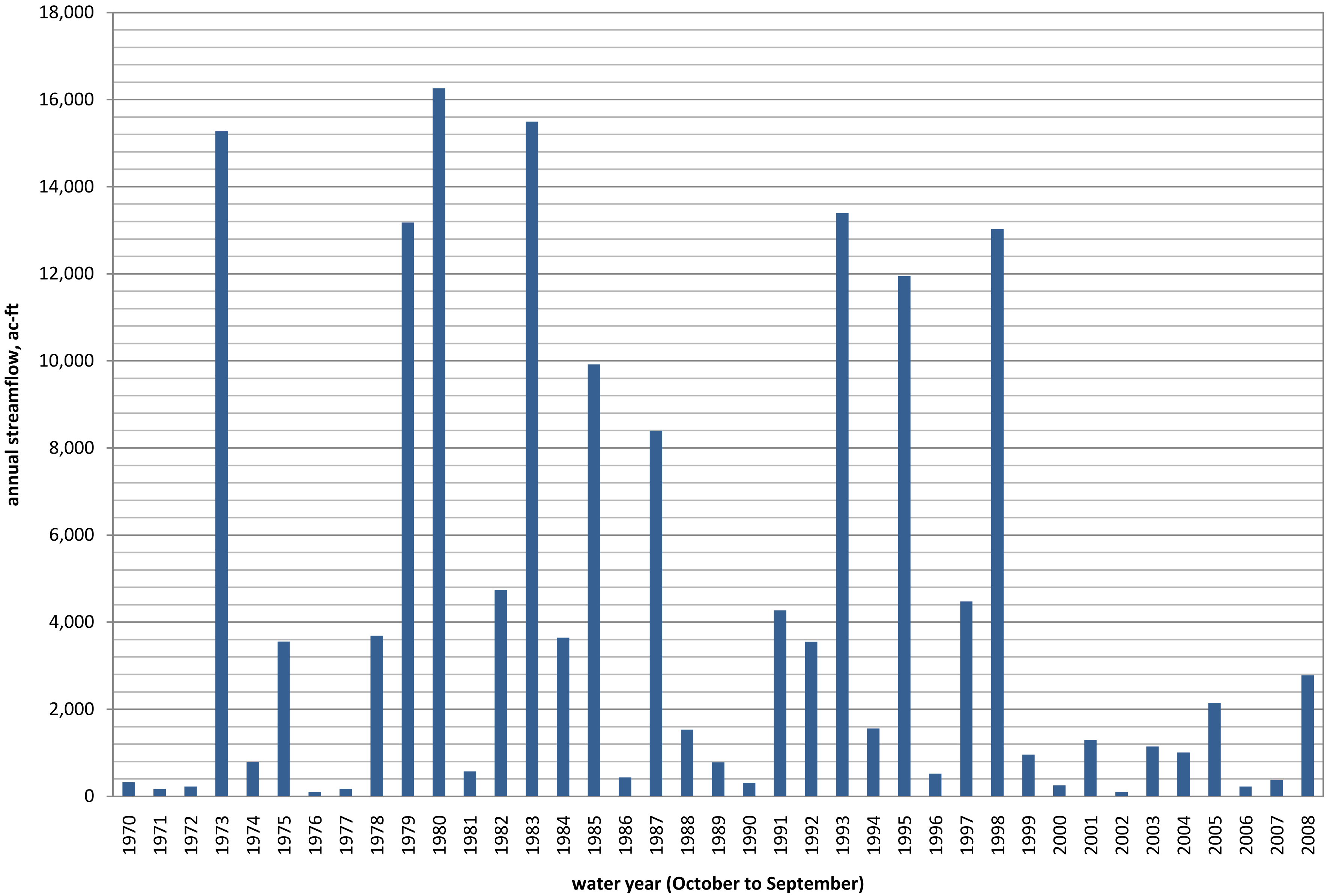

Figure 3. Annual streamflow at the Rio Nutria near Ramah, NM for the 1970 to 2008 period (USGS gage 09386900).

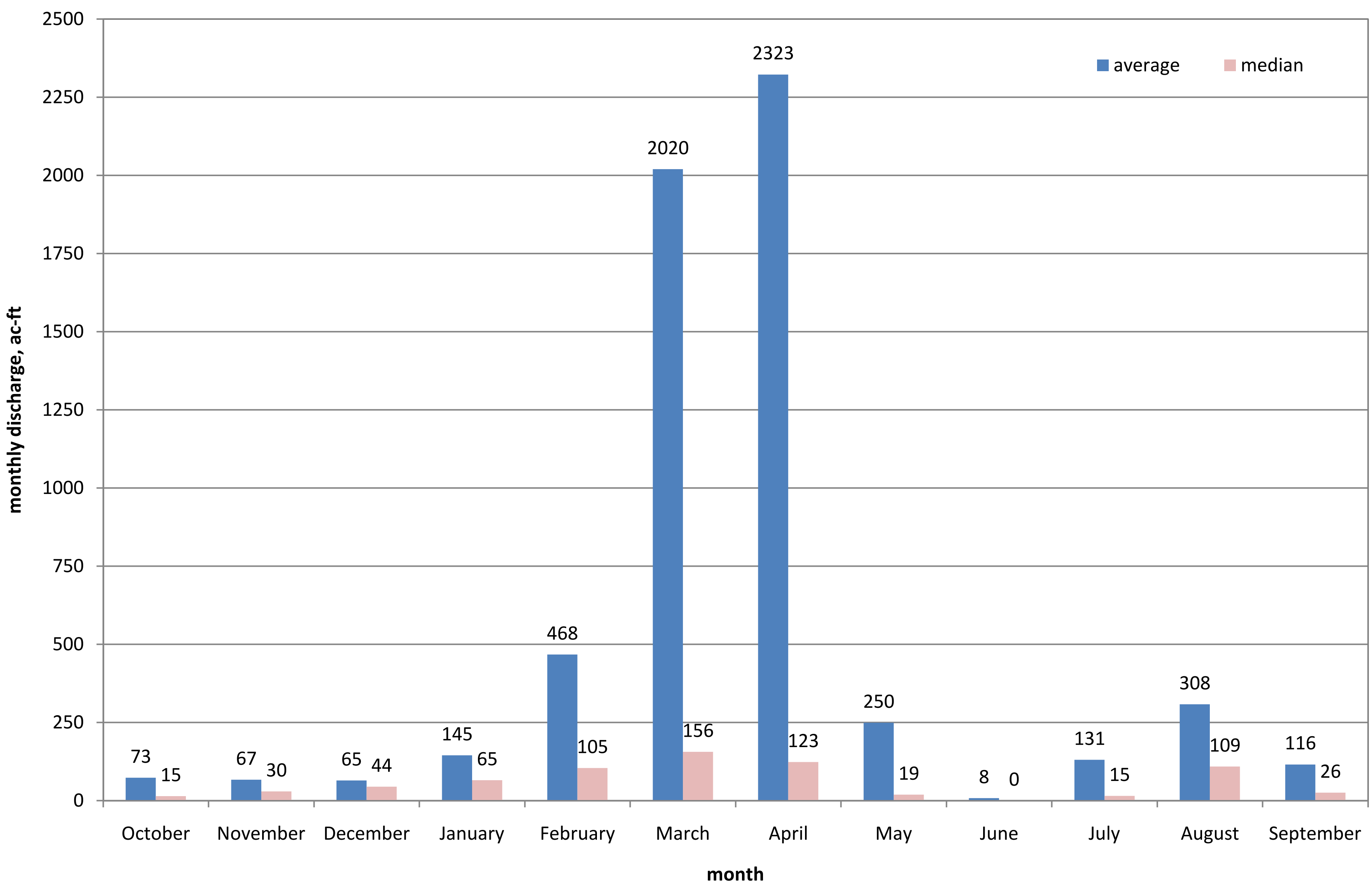

Figure 4. Monthly discharge at the USGS gage Zuni River above Black Rock Reservoir, NM (Water Years 1970 to 2008).

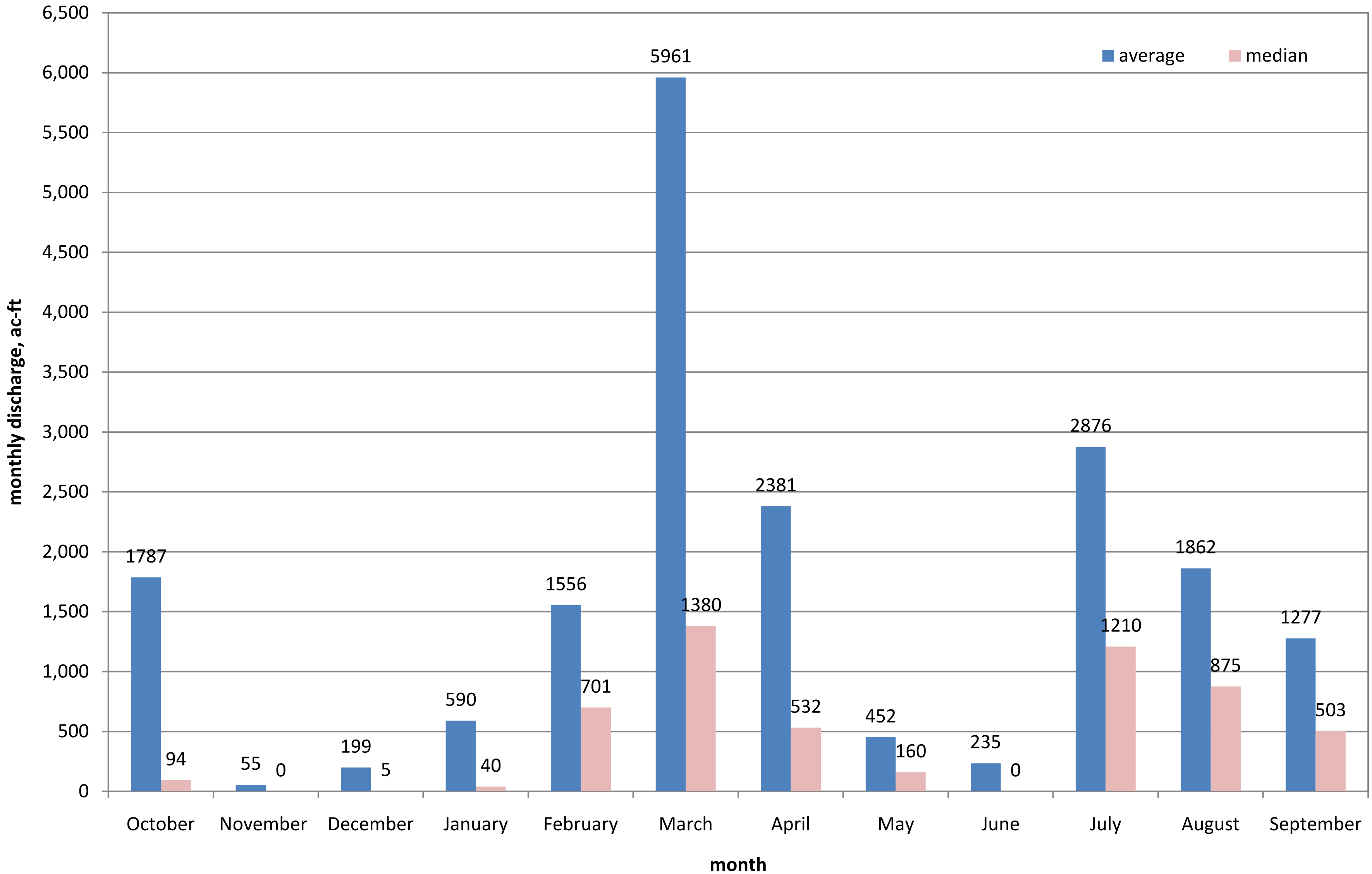

Figure 5. Estimated monthly discharge at the Zuni River at Black Rock Reservoir, NM (Water Years 1911 to 1930).

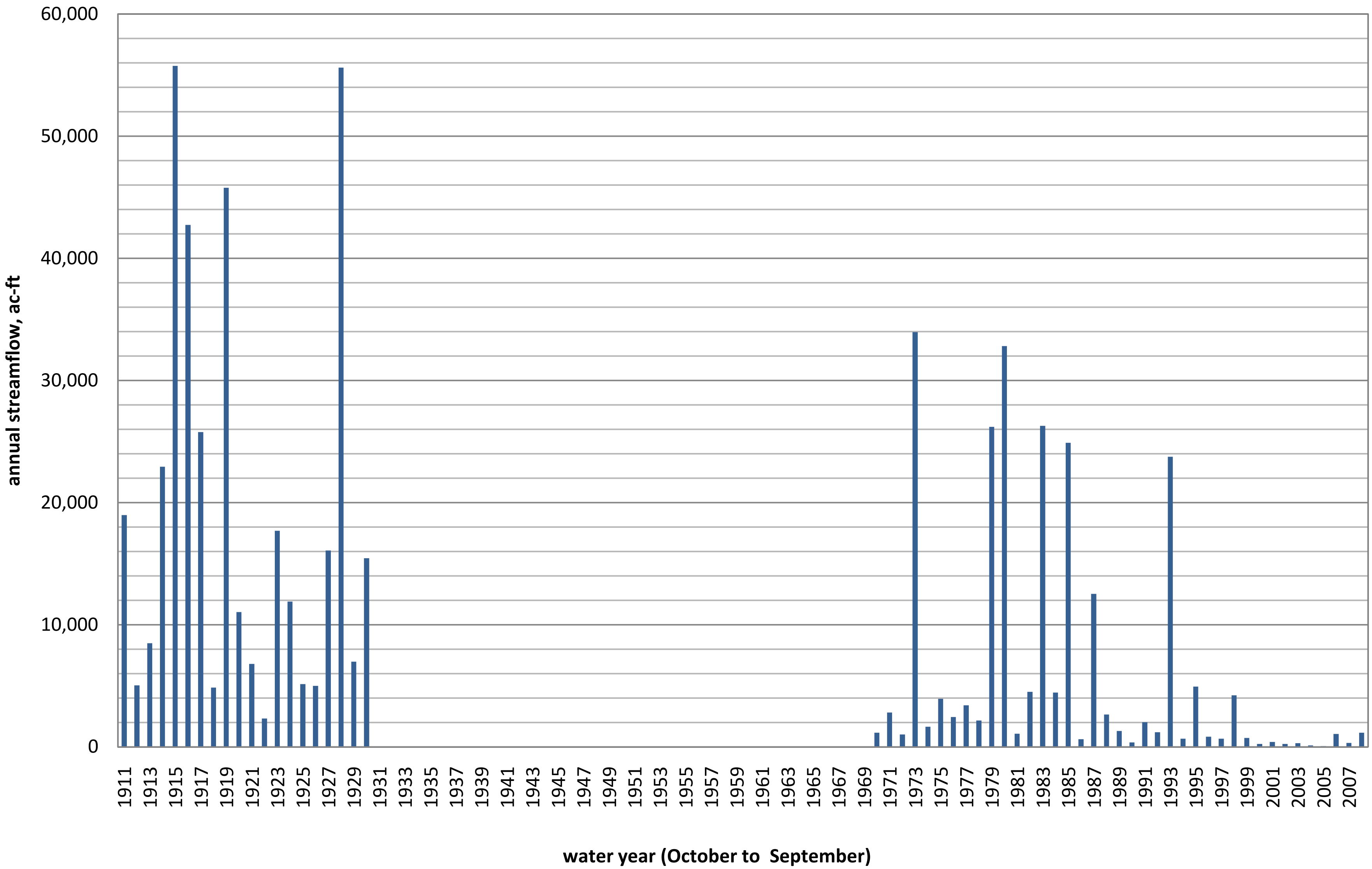

Figure 6. Annual streamflow at the Zuni River at Black Rock, NM estimated for the 1911-1930 period (from USGS, 1954) and at the Zuni River above Black Rock Reservoir, NM for the 1970 to 2008 period (USGS gage 09386950) .

APPENDIX

Appendix A:

USGS streamflow gages from http://waterdata.usgs.gov/nwis/sw in the Zuni River Basin.

Table A1. USGS gages of daily streamflow in the Zuni River Basin.
Gages used in this study are shaded in gray.
(from the USGS National Water Information System, http://waterdata.usgs.gov/nwis/sw)

USGS Gaging Station Name	USGS Gaging Station ID	Drainage area, sq. miles	Period of record for daily discharge: start	Period of record for daily discharge: end
Rio Nutria Near Ramah, NM	09386900	71.4	10/1/1969	present
Conservation Draw at Nutria Village, NM	09386910	Nr	5/14/1992	9/30/1994
Garcia Draw above Reservoir No. 3 near Lower Nutria, NM	09386917	23.5	3/29/1994	9/30/1995
Spillway Channel below Reservoir No. 3 near Lower Nutria, NM	09386919	151.9	12/16/1993	9/30/1995
Y-Unit Draw at State Highway 602 near Zuni, NM	09386925	Nr	7/1/1992	9/30/1994
Zuni River above Black Rock Reservoir, NM	09386950	835	10/1/1969	present
Zuni River near NM-AZ State Line, NM	09387300	1314	10/1/1987	9/30/1994

Appendix B.

A summary of irrigated area and irrigation diversion requirements from Allen (2008) for the agricultural units on the Zuni Indian Reservation and stream and spring flow data.

Table B1. Irrigated area and irrigation diversion requirements for agricultural units on the Zuni Indian Reservation from Allen (2008, Table 4-4) and estimated stream and/or spring flow

Unit	Estimated annual stream and/or spring flow, ac-ft	Estimated range in annual stream and or spring flow, ac-ft	Irrigated area (acres)	Diversion (ac-ft)
Nutria	1,530 (median)+150[a]	250 – 16,410[a]	976.6	4,401.7
Pescado	>800[b]	> 800 [b]	1,317.9	5,096.9
Zuni	1,300 (1970-2008) to 5,060 (1911-1930) (median) [c]	60 – 55,770[c]	3,629.8	17,901.4
Tekapo	unknown	Unknown	320.6	1,383.0
Ojo Caliente	--	680 to 1,810 ac-ft [d]	773.7	2,967.9

[a] Based on annual streamflow recorded at the USGS gage Rio Nutria near Ramah, NM between water years 1970 and 2008 and spring flow at Nutria Spring, estimated here to be 150 ac-ft (based on 90 gpm flow).

[b] Based on Orr (1987). Upstream diversions may affect available supply at this location. They are not accounted for here.

[c] Based on annual streamflow recorded at the USGS gage Zuni River above Black Rock Reservoir, NM between water years 1970 and 2008 and Zuni River at Black Rock, NM from 1911 to 1930 reported in USGS (1954). Upstream diversions may affect available supply at this location. They are not accounted for here.

[d] Based on the range in reported spring flow at Ojo Caliente.

Appendix C.

Evaluation of historical supply for the Nutria, Zuni, and Ojo Caliente units.

Table C1. Evaluation of historical supply for the Nutria Unit from 1970 to 2007 with no storage in Nutria Diversion Reservoir

976.6 = irrigated area for Nutria Unit (acres)

		April					May					June					July					August					September					October					Annual Totals		
year	monthly Nutria Springflow, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly discharge plus springflow, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1970	12	119	131	1.04	84.6	0.0	11	23	8.37	681	658	4	16	13.06	1063	1047	10	22	12.88	1048	1026	93	105	9.92	807	702	7	19	6.01	489	470	6	18	2.99	243	225	4417	4128	7%
1971	12	8	20	1.04	84.6	64.8	6	18	8.37	681	663	5	17	13.06	1063	1046	3	15	12.88	1048	1033	2	14	9.92	807	793	73	85	6.01	489	404	21	33	2.99	243	210	4417	4215	5%
1972	12	8	20	1.04	84.6	64.4	6	18	8.37	681	663	4	16	13.06	1063	1047	5	17	12.88	1048	1032	4	16	9.92	807	792	3	15	6.01	489	474	149	161	2.99	243	82	4417	4153	6%
1973	12	11127	11139	1.04	84.6	0.0	2078	2090	8.37	681	0	79	91	13.06	1063	972	11	23	12.88	1048	1026	23	35	9.92	807	772	6	18	6.01	489	471	2	14	2.99	243	229	4417	3469	21%
1974	12	26	38	1.04	84.6	46.4	13	25	8.37	681	656	6	18	13.06	1063	1045	181	193	12.88	1048	855	76	88	9.92	807	719	10	22	6.01	489	467	36	48	2.99	243	195	4417	3984	10%
1975	12	1827	1839	1.04	84.6	0.0	64	76	8.37	681	605	7	19	13.06	1063	1044	31	43	12.88	1048	1005	6	18	9.92	807	789	7	19	6.01	489	470	4	16	2.99	243	227	4417	4140	6%
1976	12	7	19	1.04	84.6	65.7	5	17	8.37	681	664	3	15	13.06	1063	1048	5	17	12.88	1048	1031	29	41	9.92	807	766	10	22	6.01	489	467	4	16	2.99	243	227	4417	4269	3%
1977	12	18	30	1.04	84.6	54.7	9	21	8.37	681	660	7	19	13.06	1063	1044	19	31	12.88	1048	1017	39	51	9.92	807	756	7	19	6.01	489	470	2	14	2.99	243	229	4417	4230	4%
1978	12	449	461	1.04	84.6	0.0	32	44	8.37	681	638	4	16	13.06	1063	1047	3	15	12.88	1048	1033	4	16	9.92	807	791	4	16	6.01	489	473	4	16	2.99	243	228	4417	4209	5%
1979	12	8634	8646	1.04	84.6	0.0	561	573	8.37	681	108	64	76	13.06	1063	987	4	16	12.88	1048	1032	82	94	9.92	807	714	2	14	6.01	489	475	4	16	2.99	243	228	4417	3544	20%
1980	12	9467	9479	1.04	84.6	0.0	621	633	8.37	681	48	32	44	13.06	1063	1019	3	15	12.88	1048	1033	4	16	9.92	807	792	6	18	6.01	489	471	9	21	2.99	243	223	4417	3585	19%
1981	12	173	185	1.04	84.6	0.0	6	18	8.37	681	663	6	18	13.06	1063	1045	18	30	12.88	1048	1018	144	156	9.92	807	651	25	37	6.01	489	452	26	38	2.99	243	206	4417	4034	9%
1982	12	708	720	1.04	84.6	0.0	72	84	8.37	681	597	19	31	13.06	1063	1031	216	228	12.88	1048	820	182	194	9.92	807	613	24	36	6.01	489	453	7	19	2.99	243	224	4417	3738	15%
1983	12	8164	8176	1.04	84.6	0.0	543	555	8.37	681	126	67	79	13.06	1063	984	82	94	12.88	1048	954	138	150	9.92	807	658	2	14	6.01	489	475	145	157	2.99	243	86	4417	3284	26%
1984	12	2083	2095	1.04	84.6	0.0	39	51	8.37	681	630	2	14	13.06	1063	1049	4	16	12.88	1048	1032	8	20	9.92	807	787	114	126	6.01	489	363	65	77	2.99	243	166	4417	4029	9%
1985	12	1857	1869	1.04	84.6	0.0	873	885	8.37	681	0	70	82	13.06	1063	981	25	37	12.88	1048	1011	18	30	9.92	807	777	12	24	6.01	489	465	12	24	2.99	243	219	4417	3453	22%
1986	12	71	83	1.04	84.6	1.8	9	21	8.37	681	660	9	21	13.06	1063	1042	9	21	12.88	1048	1027	60	72	9.92	807	736	9	21	6.01	489	469	65	77	2.99	243	166	4417	4101	7%
1987	12	4790	4802	1.04	84.6	0.0	370	382	8.37	681	300	23	35	13.06	1063	1028	21	33	12.88	1048	1015	295	307	9.92	807	501	49	61	6.01	489	428	17	29	2.99	243	215	4417	3486	21%
1988	12	684	696	1.04	84.6	0.0	87	99	8.37	681	582	23	35	13.06	1063	1028	17	29	12.88	1048	1020	39	51	9.92	807	756	8	20	6.01	489	469	10	22	2.99	243	222	4417	4076	8%
1989	12	15	27	1.04	84.6	57.8	9	21	8.37	681	661	12	24	13.06	1063	1039	185	197	12.88	1048	851	16	28	9.92	807	780	48	60	6.01	489	430	9	21	2.99	243	222	4417	4039	9%
1990	12	11	23	1.04	84.6	61.7	25	37	8.37	681	644	21	33	13.06	1063	1030	81	93	12.88	1048	955	83	95	9.92	807	712	27	39	6.01	489	450	7	19	2.99	243	225	4417	4078	8%
1991	12	2344	2356	1.04	84.6	0.0	24	36	8.37	681	645	5	17	13.06	1063	1046	5	17	12.88	1048	1031	5	17	9.92	807	790	107	119	6.01	489	370	12	24	2.99	243	219	4417	4101	7%
1992	12	402	414	1.04	84.6	0.0	73	85	8.37	681	596	10	22	13.06	1063	1041	2	14	12.88	1048	1035	440	452	9.92	807	356	6	18	6.01	489	471	11	23	2.99	243	220	4417	3718	16%
1993	12	1434	1446	1.04	84.6	0.0	336	348	8.37	681	333	29	41	13.06	1063	1022	1	13	12.88	1048	1035	12	24	9.92	807	783	5	17	6.01	489	472	2	14	2.99	243	230	4417	3875	12%
1994	12	51	63	1.04	84.6	21.8	17	29	8.37	681	652	9	21	13.06	1063	1042	2	14	12.88	1048	1034	3	15	9.92	807	792	7	19	6.01	489	470	7	19	2.99	243	225	4417	4236	4%
1995	12	857	869	1.04	84.6	0.0	215	227	8.37	681	455	10	22	13.06	1063	1041	3	15	12.88	1048	1033	207	219	9.92	807	589	12	24	6.01	489	465	11	23	2.99	243	221	4417	3803	14%
1996	12	25	37	1.04	84.6	47.6	53	65	8.37	681	616	11	23	13.06	1063	1040	15	27	12.88	1048	1021	149	161	9.92	807	646	198	210	6.01	489	279	28	40	2.99	243	203	4417	3854	13%
1997	12	445	457	1.04	84.6	0.0	21	33	8.37	681	648	33	45	13.06	1063	1018	116	128	12.88	1048	921	861	873	9.92	807	0	359	371	6.01	489	118	11	23	2.99	243	220	4417	2924	34%
1998	12	2529	2541	1.04	84.6	0.0	38	50	8.37	681	631	6	18	13.06	1063	1045	30	42	12.88	1048	1006	21	33	9.92	807	774	6	18	6.01	489	471	232	244	2.99	243	0	4417	3927	11%
1999	12	65	77	1.04	84.6	7.2	18	30	8.37	681	651	8	20	13.06	1063	1043	61	73	12.88	1048	975	144	156	9.92	807	651	18	30	6.01	489	459	8	20	2.99	243	223	4417	4010	9%
2000	12	68	80	1.04	84.6	4.8	4	16	8.37	681	665	11	23	13.06	1063	1040	4	16	12.88	1048	1032	11	23	9.92	807	785	18	30	6.01	489	459	15	27	2.99	243	216	4417	4202	5%
2001	12	28	40	1.04	84.6	45.0	2	14	8.37	681	668	3	15	13.06	1063	1048	4	16	12.88	1048	1032	259	271	9.92	807	536	5	17	6.01	489	472	8	20	2.99	243	223	4417	4023	9%
2002	12	2	14	1.04	84.6	70.3	6	18	8.37	681	663	5	17	13.06	1063	1046	5	17	12.88	1048	1031	5	17	9.92	807	790	30	42	6.01	489	447	6	18	2.99	243	225	4417	4273	3%
2003	12	43	55	1.04	84.6	29.6	40	52	8.37	681	629	4	16	13.06	1063	1047	4	16	12.88	1048	1032	11	23	9.92	807	784	5	17	6.01	489	472	14	26	2.99	243	217	4417	4212	5%
2004	12	444	456	1.04	84.6	0.0	3	15	8.37	681	666	2	14	13.06	1063	1049	16	28	12.88	1048	1021	3	15	9.92	807	793	3	15	6.01	489	474	5	17	2.99	243	226	4417	4228	4%
2005	12	195	207	1.04	84.6	0.0	14	26	8.37	681	655	0	12	13.06	1063	1051	0	12	12.88	1048	1036	65	77	9.92	807	731	0	12	6.01	489	477	0	12	2.99	243	231	4417	4181	5%
2006	12	1	13	1.04	84.6	71.6	0	12	8.37	681	669	0	12	13.06	1063	1051	0	12	12.88	1048	1036	179	191	9.92	807	616	43	55	6.01	489	434	0	12	2.99	243	231	4417	4109	7%
2007	12	104	116	1.04	84.6	0.0	1	13	8.37	681	668	0	12	13.06	1063	1051	8	20	12.88	1048	1029	17	29	9.92	807	778	3	15	6.01	489	474	0	12	2.99	243	231	4417	4231	4%
																																						average	11%
																																						maximum	34%
																																						minimum	3%

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly discharge from USGS gage (USGS ID 09386900 RIO NUTRIA NEAR RAMAH, NM). Nutria spring monthly flow based on information from Drakos and Riesterer (2009)

Table C2. Evaluation of historical supply for the Nutria Unit from 1970 to 2007 with storage in Nutria Diversion Reservoir.

976.6 = irrigated area for Nutria unit (acres)

				April							May						
year	reservoir capacity, ac-ft*	Starting reservoir storage, ac-ft (based on previous five months of spring and surface flow, plus any storage remaining in October of previous year)	monthly Nutria Springflow, ac-ft	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1970	120	120	12	119	251	1.04	85	0	166	120	11	143	8.37	681	538	0	0
1971	120	120	12	8	140	1.04	85	0	55	55	6	73	8.37	681	608	0	0
1972	120	120	12	8	140	1.04	85	0	56	56	6	73	8.37	681	608	0	0
1973	120	120	12	11127	11259	1.04	85	0	11175	120	2078	2210	8.37	681	0	1529	120
1974	120	120	12	26	158	1.04	85	0	74	74	13	99	8.37	681	582	0	0
1975	120	120	12	1827	1959	1.04	85	0	1874	120	64	196	8.37	681	485	0	0
1976	120	93	12	7	112	1.04	85	0	27	27	5	45	8.37	681	636	0	0
1977	120	120	12	18	150	1.04	85	0	65	65	9	87	8.37	681	594	0	0
1978	120	120	12	449	581	1.04	85	0	497	120	32	164	8.37	681	518	0	0
1979	120	120	12	8634	8766	1.04	85	0	8681	120	561	693	8.37	681	0	12	12
1980	120	120	12	9467	9599	1.04	85	0	9514	120	621	753	8.37	681	0	72	72
1981	120	120	12	173	305	1.04	85	0	221	120	6	138	8.37	681	543	0	0
1982	120	120	12	708	840	1.04	85	0	755	120	72	204	8.37	681	477	0	0
1983	120	120	12	8164	8296	1.04	85	0	8211	120	543	675	8.37	681	6	0	0
1984	120	120	12	2083	2215	1.04	85	0	2130	120	39	171	8.37	681	510	0	0
1985	120	120	12	1857	1989	1.04	85	0	1904	120	873	1005	8.37	681	0	324	120
1986	120	120	12	71	203	1.04	85	0	118	118	9	139	8.37	681	542	0	0
1987	120	120	12	4790	4922	1.04	85	0	4837	120	370	502	8.37	681	180	0	0
1988	120	120	12	684	816	1.04	85	0	732	120	87	219	8.37	681	462	0	0
1989	120	120	12	15	147	1.04	85	0	62	62	9	83	8.37	681	598	0	0
1990	120	117	12	11	140	1.04	85	0	55	55	25	92	8.37	681	589	0	0
1991	120	120	12	2344	2476	1.04	85	0	2392	120	24	156	8.37	681	525	0	0
1992	120	120	12	402	534	1.04	85	0	449	120	73	205	8.37	681	476	0	0
1993	120	120	12	1434	1566	1.04	85	0	1481	120	336	468	8.37	681	213	0	0
1994	120	120	12	51	183	1.04	85	0	98	98	17	128	8.37	681	553	0	0
1995	120	120	12	857	989	1.04	85	0	904	120	215	347	8.37	681	335	0	0
1996	120	120	12	25	157	1.04	85	0	72	72	53	137	8.37	681	544	0	0
1997	120	120	12	445	577	1.04	85	0	492	120	21	153	8.37	681	528	0	0
1998	120	120	12	2529	2661	1.04	85	0	2576	120	38	170	8.37	681	511	0	0
1999	120	120	12	65	197	1.04	85	0	113	113	18	143	8.37	681	539	0	0
2000	120	120	12	68	200	1.04	85	0	115	115	4	132	8.37	681	550	0	0
2001	120	120	12	28	160	1.04	85	0	75	75	2	89	8.37	681	593	0	0
2002	120	98	12	2	112	1.04	85	0	28	28	6	45	8.37	681	636	0	0
2003	120	120	12	43	175	1.04	85	0	90	90	40	142	8.37	681	539	0	0
2004	120	120	12	444	576	1.04	85	0	491	120	3	135	8.37	681	546	0	0
2005	120	120	12	195	327	1.04	85	0	242	120	14	146	8.37	681	535	0	0
2006	120	61	12	1	74	1.04	85	10	0	0	0	12	8.37	681	669	0	0
2007	120	0	12	104	116	1.04	85	0	31	31	1	44	8.37	681	637	0	0

	June							July						
year	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1970	4	16	13.06	1063	1047	0	0	10	22	12.88	1048	1026	0	0
1971	5	17	13.06	1063	1046	0	0	3	15	12.88	1048	1033	0	0
1972	4	16	13.06	1063	1047	0	0	5	17	12.88	1048	1032	0	0
1973	79	211	13.06	1063	852	0	0	11	23	12.88	1048	1026	0	0
1974	6	18	13.06	1063	1045	0	0	181	193	12.88	1048	855	0	0
1975	7	19	13.06	1063	1044	0	0	31	43	12.88	1048	1005	0	0
1976	3	15	13.06	1063	1048	0	0	5	17	12.88	1048	1031	0	0
1977	7	19	13.06	1063	1044	0	0	19	31	12.88	1048	1017	0	0
1978	4	16	13.06	1063	1047	0	0	3	15	12.88	1048	1033	0	0
1979	64	87	13.06	1063	976	0	0	4	16	12.88	1048	1032	0	0
1980	32	116	13.06	1063	947	0	0	3	15	12.88	1048	1033	0	0
1981	6	18	13.06	1063	1045	0	0	18	30	12.88	1048	1018	0	0
1982	19	31	13.06	1063	1031	0	0	216	228	12.88	1048	820	0	0
1983	67	79	13.06	1063	984	0	0	82	94	12.88	1048	954	0	0
1984	2	14	13.06	1063	1049	0	0	4	16	12.88	1048	1032	0	0
1985	70	202	13.06	1063	861	0	0	25	37	12.88	1048	1011	0	0
1986	9	21	13.06	1063	1042	0	0	9	21	12.88	1048	1027	0	0
1987	23	35	13.06	1063	1028	0	0	21	33	12.88	1048	1015	0	0
1988	23	35	13.06	1063	1028	0	0	17	29	12.88	1048	1020	0	0
1989	12	24	13.06	1063	1039	0	0	185	197	12.88	1048	851	0	0
1990	21	33	13.06	1063	1030	0	0	81	93	12.88	1048	955	0	0
1991	5	17	13.06	1063	1046	0	0	5	17	12.88	1048	1031	0	0
1992	10	22	13.06	1063	1041	0	0	2	14	12.88	1048	1035	0	0
1993	29	41	13.06	1063	1022	0	0	1	13	12.88	1048	1035	0	0
1994	9	21	13.06	1063	1042	0	0	2	14	12.88	1048	1034	0	0
1995	10	22	13.06	1063	1041	0	0	3	15	12.88	1048	1033	0	0
1996	11	23	13.06	1063	1040	0	0	15	27	12.88	1048	1021	0	0
1997	33	45	13.06	1063	1018	0	0	116	128	12.88	1048	921	0	0
1998	6	18	13.06	1063	1045	0	0	30	42	12.88	1048	1006	0	0
1999	8	20	13.06	1063	1043	0	0	61	73	12.88	1048	975	0	0
2000	11	23	13.06	1063	1040	0	0	4	16	12.88	1048	1032	0	0
2001	3	15	13.06	1063	1048	0	0	4	16	12.88	1048	1032	0	0
2002	5	17	13.06	1063	1046	0	0	5	17	12.88	1048	1031	0	0
2003	4	16	13.06	1063	1047	0	0	4	16	12.88	1048	1032	0	0
2004	2	14	13.06	1063	1049	0	0	16	28	12.88	1048	1021	0	0
2005	0	12	13.06	1063	1051	0	0	0	12	12.88	1048	1036	0	0
2006	0	12	13.06	1063	1051	0	0	0	12	12.88	1048	1036	0	0
2007	0	12	13.06	1063	1051	0	0	8	20	12.88	1048	1029	0	0

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from USGS gage (USGS ID 09386900 RIO NUTRIA NEAR RAMAH, NM). Nutria spring monthly flow based on information from Drakos and Riesterer (2009).

* Reservoir capacity based on information from U.S. Army Corps of Engineers (1993).

(continued)

	August							September						
year	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1970	93	105	9.92	807	702	0	0	7	19	6.01	489	470	0	0
1971	2	14	9.92	807	793	0	0	73	85	6.01	489	404	0	0
1972	4	16	9.92	807	792	0	0	3	15	6.01	489	474	0	0
1973	23	35	9.92	807	772	0	0	6	18	6.01	489	471	0	0
1974	76	88	9.92	807	719	0	0	10	22	6.01	489	467	0	0
1975	6	18	9.92	807	789	0	0	7	19	6.01	489	470	0	0
1976	29	41	9.92	807	766	0	0	10	22	6.01	489	467	0	0
1977	39	51	9.92	807	756	0	0	7	19	6.01	489	470	0	0
1978	4	16	9.92	807	791	0	0	4	16	6.01	489	473	0	0
1979	82	94	9.92	807	714	0	0	2	14	6.01	489	475	0	0
1980	4	16	9.92	807	792	0	0	6	18	6.01	489	471	0	0
1981	144	156	9.92	807	651	0	0	25	37	6.01	489	452	0	0
1982	182	194	9.92	807	613	0	0	24	36	6.01	489	453	0	0
1983	138	150	9.92	807	658	0	0	2	14	6.01	489	475	0	0
1984	8	20	9.92	807	787	0	0	114	126	6.01	489	363	0	0
1985	18	30	9.92	807	777	0	0	12	24	6.01	489	465	0	0
1986	60	72	9.92	807	736	0	0	9	21	6.01	489	469	0	0
1987	295	307	9.92	807	501	0	0	49	61	6.01	489	428	0	0
1988	39	51	9.92	807	756	0	0	8	20	6.01	489	469	0	0
1989	16	28	9.92	807	780	0	0	48	60	6.01	489	430	0	0
1990	83	95	9.92	807	712	0	0	27	39	6.01	489	450	0	0
1991	5	17	9.92	807	790	0	0	107	119	6.01	489	370	0	0
1992	440	452	9.92	807	356	0	0	6	18	6.01	489	471	0	0
1993	12	24	9.92	807	783	0	0	5	17	6.01	489	472	0	0
1994	3	15	9.92	807	792	0	0	7	19	6.01	489	470	0	0
1995	207	219	9.92	807	589	0	0	12	24	6.01	489	465	0	0
1996	149	161	9.92	807	646	0	0	198	210	6.01	489	279	0	0
1997	861	873	9.92	807	0	66	66	359	437	6.01	489	52	0	0
1998	21	33	9.92	807	774	0	0	6	18	6.01	489	471	0	0
1999	144	156	9.92	807	651	0	0	18	30	6.01	489	459	0	0
2000	11	23	9.92	807	785	0	0	18	30	6.01	489	459	0	0
2001	259	271	9.92	807	536	0	0	5	17	6.01	489	472	0	0
2002	5	17	9.92	807	790	0	0	30	42	6.01	489	447	0	0
2003	11	23	9.92	807	784	0	0	5	17	6.01	489	472	0	0
2004	3	15	9.92	807	793	0	0	3	15	6.01	489	474	0	0
2005	65	77	9.92	807	731	0	0	0	12	6.01	489	477	0	0
2006	179	191	9.92	807	616	0	0	43	55	6.01	489	434	0	0
2007	17	29	9.92	807	778	0	0	3	15	6.01	489	474	0	0

	October							Annual Totals		
year	monthly discharge, ac-ft	monthly supply with springflow and reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1970	6	18	2.99	243	225	0	0	4417	4008	9%
1971	21	33	2.99	243	210	0	0	4417	4095	7%
1972	149	161	2.99	243	82	0	0	4417	4033	9%
1973	2	14	2.99	243	229	0	0	4417	3349	24%
1974	36	48	2.99	243	195	0	0	4417	3864	13%
1975	4	16	2.99	243	227	0	0	4417	4020	9%
1976	4	16	2.99	243	227	0	0	4417	4176	5%
1977	2	14	2.99	243	229	0	0	4417	4110	7%
1978	4	16	2.99	243	228	0	0	4417	4089	7%
1979	4	16	2.99	243	228	0	0	4417	3424	22%
1980	9	21	2.99	243	223	0	0	4417	3465	22%
1981	26	38	2.99	243	206	0	0	4417	3914	11%
1982	7	19	2.99	243	224	0	0	4417	3618	18%
1983	145	157	2.99	243	86	0	0	4417	3164	28%
1984	65	77	2.99	243	166	0	0	4417	3909	12%
1985	12	24	2.99	243	219	0	0	4417	3333	25%
1986	65	77	2.99	243	166	0	0	4417	3981	10%
1987	17	29	2.99	243	215	0	0	4417	3366	24%
1988	10	22	2.99	243	222	0	0	4417	3956	10%
1989	9	21	2.99	243	222	0	0	4417	3919	11%
1990	7	19	2.99	243	225	0	0	4417	3961	10%
1991	12	24	2.99	243	219	0	0	4417	3981	10%
1992	11	23	2.99	243	220	0	0	4417	3598	19%
1993	2	14	2.99	243	230	0	0	4417	3755	15%
1994	7	19	2.99	243	225	0	0	4417	4116	7%
1995	11	23	2.99	243	221	0	0	4417	3683	17%
1996	28	40	2.99	243	203	0	0	4417	3734	15%
1997	11	23	2.99	243	220	0	0	4417	2739	38%
1998	232	244	2.99	243	0	1	1	4417	3807	14%
1999	8	20	2.99	243	223	0	0	4417	3890	12%
2000	15	27	2.99	243	216	0	0	4417	4082	8%
2001	8	20	2.99	243	223	0	0	4417	3903	12%
2002	6	18	2.99	243	225	0	0	4417	4176	5%
2003	14	26	2.99	243	217	0	0	4417	4092	7%
2004	5	17	2.99	243	226	0	0	4417	4108	7%
2005	0	12	2.99	243	231	0	0	4417	4061	8%
2006	0	12	2.99	243	231	0	0	4417	4048	8%
2007	0	12	2.99	243	231	0	0	4417	4200	5%
									average	13%
									maximum	38%
									minimum	5%

Table C3. Evaluation of historical supply for the Zuni unit from 1970 to 2007 with no storage in Black Rock Reservoir

3629.8 = irrigated area for Zuni unit (acres)

	March				April				May			
year	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft
1970	59	0.18	54	0	77	2.31	699	621	17	10.07	3046	3029
1971	41	0.18	54	14	479	2.31	699	220	1	10.07	3046	3045
1972	109	0.18	54	0	1	2.31	699	698	15	10.07	3046	3031
1973	8553	0.18	54	0	18321	2.31	699	0	4015	10.07	3046	0
1974	115	0.18	54	0	121	2.31	699	578	55	10.07	3046	2991
1975	892	0.18	54	0	1166	2.31	699	0	333	10.07	3046	2713
1976	170	0.18	54	0	121	2.31	699	578	5	10.07	3046	3041
1977	125	0.18	54	0	67	2.31	699	632	24	10.07	3046	3022
1978	922	0.18	54	0	744	2.31	699	0	34	10.07	3046	3012
1979	7422	0.18	54	0	16792	2.31	699	0	469	10.07	3046	2577
1980	9174	0.18	54	0	17970	2.31	699	0	482	10.07	3046	2564
1981	160	0.18	54	0	141	2.31	699	558	39	10.07	3046	3007
1982	861	0.18	54	0	952	2.31	699	0	249	10.07	3046	2797
1983	8252	0.18	54	0	15798	2.31	699	0	535	10.07	3046	2511
1984	156	0.18	54	0	274	2.31	699	425	45	10.07	3046	3001
1985	16147	0.18	54	0	2065	2.31	699	0	2250	10.07	3046	796
1986	124	0.18	54	0	123	2.31	699	576	46	10.07	3046	3000
1987	3794	0.18	54	0	7361	2.31	699	0	231	10.07	3046	2815
1988	345	0.18	54	0	195	2.31	699	504	122	10.07	3046	2924
1989	145	0.18	54	0	57	2.31	699	641	11	10.07	3046	3035
1990	97	0.18	54	0	38	2.31	699	660	7	10.07	3046	3039
1991	170	0.18	54	0	1375	2.31	699	0	19	10.07	3046	3027
1992	195	0.18	54	0	397	2.31	699	301	55	10.07	3046	2991
1993	14099	0.18	54	0	3427	2.31	699	0	114	10.07	3046	2932
1994	135	0.18	54	0	100	2.31	699	599	10	10.07	3046	3036
1995	3542	0.18	54	0	450	2.31	699	248	282	10.07	3046	2764
1996	459	0.18	54	0	168	2.31	699	530	0	10.07	3046	3046
1997	190	0.18	54	0	27	2.31	699	672	0	10.07	3046	3046
1998	1998	0.18	54	0	1654	2.31	699	0	253	10.07	3046	2793
1999	58	0.18	54	0	65	2.31	699	634	15	10.07	3046	3031
2000	52	0.18	54	3	22	2.31	699	676	0	10.07	3046	3046
2001	65	0.18	54	0	9	2.31	699	690	0	10.07	3046	3046
2002	15	0.18	54	39	5	2.31	699	694	0	10.07	3046	3046
2003	66	0.18	54	0	9	2.31	699	690	0	10.07	3046	3046
2004	42	0.18	54	13	17	2.31	699	681	0	10.07	3046	3046
2005	17	0.18	54	38	0	2.31	699	698	0	10.07	3046	3046
2006	0	0.18	54	54	0	2.31	699	699	0	10.07	3046	3046
2007	5	0.18	54	49	0	2.31	699	698	0	10.07	3046	3046

	June				July				August			
year	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft
1970	0	13.62	4120	4120	220	12.73	3851	3631	413	10.33	3125	2712
1971	0	13.62	4120	4120	0	12.73	3851	3851	1445	10.33	3125	1680
1972	3	13.62	4120	4116	23	12.73	3851	3828	139	10.33	3125	2986
1973	13	13.62	4120	4107	769	12.73	3851	3082	732	10.33	3125	2393
1974	0	13.62	4120	4120	98	12.73	3851	3752	1033	10.33	3125	2092
1975	9	13.62	4120	4111	54	12.73	3851	3797	32	10.33	3125	3093
1976	0	13.62	4120	4120	610	12.73	3851	3241	1285	10.33	3125	1840
1977	0	13.62	4120	4120	1574	12.73	3851	2277	1451	10.33	3125	1674
1978	0	13.62	4120	4120	48	12.73	3851	3802	34	10.33	3125	3091
1979	117	13.62	4120	4003	0	12.73	3851	3851	204	10.33	3125	2921
1980	16	13.62	4120	4103	124	12.73	3851	3727	104	10.33	3125	3021
1981	1	13.62	4120	4119	260	12.73	3851	3591	219	10.33	3125	2906
1982	20	13.62	4120	4100	15	12.73	3851	3836	1433	10.33	3125	1692
1983	3	13.62	4120	4117	107	12.73	3851	3744	615	10.33	3125	2510
1984	0	13.62	4120	4120	287	12.73	3851	3564	317	10.33	3125	2808
1985	64	13.62	4120	4056	413	12.73	3851	3438	364	10.33	3125	2761
1986	4	13.62	4120	4115	18	12.73	3851	3832	0	10.33	3125	3125
1987	32	13.62	4120	4088	111	12.73	3851	3739	109	10.33	3125	3016
1988	25	13.62	4120	4095	22	12.73	3851	3829	140	10.33	3125	2984
1989	0	13.62	4120	4120	239	12.73	3851	3612	14	10.33	3125	3110
1990	0	13.62	4120	4120	0	12.73	3851	3851	39	10.33	3125	3085
1991	0	13.62	4120	4120	0	12.73	3851	3851	5	10.33	3125	3120
1992	4	13.62	4120	4116	49	12.73	3851	3802	57	10.33	3125	3068
1993	0	13.62	4120	4120	0	12.73	3851	3851	0	10.33	3125	3125
1994	0	13.62	4120	4120	9	12.73	3851	3842	21	10.33	3125	3104
1995	2	13.62	4120	4118	0	12.73	3851	3851	133	10.33	3125	2991
1996	0	13.62	4120	4120	0	12.73	3851	3850	0	10.33	3125	3125
1997	0	13.62	4120	4120	0	12.73	3851	3851	77	10.33	3125	3047
1998	1	13.62	4120	4119	7	12.73	3851	3843	2	10.33	3125	3123
1999	0	13.62	4120	4120	14	12.73	3851	3837	167	10.33	3125	2957
2000	0	13.62	4120	4120	0	12.73	3851	3851	2	10.33	3125	3123
2001	0	13.62	4120	4120	0	12.73	3851	3851	148	10.33	3125	2976
2002	0	13.62	4120	4120	0	12.73	3851	3851	0	10.33	3125	3125
2003	0	13.62	4120	4120	1	12.73	3851	3850	51	10.33	3125	3074
2004	0	13.62	4120	4120	0	12.73	3851	3850	0	10.33	3125	3125
2005	0	13.62	4120	4120	0	12.73	3851	3851	0	10.33	3125	3125
2006	0	13.62	4120	4120	6	12.73	3851	3844	1033	10.33	3125	2092
2007	0	13.62	4120	4120	31	12.73	3851	3819	164	10.33	3125	2961

	September				October				November				Annual Totals		
year	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1970	33	6.01	1818	1785	27	3.80	1149	1122	0	0.13	39	39	17901	17060	5%
1971	774	6.01	1818	1044	153	3.80	1149	996	47	0.13	39	0	17901	14970	16%
1972	392	6.01	1818	1426	485	3.80	1149	665	3	0.13	39	36	17901	16786	6%
1973	277	6.01	1818	1541	0	3.80	1149	1149	17	0.13	39	22	17901	12294	31%
1974	6	6.01	1818	1812	358	3.80	1149	792	245	0.13	39	0	17901	16136	10%
1975	607	6.01	1818	1211	45	3.80	1149	1105	26	0.13	39	13	17901	16042	10%
1976	3	6.01	1818	1815	0	3.80	1149	1149	0	0.13	39	39	17901	15823	12%
1977	92	6.01	1818	1726	40	3.80	1149	1110	74	0.13	39	0	17901	14559	19%
1978	36	6.01	1818	1782	40	3.80	1149	1110	56	0.13	39	0	17901	16916	6%
1979	0	6.01	1818	1818	104	3.80	1149	1046	84	0.13	39	0	17901	16214	9%
1980	195	6.01	1818	1623	0	3.80	1149	1149	15	0.13	39	24	17901	16212	9%
1981	56	6.01	1818	1762	127	3.80	1149	1023	27	0.13	39	12	17901	16977	5%
1982	228	6.01	1818	1590	22	3.80	1149	1128	121	0.13	39	0	17901	15142	15%
1983	45	6.01	1818	1773	775	3.80	1149	375	815	0.13	39	0	17901	15030	16%
1984	1041	6.01	1818	777	183	3.80	1149	967	104	0.13	39	0	17901	15661	13%
1985	26	6.01	1818	1792	33	3.80	1149	1116	65	0.13	39	0	17901	13958	22%
1986	9	6.01	1818	1809	67	3.80	1149	1082	71	0.13	39	0	17901	17540	2%
1987	29	6.01	1818	1789	27	3.80	1149	1122	127	0.13	39	0	17901	16569	7%
1988	139	6.01	1818	1679	95	3.80	1149	1054	131	0.13	39	0	17901	17070	5%
1989	0	6.01	1818	1818	7	3.80	1149	1143	9	0.13	39	31	17901	17510	2%
1990	14	6.01	1818	1804	15	3.80	1149	1135	24	0.13	39	16	17901	17710	1%
1991	161	6.01	1818	1657	15	3.80	1149	1135	90	0.13	39	0	17901	16909	6%
1992	0	6.01	1818	1818	4	3.80	1149	1145	30	0.13	39	10	17901	17250	4%
1993	0	6.01	1818	1818	0	3.80	1149	1149	39	0.13	39	0	17901	16994	5%
1994	129	6.01	1818	1689	82	3.80	1149	1067	64	0.13	39	0	17901	17456	2%
1995	1	6.01	1818	1817	5	3.80	1149	1145	32	0.13	39	8	17901	16941	5%
1996	0	6.01	1818	1818	0	3.80	1149	1149	3	0.13	39	37	17901	17675	1%
1997	26	6.01	1818	1792	8	3.80	1149	1142	99	0.13	39	0	17901	17669	1%
1998	0	6.01	1818	1818	66	3.80	1149	1084	114	0.13	39	0	17901	16779	6%
1999	1	6.01	1818	1817	0	3.80	1149	1149	1	0.13	39	38	17901	17583	2%
2000	0	6.01	1818	1818	0	3.80	1149	1149	0	0.13	39	39	17901	17825	0.4%
2001	0	6.01	1818	1818	0	3.80	1149	1149	0	0.13	39	39	17901	17689	1%
2002	140	6.01	1818	1678	0	3.80	1149	1149	20	0.13	39	19	17901	17721	1%
2003	43	6.01	1818	1775	0	3.80	1149	1149	0	0.13	39	39	17901	17743	1%
2004	0	6.01	1818	1818	0	3.80	1149	1149	0	0.13	39	39	17901	17841	0.3%
2005	0	6.01	1818	1818	0	3.80	1149	1149	0	0.13	39	39	17901	17884	0.1%
2006	19	6.01	1818	1799	2	3.80	1149	1147	0	0.13	39	39	17901	16840	6%
2007	0	6.01	1818	1818	5	3.80	1149	1144	0	0.13	39	39	17901	17696	1%
														average	7%
														maximum	31%
														minimum	0.1%

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from USGS gage (USGS ID 09386950 ZUNI RIVER ABV BLACK ROCK RESERVOIR, NM).

Table C4. Evaluation of historical supply for the Zuni unit from 1970 to 2007 with storage in Black Rock Reservoir.

3629.8 = irrigated area for Zuni unit (acres)

year	reservoir capacity, ac-ft*	Starting reservoir storage, ac-ft (December through February plus ending storage in previous November)	March monthly discharge, ac-ft	March monthly supply with reservoir storage, ac-ft	March monthly Irrigation Unit Diversion Require-ments, in	March demand, ac-ft	March shortage, ac-ft	March surplus, ac-ft	March Ending reservoir Storage, ac-ft	April monthly discharge, ac-ft	April monthly supply with reservoir storage, ac-ft	April monthly Irrigation Unit Diversion Require-ments, in	April demand, ac-ft	April shortage, ac-ft	April surplus, ac-ft	April Ending reservoir Storage, ac-ft
1970	2230	204	59	263	0.18	54	0	209	209	77	286	2.31	699	413	0	0
1971	2230	52	41	93	0.18	54	0	39	39	479	518	2.31	699	181	0	0
1972	2230	138	109	247	0.18	54	0	193	193	1	193	2.31	699	506	0	0
1973	2230	816	8553	9369	0.18	54	0	9315	2230	18321	20551	2.31	699	0	19853	2230
1974	2230	202	115	317	0.18	54	0	262	262	121	383	2.31	699	316	0	0
1975	2230	447	892	1338	0.18	54	0	1284	1284	1166	2450	2.31	699	0	1751	1751
1976	2230	176	170	346	0.18	54	0	291	291	121	412	2.31	699	286	0	0
1977	2230	72	125	198	0.18	54	0	143	143	67	210	2.31	699	489	0	0
1978	2230	265	922	1187	0.18	54	0	1132	1132	744	1876	2.31	699	0	1178	1178
1979	2230	1094	7422	8516	0.18	54	0	8462	2230	16792	19022	2.31	699	0	18323	2230
1980	2230	2230	9174	11404	0.18	54	0	11350	2230	17970	20200	2.31	699	0	19502	2230
1981	2230	182	160	343	0.18	54	0	288	288	141	429	2.31	699	269	0	0
1982	2230	599	861	1460	0.18	54	0	1405	1405	952	2357	2.31	699	0	1659	1659
1983	2230	886	8252	9138	0.18	54	0	9083	2230	15798	18028	2.31	699	0	17330	2230
1984	2230	1500	156	1656	0.18	54	0	1602	1602	274	1876	2.31	699	0	1177	1177
1985	2230	2230	16147	18377	0.18	54	0	18322	2230	2065	4295	2.31	699	0	3596	2230
1986	2230	240	124	363	0.18	54	0	309	309	123	432	2.31	699	267	0	0
1987	2230	786	3794	4580	0.18	54	0	4525	2230	7361	9591	2.31	699	0	8892	2230
1988	2230	1593	345	1938	0.18	54	0	1884	1884	195	2078	2.31	699	0	1379	1379
1989	2230	702	145	847	0.18	54	0	793	793	57	850	2.31	699	0	151	151
1990	2230	149	97	245	0.18	54	0	191	191	38	229	2.31	699	470	0	0
1991	2230	251	170	421	0.18	54	0	367	367	1375	1742	2.31	699	0	1043	1043
1992	2230	384	195	578	0.18	54	0	524	524	397	921	2.31	699	0	223	223
1993	2230	2230	14099	16329	0.18	54	0	16275	2230	3427	5657	2.31	699	0	4959	2230
1994	2230	231	135	366	0.18	54	0	312	312	100	412	2.31	699	287	0	0
1995	2230	400	3542	3942	0.18	54	0	3888	2230	450	2680	2.31	699	0	1982	1982
1996	2230	162	459	620	0.18	54	0	566	566	168	734	2.31	699	0	36	36
1997	2230	344	190	534	0.18	54	0	479	479	27	507	2.31	699	192	0	0
1998	2230	262	1998	2260	0.18	54	0	2206	2206	1654	3860	2.31	699	0	3161	2230
1999	2230	303	58	361	0.18	54	0	307	307	65	371	2.31	699	327	0	0
2000	2230	163	52	214	0.18	54	0	160	160	22	182	2.31	699	516	0	0
2001	2230	177	65	242	0.18	54	0	187	187	9	196	2.31	699	503	0	0
2002	2230	70	15	85	0.18	54	0	31	31	5	36	2.31	699	663	0	0
2003	2230	116	66	182	0.18	54	0	127	127	9	137	2.31	699	562	0	0
2004	2230	64	42	106	0.18	54	0	51	51	17	68	2.31	699	630	0	0
2005	2230	42	17	59	0.18	54	0	5	5	0	5	2.31	699	694	0	0
2006	2230	0	0	0	0.18	54	54	0	0	0	0	2.31	699	699	0	0
2007	2230	111	5	116	0.18	54	0	62	62	0	62	2.31	699	637	0	0

year	May monthly discharge, ac-ft	May monthly supply with reservoir storage, ac-ft	May monthly Irrigation Unit Diversion Require-ments, in	May demand, ac-ft	May shortage, ac-ft	May surplus, ac-ft	May Ending reservoir Storage, ac-ft	June monthly discharge, ac-ft	June monthly supply with reservoir storage, ac-ft	June monthly Irrigation Unit Diversion Require-ments, in	June demand, ac-ft	June shortage, ac-ft	June surplus, ac-ft	June Ending reservoir Storage, ac-ft	July monthly discharge, ac-ft	July monthly supply with reservoir storage, ac-ft	July monthly Irrigation Unit Diversion Require-ments, in	July demand, ac-ft	July shortage, ac-ft	July surplus, ac-ft	July Ending reservoir Storage, ac-ft
1970	17	17	10.07	3046	3029	0	0	0	0	13.62	4120	4120	0	0	220	220	12.73	3851	3631	0	0
1971	1	1	10.07	3046	3045	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
1972	15	15	10.07	3046	3031	0	0	3	3	13.62	4120	4116	0	0	23	23	12.73	3851	3828	0	0
1973	4015	6245	10.07	3046	0	3199	2230	13	2243	13.62	4120	1877	0	0	769	769	12.73	3851	3082	0	0
1974	55	55	10.07	3046	2991	0	0	0	0	13.62	4120	4120	0	0	98	98	12.73	3851	3752	0	0
1975	333	2084	10.07	3046	962	0	0	9	9	13.62	4120	4111	0	0	54	54	12.73	3851	3797	0	0
1976	5	5	10.07	3046	3041	0	0	0	0	13.62	4120	4120	0	0	610	610	12.73	3851	3241	0	0
1977	24	24	10.07	3046	3022	0	0	0	0	13.62	4120	4120	0	0	1574	1574	12.73	3851	2277	0	0
1978	34	1212	10.07	3046	1834	0	0	0	0	13.62	4120	4120	0	0	48	48	12.73	3851	3802	0	0
1979	469	2699	10.07	3046	347	0	0	117	117	13.62	4120	4003	0	0	0	0	12.73	3851	3851	0	0
1980	482	2712	10.07	3046	334	0	0	16	16	13.62	4120	4103	0	0	124	124	12.73	3851	3727	0	0
1981	39	39	10.07	3046	3007	0	0	1	1	13.62	4120	4119	0	0	260	260	12.73	3851	3591	0	0
1982	249	1908	10.07	3046	1138	0	0	20	20	13.62	4120	4100	0	0	15	15	12.73	3851	3836	0	0
1983	535	2765	10.07	3046	281	0	0	3	3	13.62	4120	4117	0	0	107	107	12.73	3851	3744	0	0
1984	45	1222	10.07	3046	1824	0	0	0	0	13.62	4120	4120	0	0	287	287	12.73	3851	3564	0	0
1985	2250	4480	10.07	3046	0	1434	1434	64	1499	13.62	4120	2621	0	0	413	413	12.73	3851	3438	0	0
1986	46	46	10.07	3046	3000	0	0	4	4	13.62	4120	4115	0	0	18	18	12.73	3851	3832	0	0
1987	231	2461	10.07	3046	585	0	0	32	32	13.62	4120	4088	0	0	111	111	12.73	3851	3739	0	0
1988	122	1502	10.07	3046	1544	0	0	25	25	13.62	4120	4095	0	0	22	22	12.73	3851	3829	0	0
1989	11	163	10.07	3046	2883	0	0	0	0	13.62	4120	4120	0	0	239	239	12.73	3851	3612	0	0
1990	7	7	10.07	3046	3039	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
1991	19	1062	10.07	3046	1984	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
1992	55	278	10.07	3046	2768	0	0	4	4	13.62	4120	4116	0	0	49	49	12.73	3851	3802	0	0
1993	114	2344	10.07	3046	702	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
1994	10	10	10.07	3046	3036	0	0	0	0	13.62	4120	4120	0	0	9	9	12.73	3851	3842	0	0
1995	282	2264	10.07	3046	782	0	0	2	2	13.62	4120	4118	0	0	0	0	12.73	3851	3851	0	0
1996	0	36	10.07	3046	3010	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3850	0	0
1997	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
1998	253	2483	10.07	3046	563	0	0	1	1	13.62	4120	4119	0	0	7	7	12.73	3851	3843	0	0
1999	15	15	10.07	3046	3031	0	0	0	0	13.62	4120	4120	0	0	14	14	12.73	3851	3837	0	0
2000	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
2001	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
2002	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
2003	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	1	1	12.73	3851	3850	0	0
2004	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3850	0	0
2005	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	0	0	12.73	3851	3851	0	0
2006	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	6	6	12.73	3851	3844	0	0
2007	0	0	10.07	3046	3046	0	0	0	0	13.62	4120	4120	0	0	31	31	12.73	3851	3819	0	0

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from USGS gage (USGS ID 09386950 ZUNI RIVER ABV BLACK ROCK RESERVOIR, NM)

* Reservoir capacity based on information from U.S. Army Corps of Engineers (1993).

(continued)

year	August monthly discharge, ac-ft	August monthly supply with reservoir storage, ac-ft	August monthly Irrigation Unit Diversion Require-ments, in	August demand, ac-ft	August shortage, ac-ft	August surplus, ac-ft	August Ending reservoir Storage, ac-ft	September monthly discharge, ac-ft	September monthly supply with reservoir storage, ac-ft	September monthly Irrigation Unit Diversion Require-ments, in	September demand, ac-ft	September shortage, ac-ft	September surplus, ac-ft	September Ending reservoir Storage, ac-ft
1970	413	413	10.33	3125	2712	0	0	33	33	6.01	1818	1785	0	0
1971	1445	1445	10.33	3125	1680	0	0	774	774	6.01	1818	1044	0	0
1972	139	139	10.33	3125	2986	0	0	392	392	6.01	1818	1426	0	0
1973	732	732	10.33	3125	2393	0	0	277	277	6.01	1818	1541	0	0
1974	1033	1033	10.33	3125	2092	0	0	6	6	6.01	1818	1812	0	0
1975	32	32	10.33	3125	3093	0	0	607	607	6.01	1818	1211	0	0
1976	1285	1285	10.33	3125	1840	0	0	3	3	6.01	1818	1815	0	0
1977	1451	1451	10.33	3125	1674	0	0	92	92	6.01	1818	1726	0	0
1978	34	34	10.33	3125	3091	0	0	36	36	6.01	1818	1782	0	0
1979	204	204	10.33	3125	2921	0	0	0	0	6.01	1818	1818	0	0
1980	104	104	10.33	3125	3021	0	0	195	195	6.01	1818	1623	0	0
1981	219	219	10.33	3125	2906	0	0	56	56	6.01	1818	1762	0	0
1982	1433	1433	10.33	3125	1692	0	0	228	228	6.01	1818	1590	0	0
1983	615	615	10.33	3125	2510	0	0	45	45	6.01	1818	1773	0	0
1984	317	317	10.33	3125	2808	0	0	1041	1041	6.01	1818	777	0	0
1985	364	364	10.33	3125	2761	0	0	26	26	6.01	1818	1792	0	0
1986	0	0	10.33	3125	3125	0	0	9	9	6.01	1818	1809	0	0
1987	109	109	10.33	3125	3016	0	0	29	29	6.01	1818	1789	0	0
1988	140	140	10.33	3125	2984	0	0	139	139	6.01	1818	1679	0	0
1989	14	14	10.33	3125	3110	0	0	0	0	6.01	1818	1818	0	0
1990	39	39	10.33	3125	3085	0	0	14	14	6.01	1818	1804	0	0
1991	5	5	10.33	3125	3120	0	0	161	161	6.01	1818	1657	0	0
1992	57	57	10.33	3125	3068	0	0	0	0	6.01	1818	1818	0	0
1993	0	0	10.33	3125	3125	0	0	0	0	6.01	1818	1818	0	0
1994	21	21	10.33	3125	3104	0	0	129	129	6.01	1818	1689	0	0
1995	133	133	10.33	3125	2991	0	0	1	1	6.01	1818	1817	0	0
1996	0	0	10.33	3125	3125	0	0	0	0	6.01	1818	1818	0	0
1997	77	77	10.33	3125	3047	0	0	26	26	6.01	1818	1792	0	0
1998	2	2	10.33	3125	3123	0	0	0	0	6.01	1818	1818	0	0
1999	167	167	10.33	3125	2957	0	0	1	1	6.01	1818	1817	0	0
2000	2	2	10.33	3125	3123	0	0	0	0	6.01	1818	1818	0	0
2001	148	148	10.33	3125	2976	0	0	0	0	6.01	1818	1818	0	0
2002	0	0	10.33	3125	3125	0	0	140	140	6.01	1818	1678	0	0
2003	51	51	10.33	3125	3074	0	0	43	43	6.01	1818	1775	0	0
2004	0	0	10.33	3125	3125	0	0	0	0	6.01	1818	1818	0	0
2005	0	0	10.33	3125	3125	0	0	0	0	6.01	1818	1818	0	0
2006	1033	1033	10.33	3125	2092	0	0	19	19	6.01	1818	1799	0	0
2007	164	164	10.33	3125	2961	0	0	0	0	6.01	1818	1818	0	0

year	October monthly discharge, ac-ft	October monthly supply with reservoir storage, ac-ft	October monthly Irrigation Unit Diversion Require-ments, in	October demand, ac-ft	October shortage, ac-ft	October surplus, ac-ft	October Ending reservoir Storage, ac-ft	November monthly discharge, ac-ft	November monthly supply with reservoir storage, ac-ft	November monthly Irrigation Unit Diversion Require-ments, in	November demand, ac-ft	November shortage, ac-ft	November surplus, ac-ft	November Ending reservoir Storage, ac-ft	Annual Totals demand, ac-ft	Annual Totals shortage, ac-ft	Annual Totals Percent Supply
1970	27	27	3.80	1149	1122	0	0	0	0	0.13	39	39	0	0	17901	16852	6%
1971	153	153	3.80	1149	996	0	0	47	47	0.13	39	0	8	8	17901	14917	17%
1972	485	485	3.80	1149	665	0	0	3	3	0.13	39	36	0	0	17901	16593	7%
1973	0	0	3.80	1149	1149	0	0	17	17	0.13	39	22	0	0	17901	10064	44%
1974	358	358	3.80	1149	792	0	0	245	245	0.13	39	0	205	205	17901	15874	11%
1975	45	45	3.80	1149	1105	0	0	26	26	0.13	39	13	0	0	17901	14291	20%
1976	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	15531	13%
1977	40	40	3.80	1149	1110	0	0	74	74	0.13	39	0	34	34	17901	14416	19%
1978	40	40	3.80	1149	1110	0	0	56	56	0.13	39	0	16	16	17901	15739	12%
1979	104	104	3.80	1149	1046	0	0	84	84	0.13	39	0	45	45	17901	13984	22%
1980	0	0	3.80	1149	1149	0	0	15	15	0.13	39	24	0	0	17901	13982	22%
1981	127	127	3.80	1149	1023	0	0	27	27	0.13	39	12	0	0	17901	16689	7%
1982	22	22	3.80	1149	1128	0	0	121	121	0.13	39	0	81	81	17901	13484	25%
1983	775	775	3.80	1149	375	0	0	815	815	0.13	39	0	776	776	17901	12800	28%
1984	183	183	3.80	1149	967	0	0	104	104	0.13	39	0	65	65	17901	14059	21%
1985	33	33	3.80	1149	1116	0	0	65	65	0.13	39	0	26	26	17901	11728	34%
1986	67	67	3.80	1149	1082	0	0	71	71	0.13	39	0	32	32	17901	17231	4%
1987	27	27	3.80	1149	1122	0	0	127	127	0.13	39	0	88	88	17901	14339	20%
1988	95	95	3.80	1149	1054	0	0	131	131	0.13	39	0	92	92	17901	15186	15%
1989	7	7	3.80	1149	1143	0	0	9	9	0.13	39	31	0	0	17901	16717	7%
1990	15	15	3.80	1149	1135	0	0	24	24	0.13	39	16	0	0	17901	17519	2%
1991	15	15	3.80	1149	1135	0	0	90	90	0.13	39	0	51	51	17901	15867	11%
1992	4	4	3.80	1149	1145	0	0	30	30	0.13	39	10	0	0	17901	16727	7%
1993	0	0	3.80	1149	1149	0	0	39	39	0.13	39	0	0	0	17901	14764	18%
1994	82	82	3.80	1149	1067	0	0	64	64	0.13	39	0	25	25	17901	17144	4%
1995	5	5	3.80	1149	1145	0	0	32	32	0.13	39	8	0	0	17901	14711	18%
1996	0	0	3.80	1149	1149	0	0	3	3	0.13	39	37	0	0	17901	17109	4%
1997	8	8	3.80	1149	1142	0	0	99	99	0.13	39	0	60	60	17901	17190	4%
1998	66	66	3.80	1149	1084	0	0	114	114	0.13	39	0	75	75	17901	14549	19%
1999	0	0	3.80	1149	1149	0	0	1	1	0.13	39	38	0	0	17901	17276	3%
2000	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	17662	1.3%
2001	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	17502	2%
2002	0	0	3.80	1149	1149	0	0	20	20	0.13	39	19	0	0	17901	17651	1%
2003	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	17616	2%
2004	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	17778	0.7%
2005	0	0	3.80	1149	1149	0	0	0	0	0.13	39	39	0	0	17901	17842	0.3%
2006	2	2	3.80	1149	1147	0	0	0	0	0.13	39	39	0	0	17901	16840	6%
2007	5	5	3.80	1149	1144	0	0	0	0	0.13	39	39	0	0	17901	17585	2%
																average	12%
																maximum	44%
																minimum	0.3%

Table C5. Evaluation of historical supply for the Zuni Unit from 1911 to 1929 with no storage in Black Rock Reservoir

3629.8 = irrigated area for Zuni unit (acres)

	March				April				May				June				July			
year	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft
1911	5200	0.18	54	0	0	2.31	699	699	0	10.07	3046	3046	0	13.62	4120	4120	8820	12.73	3851	0
1912	350	0.18	54	0	400	2.31	699	299	0	10.07	3046	3046	0	13.62	4120	4120	1800	12.73	3851	2051
1913	1380	0.18	54	0	1470	2.31	699	0	0	10.07	3046	3046	0	13.62	4120	4120	1380	12.73	3851	2471
1914	5190	0.18	54	0	800	2.31	699	0	1200	10.07	3046	1846	200	13.62	4120	3920	7200	12.73	3851	0
1915	26690	0.18	54	0	13740	2.31	699	0	5080	10.07	3046	0	1940	13.62	4120	2180	1380	12.73	3851	2471
1916	20230	0.18	54	0	4780	2.31	699	0	60	10.07	3046	2986	0	13.62	4120	4120	1440	12.73	3851	2411
1917	1230	0.18	54	0	354	2.31	699	345	134	10.07	3046	2912	98	13.62	4120	4022	0	12.73	3851	3851
1918	1240	0.18	54	0	0	2.31	699	699	28	10.07	3046	3018	558	13.62	4120	3562	890	12.73	3851	2961
1919	6060	0.18	54	0	1040	2.31	699	0	0	10.07	3046	3046	0	13.62	4120	4120	22390	12.73	3851	0
1920	460	0.18	54	0	1510	2.31	699	0	0	10.07	3046	3046	980	13.62	4120	3140	342	12.73	3851	3509
1921	60	0.18	54	0	27	2.31	699	672	220	10.07	3046	2826	165	13.62	4120	3955	5140	12.73	3851	0
1922	6	0.18	54	48	186	2.31	699	513	189	10.07	3046	2857	0	13.62	4120	4120	210	12.73	3851	3641
1923	1380	0.18	54	0	101	2.31	699	598	0	10.07	3046	3046	0	13.62	4120	4120	493	12.73	3851	3358
1924	172	0.18	54	0	5890	2.31	699	0	457	10.07	3046	2589	0	13.62	4120	4120	200	12.73	3851	3651
1925	320	0.18	54	0	10	2.31	699	689	185	10.07	3046	2861	60	13.62	4120	4060	1560	12.73	3851	2291
1926	721	0.18	54	0	664	2.31	699	35	554	10.07	3046	2492	0	13.62	4120	4120	636	12.73	3851	3215
1927	7310	0.18	54	0	0	2.31	699	699	410	10.07	3046	2636	0	13.62	4120	4120	788	12.73	3851	3063
1928	34010	0.18	54	0	14560	2.31	699	0	309	10.07	3046	2737	0	13.62	4120	4120	1820	12.73	3851	2031
1929	1900	0.18	54	0	2080	2.31	699	0	207	10.07	3046	2839	0	13.62	4120	4120	0	12.73	3851	3851

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from USGS (1954), Zuni River at Blackrock, N. Mex.

(continued)

August				September				October				November				Annual Totals		
monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1660	10.33	3125	1465	760	6.01	1818	1058	1340	3.80	1149	0	50	0.13	39	0	17901	10387	42%
1100	10.33	3125	2025	0	6.01	1818	1818	380	3.80	1149	769	0	0.13	39	39	17901	14167	21%
300	10.33	3125	2825	3480	6.01	1818	0	2200	3.80	1149	0	120	0.13	39	0	17901	12461	30%
800	10.33	3125	2325	500	6.01	1818	1318	450	3.80	1149	699	0	0.13	39	39	17901	10147	43%
760	10.33	3125	2365	955	6.01	1818	863	0	3.80	1149	1149	30	0.13	39	9	17901	9037	50%
1280	10.33	3125	1845	1320	6.01	1818	498	22070	3.80	1149	0	38	0.13	39	1	17901	11860	34%
600	10.33	3125	2525	505	6.01	1818	1313	102	3.80	1149	1047	0	0.13	39	39	17901	16054	10%
790	10.33	3125	2335	335	6.01	1818	1483	540	3.80	1149	609	35	0.13	39	4	17901	14671	18%
14730	10.33	3125	0	697	6.01	1818	1121	386	3.80	1149	763	0	0.13	39	39	17901	9090	49%
630	10.33	3125	2495	372	6.01	1818	1446	0	3.80	1149	1149	10	0.13	39	29	17901	14814	17%
227	10.33	3125	2898	280	6.01	1818	1538	0	3.80	1149	1149	0	0.13	39	39	17901	13077	27%
1110	10.33	3125	2015	286	6.01	1818	1532	153	3.80	1149	996	46	0.13	39	0	17901	15722	12%
5740	10.33	3125	0	8850	6.01	1818	0	7	3.80	1149	1142	681	0.13	39	0	17901	12264	31%
1200	10.33	3125	1925	210	6.01	1818	1608	19	3.80	1149	1130	0	0.13	39	39	17901	15062	16%
1820	10.33	3125	1305	1060	6.01	1818	758	85	3.80	1149	1064	0	0.13	39	39	17901	13067	27%
681	10.33	3125	2444	1380	6.01	1818	438	0	3.80	1149	1149	0	0.13	39	39	17901	13932	22%
950	10.33	3125	2175	4200	6.01	1818	0	0	3.80	1149	1149	0	0.13	39	39	17901	13881	22%
400	10.33	3125	2725	0	6.01	1818	1818	0	3.80	1149	1149	0	0.13	39	39	17901	14619	18%
2260	10.33	3125	865	350	6.01	1818	1468	8010	3.80	1149	0	90	0.13	39	0	17901	13142	27%

1911-1929	average	27%
1911-1929	maximum	50%
1911-1929	minimum	10%
1911-1918	average	31%
1911-1918	maximum	50%
1911-1918	minimum	10%

Table C6. Evaluation of historical supply for the Zuni Unit from 1911 to 1918 with storage in Black Rock Reservoir

3629.8 = irrigated area for Zuni unit (acres)

year	reservoir capacity, ac-ft*	Starting reservoir storage, ac-ft (December through February plus ending storage in previous November)	March						
			monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	7069	2540	5200	7740	0.18	54	0	7686	7069
1912	7069	2648	350	2998	0.18	54	0	2944	2944
1913	6013	90	1380	1470	0.18	54	0	1416	1416
1914	6013	6013	5190	11203	0.18	54	0	11149	6013
1915	5213	4778	26690	31468	0.18	54	0	31414	5213
1916	5213	5213	20230	25443	0.18	54	0	25389	5213
1917	5213	5213	1230	6443	0.18	54	0	6389	5213
1918	5213	920	1240	2160	0.18	54	0	2106	2106

year	April						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	0	7069	2.31	699	0	6370	6370
1912	400	3344	2.31	699	0	2645	2645
1913	1470	2886	2.31	699	0	2187	2187
1914	800	6813	2.31	699	0	6114	6013
1915	13740	18953	2.31	699	0	18254	5213
1916	4780	9993	2.31	699	0	9294	5213
1917	354	5567	2.31	699	0	4868	4868
1918	0	2106	2.31	699	0	1407	1407

year	May						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	0	6370	10.07	3046	0	3324	3324
1912	0	2645	10.07	3046	401	0	0
1913	0	2187	10.07	3046	859	0	0
1914	1200	7213	10.07	3046	0	4167	4167
1915	5080	10293	10.07	3046	0	7247	5213
1916	60	5273	10.07	3046	0	2227	2227
1917	134	5002	10.07	3046	0	1956	1956
1918	28	1435	10.07	3046	1611	0	0

year	June						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	0	3324	13.62	4120	796	0	0
1912	0	0	13.62	4120	4120	0	0
1913	0	0	13.62	4120	4120	0	0
1914	200	4367	13.62	4120	0	247	247
1915	1940	7153	13.62	4120	0	3033	3033
1916	0	2227	13.62	4120	1893	0	0
1917	98	2054	13.62	4120	2066	0	0
1918	558	558	13.62	4120	3562	0	0

year	July						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	8820	8820	12.73	3851	0	4969	4969
1912	1800	1800	12.73	3851	2051	0	0
1913	1380	1380	12.73	3851	2471	0	0
1914	7200	7447	12.73	3851	0	3597	3597
1915	1380	4413	12.73	3851	0	563	563
1916	1440	1440	12.73	3851	2411	0	0
1917	0	0	12.73	3851	3851	0	0
1918	890	890	12.73	3851	2961	0	0

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from USGS (1954), Zuni River at Blackrock, N. Mex.

* Reservoir capacity from 1911 to 1918 based on Robinson (1918). Reservoir capacity used for years 1911 to 1914 was estimated for the 990 contour for 1912 and 1914. Reservoir capacity used for years 1915 to 1918 was estimated for 1918 at the 991 contour. The spillway was approximately at elevation 991.

(continued)

year	August						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	1660	6629	10.33	3125	0	3505	3505
1912	1100	1100	10.33	3125	2025	0	0
1913	300	300	10.33	3125	2825	0	0
1914	800	4397	10.33	3125	0	1272	1272
1915	760	1323	10.33	3125	1802	0	0
1916	1280	1280	10.33	3125	1845	0	0
1917	600	600	10.33	3125	2525	0	0
1918	790	790	10.33	3125	2335	0	0

year	September						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	760	4265	6.01	1818	0	2447	2447
1912	0	0	6.01	1818	1818	0	0
1913	3480	3480	6.01	1818	0	1662	1662
1914	500	1772	6.01	1818	46	0	0
1915	955	955	6.01	1818	863	0	0
1916	1320	1320	6.01	1818	498	0	0
1917	505	505	6.01	1818	1313	0	0
1918	335	335	6.01	1818	1483	0	0

year	October						
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1911	1340	3787	3.80	1149	0	2637	2637
1912	380	380	3.80	1149	769	0	0
1913	2200	3862	3.80	1149	0	2713	2713
1914	450	450	3.80	1149	699	0	0
1915	0	0	3.80	1149	1149	0	0
1916	22070	22070	3.80	1149	0	20921	5213
1917	102	102	3.80	1149	1047	0	0
1918	540	540	3.80	1149	609	0	0

year	November							Annual Totals		
	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	demand, ac-ft	shortage, ac-ft	percent supply
1911	50	2687	0.13	39	0	2648	2648	17901	796	96%
1912	0	0	0.13	39	39	0	0	17901	11223	37%
1913	120	2833	0.13	39	0	2793	2793	17901	10274	43%
1914	0	0	0.13	39	39	0	0	17901	785	96%
1915	30	30	0.13	39	9	0	0	17901	3824	79%
1916	38	5251	0.13	39	0	5212	5212	17901	6646	63%
1917	0	0	0.13	39	39	0	0	17901	10841	39%
1918	35	35	0.13	39	4	0	0	17901	12565	30%
									average	60%
									maximum	96%
									minimum	30%

Table C7. Evaluation of historical supply for the Ojo Caliente Unit for different estimates of spring flow with no storage in Ojo Caliente Reservoir

773.7 = irrigated area for Ojo Caliente unit (acres)

	March				April				May				June				July			
Scenario	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft
1 cfs	61	0.14	9	0	60	1.79	115	56	61	7.83	505	443	60	10.59	683	623	61	9.90	638	577
2.5 cfs	123	0.14	9	0	119	1.79	115	0	123	7.83	505	382	119	10.59	683	564	123	9.90	638	515
2.0 cfs	154	0.14	9	0	149	1.79	115	0	154	7.83	505	351	149	10.59	683	534	154	9.90	638	485

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow from Orr (1987) and from two unpublished documents (see report for description)

(continued)

	August				September				October				November				Annual Totals		
Scenario	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	monthly discharge, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1 cfs	61	8.03	518	456	60	4.68	302	242	61	2.96	191	129	60	0.10	6	0	2967	2527	15%
2.5 cfs	123	8.03	518	395	119	4.68	302	183	123	2.96	191	68	119	0.10	6	0	2967	2106	29%
2.0 cfs	154	8.03	518	364	149	4.68	302	153	154	2.96	191	37	149	0.10	6	0	2967	1924	35%

Table C8. Evaluation of historical supply for Ojo Caliente Unit for different estimates of spring flow with storage in Ojo Caliente Reservoir

773.7 = irrigated area for Ojo Caliente unit (acres)

			March							April						
Scenario	reservoir capacity, ac-ft	Starting reservoir storage, ac-ft (December through February plus ending storage in previous November)	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1 cfs	250	232	61	293	0.14	9	0	284	250	60	310	1.79	115	0	194	194
2 cfs	250	250	123	373	0.14	9	0	364	250	119	369	1.79	115	0	254	250
2.5 cfs	250	250	154	404	0.14	9	0	395	250	149	399	1.79	115	0	283	250

	May							June							July					
Scenario	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft
1 cfs	61	256	7.83	505	249	0	0	60	60	10.59	683	623	0	0	61	61	9.90	638	577	0
2 cfs	123	373	7.83	505	132	0	0	119	119	10.59	683	564	0	0	123	123	9.90	638	515	0
2.5 cfs	154	404	7.83	505	101	0	0	149	149	10.59	683	534	0	0	154	154	9.90	638	485	0

Notes: Acreage, monthly irrigation unit diversion requirements, and demand based on information from Allen (2008). Monthly flow and reservoir capacity from Orr (1987) and from two unpublished documents (see report for description)

(continued)

	August							September						
Scenario	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft
1 cfs	61	61	8.03	518	456	0	0	60	60	4.68	302	242	0	0
2 cfs	123	123	8.03	518	395	0	0	119	119	4.68	302	183	0	0
2.5 cfs	154	154	8.03	518	364	0	0	149	149	4.68	302	153	0	0

	October							November							Annual Totals		
Scenario	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	monthly discharge, ac-ft	monthly supply with reservoir storage, ac-ft	monthly Irrigation Unit Diversion Require-ments, in	demand, ac-ft	shortage, ac-ft	surplus, ac-ft	Ending reservoir Storage, ac-ft	demand, ac-ft	shortage, ac-ft	Percent Supply
1 cfs	61	61	2.96	191	129	0	0	60	60	0.10	6	0	53	53	2967	2277	23%
2 cfs	123	123	2.96	191	68	0	0	119	119	0.10	6	0	113	113	2967	1856	37%
2.5 cfs	154	154	2.96	191	37	0	0	149	149	0.10	6	0	142	142	2967	1674	44%