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Who Speaks for the Rio Jemez? A Management Plan for the Lower Jemez River Basin

Tom Krause

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Completed in partial fulfillment of the requirements for the Master of Water Resources Administration Degree, University of New Mexico, Albuquerque, New Mexico.

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Abstract

The Rio Jemez Watershed can logically be divided into an upper watershed and a lower watershed based on terrain, climate, and river characteristics. Water in the upper watershed is plentiful and more than adequate to meet the water rights claims located there. However, water in the lower watershed is not adequate to meet claims throughout the growing season of April through October. Irrigation diversions use all of the available water in the river during the months of July, August, and September, often leaving the Rio Jemez a dry channel below the community of San Ysidro. This practice has negative impacts on the ecosystem by denying life-sustaining water to many lower watershed users during the hottest part of the year.

The inequities in water availability in the lower watershed are not so much an issue of not enough water as they are an issue of not enough water storage. A volume of water adequate to meet all water rights claims in the lower watershed flows down the river channel during the months of April and May. However, for the remainder of the growing season, river flow is much reduced. This paper uses the concepts of sustainable development and ecosystem management to propose a solution to the water-related problems in the Rio Jemez Watershed.

A strategically placed reservoir would help solve the problems in the lower watershed by evening out the flow throughout the growing season. A reservoir is proposed and three scenarios are evaluated to determine how much water is available for three equally important uses: irrigation, instream flow, and recreation. The three scenarios considered are: a maximum use scenario where all irrigators receive 100% of their water rights claims, a medium use scenario (75% of claims), and a minimum use scenario (50% of claims). After a water budget evaluation for the three scenarios, the minimum use scenario emerges as the most viable. This scenario provides irrigators with approximately double the water they are currently receiving, maintains instream flows throughout the growing season, and allows for recreational activities on the newly created reservoir through summer and early fall.

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1.0 Introduction and Problem Statement

The demands for water on the Rio Jemez exceed the ability of the river to provide for human activities and also maintain instream flows throughout the year. This professional paper will evaluate the Rio Jemez watershed for conflicts between water availability and water uses. It will explore ways to resolve identified conflicts, provide adequate water for agricultural users, and maintain the integrity of the ecosystem by reserving water for instream flow. This paper will use the concepts of ecosystem management and sustainable development to address and resolve water-related conflicts identified in the Rio Jemez watershed.

The Rio Jemez watershed is located primarily in Sandoval County, New Mexico (see Figure 1). The river rises high in the Jemez Mountains at an elevation exceeding 11,000 feet and flows in a generally southeasterly direction until it empties into the Rio Grande at an elevation of 5120 feet (United States Corps of Engineers [COE] 1994). The watershed is approximately 65 miles long, 20 miles wide, and 1040 square miles in area. The river flows through several small communities, including Jemez Springs, Cañon, Jemez Pueblo, San Ysidro, and Zia Pueblo, which rely on the river for irrigation water. The watershed can be considered as two distinct areas, the upper watershed and the lower watershed, divided below the confluence of the Rio Guadalupe and the Rio Jemez (see Plate 1).

The upper watershed is defined by generally mountainous terrain where the river is confined in narrow canyons. The climate and vegetative cover is alpine to sub-alpine, the soils are typical of volcanic mountainous areas in the Southern Rocky Mountain geographic province (COE 1994). The river is perennial in the upper watershed. The lower watershed is dramatically different from the upper watershed. In this area, the terrain is generally flat and the river flows in a braided channel. The climate and vegetation are typical of southwestern high desert plateaus with scattered pinyon/juniper and wide expanses of sage, cactus, and desert grasses. Soils are highly erodible, sandy to

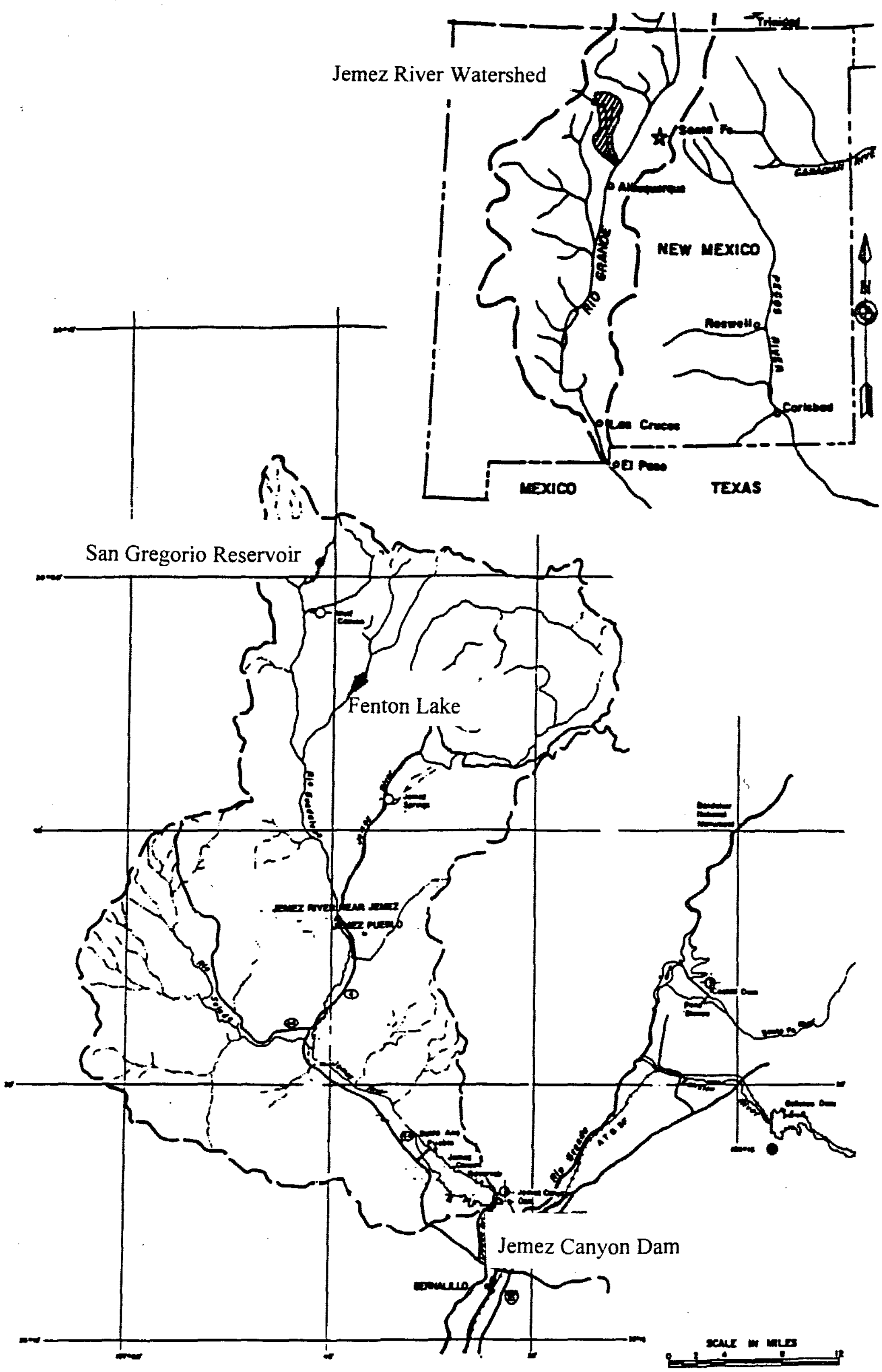


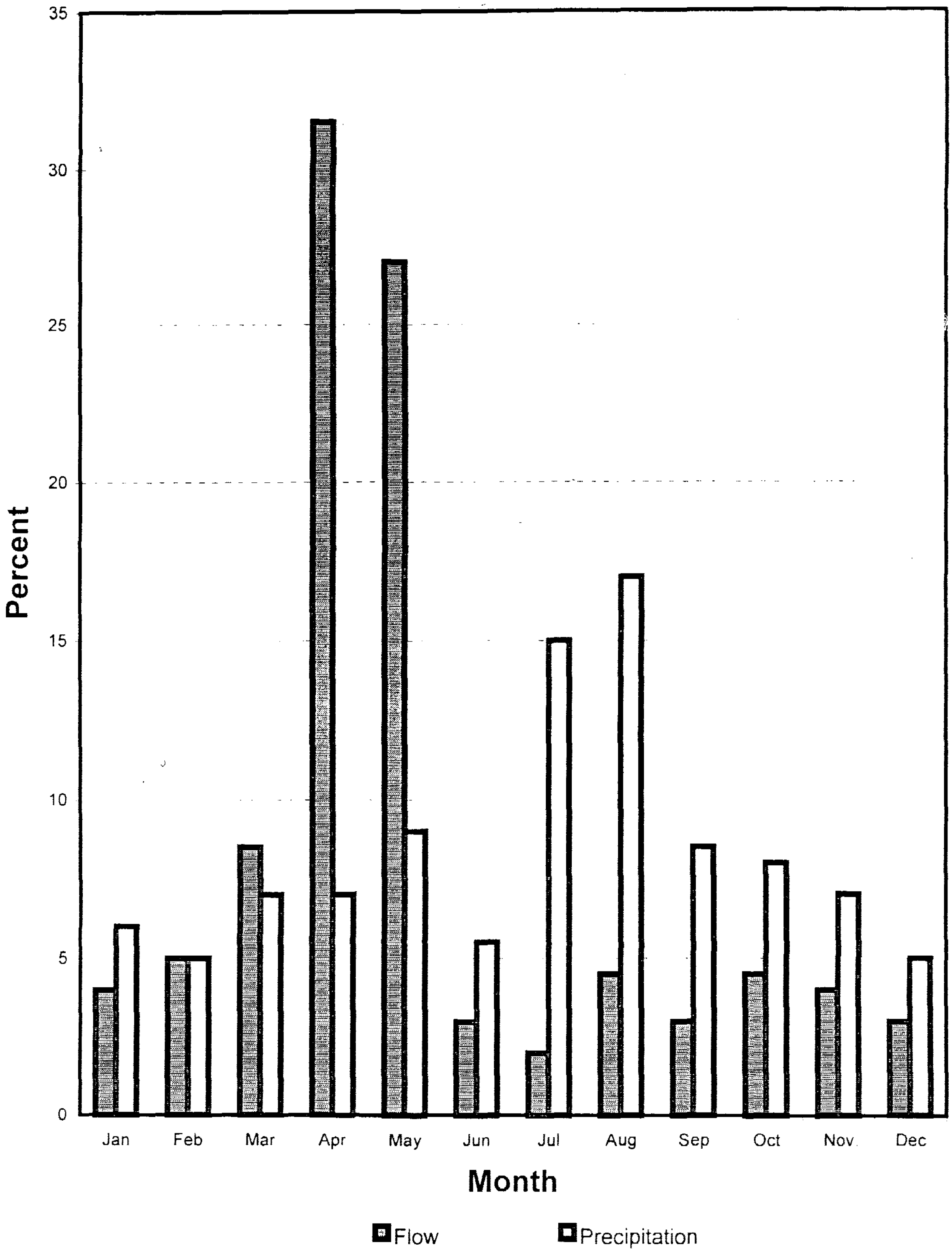
Figure 1: Location of the Rio Jemez Watershed (from COE 1994)

clayey in nature, and derived from the igneous rocks of the Jemez Mountains and the exposed Sante Fe Formation. The river is ephemeral in the lower watershed.

There are currently three water control structures on the river; the largest is the Jemez Canyon Dam located just above the confluence of the Rio Jemez and the Rio Grande. This dam was built in the early 1950s and placed in operation in 1953, providing flood control and sediment retention for the Rio Jemez as part of a much larger scheme to control flooding in the Rio Grande watershed. The other two control structures are located on the main tributary to the Rio Jemez, the Rio Guadalupe. These dams are located at Fenton Lake and San Gregorio Reservoir and are much smaller than the Jemez Canyon Dam. Fenton Lake is a recreational facility and San Gregorio Reservoir provides water to a trans-mountain diversion for irrigation near Cuba, New Mexico (see Figure 1).

Precipitation in the watershed averages 17 inches per year, but varies considerably by elevation and season (COE 1994). Precipitation in the upper watershed averages 30 inches per year, which includes over 100 inches of snow. Precipitation in the lower watershed averages 8 inches per year, which includes only about 10 inches of snow. Peak precipitation occurs during the months of July and August in the form of thunderstorms. Flow characteristics of the Rio Jemez are influenced by precipitation patterns, channel configurations, evaporation rates, soil types, and human activities. Peak monthly flows occur throughout the watershed in April and May as the winter snowpack melts. During these months, flow is relatively constant due to the high volumes of water being fed into the system. Average monthly flow decreases during the remainder of the year but is influenced by the late summer thunderstorms. These storms are short-lived, high-intensity precipitation events that result in high instantaneous discharge and resultant flow surges. Figure 2 shows the relationship between precipitation and stream flow by month, as a percent of the annual total.

In the upper watershed, stream channels are generally narrow, steep-sided, and rock-armored, which results in low infiltration (COE 1994). In the lower watershed, stream



Note: Stream flow based on measurements at Stations 1. 2. and 3. Precipitation based on measurements at Jemez Canyon Dam. Jemez Springs. Wolf Canyon. and Los Alamos.

Figure 2: Percent of Annual Precipitation and Stream Flow by Month (from COE 1994)

channels are wide, flat, and shallow; the river often flows in braided channels; and the sandy nature of the river bed allows for much higher infiltration. Evaporation rates in the lower watershed are high due to the wide, flat stream channel and associated shallow flow, less vegetative cover, and higher temperatures. Evaporation for the lower watershed is approximately 100 inches per year, with 79 inches of evaporation occurring in the months of April through October. In elevations above 10,000 feet, evaporation diminishes to less than 50 inches per year.

Water diversions in the Rio Jemez watershed are dominated by irrigated agriculture (HydroLogic, Inc. 1998). The majority of diversions are located in the lower watershed, in the area between Cañon and Zia Pueblo. These diversions contribute significantly to the ephemeral nature of the Rio Jemez in its lower reaches (COE 1994; New Mexico Water Dialogue 1996; United States [US] v. Abousleman 1996). The irrigators near San Ysidro and Zia Pueblo are often denied adequate water even in years of average flow because of diversions made near Cañon, Jemez Pueblo, and Ponderosa. Flow data and water use information indicate that the Rio Jemez is often dry below the community of San Ysidro from July through September in any given year (COE 1998; United States Geological Survey [USGS] 1998; New Mexico State Engineer Office [SEO] 1986; SEO 1992; SEO 1997). This is due to water diversions in conjunction with stream channel and climatic conditions. Section 2.0 of this paper presents flow data and an evaluation of this data in relation to water rights.

In 1983, the United States initiated an adjudication lawsuit on behalf of the three pueblos located on the Rio Jemez (i.e., Jemez Pueblo, Zia Pueblo, and Santa Ana Pueblo) (Judy Stoft[1], personal communication, 1998). Because of the consistent lack of adequate flow to fulfill the water rights of the pueblos, the federal government initiated the adjudication

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[1] Ms. Stoft is the owner of HydroLogic, Inc., the data manager in the adjudication lawsuit *United States v. Abousleman et al.* Ms. Stoft has compiled water rights data for the Jemez watershed from the inception of the lawsuit in 1983 and is considered by the courts to be one of the most knowledgeable people concerning the adjudication history on the Rio Jemez.

lawsuit styled *United States v. Abousleman et. al.* This lawsuit asks the federal court to determine priority and quantity for all of the water rights on the Rio Jemez.

In general, Indian water rights are considered senior to other uses on a river (Gould and Grant 1995). In the case of the Rio Jemez, the non-pueblo irrigation ditch associations recognize that their water rights are junior to those of the pueblos. This is indicated in the Agreement signed by representatives of the non-pueblo ditch associations and the pueblos in 1996 to address diversion schedules in times of low flow (U.S. v. Abousleman 1996). The Agreement gives priority of diversion to the pueblos, but also allows for some amount of water to be delivered to all users on the Rio Jemez in times of low flow.

Although the Agreement addresses the needs of irrigated agriculture, it does not fully address the issue of instream flow. It recognizes that Zia Pueblo relies on the river for irrigation as well as water for religious purposes, which presumably has some instream component. However, nowhere does the Agreement mention a desire by any party to preserve instream flow to maintain the integrity of the river or the ecosystem, of which the river is an integral part.

Currently, no one speaks for the Rio Jemez. Water users appear to be interested only in diverting water from the river to meet their needs and leaving nothing for the river itself. Because the Rio Jemez flows through semi-arid to arid country, some level of instream flow is critical. Currently, instream flow is diminished or eliminated in the most arid portion of the watershed and during the hottest portion of the year. Water for wildlife, streamside vegetation, and human activities is lacking during the period of highest use and highest need. This water deficiency and inequity undoubtedly have negative impacts on the ecosystem.

2.0 Water Rights and Average Flows

In order to develop a management plan for the Rio Jemez, water rights information and flow data were evaluated to pinpoint specific areas of the watershed with existing or potential inequities between average flows and uses. Water rights information was provided by HydroLogic, Inc., the data manager for *U.S. v. Abousleman et al.* Because the preponderance of water rights are designated as diversions from surface water for irrigated agriculture (approximately 92%), other water rights (i.e., domestic use, livestock use, diversions from wells and springs, fire protection) were not considered. Table 1 summarizes water rights in the watershed and indicates which water rights are claimed by the pueblos (i.e., Indian water rights). Diversion points for irrigation rights are shown Plate 1. Detailed water rights information is provided in Appendix A.

Water rights are based on total irrigated acres and provide for conveyance losses from the point of diversion to the point of use and also losses in the farmer's field due to infiltration and evaporation. These losses are reflected in the difference between the project delivery requirement (PDR), the farm delivery requirement (FDR), and the consumptive irrigation requirement (CIR). To determine the total diversion in acre feet allowed by water right, the PDR in acre feet per acre is multiplied by the total irrigated acres (TIA). To determine the actual consumptive use in acre feet by water right, the CIR in acre feet per acre is multiplied by the TIA. The difference between these calculated numbers represents the conveyance losses due to infiltration and evaporation. Water rights in the Rio Jemez watershed allow for an approximate 65% loss of surface water due to evaporation and infiltration between the point of diversion (i.e., PDR) and the consumptive use (i.e., CIR). It should be noted that this is a loss to surface flow, not a loss of water from the hydrologic system. However, for the purposes of this paper, the concern is adequate instream (i.e., surface) flow and the 65% conveyance loss of water reflected in water rights claims provides a way to make an initial estimate of instream conveyance losses in the lower watershed.

Table 1: Annual Water Rights and Water Use in the Jemez Watershed

Water Rights Data

Diversion (Plate 1 location)	TIA (ac)	PDR (af/ac)	Diversion (af)	FDR (af/ac)	Delivery (af)	CIR (af/ac)	Depletion (af)
Upper Watershed--Jemez Mainstem							
East Lateral Ditch (3)	11	4.03	45	2.82	31	1.41	16
Jemez Springs Ditch (6)	46	4.03	185	2.82	130	1.41	65
La Cueva Ditch (7)	54	2.37	128	1.66	90	0.83	45
Pueblo Ditch (10)	25	4.24	106	3.14	79	1.57	39
South Upper Ditch (12)	21	4.03	84	2.82	59	1.41	30
Upper East Ditch (13)	2	4.03	8	2.82	6	1.41	3
Upper West Ditch (14)	7	4.03	28	2.82	20	1.41	10
West Ditch (15)	10	4.03	39	2.82	28	1.41	14
West Lateral Ditch (16)	7	4.03	30	2.82	20	1.41	10
West Side Ditch (18)	9	4.03	36	2.82	25	1.41	13
Subtotal	192		689		487		243
Upper Watershed--Rio Guadalupe							
Canon Community Ditch (2)	202	4.03	812	2.82	570	1.41	285
Fenton Ditch (4)	7	2.37	15	1.66	12	0.83	6
George Fenton Ditch (5)	5	2.37	13	1.66	8	0.83	4
Subtotal	214		840		590		295
Cuba Diversion (1)	716	3.26	2333	2.28	1632	1.14	816
Lower Watershed--Jemez Mainstem							
Padilla Irrigation System (8)	9	4.94	47	3.46	31	1.73	16
San Ysidro Ditch (11)	510	4.94	2517	3.46	1765	1.73	882
West Main Ditch (17)	11	4.03	43	2.82	31	1.41	16
Jemez Pueblo (JP)*	2735	4.94	13509	3.46	9463	1.73	4732
Zia Pueblo (ZP)*	1233	4.94	6091	3.46	4266	1.73	2133
Santa Ana Pueblo (SAP)*	17	4.94	82	3.46	59	1.73	29
Subtotal	4515		22289		15615		7807
Lower Watershed -- Vallecito Creek							
Ponderosa Com. Ditch (9)	301	4.03	1211	2.82	849	1.41	424

Water Use Data

	Water Rights	Water Use 1995	Water Use 1990	Water Use 1985
Jemez Basin				
Acres	5222	1600	1700	1933
Diversion (af)	25029	7580	6314	6086
Conveyance Loss (af)	8337	2274	1894	NA
Delivery (af)	16692	5306	4420	NA
Farm Loss (af)	7923	2261	1883	NA
Depletion (af)	8769	3045	2537	NA
Cuba Diversion (af)	2333	750**	750**	750**
Acres	716	NA	NA	NA

* Indian water rights claims
** estimate (personal communication, Judy Stoft, 1998)
ac = acre af = acre feet af/ac = acre feet per acre
CIR = consumptive irrigation requirement; a measure of depletion or beneficial use
FDR = farm delivery requirement; amount of water diverted at the farm headgate
NA = not available
PDR = project delivery requirement; amount of water diverted from the river
TIA = total irrigated acres
Delivery = (FDR x TIA) Depletion = (CIR x TIA) Diversion = (PDR x TIA)

The SEO periodically publishes data concerning water use, by watershed, throughout New Mexico. This information shows that actual diversion and use for irrigation in the Rio Jemez watershed is 24% to 30% (average 27%) of the water rights for the period of 1985 through 1995 (SEO 1986; SEO 1992; SEO 1997). This information is also presented in Table 1. The SEO uses a 60% conveyance loss to calculate water use. This conveyance loss estimate agrees closely with that used for water rights calculations.

Flow data were taken from the USGS and COE for three points in the watershed (see Plate 1). These points included the following:

- Station 1; gaging station located below the confluence of the East Fork and the Rio Jemez mainstem
- Station 2; gaging station located below the confluence of the Rio Guadalupe and the Rio Jemez mainstem
- Station 3; combination of gaging station data measured at the ancient Santa Ana Pueblo and calculated inflow data for the Jemez Canyon Reservoir

Evaluation of flow data at these three stations provides information concerning average flows in the upper watershed and the lower watershed, both above and below points of diversion. USGS flow data below the Jemez Canyon Dam were also evaluated for the purpose of determining the number of "zero flow" days in certain months. However, these data were not used to determine average flows because of the complications from dam operation for flood control. Specifically, this gaging station may show zero or diminished flow for many days in April, May, and June due to retention of spring runoff for flood control in the Rio Grande (COE 1994).

For the purpose of comparing flows and water rights claims, average monthly data are used for the period of April through October. Because the preponderance of water rights claims are dedicated to irrigated agriculture, this comparison period represents the growing season, or the practical period of maximum water use in the Rio Jemez watershed. USGS gaging station data were summarized from daily flow measurements made at Stations 1 and 2. COE data for Station 3 were provided as monthly flows. Table 2 shows average monthly flows for Stations 1, 2, and 3. This table shows very high flows for the months of April and May, with flows diminishing for the remainder of the growing season (June through October). Flow data for the three stations, presented by month and year, are included in Appendix B.

Table 2: Average Monthly Flows in the Rio Jemez
(Flows in acre feet)

Station	Apr	May	Jun	Jul	Aug	Sep	Oct
1	8017	4244	1148	1031	1397	1080	1244
2	15,730	13,933	3852	2014	2665	2078	2204
3	14,841	12,115	2988	1517	2829	1656	1920

Table 3 presents a comparison between average monthly flows, average monthly availability (flow adjusted for instream conveyance loss), monthly water rights claims, and monthly use. Water availability was calculated as 40% of flows measured at Station 1 for the upper watershed and Station 2 for the lower watershed, which assumes a 60% loss in conveyance by the river. A 60% river conveyance loss was used as a first approximation for this exercise based on conveyance losses for irrigation works reflected in the water rights and water use information. To calculate monthly claims and monthly use, total water rights and total uses, respectively, from Table 1 were divided over the seven-month irrigation season based on a percentage of total claims or use for each month. To determine the monthly percentage for claims and use, the Blaney-Criddle formula and published data for the Jemez Springs area were used (SEO 1965). The Blaney-Criddle method relates water use to several key factors. For the monthly percentages, the following factors were used:

- monthly consumptive-use factor (f),
- monthly empirical crop consumptive-use coefficient (k),
- monthly consumptive use (u); u = kf,
- monthly effective rainfall (r), and
- monthly CIR; CIR = u-r.

Table 3: Comparison of Average Monthly Flow, Water Availability, Water Allocation, and Water Use for the Jemez Watershed (All figures in acre feet except percent)

Upper Jemez Watershed					
Month	**Flow[1]**	**Water Availability[2]**	**Monthly Percentage[3]**	**Water Allocation[4]**	**Water Use[5]**
April	8017	3207	8.4	47	13
May	4244	1698	14.0	79	21
June	1148	459	20.4	114	31
July	1031	412	22.4	126	33
August	1397	559	17.6	99	27
September	1080	432	11.3	63	17
October	1244	498	5.9	33	9
Total	18,161	7265	100.0	561	151

Lower Jemez Watershed					
Month	**Flow[1]**	**Water Availability[2]**	**Monthly Percentage[3]**	**Water Allocation[6]**	**Water Use[7]**
April	15,730	6292	8.4	1872	518
May	13,933	5573	14.0	3120	864
June	3852	1541	20.4	4547	1259
July	2014	806	22.4	4993	1382
August	2665	1066	17.6	3923	1086
September	2078	831	11.3	2519	697
October	2204	882	5.9	1315	364
Total	42,476	16,991	100.0	22,289	6170

[1] Flow measured at Station 1 for upper watershed; Flow measured at Station 2 for lower watershed
[2] 40% of measured flow, assumes 60% instream conveyance loss
[3] Calculated as monthly CIR, see Appendix C
[4] Allocation taken as total PDR from Upper watershed - Jemez mainstem (Table 1) except for La Cueva Ditch, adjusted by monthly percentage
[5] Assumes 27% of PDR based on Water Use data from Table 1, adjusted by monthly percentage
[6] Allocation taken as total PDR from Lower watershed - Jemez mainstem (Table 1), adjusted by monthly percentage
[7] Assumes 27% of PDR based on Water Use data from Table 1, adjusted by monthly percentage

It should be noted that f and r vary by month and k varies by both crop and month. Therefore, u and CIR will also vary by month. These factors were used to calculate monthly CIR for a representative crop mix described in a New Mexico State University (NMSU) Agricultural Experiment Station Bulletin (NMSU 1968). The representative crop mix for the Jemez Springs area is as follows: alfalfa (21%), pasture/hay (58%), spring grains (8.5%), corn (6.25%), and beans (6.25%). Monthly CIR for each crop was totaled for the growing season and then a monthly percent CIR was determined for the April through October time period. These monthly percentages can be applied to both the water claims and use over the growing season. Appendix C includes the determination of monthly percentages.

For the upper watershed, claims and use for the La Cueva Ditch were not included because this diversion is upstream from Station 1 and so any use from this diversion is already reflected in the flow data. Similarly, no claim or use figures were included for diversions on the Rio Guadalupe or Vallecito Creek because these diversions are upstream of the flow measurement stations.

This comparison shows that the upper watershed appears to be capable of providing adequate flow to satisfy all water rights claims, while water use appears to be limited by availability in the lower watershed. Monthly use in the lower watershed is 93% of the monthly availability for June through October, and 109% of availability for June through August, the highest use months. Of even more concern, water rights claims are 337% of the monthly availability for June through October, and 394% of availability for June through August. This suggests irrigation diversions likely will use all or nearly all available water during the months of June through October. Because of this, the river will be dry or nearly dry below San Ysidro for a majority of the time during these months.

An examination of USGS daily flow data below Jemez Canyon Dam seems to confirm this situation. For every year that flow data are available, the USGS gage below the dam indicates zero flow for nearly every day from the period of July through September (USGS 1998). The dam is operated as a flood control structure, retaining the high spring flows during April and May and releasing these flows as soon as downstream conditions allow (COE 1994). By late June or early July, the floodgates are usually left open to allow immediate flow through of any water in the Rio Jemez. Daily flow data reflect late summer thunderstorm activity as several days of significant flow during a month, with all other days showing zero flow. Appendix D shows typical daily flow data for the USGS gage below Jemez Canyon Dam. Data are included for an average flow year, and above-average flow year, and a below-average flow year. Calculated inflows to Jemez Canyon

Reservoir at Station 3 also indicate many years of zero or extremely low flows, on a monthly basis, in the river during the July through September time period (see Table B-3).

This month-by-month comparison of flow, availability, allocation, and use indicates several key points about the current state of the Rio Jemez watershed. These points can be summarized as follows:

- Existing water rights claims on the Rio Jemez, particularly in the lower watershed, far exceed water availability on a monthly basis for much of the growing season.
- Irrigation diversions consume all or nearly all available water for much of the growing season, leaving the river dry in its lower reaches.
- Water use is limited by water availability for the months of June through August.
- Average flows during April and May far exceed water rights claims and water use for those months.
- Average flows during April and May are adequate to meet water rights claims for the entire growing season.

3.0 Impacts to the Ecosystem

The river has become a victim of the irrigation demands along its length. It becomes a dry sandy channel below San Ysidro during much of the year. It is difficult to imagine today what the natural state of the Rio Jemez was before human development for irrigated agriculture. It is possible that the river naturally ran dry for several months due to infiltration and evaporation. If this is the case, the state of the river today may not be too much different than its natural state and then the purpose of this paper may be called into question. A solution will be presented whereby a minimum instream flow is provided after fulfilling irrigation claims. If the river continues to run dry in its lower reaches, there is little else that can be done.

However, it is doubtful that irrigation diversions have had little or no impact on the river. The comparison of water availability and claims/use shown in Table 3 indicates that irrigation diversions exceed availability for at least July and August. Even if calculated availability was based on a 40% conveyance loss in the river channel as opposed to the 60% used in Table 3, water use would still exceed availability for the month of July and consume 62% of the available water for the June through October period. In addition, claims would be 225% of availability for June through October. Clearly irrigation diversions are negatively impacting the river and are at least contributing to, if not causing, the problem of a dry river channel below San Ysidro for much of the year.

Certain parties may suggest that limiting or eliminating irrigation on the Rio Jemez would solve the problem. But this is not a workable solution. The pueblos have relied on the river for water supplies for many hundreds of years. Similarly, communities such as San Ysidro have been a part of the Rio Jemez ecosystem for several hundred years. Human beings are as much a part of the Rio Jemez ecosystem as wildlife, streamside vegetation, and the river itself. Denying these communities irrigation water would thus have negative impacts on the human components of the ecosystem. The elimination of irrigated agriculture to maintain instream flows is not an option.

The demands on the Rio Jemez are likely to increase in the coming years. Population increases in the region will undoubtedly result in increased demand for domestic water. The water rights battle continues in *U.S. v Abousleman,* and after 15 years, no resolution has been reached. Portions of the upper watershed have been included in the Jemez National Recreation Area (JNRA) (Public Law 103-104), which will bring increased attention and tourism to the area, with an associated increase in demands for domestic and recreational water supplies.

The comparison of monthly flow, availability, claims, and use for water along the Rio Jemez has indicated that there is a lack of adequate water during the June through October period in the lower watershed. However, the total flow of the river for the entire growing season is adequate to fulfill all existing water claims, with enough remaining to provide for instream flow. Therefore, the cause of water-related conflicts in the Rio Jemez watershed is not so much a problem of inadequate water supply as it is a problem of inadequate water storage. A strategically located water storage facility along the river would "even out" the monthly flows during the growing season, thereby providing adequate water to meet irrigation needs and also allow for instream flow.

Reservoir development projects have fallen out of favor in recent years as a way to resolve water-related conflicts. The Animas-La Plata Project in southwestern Colorado was proposed in part to resolve conflicts over water rights. However, this project has faced numerous legal and public opinion battles. The originally proposed project may never be built, and even a scaled down version faces many hurdles. Public opinion now favors resolving water conflicts with a minimum of development. Preserving and maintaining river systems that reflect a more natural state is the preferred approach.

While developing a storage facility within the Rio Jemez watershed will have some obvious impacts to the ecosystem, the ecosystem as a whole will benefit. The approach to developing a storage facility is an important consideration in keeping negative impacts to a minimum. By limiting the size of a dam and reservoir, negative impacts will also be limited. Public opinion may also be more accepting of a smaller facility. But the storage facility must be capable of storing an adequate volume of water to meet irrigation claims throughout the growing season as well as provide instream flows.

Siting and building a reservoir is a complex process involving many parties. Sites must be evaluated for geotechnical and hydrologic feasibility, engineering design feasibility, and property aquisition costs. This paper does not explore these aspects of reservoir design and construction. Rather, the focus of this paper is to explore the possibility of using a water storage facility to satisfy water rights claims while maintaining an instream flow throughout the growing season. Other aspects of reservoir feasibility are left for future study.

Because the Rio Jemez is part of a much larger river system, the Rio Grande, any proposal for a reservoir must also consider water claims downstream of the Rio Jemez. Natural flows in the Rio Jemez may already be allocated to downstream users and so any storage of these flows in the Rio Jemez watershed, as well as resulting evaporation losses, may impair water rights claims elsewhere in the Rio Grande system. This paper does not seek to resolve water conflicts outside the Rio Jemez watershed. An adjudication of water rights throughout the middle and lower Rio Grande may be required to fully resolve any potential conflicts between a reservoir project on the Rio Jemez and downstream water rights claims. This sort of investigation is also left for future study.

4.0 Seeking a Solution

The concepts of sustainable development and ecosystem management (EM) provide guidelines to solve the water conflicts identified in the Rio Jemez watershed. Sustainable development is defined as development that meets the needs of today's generation without interfering with future generations' ability to meet their needs (World Commission on Environment and Development 1987).

EM has been proposed as a way to manage federal land and natural resources and as a way to integrate the management approaches of both federal and non-federal landholders (Haeuber 1996). EM is also seen as a way to overcome political boundaries and view a natural system in a holistic manner – considering all aspects of the system and managing the whole for the good of all its components. Watersheds are often seen as appropriate units for implementation of EM, providing boundaries that define a natural system.

EM includes several management principles that should be applied to the situation under study. The application of sustainable development and EM to the problems identified in the Rio Jemez watershed, and the proposed solution, is discussed in Section 5.0. The EM management principles include the following:

Sustainability: Ecological, cultural, and socioeconomic sustainability are considered preconditions for management.

Systems Perspective: EM requires an understanding of the ecosystem as a whole, not a narrow view of only one component.

Broad Spatial and Temporal Scales: EM requires management based on ecological boundaries, crossing administrative, political, and ownership boundaries.

Humans as Ecosystem Components: EM accommodates human activities within ecosystems and views humans as integral elements of sustainable solutions.

Socially Defined Goals and Objectives: EM is a socially defined process, and human values play a dominant role in setting goals.

Collaborative Decision Building: EM requires decision making involving multiple stakeholders.

Organizational Change: EM decision making requires change on several levels; intragovernment, intergovernment, and public-private.

Adaptive Management: EM is a science-based process which builds on the results of past management actions.

Monitoring: Management must be tracked, successes and failures monitored, and results incorporated into future actions.

Data Collection: EM requires continuing research and data collection.

To design a storage facility, a desired minimum instream flow must be determined and an estimate of future water use for irrigation must be made. Once this information is developed, the capacity of the reservoir can be determined. Finally, an annual water budget must be used to determine the operation of the reservoir and the adequacy of the proposed solution. The following sections discuss these steps.

4.1 Desired Instream Flow

To arrive at a realistic instream flow as well as realistic conveyance losses for the river, average monthly flow data from Stations 2 and 3 were compared for years where data were available for both stations (see Appendix E). In performing this comparison, several issues become apparent. First, the data indicate that downstream flow (Station 3) is sometimes greater than upstream flow (Station 2) for a given month. This seems odd because there are no major tributaries downstream of Station 2 except for Vallecito Creek and Salado Wash (see Plate 1). Through personal observation, it has been noted that both of these tributaries are dry at their confluence with the Rio Jemez much of the year and so do not provide significant contributions to overall flow.

The phenomenon of flow measured at Station 3 greater than flow measured at Station 2 for the same month increases in frequency slightly in the late summer and fall. There is an average of 10 instances of greater flow at Station 3 than Station 2 for the months of April through June and an average of 14 instances of greater flow at Station 3 than Station 2 for the months of July through October, with a maximum of 21 instances in August. Because of this pattern, it is thought this phenomenon is a reflection of thunderstorm activity in the late summer and early fall. These events provide high instantaneous discharges that result in short-term flow surges and do not provide a sustained instream flow. Therefore, these data were eliminated from consideration. While this will not eliminate all storm activity from the determination, it will serve to eliminate the more severe storm events.

Also eliminated from consideration were periods for which flow at Station 3 was reported zero acre feet for a given month. Inadequate instream flow is the problem this paper seeks to solve and zero flow is clearly not a desirable situation. Again, while eliminating months that show zero flow certainly does not eliminate all zero flow days, it does serve to eliminate the most severe zero flow periods. So for the purposes of determining instream flow, only month/year combinations that showed flow at Station 3 at 1-99% of flow at Station 2 were considered. Appendix E also includes a table that shows the corrected flow data used for this determination.

After evaluating flow data from Stations 2 and 3, a clearer picture of the Rio Jemez system becomes evident. Instream conveyance losses in the lower watershed (that is, between Stations 2 and 3) were calculated as the percent of Station 2 flow measured at Station 3 for a given month. While water rights and water use calculations assume a nominal 60% conveyance loss, the river exhibits losses that vary with flow. Table 4 summarizes the results of the flow data comparison. During periods of high flow (i.e., April and May), conveyance losses are 12% and 23% respectively, significantly less than 60%. During periods of lower flow (i.e., June through October), losses average 52%. The discrepancy between conveyance loss estimates for water rights claims and water use calculations and this data are likely due to the lower overall volume of water in irrigation systems as compared to the river channel, as well as the complicating factor of storm activity. The inverse relationship between flow rate and percentage of water lost is evident in Table 4. Note that for the month of September, the total volume of water in the system is lowest, while the percentage lost in conveyance is highest. Figure 3 presents the inverse relationship between flow measured at Station 2 and conveyance loss (i.e, percent of Station 2 flow that is lost between Stations 2 and 3), graphically.

To arrive at a desired instream flow for the design of a proposed reservoir, a range of 40% to 50% of upstream flow will be used. This range reflects actual flow data for the July through September timeframe in years that exhibit flow for this period. This period is chosen for determining desired instream flow because it has the highest proportion of zero flow days. It should be noted that this is the desired instream flow after irrigation withdrawals. For instream conveyance losses, a figure of 15% will be used for April, 25% for May, and 55% for the rest of the growing season. These figures are slightly conservative in that actual flow data show conveyance losses of 12% for April, 23% for May, and an average of 52% for June through October.

4.2 Determining River Capability

To determine if the river is capable of meeting desired uses, the desired instream flow figures and instream conveyance loss figures are used along with an estimate of water use. Recall that irrigation withdrawals in the lower watershed appear to be limited by water availability. If this is true, and additional water is made available, additional water

Table 4: Percent of Upstream Flow (Station 2) Measured Downstream (Station 3)

Month	Upstream Flow[1] (acre feet)	Downstream Flow[2] (acre feet)	Percent Flow Downstream[3]	Percent Loss[4]
April	15,009	13,205	88	12
May	12,915	9885	77	23
June	3507	2018	56	44
July	1998	888	44	56
August	2377	1391	59	41
September	1784	617	35	65
October	1829	862	47	53
Total	39,419	28,866	73	27

[1] Measured at Station 2
[2] Measured at Station 3
[3] Calculated as: [(Downstream flow) / (Upstream flow)] x 100
[4] Calculated as: [(Upstream flow) - (Downstream flow) / (Upstream flow)] x 100

will likely be withdrawn. How much additional water is hard to determine, but it could never exceed water rights claims. For the purpose of determining the river's capabilities, a range of one-half the claims to the full claims will be used. Using the monthly flows measured at Station 2, the estimated monthly instream conveyance losses, the range of monthly irrigation withdrawals (i.e, water rights claims), and the range of desired instream flows; a range of differences between water availability and water uses can be calculated. Note that water uses include both irrigated agriculture and instream flow. These monthly differences can then be related to the river's capability to meet desired uses.

First, several adjustments must be made to the flow measured at Station 2 to ensure that all uses are accounted for. There are numerous water users in the upper watershed that are likely taking only a portion of their water rights claims. From Tables 1 and 3, an estimate can be made of additional potential diversions upstream of Station 2 that are not reflected in the flow data. These additional diversions must be subtracted from the flows measured at Station 2 as part of determining the river's capabilities to meet uses. Table 5 summarizes these upstream additional potential diversions and shows a range of flow adjustments to be made at Station 2 as part of calculating the river's capabilities to meet desired uses. The minimum adjustment reflects half of the water rights claims minus

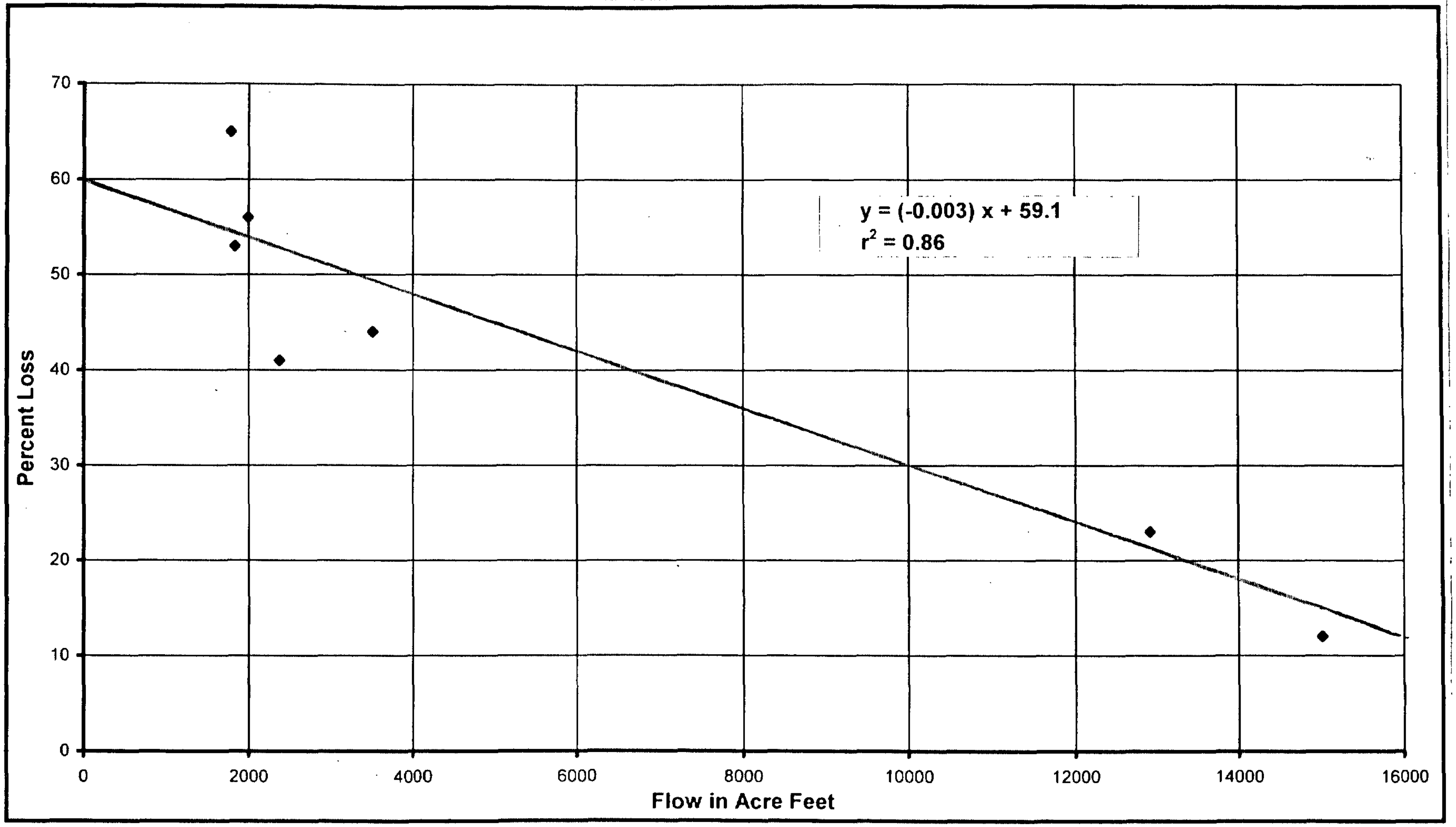


Figure 3: Relationship Between Instream Flow Measured at Station 2 and Conveyance Loss in the Lower Watershed

current use, while the maximum adjustment reflects full water rights claims minus current use. Current use is estimated as 750 acre feet per year for the Cuba trans-mountain diversion and 27% of full water rights for all other users in the Rio Jemez watershed. These current use estimates agree with water use data from SEO (1986; 1992; 1997) (see Table 1).

From Table 5, the adjustment to flow data at Station 2 ranges from 766 to 2697 acre feet for the period of April to October. These adjustments are used in the calculation of the river's capabilities to meet uses. Capability is reflected in the difference between adjusted flow at Station 2 minus conveyance losses in the river and water use in the lower watershed. Recall that water use includes both water rights claims and instream flow. Table 6 shows the determination of these differences. Two scenarios are considered that reflect minimum and maximum use. Minimum use assumes that irrigators divert one half of their claimed water rights and that instream flows are maintained at 40% of average flow at Station 2 for the period of June through October after conveyance losses. Maximum use assumes that irrigators divert their full water rights claims and instream flows are maintained at 50% of average flow at Station 2 for the period of June through October after conveyance losses. For consistency, both the adjustments for upper watershed uses and claims in the lower watershed are distributed according to the monthly percentages determined in Section 2.0, (see Table 3). These two scenarios will serve as a first estimate of the river's capability to meet desired uses. If the total in a difference column is a positive number, it indicates that the river is capable of meeting the uses for that scenario. Table 6 indicates that the river appears to be capable of meeting the maximum use scenario with approximately 2200 acre feet per year to spare.

It should be noted that all calculations incorporate average monthly flows. Actual flows in the Rio Jemez can vary from the average quite dramatically in a given year (see Appendix B). This paper attempts to provide a broad overview solution to the problems identified in the Rio Jemez watershed. Any final solution will need to be refined to account for variations in flow on an annual basis.

Table 5: Adjustments to Flow at Station 2
(all figures in acre feet)

Diversion (Plate 1 location)	Current Use[1]	Half Allocation	Full Allocation	Adjustment Min[2]	Adjustment Max[3]
Cuba (1)	750	1167	2333	417	1583
East Lateral Ditch (3)	12	23	45	11	33
Jemez Springs Ditch (6)	50	93	185	43	135
La Cueva Ditch (7)	35	64	128	29	93
Pueblo Ditch (10)	29	53	106	24	77
South Upper Ditch (12)	23	42	84	19	61
Upper East Ditch (13)	2	4	8	2	6
Upper West Ditch (14)	8	14	28	6	20
West Ditch (15)	11	20	39	9	28
West Lateral Ditch (16)	8	15	30	7	22
West Side Ditch (18)	10	18	36	8	26
Cañon Community Ditch (2)	219	406	812	187	593
Fenton Ditch (7)	4	8	15	4	11
George Fenton Ditch (5)	4	7	13	3	9
Total	1165	1931	3862	766	2697

[1] 27% of full water rights based on water use data (see Table 1)
[2] Min adjustment = (half water rights) – (current use)
[3] Max adjustment = (full water rights) – (current use)

4.3 Proposed Reservoir Design

The results from the capability demonstration in Table 6 can also be used to determine the required storage capacity needed to meet desired water uses in the lower watershed. Assuming that the maximum use scenario represents the desired conditions for management of the Rio Jemez watershed, the total of the negative numbers in the maximum difference column provides an estimate of required storage capacity to meet uses under this scenario in an average flow year. From Table 6, the required storage capacity is approximately 15,000 acre feet. Reservoir losses due to evaporation must be added to this capacity to ensure adequate water can be provided to the lower watershed to meet projected uses under this scenario. Evaporation losses must also be accounted for in the distribution of water to meet water rights claims. This accounting is addressed in Section 4.4. Reservoir losses due to infiltration will be ignored as there is no adequate way to estimate these losses. Geotechnical investigations of the porosity and permeability of the proposed reservoir site are left for future study.

Table 6: Monthly Capability of the Rio Jemez
(all figures in acre feet)

Month	Flow[1]	Water Rights Adjustment[2]		Adjusted Flow[3]		Flow after Loss[4]		Water Rights Claims[5]		Desired Instream Flow[6]		River Capability Scenario[7]	
		Full	Half	Min	Max	Min	Max	Full	Half	50%	40%	Max Use	Min Use
April	15,730	226	64	15,504	15,666	13,178	13,316	1872	936	517	413	10,789	11,967
May	13,933	377	107	13,556	13,826	10,167	10,370	3120	1560	517	413	6530	8397
June	3852	550	156	3302	3696	1486	1663	4547	2274	517	413	-3578	-1024
July	2014	604	172	1410	1842	634	829	4993	2496	517	413	-4876	-2080
August	2665	474	135	2191	2530	986	1139	3923	1962	517	413	-3454	-1236
September	2078	305	87	1773	1991	798	896	2519	1259	517	413	-2238	-776
October	2204	159	45	2045	2159	920	972	1315	658	517	413	-912	-99
Total	42,476	2695	766	39,781	41,710	28,169	29,185	22,289	11,145	3619	2891	2261	15,149

[1] Flow measured at Station 2

[2] Adjustment for upper watershed users (see Table 5) based on monthly percentage of use (see Table 3)

[3] Min adjusted flow = (Flow) – (Full water rights adjustment); Max adjusted flow = (Flow) – (Half water rights adjustment)

[4] Conveyance loss between Station 2 and Station 3 calculated on adjusted flow; 15% loss for April, 25% loss for May, 55% loss for June through October

[5] Water rights claims of lower watershed users based on monthly percentage of use (see Table 3)

[6] Desired instream flow after irrigation withdrawals; based on average flow after loss (min + max/2) for June through October

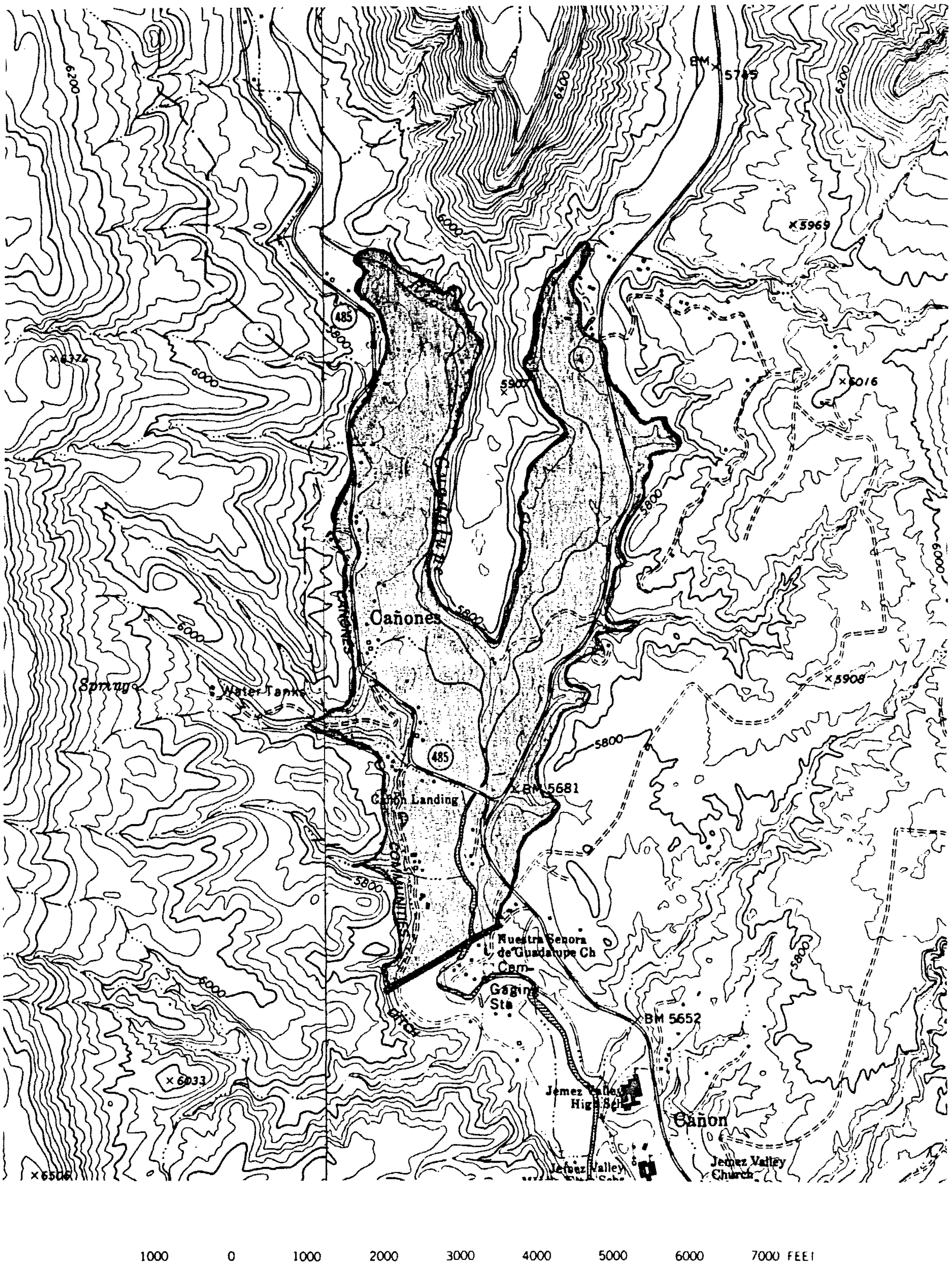
[7] River capability scenarios calculated as follows: Max Use = (Min flow after loss) – (full water rights claims) – (50% instream flow) ; Min Use = (Max flow after loss) – (half water rights claims) – (40% instream flow)

The most accepted way to determine evaporation losses from a reservoir is to use the pan approach (SEO 1997). To determine evaporation losses using this approach, the storage capacity versus surface area of the reservoir must be known. To determine these figures, a reservoir location must be chosen so that accurate estimates of storage capacity and surface area can be made. The reservoir location should provide for adequate storage volume with a minimum of surface area to minimize evaporation losses and the amount of land needed. It should also be located upstream of the lower watershed so that irrigation water can be provided to the lower watershed users without pumping the water to the point of use. With these criteria in mind, the reservoir was located at the confluence of the Rio Jemez and the Rio Guadalupe (see Plate 1 and Figure 4).

The toe of the dam is at an elevation of 5640 feet and the crest at 5750 feet. With the spillway located at 5740 feet, the design allows 10 feet of freeboard at maximum capacity. Water surface area and volume were determined for various elevations. Area was determined by counting equivalent squares of 1,000,000 square feet (1000 feet per side). Volume was determined by multiplying area by depth of water assumed to be one-half the incremental depth of water at the dam for a given elevation. Total surface area of the reservoir at maximum capacity is approximately 400 acres and volume is approximately 20,000 acre feet.

4.4 Water Budget Evaluation

To completely determine the capability of the Rio Jemez to meet desired uses, a water budget was developed for three scenarios: the maximum and minimum use scenarios discussed previously, as well as a medium use scenario where all water users diverted 75% of their water rights claims. The third scenario was added when it became clear that the maximum use scenario would not provide instream flow for the entire growing season. Water budgets incorporated the following parameters on a monthly basis: reservoir evaporation, adjusted inflow from the upper watershed, conveyance losses in the river channel, and irrigation diversions. Reservoir operation considered three equivalent priorities for the growing season: maintenance of a reservoir level conducive to



CONTOUR INTERVAL 40 FEET

Figure 4: Location and Configuration of Proposed Dam and Reservoir (Shown at Full Capacity)

recreation, provision of adequate water for irrigation diversions, and an instream flow after irrigation diversions and conveyance losses of 40% to 50% of flow as released from the reservoir.

Reservoir surface area and volume calculations were used to construct a graph of surface area versus volume. Evaporation rates for each month were determined using average Class A land pan measurements and precipitation measurements from Jemez Canyon Dam (COE 1994). A pan coefficient of 0.70 was used per recommendations in SEO (1997). The graph of flow versus conveyance loss in the river channel (Figure 3) was used to determine conveyance loss for a given discharge from the dam. All of this information is provided in Appendix F.

For each scenario, the monthly water budget was calculated using the following steps:

1. A beginning reservoir volume and associated surface area was chosen from the area/volume curve in Appendix F.

2. Evaporation was determined using the appropriate net evaporation rate.

3. An adjusted beginning reservoir volume was determined (i.e., beginning volume - evaporation).

4. An upstream inflow was added to the adjusted volume calculated in Step 3 to arrive at a total volume. Upstream inflow for each scenario assumes diversion of 100%, 75%, or 50% of water rights claims upstream of the reservoir, as appropriate.

5. An end reservoir volume was chosen. This end volume is then used as the beginning volume in Step 1 for the following month.

6. Reservoir discharge was determined (total volume - end reservoir volume).

7. Flow after loss volume was calculated using the volume/percent loss curve in Appendix F.

8. Irrigation diversions were subtracted from the flow volume.

9. Instream flow volume was calculated (flow volume - diversions).

10. Several iterations were performed to satisfy the three equivalent priorities.

The results of the three water budget exercises are shown in Table 7. The maximum use scenario is clearly undesirable as instream flow is negative for three months which indicates that irrigation diversions exceed flow after considering conveyance loss in the river channel. The medium use scenario can provide adequate water to meet irrigation diversions and provide instream flow. However, the instream flow is only 25% of flow after conveyance loss. While the monthly instream flow exceeds the target volumes proposed in Table 6 (40% to 50% of natural upstream flow after loss for the June through October period), it does not meet the 40% to 50% target for the flow after loss using the reservoir. Also, the reservoir is drained quite quickly from June through August and is left with very little water by the end of the growing season. This type of reservoir operation is not conducive to recreation.

The minimum use scenario appears to be the most workable solution for management of the Rio Jemez. This scenario provides adequate water for irrigation diversions at 50% of water rights claims. Recall that basin-wide diversions are estimated at 27% of water rights claims, so this scenario provides nearly double the irrigation water currently available. More importantly, it provides water throughout the growing season at an adequate rate to sustain irrigated agriculture. Instream flows are maintained at an average of 44% of seasonal flows after conveyance loss. This meets the target range for instream flow of 40% to 50% of flow after conveyance loss. Finally, the reservoir is operated in such a way as to provide for recreational opportunities during spring, summer, and early fall. This scenario also accounts for evaporation losses in the reservoir to be taken from the water rights claims of lower watershed users. Because only 50% of water rights claims are earmarked for irrigated agriculture, the remaining 50% can be dedicated to the evaporation losses and instream flow volumes in Table 7. Once again, it should be noted that the water budget calculations are based on average monthly flows. Therefore, adjustments to the recommended scenario would be needed for years of lower-than-average or higher-than-average flows.

Table7: Water Budget Determinations for Maximum, Medium, and Minimum Use Scenarios
(All Figures in Acre Feet Unless Indicated)

Maximum Use Scenario (100% Water Rights Allocation)

Month	Begin Res volume	Begin Res area (ac)	Net Evap rate (feet)	Evap volume	Adj Res volume	Upstream Inflow	Total volume	End Res volume	Discharge	Flow after loss	Diversion	Instream Flow
Apr	1500	125	0.53	66	1434	15,504	16,938	12,000	4938	2469	1872	597
May	12,000	300	0.69	206	11,794	13,556	25,350	18,500	6850	3768	3120	648
Jun	18,500	380	0.80	304	18,196	3302	21,498	13,500	7998	5199	4547	652
Jul	13,500	320	0.69	220	13,280	1410	14,690	6000	8690	5649	4993	656
Aug	6000	210	0.55	115	5885	2191	8076	1500	6576	3617	3923	-306
Sep	1500	125	0.46	57	1443	1773	3216	1000	2216	997	2519	-1522
Oct	1000	112	0.31	35	965	2045	3010	500	2510	1129	1315	-186

Medium Use Scenario (75% Water Rights Allocation)

Month	Begin Res volume	Begin Res area (ac)	Net Evap rate (feet)	Evap volume	Adj Res volume	Upstream Inflow	Total volume	End Res volume	Discharge	Flow after loss	Diversion	Instream Flow
Apr	1500	125	0.53	66	1434	15,585	17,019	12,500	4519	2259	1404	855
May	12,500	310	0.69	213	12,287	13,691	25,978	20,000	5978	3288	2304	984
Jun	20,000	400	0.80	320	19,680	3499	23,179	16,000	7179	4308	3410	898
Jul	16,000	350	0.69	240	15,760	1626	17,386	10,000	7386	4431	3745	686
Aug	10,000	275	0.55	151	9849	2360	12,209	5500	6709	3690	2942	748
Sep	5500	205	0.46	93	5407	1882	7289	2500	4789	2634	1889	745
Oct	2500	147	0.31	46	2454	2102	4556	1000	3556	1600	986	614

Minimum Use Scenario (50% Water Rights Allocation)

Month	Begin Res volume	Begin Res area (ac)	Net Evap rate (feet)	Evap volume	Adj Res volume	Upstream Inflow	Total volume	End Res volume	Discharge	Flow after loss	Diversion	Instream Flow
Apr	1500	125	0.53	66	1434	15,666	17,100	12,500	4600	2300	936	1364
May	12,500	310	0.69	213	12,287	13,826	26,113	20,000	6113	3362	1560	1802
Jun	20,000	400	0.80	320	19,680	3696	23,376	17,000	6376	3507	2274	1233
Jul	17,000	365	0.69	251	16,749	1842	18,591	12,500	6091	3350	2496	854
Aug	12,500	310	0.55	170	12,330	2530	14,860	9500	5360	2948	1962	986
Sep	9500	270	0.46	123	9377	1991	11,368	6500	4868	2434	1259	1175
Oct	6500	225	0.31	71	6429	2159	8588	4500	4088	1840	658	1182

5.0 Conclusions and Recommendations

An evaluation of the Rio Jemez watershed has shown that the river is not capable of meeting the existing water rights claims and maintaining instream flow throughout the growing season. Based on average flows, the river contains enough water volume to the claims, but the water is not available during the growing season so that it can be used for agriculture. Based on flow data recorded at Station 2, 70% of the water for the entire growing season passes down the Rio Jemez in April and May, while the remaining 30% is spread out over the months of June through October (see Table 3). Conversely, the highest need of water for irrigation occurs during the months of June, July, and August. To complicate matters, natural soil and climatic conditions cause proportionately higher water losses as flow decreases (see Table 4 and Figure 3). These conditions cause the available water to be completely used up for much of the growing season, leaving the river dry, and negatively impacting the ecosystem.

This paper provides one solution to help solve the problem of the Rio Jemez being dry during the period of greatest need. It may not be the only solution, it may not be the most favorable solution, but it is presented as a possible solution for consideration. By building a reservoir, the flow of the Rio Jemez can be "evened out" during the growing season. Three scenarios were considered and one, the minimum use scenario, was found to be the most effective at meeting the mutually preferred goals of supplying additional water to meet existing water rights claims, maintaining instream flows, and providing recreational opportunities. In years or average or higher-than-average flows, this approach would supply adequate water to irrigators throughout the watershed to meet 50% of existing water rights claims, maintain instream flows throughout the growing season, and provide a newly created lake for fishing, swimming, and boating.

For this approach to work, however, a great deal of cooperation among the residents of the Rio Jemez watershed is required. Luckily, some of the major players in this solution, namely the irrigation districts and the pueblos, have demonstrated that they can cooperate to institute change for the benefit of all residents. The Agreement enacted in 1996 between the ditch associations and the pueblos shows these parties are willing to work together and they understand that the best way to address water shortage is to allocate it fairly. Given the opportunity to make significant changes to the watershed to benefit themselves, as well as wildlife, natural vegetation, visitors to the JNRA, and the river; it is thought the residents of the Rio Jemez watershed would agree to the following requirements to make the proposed solution work.

First, the reservoir would need to be built. This would entail buying up private property with existing homes, as well as committing certain federal land for this purpose. This may be the most difficult aspect of the proposed solution. Many of the property owners where the reservoir is to be built may be reluctant to sell their land. Some ways to acquire this land may include an equivalent acreage exchange of federal land for the private property, payments of 110% of fair market value, or condemnation. An environmental impact statement would be required for the reservoir project under the National Environmental Policy Act (NEPA). To ease approval of the project under NEPA, positive local sentiment is critical. A demonstration that property owners are being treated fairly would certainly further this goal.

Second, to ensure that instream flows would become a reality again, another agreement between all water rights holders would be needed. This agreement would require water users to leave enough water in the river to maintain instream flows. Water users could dedicate a portion of their water rights, not to exceed 50% in a given year, for this purpose. Recently, the New Mexico Attorney General released an opinion that allows water rights holders to apply for a change of use whereby the water would be left for instream flows for recreational, fish or wildlife, or ecological purposes (OAG 1998). This opinion provides legal protection of the water rights so long as there are measuring devices (e.g., gaging stations) available to quantify the instream flow beneficially used. The agreement and the attorney general's opinion would ensure that adequate water would be provided for instream flows and that this water would not be subject to forfeiture and then lost to future appropriations.

Finally, a governing entity to oversee and regulate water use in the Rio Jemez watershed should be established so that the benefits realized by the proposed solution would also be realized for future generations. Again, the Agreement signed in 1996 provides for such a governing body, or at least the beginnings of one (U.S. v. Abousleman 1996). The document specifies that the parties request the court to appoint a Water Master to administer and enforce the Agreement. If the court fails to appoint a Water Master, the document designates the SEO and the Bureau of Indian Affairs (BIA) to jointly administer and enforce the Agreement. Therefore, the key players in the proposed solution have already agreed to be regulated by a governing body.

It is clear from this discussion that the residents of the Rio Jemez watershed would need to support this approach to meet the needs of the entire ecosystem. While it seems that currently no one speaks for the Rio Jemez, for this approach to be successful, the human component of the ecosystem would need to take on this responsibility. The pueblos, the ditch associations, and all of the other residents, as well as the government organizations would need to speak for the Rio Jemez.

To demonstrate that the proposed solution fits into the concepts of sustainable development and EM, the following discussion is provided. The concepts of sustainable development and EM are interpreted for the proposed solution as applied to the Rio Jemez.

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987, p. 43). The development of a dam and reservoir fits into this definition and applies the concept of sustainable development to the Rio Jemez watershed. The proposed solution will not only meet the needs of the present but will also enhance the ability of future generations to meet their own needs.

As mentioned in Section 4.0, EM has several "Management Principles" that should be interpreted and applied to the specific situation being studied (Haeuber 1996). These principles and their applicability to the Rio Jemez watershed are as follows:

Sustainability: Ecological, cultural, and socioeconomic sustainability are considered preconditions for management. As explored under the discussion of sustainable development, the reservoir will provide current and future generations with an adequate, sustainable water supply. This facility will also sustain the agrarian cultures of the communities found along the river. Finally, the reservoir will sustain the ecosystem by providing instream flows throughout the year and along most, if not all, of the river's channel.

Systems Perspective: EM requires an understanding of the ecosystem as a whole, not a narrow view of only one component. The reservoir will provide an improvement to the overall ecosystem and benefit its components.

Broad Spatial and Temporal Scales: EM requires management based on ecological boundaries, crossing administrative, political, and ownership boundaries. Some of the problems in the Rio Jemez watershed can be traced to a piecemeal approach to river management. The river has been managed for particular needs at particular places along its length. This approach must be abandoned and the river must be viewed as a resource to be managed throughout its length and for years into the future. The current management approach fulfills the needs of water users in the upper watershed, with the users, and the river itself, being shortchanged in the lower watershed. The reservoir will provide for the needs of all users and allow the river to maintain its integrity.

Humans as Ecosystem Components: EM accommodates human activities within ecosystems and views humans as integral elements of sustainable solutions. The human activity of irrigated agriculture is an integral component of the Rio Jemez ecosystem and by providing a storage facility, this activity will be maintained along with the integrity of the river.

Socially Defined Goals and Objectives: EM is a socially defined process, and human values play a dominant role in setting goals. The three defined goals of operating the reservoir (i.e., providing irrigation water, maintaining instream flows, recreation) fulfill many human values. The irrigators will realize a nearly 100% increase in available water for use during the growing season. Instream flows throughout the summer and fall will provide a positive aesthetic for the public at large and certainly to anyone who desires a flowing river as opposed to a dry channel. Recreational opportunities will be enhanced for both visitors to the area and residents.

Collaborative Decision Building: EM requires decision making involving multiple stakeholders. The key players concerning water use in the Rio Jemez watershed have demonstrated that they can cooperate to provide benefits to all parties. If the proposed solution can be implemented, this spirit of cooperation will continue and all ecosystem components will benefit.

Organizational Change: EM decision making requires change on several levels: intragovernment, intergovernment, and public-private. The proposed solution would require certain changes to the way in which water has been managed in the watershed. The changes are thought to be positive ones, but would require change on numerous levels. The tribes, community governments, federal organizations (i.e., Sante Fe National Forest, BIA, federal court), and private citizens would need to understand and support the development of the reservoir as a way to solve many of the water-related problems. Without this organizational change and cooperative support, the reservoir will likely not be approved because of the difficulty of funding water projects. The organizations involved with water use must realize that the current way of managing the river is no longer a viable approach.

Adaptive Management: EM is a science-based process which builds on the results of past management actions. Certainly past management practices are not working to the benefit of the ecosystem. Using scientific data and working within the constraints of the natural system and the law which governs water use, the proposed solution takes into account the fallacies of past practices and measured, realistic water availability.

Monitoring: Management must be tracked, successes and failures monitored, and results incorporated into future actions. The OAG opinion concerning instream water rights claims requires some level of monitoring. The USGS gaging stations located on the river will continue to provide needed data concerning river flow. But additional monitoring will be required so that the agreement to divert only 50% of water rights claims at any given location is enforced throughout the watershed. Additional monitoring will be required at the dam and continued monitoring of the snowpack to estimate spring flows and storage needs. Finally, the state of the ecosystem in the portion of the river that currently is dry each summer should be monitored so that any improvements can be documented, or problems resolved for future incorporation into river management plans.

Data Collection: EM requires continuing research and data collection. Certainly more work needs to be done to arrive at a final solution. This paper has pointed out several areas for additional work, such as a determination if water is legally available for management in the Rio Jemez watershed or if this water is claimed elsewhere in the Rio Grande watershed. An economic analysis should be performed to determine if irrigated cropland may be put to better use for higher value crops. Water saving measures should be practiced on the farms to make better use of the additional water that will be made available. The site of the proposed reservoir needs to be evaluated for its suitability. All of this research and data collection is left for future endeavors.

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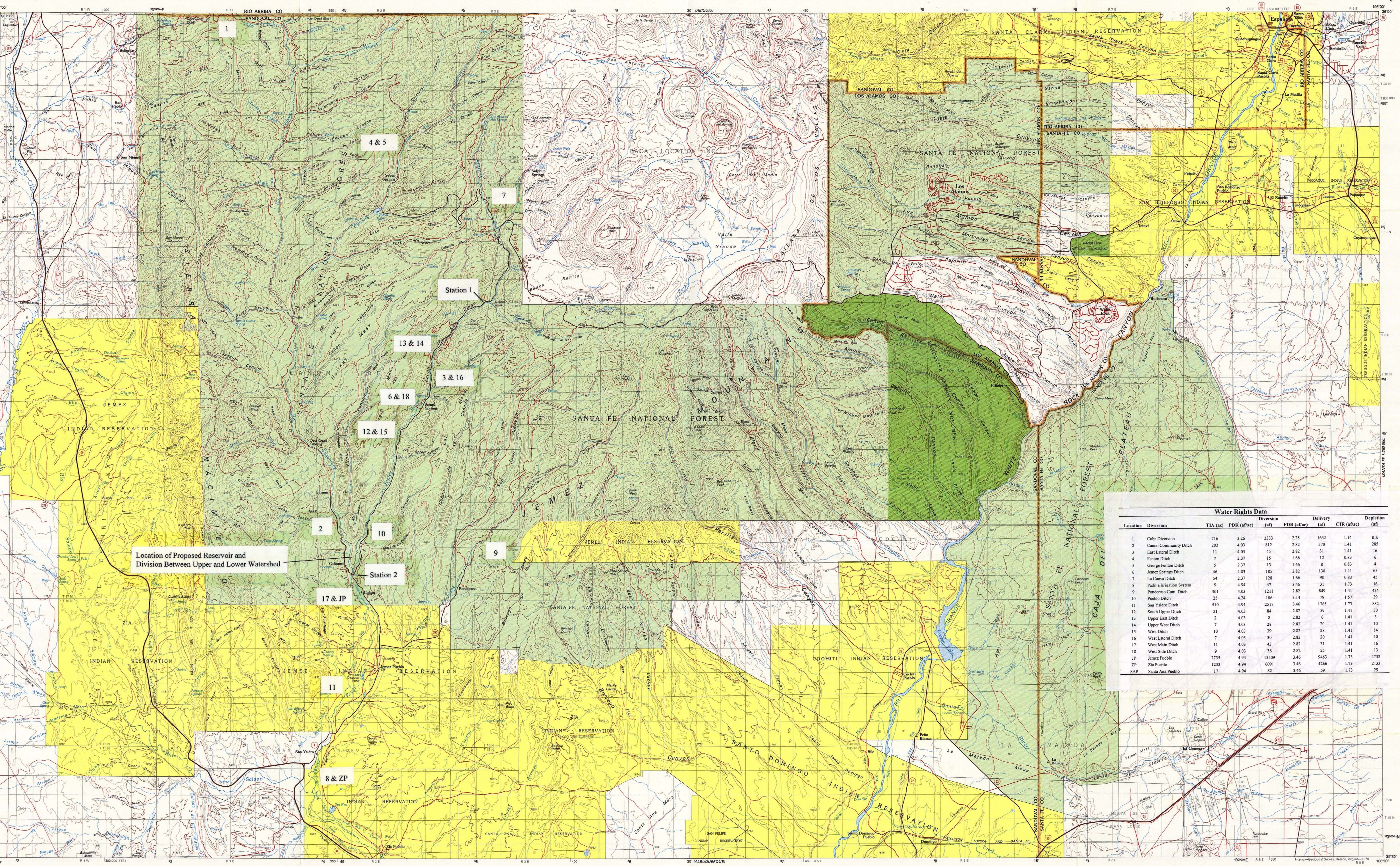
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LOS ALAMOS QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES (TOPOGRAPHIC)



Location	Diversion	TIA (ac)	PDR (af/ac)	Diversion (af)	FDR (af/ac)	Delivery (af)	CIR (af/ac)	Depletion (af)
1	Cuba Diversion	716	3.26	2333	2.28	1632	1.14	816
2	Canon Community Ditch	202	4.03	812	2.82	570	1.41	285
3	East Lateral Ditch	11	4.03	45	2.82	31	1.41	16
4	Fenton Ditch	7	2.37	15	1.66	12	0.83	6
5	George Fenton Ditch	5	2.37	13	1.66	8	0.83	4
6	Jemez Springs Ditch	46	4.03	185	2.82	130	1.41	65
7	La Cueva Ditch	54	2.37	128	1.66	90	0.83	45
8	Padilla Irrigation System	9	4.94	47	3.46	31	1.73	16
9	Ponderosa Com. Ditch	301	4.03	1211	2.82	849	1.41	424
10	Pueblo Ditch	25	4.24	106	3.14	79	1.57	39
11	San Ysidro Ditch	510	4.94	2517	3.46	1765	1.73	882
12	South Upper Ditch	21	4.03	84	2.82	59	1.41	30
13	Upper East Ditch	2	4.03	8	2.82	6	1.41	3
14	Upper West Ditch	7	4.03	28	2.82	20	1.41	10
15	West Ditch	10	4.03	39	2.82	28	1.41	14
16	West Lateral Ditch	7	4.03	30	2.82	20	1.41	10
17	West Main Ditch	11	4.03	43	2.82	31	1.41	16
18	West Side Ditch	9	4.03	36	2.82	25	1.41	13
JP	Jemez Pueblo	2735	4.94	13509	3.46	9463	1.73	4732
ZP	Zia Pueblo	1233	4.94	6091	3.46	4266	1.73	2133
SAP	Santa Ana Pueblo	17	4.94	82	3.46	59	1.73	29

Water Rights Data

Mapped, edited, and published by the Geological Survey

Compiled from USGS 1:24 000-scale topographic maps dated 1951–1970. See index for dates of individual maps. Partially revised from aerial photographs taken 1974 and 1976 and from other official sources. Revised information not field checked. Map edited 1978

Projection and 10 000-meter grid, zone 13: Universal Transverse Mercator. 50 000-foot grid ticks based on New Mexico coordinate system, central zone. 1927 North American datum

INDEX TO 1:24 000-SCALE MAPS

UTM GRID AND 1978 MAGNETIC NORTH DECLINATION AT CENTER OF MAP

SCALE 1:100 000

CONTOUR INTERVAL 50 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

LEGEND

- Perennial stream, lake
- Intermittent stream, lake
- Village or locality
- Landmark structure
- Public park or recreation area
- Forest or game land area
- Other public area or Military or Indian reservation

ROAD CLASSIFICATION

- Primary highway, hard surface
- Secondary highway, hard surface
- Light-duty road, hard or improved surface
- Street or unimproved road
- Trail
- Interstate route — U.S. route — State route

This map complies with national map accuracy standards
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225 OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

Plate 1, Part A

1978

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ALBUQUERQUE QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Compiled from USGS 1:24 000 and 1:62 500-scale topographic maps dated 1954–1961. See index for dates of individual maps
Partially revised from aerial photographs taken 1975 and 1976 and from other official sources. Revised information not field checked
Map edited 1978

Projection and 10 000-meter grid, zone 13
Universal Transverse Mercator
50 000-foot grid ticks based on New Mexico coordinate system, central zone. 1927 North American datum

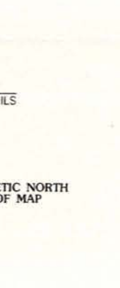
Areas covered by dashed light-blue pattern are subject to controlled inundation

Some grant boundaries adjacent to Rio Grande and Rio Puerco are omitted because of insufficient data

INDEX TO 1:24 000 AND 1:62 500-SCALE MAPS

1	2	3	4	5	6	7
8	9	10	11	12	13	7
14	15	16	17	18	19	20 / 21
22	23	24	25	26	27	28 / 21

1 Sky Village NW – 1960
2 Sky Village NE – 1960
3 Bernalillo NW – 1953
4 Santa Ana Pueblo – 1954
5 San Felipe Pueblo – 1954
6 San Felipe Pueblo NE – 1954
7 Madrid – 1961
8 Sky Village – 1954
9 Sky Village SE – 1954 (Photorevised – 1972)
10 Loma Machete – 1954 (Photorevised – 1972)
11 Bernalillo – 1954 (Photorevised – 1972)
12 Placitas – 1954
13 Hagan – 1954
14 Benavidez Ranch – 1954
15 Volcano Ranch – 1954 (Photorevised – 1972)
16 Los Griegos – 1960 (Photorevised – 1972)
17 Alameda – 1960 (Photorevised – 1972)
18 Sandia Crest – 1961 (Photorevised – 1972)
19 Sandia Park – 1954
20 San Pedro – 1954
21 Edgewood – 1956
22 La Mesita Negra – 1954 (Photorevised – 1971)
23 La Mesita Negra SE – 1954 (Photorevised – 1973)
24 Albuquerque West – 1960 (Photorevised – 1972)
25 Albuquerque East – 1960 (Photorevised – 1972)
26 Tijeras – 1961 (Photorevised – 1972)
27 Sedillo – 1954
28 Edgewood – 1954



UTM GRID AND 1978 MAGNETIC NORTH DECLINAN AT CENTER OF MAP

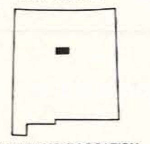
SCALE 1:100 000

KILOMETERS: 1 0 1 2 3 4 5 6 7 8 9 10
MILES: 1 0 1 2 3 4 5
FEET: 5000 0 5000 10000 15000 20000 25000

CONTOUR INTERVAL 50 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

This map complies with national map accuracy standards
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225 OR RESTON, VIRGINIA 22092

NEW MEXICO



QUADRANGLE LOCATION

LEGEND

- Perennial stream, lake
- Intermittent stream, lake
- Village or locality
- Landmark structure
- Public park or recreation area
- Forest or game land area
- Other public area or Military or Indian reservation
- Built-up area

ROAD CLASSIFICATION

- Primary highway, hard surface
- Secondary highway, hard surface
- Light-duty road, hard or improved surface
- Street or unimproved road
- Trail
- Interstate route — U.S. route — State route

Plate 1, Part B

1978

Appendix A

Water Rights Information for the Rio Jemez Watershed

Jemez River System Non-Pueblo Ditch Irrigation

Ditch	Priority Date	Acres	Total Diversion	PDR	FDR	CIR	Point of Diversion
Ballejos Ditch No. 1	1882-12-31	9.860	32.144	3.26	2.28	1.14	SW¼ NE¼ SE¼ Sec. 35, T.21N, R. 1W
Canon Community Ditch	1798-12-31	201.480	811.964	4.03	2.82	1.41	NE¼ NE¼ SW¼ Sec. 17, T.17N, R. 2E sd
Copper City Ditch No. 1	1882-12-31	130.720	426.147	3.26	2.28	1.14	NE¼ SW¼ SW¼ Sec. 36, T.21N, R. 1W
Domingo Vigil Ditch	1882-12-31	46.610	151.949	3.26	2.28	1.14	SE¼ NW¼ NW¼ Sec. 32, T.21N, R. 1W
East Lateral Ditch	1865-12-31	11.140	44.894	4.03	2.82	1.41	NW¼ NW¼ SW¼ Sec. 13, T.18N, R. 2E sd
Fenton Ditch	1899-12-31	6.500	15.405	2.37	1.66	0.83	SE¼ NE¼ NE¼ Sec. 34, T.20N, R. 2E
Francisco Chavez Ditch No. 6	1882-12-31	195.580	637.591	3.26	2.28	1.14	SW¼ SW¼ NW¼ Sec. 34, T.21N, R. 1W
Gabriel Montoya Ditch No. 7	1882-12-31	47.970	156.382	3.26	2.28	1.14	SW¼ SW¼ NW¼ Sec. 34, T.21N, R. 1W
George Fenton Ditch	1899-12-31	5.450	12.917	2.37	1.66	0.83	NW¼ NE¼ SE¼ Sec. 34, T.20N, R. 2E
Jemez Springs Ditch	1865-12-31	45.890	184.937	4.03	2.82	1.41	SW¼ SE¼ NE¼ Sec. 23, T.18N, R. 2E sd
La Cueva Ditch	1886-12-31	53.940	127.838	2.37	1.66	0.83	SW¼ NW¼ SW¼ Sec. 8, T.19N, R. 3E
Madrlena Atencio Ditch No. 2	1882-12-31	23.010	75.013	3.26	2.28	1.14	NW¼ SW¼ SW¼ Sec. 36, T.21N, R. 1W
Nacimiento Ditch	1882-12-31	247.190	805.839	3.26	2.28	1.14	SE¼ NW¼ SE¼ Sec. 35, T.21N, R. 1W
Nerio Montoya Ditch	1882-12-31	14.680	47.857	3.26	2.28	1.14	NW¼ NW¼ NW¼ Sec. 33, T.21N, R. 1W
Nestor R. Padilla Irrigation System	1948-08-12	9.430	46.584	4.94	3.46	1.73	NE¼ NW¼ SW¼ Sec. 6, T.15N, R. 2E sy
Ponderosa Community Ditch	Varies	300.590	1211.378	4.03	2.82	1.41	NW¼ SW¼ SW¼ Sec. 20, T.17N, R. 3E sj
Upper Vallecitos priority date is 1768. Middle and Lower Vallecitos priority date is 1815.							
Pueblo Ditch	Varies	24.620	106.153	0.00	0.00	0.00	SW¼ SW¼ NW¼ Sec. 22, T.17N, R. 2E sd
North of the Jemez Pueblo boundary: PDR= 4.03 acre-feet per acre per year, FDR= 2.82 acre-feet per acre per year and CIR= 1.41 acre-feet per acre per year. South of the Jemez Pueblo boundary: PDR= 4.94 acre-feet per acre per year, FDR= 3.46 acre-feet per acre per year and CIR= 1.73 acre-feet per acre per year. Of the total acreage under this ditch, 7.62 acres is located south of the Jemez Pueblo boundary.							
San Ysidro Ditch	1786-12-31	509.620	2517.523	4.94	3.46	1.73	NW¼ NW¼ NE¼ Sec. 29, T.16N, R. 2E j

Ditch	Priority Date	Acres	Total Diversion	PDR	FDR	CIR	Point of Diversion
South Upper Ditch	1865-12-31	20.850	84.026	4.03	2.82	1.41	NE¼ SW¼ SW¼ Sec. 26, T.18N, R. 2E sd
Upper East Ditch	1873-12-31	1.973	7.951	4.03	2.82	1.41	SW¼ NE¼ SW¼ Sec. 12, T.18N, R. 2E sd
Upper West Ditch	1873-12-31	6.918	27.880	4.03	2.82	1.41	NE¼ NE¼ SW¼ Sec. 12, T.18N, R. 2E sd
West Ditch	1865-12-31	9.650	38.890	4.03	2.82	1.41	NW¼ NE¼ SW¼ Sec. 26, T.18N, R. 2E sd
West Lateral Ditch	1865-12-31	7.410	29.862	4.03	2.82	1.41	NW¼ NW¼ SW¼ Sec. 13, T.18N, R. 2E sd
West Main Ditch	1798-12-31	10.570	42.597	4.03	2.82	1.41	SW¼ SW¼ NW¼ Sec. 33, T.17N, R. 2E sd
West Side Ditch	1865-12-31	8.950	36.069	4.03	2.82	1.41	NW¼ NE¼ SE¼ Sec. 23, T.18N, R. 2E sd

Notes on the Printout: Jemez River System Non-Pueblo Ditch Irrigation

Total Diversion:	Acres*PDR in acre-feet per year.
PDR:	Project Delivery Requirement. The amount diverted by the ditch from the surface source of water in acre-feet per acre per year.
FDR:	Farm Delivery Requirement. The amount diverted at the farm headgate in acre-feet per acre per year.
CIR:	Consumptive Irrigation Requirement. Quantity of water, exclusive of effective precipitation, used by plants or that evaporates from the soil surface. CIR is a measure of depletion or beneficial consumptive use. Acre-feet per acre per year.

Notations at the ends of legal descriptions indicate:

sd	Legal description projected within the Cañon De San Diego Grant
psd	Legal description partly projected within the Cañon De San Diego Grant
sj	Legal description projected within the Ojo De San Jose Grant
psj	Legal description partly projected within the Ojo De San Jose Grant
sy	Legal description projected within the San Ysidro Grant
psy	Legal description partly projected within the San Ysidro Grant
b	Legal description projected within the Baca Location No. 1 Grant
j	Legal description within the Jemez Indian Reservation
oes	Legal description projected within the Ojo Del Espiritu Santo Grant

Total Diversion of Water for Non-Pueblo, Non-Federal Ditch Irrigation Rights

1. Total number of acres under irrigation by ditch is: 1,950.60
   Total diversion amount in acre-feet per year is: 7,679.79

2. One irrigation right for 4.11 acres on the Ponderosa Community Ditch is currently in dispute.

3. Total acreage in the Cuba area which uses the trans-basin diversion is: 716.62
   Total diversion amount in acre-feet per year is: 2,336.18
   Nacimiento Creek is a source of water for the Cuba area irrigation as well as the trans-basin diversion. It is unclear at this point if the entire 2,336.18 acre-feet can be diverted from the trans-basin diversion.

Total Diversion of Water from Wells and Springs for Non-Pueblo, Non-Federal Irrigation Rights

	Acres	FDR	CIR
Wells:	21.27	2.82	1.41
	6.72	1.66	0.83
	45.60	1.28	-
	73.55		
Springs:	1.00	2.82	1.41
	9.60	1.66	0.83
	10.60		

Total Diversion of Water for Pueblo Ditch Irrigation

	Acres	PDR	FDR	CIR
Jemez	2,734.7	4.94	3.46	1.73
Zia	1,232.9	4.94	3.46	1.73
Santa Ana	16.5	4.94	3.46	1.73
	3,984.10			

Water Use Other Than Irrigation

1. *Non-Pueblo, Non-Federal.*
   There are 475 domestic/stock uses with a total annual diversion of 1,352.69 acre-feet. That's the maximum. Most domestic rights actually use far less than the standard 3.0 acre-feet per year adjudicated. There are 30 other rights (e.g., mutual domestic water associations, commercial) with a total annual diversion of 376.17 acre-feet.

2. *Pueblo*
   37 springs with a total annual diversion of 287.75 acre-feet. 58 well with a total annual diversion of 219.50 acre-feet. Annual diversion from the Jemez River for livestock of 6.0 acre-feet.

3. *Federal Agency*
   13 wells with a total annual diversion of 33.95 acre-feet. 103 springs with a total annual diversion of 80.41 acre-feet. 10 acre-feet per year is reserved for fire protection.

Note: I have excluded stock ponds, erosion control dams and information of storage in reservoirs from this report.

Jemez River System Non-Pueblo Ditch Diversions

Those you do not find on your printout are ditches for which all irrigation rights have been denied by the Court.

SOURCE OF WATER	DITCHES
(1) Nacimiento Creek, a tributary of the Rio Puerco, (2) Clear Creek, a tributary of the Rio de las Vacas and (3) Rio de las Vacas, a tributary of the Rio Guadalupe, which is a tributary of the Jemez River. (Clear Creek and the Rio de las Vacas are trans-basin diversions.)	Nacimiento Ditch Domingo Vigil Ditch Nerio Montoya Ditch Francisco Chavez Ditch No. 6 Gabriel Montoya Ditch No. 7 Ballejos Ditch No. 1 Copper City Ditch No. 1 Madrlena Atencio Ditch No. 2
Jemez River	East Lateral Ditch West Lateral Ditch Upper East Ditch Upper West Ditch Jemez Rio aka Hummingbird Ditch West Side Ditch Jemez Springs Ditch South Upper Ditch West Ditch Pueblo Ditch West Main Ditch San Ysidro Ditch
San Antonio Creek, a tributary of the Jemez River.	La Cueva Ditch
Calaveras Canyon, a tributary of the Rio Cebolla, which is a tributary of the Rio Guadalupe, which is a tributary of the Jemez River.	Fenton Ditch
Rio Cebolla, a tributary of the Rio Guadalupe, which is a tributary of the Jemez River.	George Fenton Ditch

SOURCE OF WATER	DITCHES
School Section Canyon, a tributary of the Rio de las Vacas, which is a tributary of the Rio Guadalupe, which is a tributary of the Jemez River.	Aker Ditch No. 1 Aker Ditch No. 2 Aker Ditch No. 3 Aker Spring Ditch No. 2
Three springs located north of School Section Canyon in the SE¼ SW¼ SE¼ of section 30, T.20N., R. 2E as shown on hydrographic survey map sheet no. 4I.	Aker Spring Ditch No. 1
Spring Canyon, a tributary of the Rio Cebolla, which is a tributary of the Rio Guadalupe, which is a tributary of the Jemez River.	Spring Canyon Ditch
Rio Guadalupe, a tributary of the Jemez River.	Cañon Community Ditch Delfin Garcia aka Gilman Mill Pond Ditch
Vallecitos Creek, a tributary of the Jemez River.	Ponderosa Community Ditch
San Ysidro Ditch, which diverts from the Jemez River.	Nestor R. Padilla Irrigation System

Appendix B

Average Monthly Flow Data for Stations 1, 2, and 3

Table B-1: Station 1 Monthly and Average Flow Data
Location: Jemez River Below East Fork -- USGS Gage 8321500
Flow in Acre feet

Year	Apr	May	Jun	Jul	Aug	Sep	Oct
1951			545	658	833	611	
1952			744	758	859	729	
1953			642	837	708	659	
1954			589	873	822	741	
1955			563	899	2671	855	
1956			504	643	720	563	
1957			697	927	2350	1010	
1958	25061	10229	1822	859	1279	1406	1002
1959	1802	1255	682	685	1477	802	873
1960	7888	1849	904	896	950	746	1434
1961	11995	2663	1045	1020	2164	1107	1041
1962	11706	1992	847	942	690	760	883
1963	1236	764	625	697	1142	824	691
1964	3657	838	549	860	921	698	608
1965	7053	2212	954	794	976	812	803
1966	3679	875	724	834	845	731	610
1967	760	611	596	887	2378	1416	798
1968	9074	6457	1273	1009	1620	683	731
1969	8455	3513	1160	1091	1663	1948	2968
1970	4611	1725	1418	1398	2406	1899	1245
1971	1140	768	571	762	944	780	1388
1972	950	695	801	669	1073	1061	1436
1973	11933	23604	2899	1113	1150	933	847
1974	2206	1283	681	937	954	704	1214
1975	13872	10066	1869	1554	1152	1463	903
1976	1784	1835	703	740	863	897	
1981					1002	1113	1224
1982	9037	4534	1077	956	1570	1499	1125
1983	15697	7508	2528	1445	2208	1325	1742
1984	9338	3994	1832	1352	1432	998	1580
1985	23014	12945	2728	1455	1253	1432	1875
1986	4611	2186	2210	2624	2228	1503	2443
1987	21295	8092	2273	1277	1386	1018	1166
1988	6298	2709	1416	1307	2867	2586	1463
1989	3059	1321	744	907	1340	1059	1220
1990	3265	2325	974	1428	1404	1523	1531
Ave	8017	4244	1148	1031	1397	1080	1244

Table B-2: Station 2 Monthly and Average Flow Data
Location: Jemez River Below Rio Guadalupe -- USGS Gage 8324000
Flow in Acre feet

Year	Apr	May	Jun	Jul	Aug	Sep	Oct
1937	33959	15868	5332	3612	1931	1768	2235
1938	10755	13894	2994	2235	1344	6544	3762
1939	15175	5946	1206	1594	1740	1701	1883
1940	9213	5754	1707	1887	2311	1653	1754
1950	5071	1968	907	1202	933	1393	
1953	3762	3243	1139	1485	1406	770	1113
1954	6504	4174	1019	1562	1261	1095	1354
1955	2574	3520	709	1644	6186	1441	1045
1956	6116	3303	733	920	970	662	887
1957	5627	11926	5564	1757	7407	1754	5594
1958	57075	38400	4358	1340	2182	2422	1826
1959	4520	3924	1222	971	2691	1115	1707
1960	20467	8502	2384	1457	1574	1045	2344
1961	23354	14650	2570	1839	3522	1942	2028
1962	28237	10720	1931	1822	1293	1295	1780
1963	7168	2483	766	1053	2366	1477	1295
1964	6245	4550	1127	1562	2087	1085	1059
1965	13668	15197	4520	1871	1792	1493	1533
1966	10148	5877	2008	1544	1734	1198	1075
1967	2738	1382	1067	1657	6803	2861	1558
1968	16422	22584	4308	2273	4148	1354	1344
1969	19986	17066	3776	2095	3267	3592	4851
1970	9221	11050	4004	3018	4089	3120	2295
1971	4146	2635	886	1829	2889	1907	5039
1972	2705	1483	1398	889	1491	2865	4425
1973	29021	68619	12597	2976	2245	1841	1754
1974	5762	4091	968	1236	1596	893	2109
1975	26970	31565	6894	2689	1893	2459	1348
1976	4617	4615	1269	1412	1608	1265	1358
1977	4051	2796	762	1683	2679	1348	1174
1978	12670	12771	3572	1188	1386	1028	1374
1979	36078	36226	16297	3340	2594	1404	1283
1980	21376	29138	7530	1473	1703	1366	1533
1981	7423	5356	2346	1605	1511	2651	2127
1982	13593	14405	3641	1493	2600	2538	1744
1983	29856	35733	13129	2776	4558	2014	2323
1984	16317	19873	4368	2115	2352	1471	3091
1985	46245	37711	7356	3867	2883	3083	3909
1986	13838	11183	5287	4821	3515	3744	6688
1987	37869	24400	5683	2255	2629	1717	1889
1988	13044	10187	2996	2325	5409	5465	2602
1989	8265	2924	1249	2129	2426	2111	2414
1990	7522	7815	1713	2717	2356	3649	2263
1991	20453	12731	4665	3768	5679	5693	2200
1992	37416	21998	5657	2077	2641	1671	1669
1993	29827	21473	6409	1879	2471	2039	1719
1994	7362	10963	1946	1023	2321	1729	2388
1995	14365	24223	13947	4081	2990	1954	1931
1996	1987	1837	828	622	1130	1157	1115
Ave	15730	13933	3852	2014	2665	2078	2204

Table B-3: Station 3 Monthly and Average Flow Data
Location: Jemez River Above Jemez Canyon Resevoir
Flow in Acre feet

Year	Apr	May	Jun	Jul	Aug	Sep	Oct
1937	32880	17150	5400	1720	330	250	1660
1938	10120	11760	2360	1060	0	7830	3440
1939	14150	3480	70	1570	1350	420	850
1940	7440	3290	370	1040	670	350	810
1950	3470	210	0	50	10	2040	200
1953	1310	523	21	149	286	0	52
1954	4580	3030	0	3320	1490	1640	1870
1955	948	1587	0	4124	6095	48	0
1956	3848	984	0	22	1956	0	0
1957	4786	9909	3235	377	11185	94	10944
1958	47803	31263	0	0	512	1310	1200
1959	5590	5190	6	253	8248	11	1409
1960	20147	6984	1230	0	613	0	5601
1961	22387	10743	308	35	3659	534	1372
1962	24842	7548	276	29	12	302	1321
1963	4753	492	0	0	719	423	741
1964	4980	2451	75	34	1597	163	15
1965	11180	13400	3926	1415	1599	1232	675
1966	8412	3623	470	163	3399	10	144
1967	1280	580	4675	2915	11507	5865	212
1968	15380	18401	2246	874	6663	26	20
1969	17135	16147	7934	1002	5597	2751	10784
1970	6784	8247	1740	1922	3084	1321	750
1971	2830	1150	0	260	3502	640	5963
1972	828	0	32	40	692	3011	2450
1973	25118	34692	7980	2242	974	1266	278
1974	4119	2506	0	306	976	48	2993
1975	27865	29960	6045	3093	3226	5358	384
1976	4446	4061	40	424	2860	290	420
1977	9668	2187	276	1662	1959	210	84
1978	12789	13438	3772	0	10	0	96
1979	35398	32361	16426	6189	2957	112	352
1980	20463	33954	5998	237	201	430	308
1981	6687	4049	880	1616	513	1545	1924
1982	13107	15986	1881	443	4638	4948	993
1983	32623	38968	13913	1107	3781	708	1641
1984	18422	18959	1801	1216	2469	245	3831
1985	55577	35213	6189	2086	2524	4434	4500
1986	11740	9360	4390	5860	1920	6190	9400
1987	35420	20250	8710	5630	1480	290	490
1988	12200	6790	1840	2050	5400	8600	3250
1989	9870	1080	420	1700	2620	260	
1990	7139	6403	385	3632	2513	2624	1071
1991	19015	11626	2782	4978	8477	9044	1054
1992	33332	28640	6141	857	2143	444	716
1993	30007	22661	4198	693	1891	834	686
1994	7404	11488	738	1614	7004	1817	2732
1995	15595	30533	16857	2250	1605	608	829
1996	1319	332	364	2098	1705	560	1667
Ave	14841	12115	2988	1517	2829	1656	1920

Appendix C

Determination of Monthly Consumptive Irrigation Requirement

Typical Crop Mix
(from NMSU 1968)

Crop	Percent	Adj Factor
Alfalfa	21%	0.21
Pasture/hay	58%	0.58
Spring grains	8.50%	0.085
Corn	6.25%	0.0625
Beans	6.25%	0.0625
Total	100	1

Monthly Consumptive Use Coefficients (k) for Irrigated Crops in New Mexico
(from NMSEO 1965)

Crop	Apr	May	Jun	Jul	Aug	Sep	Oct
Alfalfa	0.75	0.8	0.9	1	1	0.8	0.7
Pasture/hay	0.6	0.7	0.8	0.9	0.9	0.75	0.6
Spring grains	0.4	0.5	0.9	0.8			
Corn		0.5	0.7	0.8	0.8	0.7	
Beans		0.5	0.6	0.75	0.7		

Calculation of Monthly CIR for the Lower Jemez Watershed
(see page C-2)

Month	CIR alfalfa	CIR pasture/hay	CIR spring grains	CIR corn	CIR beans	Total	Relative Percent
Apr	0.64	1.35	0.12			2.11	8.4
May	0.90	2.12	0.21	0.15	0.15	3.53	14.0
Jun	1.21	2.94	0.49	0.27	0.23	5.14	20.4
Jul	1.35	3.28	0.42	0.31	0.28	5.63	22.4
Aug	1.16	2.81		0.26	0.22	4.44	17.6
Sep	0.75	1.90		0.19		2.84	11.3
Oct	0.46	1.03				1.49	5.9
Total	6.46	15.43	1.23	1.18	0.88	25.19	100.00

Calculation of Adjusted CIR for Crops

Calculation of Adjusted CIR for Alfalfa

Month	k	f	u	r	CIR	Adj Factor	Adj CIR
Apr	0.75	4.79	3.59	0.54	3.05	0.21	0.64
May	0.80	6.07	4.86	0.59	4.27	0.21	0.90
Jun	0.90	6.91	6.22	0.46	5.76	0.21	1.21
Jul	1.00	7.54	7.54	1.13	6.41	0.21	1.35
Aug	1.00	6.93	6.93	1.40	5.53	0.21	1.16
Sep	0.80	5.56	4.45	0.89	3.56	0.21	0.75
Oct	0.70	4.34	3.04	0.83	2.21	0.21	0.46

Calculation of Adjusted CIR for Pasture/hay

Month	k	f	u	r	CIR	Adj Factor	Adj CIR
Apr	0.60	4.79	2.87	0.54	2.33	0.58	1.35
May	0.70	6.07	4.25	0.59	3.66	0.58	2.12
Jun	0.80	6.91	5.53	0.46	5.07	0.58	2.94
Jul	0.90	7.54	6.79	1.13	5.66	0.58	3.28
Aug	0.90	6.93	6.24	1.40	4.84	0.58	2.81
Sep	0.75	5.56	4.17	0.89	3.28	0.58	1.90
Oct	0.60	4.34	2.60	0.83	1.77	0.58	1.03

Calculation of Adjusted CIR for Spring Grains

Month	k	f	u	r	CIR	Adj Factor	Adj CIR
Apr	0.40	4.79	1.92	0.54	1.38	0.085	0.12
May	0.50	6.07	3.04	0.59	2.45	0.085	0.21
Jun	0.90	6.91	6.22	0.46	5.76	0.085	0.49
Jul	0.80	7.54	6.03	1.13	4.90	0.085	0.42
Aug							
Sep							
Oct							

Calculation of Adjusted CIR for Corn

Month	k	f	u	r	CIR	Adj Factor	Adj CIR
Apr							
May	0.50	6.07	3.04	0.59	2.45	0.0625	0.15
Jun	0.70	6.91	4.84	0.46	4.38	0.0625	0.27
Jul	0.80	7.54	6.03	1.13	4.90	0.0625	0.31
Aug	0.80	6.93	5.54	1.40	4.14	0.0625	0.26
Sep	0.70	5.56	3.89	0.89	3.00	0.0625	0.19
Oct							

Calculation of Adjusted CIR for Beans

Month	k	f	u	r	CIR	Adj Factor	Adj CIR
Apr							
May	0.50	6.07	3.04	0.59	2.45	0.0625	0.15
Jun	0.60	6.91	4.15	0.46	3.69	0.0625	0.23
Jul	0.75	7.54	5.66	1.13	4.53	0.0625	0.28
Aug	0.70	6.93	4.85	1.40	3.45	0.0625	0.22
Sep							
Oct							

k = empirical crop consumptive use coefficient

f = consumptive use factor

u = consumptive use; u = kf

r = effective rainfall

CIR = consumptive irrigation requirement; CIR = u-r

Appendix D

Typical Daily Flow Below Jemez Canyon Dam

Typical Daily Flow Below Jemez Canyon Dam

Low Flow Year		High Flow Year		Average Flow Year	
Date	Flow (af)	Date	Flow (af)	Date	Flow (af)
7/1/76	0	7/1/85	1	7/1/84	21
7/2/76	0	7/2/85	3	7/2/84	9
7/3/76	0	7/3/85	3	7/3/84	0
7/4/76	0	7/4/85	3	7/4/84	0
7/5/76	0	7/5/85	3	7/5/84	0
7/6/76	0	7/6/85	3	7/6/84	0
7/7/76	0	7/7/85	3	7/7/84	0
7/8/76	0	7/8/85	2	7/8/84	0
7/9/76	0	7/9/85	2	7/9/84	0
7/10/76	0	7/10/85	2	7/10/84	0
7/11/76	0	7/11/85	2	7/11/84	0
7/12/76	0	7/12/85	2	7/12/84	0
7/13/76	0	7/13/85	2	7/13/84	0
7/14/76	0	7/14/85	2	7/14/84	0
7/15/76	0	7/15/85	6	7/15/84	0
7/16/76	0	7/16/85	2	7/16/84	0
7/17/76	0	7/17/85	93	7/17/84	0
7/18/76	0	7/18/85	222	7/18/84	0
7/19/76	0	7/19/85	120	7/19/84	216
7/20/76	0	7/20/85	1	7/20/84	253
7/21/76	0	7/21/85	1	7/21/84	26
7/22/76	0	7/22/85	1	7/22/84	26
7/23/76	0	7/23/85	51	7/23/84	13
7/24/76	0	7/24/85	101	7/24/84	1
7/25/76	2	7/25/85	42	7/25/84	0
7/26/76	6	7/26/85	34	7/26/84	0
7/27/76	15	7/27/85	51	7/27/84	0
7/28/76	21	7/28/85	50	7/28/84	0
7/29/76	9	7/29/85	50	7/29/84	0
7/30/76	2	7/30/85	38	7/30/84	0
7/31/76	1	7/31/85	31	7/31/84	0
8/1/76	2	8/1/85	32	8/1/84	0
8/2/76	1	8/2/85	32	8/2/84	0
8/3/76	19	8/3/85	32	8/3/84	0
8/4/76	49	8/4/85	33	8/4/84	0
8/5/76	11	8/5/85	33	8/5/84	0
8/6/76	6	8/6/85	34	8/6/84	0
8/7/76	5	8/7/85	34	8/7/84	0
8/8/76	3	8/8/85	33	8/8/84	0
8/9/76	1	8/9/85	32	8/9/84	146
8/10/76	0	8/10/85	31	8/10/84	108
8/11/76	35	8/11/85	30	8/11/84	0
8/12/76	0	8/12/85	165	8/12/84	0
8/13/76	0	8/13/85	276	8/13/84	0
8/14/76	0	8/14/85	184	8/14/84	0
8/15/76	0	8/15/85	24	8/15/84	25
8/16/76	0	8/16/85	24	8/16/84	160
8/17/76	0	8/17/85	24	8/17/84	165

Low Flow Year		High Flow Year		Average Flow Year	
Date	Flow (af)	Date	Flow (af)	Date	Flow (af)
8/18/76	0	8/18/85	24	8/18/84	0
8/19/76	65	8/19/85	10	8/19/84	0
8/20/76	42	8/20/85	0	8/20/84	0
8/21/76	10	8/21/85	0	8/21/84	0
8/22/76	7	8/22/85	0	8/22/84	33
8/23/76	5	8/23/85	0	8/23/84	55
8/24/76	65	8/24/85	0	8/24/84	103
8/25/76	54	8/25/85	0	8/25/84	178
8/26/76	150	8/26/85	0	8/26/84	175
8/27/76	38	8/27/85	0	8/27/84	104
8/28/76	5	8/28/85	0	8/28/84	0
8/29/76	2	8/29/85	0	8/29/84	0
8/30/76	0	8/30/85	0	8/30/84	0
8/31/76	0	8/31/85	0	8/31/84	0
9/1/76	0	9/1/85	0	9/1/84	0
9/2/76	0	9/2/85	0	9/2/84	0
9/3/76	0	9/3/85	0	9/3/84	0
9/4/76	0	9/4/85	0	9/4/84	0
9/5/76	0	9/5/85	1	9/5/84	0
9/6/76	15	9/6/85	1	9/6/84	0
9/7/76	2	9/7/85	1	9/7/84	0
9/8/76	0	9/8/85	1	9/8/84	0
9/9/76	0	9/9/85	1	9/9/84	0
9/10/76	0	9/10/85	1	9/10/84	0
9/11/76	0	9/11/85	1	9/11/84	0
9/12/76	0	9/12/85	1	9/12/84	0
9/13/76	0	9/13/85	1	9/13/84	0
9/14/76	0	9/14/85	1	9/14/84	0
9/15/76	0	9/15/85	1	9/15/84	0
9/16/76	0	9/16/85	50	9/16/84	0
9/17/76	0	9/17/85	227	9/17/84	0
9/18/76	0	9/18/85	193	9/18/84	0
9/19/76	0	9/19/85	126	9/19/84	0
9/20/76	0	9/20/85	195	9/20/84	0
9/21/76	0	9/21/85	120	9/21/84	0
9/22/76	0	9/22/85	117	9/22/84	0
9/23/76	0	9/23/85	443	9/23/84	0
9/24/76	0	9/24/85	650	9/24/84	0
9/25/76	0	9/25/85	90	9/25/84	0
9/26/76	9	9/26/85	30	9/26/84	0
9/27/76	19	9/27/85	30	9/27/84	0
9/28/76	8	9/28/85	30	9/28/84	0
9/29/76	9	9/29/85	28	9/29/84	0
9/30/76	10	9/30/85	28	9/30/84	0
10/1/76	10	10/1/85	28	10/1/84	0
10/2/76	8	10/2/85	28	10/2/84	0
10/3/76	6	10/3/85	28	10/3/84	0
10/4/76	6	10/4/85	28	10/4/84	99
10/5/76	4	10/5/85	28	10/5/84	127
10/6/76	2	10/6/85	28	10/6/84	30

Low Flow Year		High Flow Year		Average Flow Year	
Date	Flow (af)	Date	Flow (af)	Date	Flow (af)
10/7/76	2	10/7/85	28	10/7/84	30
10/8/76	2	10/8/85	15	10/8/84	30
10/9/76	5	10/9/85	3	10/9/84	29
10/10/76	4	10/10/85	5	10/10/84	53
10/11/76	3	10/11/85	6	10/11/84	67
10/12/76	4	10/12/85	0	10/12/84	36
10/13/76	2	10/13/85	0	10/13/84	21
10/14/76	6	10/14/85	0	10/14/84	21
10/15/76	2	10/15/85	151	10/15/84	20
10/16/76	0	10/16/85	319	10/16/84	139
10/17/76	1	10/17/85	316	10/17/84	214
10/18/76	1	10/18/85	269	10/18/84	97
10/19/76	0	10/19/85	217	10/19/84	27
10/20/76	4	10/20/85	215	10/20/84	23
10/21/76	7	10/21/85	97	10/21/84	23
10/22/76	8	10/22/85	1	10/22/84	62
10/23/76	7	10/23/85	2	10/23/84	155
10/24/76	6	10/24/85	5	10/24/84	106
10/25/76	10	10/25/85	12	10/25/84	23
10/26/76	12	10/26/85	16	10/26/84	23
10/27/76	10	10/27/85	16	10/27/84	23
10/28/76	12	10/28/85	16	10/28/84	23
10/29/76	11	10/29/85	14	10/29/84	45
10/30/76	7	10/30/85	14	10/30/84	90
10/31/76	9	10/31/85	12	10/31/84	88

Appendix E

Comparison of Average Monthly Flow Data for Stations 2 and 3

Comparison of Upstream and Downstream Flows
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Apr-up	Apr-down	Percent	May-up	May-dow	Percent	Jun-up	Jun-down	Percent
1937	33959	32880	97%	15868	17150	108%	5332	5400	101%
1938	10755	10120	94%	13894	11760	85%	2994	2360	79%
1939	15175	14150	93%	5946	3480	59%	1206	70	6%
1940	9213	7440	81%	5754	3290	57%	1707	370	22%
1950	5071	3470	68%	1968	210	11%	907	0	0%
1953	3762	1310	35%	3243	523	16%	1139	21	2%
1954	6504	4580	70%	4174	3030	73%	1019	0	0%
1955	2574	948	37%	3520	1587	45%	709	0	0%
1956	6116	3848	63%	3303	984	30%	733	0	0%
1957	5627	4786	85%	11926	9909	83%	5564	3235	58%
1958	57075	47803	84%	38400	31263	81%	4358	0	0%
1959	4520	5590	124%	3924	5190	132%	1222	6	0%
1960	20467	20147	98%	8502	6984	82%	2384	1230	52%
1961	23354	22387	96%	14650	10743	73%	2570	308	12%
1962	28237	24842	88%	10720	7548	70%	1931	276	14%
1963	7168	4753	66%	2483	492	20%	766	0	0%
1964	6245	4980	80%	4550	2451	54%	1127	75	7%
1965	13668	11180	82%	15197	13400	88%	4520	3926	87%
1966	10148	8412	83%	5877	3623	62%	2008	470	23%
1967	2738	1280	47%	1382	580	42%	1067	4675	438%
1968	16422	15380	94%	22584	18401	81%	4308	2246	52%
1969	19986	17135	86%	17066	16147	95%	3776	7934	210%
1970	9221	6784	74%	11050	8247	75%	4004	1740	43%
1971	4146	2830	68%	2635	1150	44%	886	0	0%
1972	2705	828	31%	1483	0	0%	1398	32	2%
1973	29021	25118	87%	68619	34692	51%	12597	7980	63%
1974	5762	4119	71%	4091	2506	61%	968	0	0%
1975	26970	27865	103%	31565	29960	95%	6894	6045	88%
1976	4617	4446	96%	4615	4061	88%	1269	40	3%
1977	4051	9668	239%	2796	2187	78%	762	276	36%
1978	12670	12789	101%	12771	13438	105%	3572	3772	106%
1979	36078	35398	98%	36226	32361	89%	16297	16426	101%
1980	21376	20463	96%	29138	33954	117%	7530	5998	80%
1981	7423	6687	90%	5356	4049	76%	2346	880	38%
1982	13593	13107	96%	14405	15986	111%	3641	1881	52%
1983	29856	32623	109%	35733	38968	109%	13129	13913	106%
1984	16317	18422	113%	19873	18959	95%	4368	1801	41%
1985	46245	55577	120%	37711	35213	93%	7356	6189	84%
1986	13838	11740	85%	11183	9360	84%	5287	4390	83%
1987	37869	35420	94%	24400	20250	83%	5683	8710	153%
1988	13044	12200	94%	10187	6790	67%	2996	1840	61%
1989	8265	9870	119%	2924	1080	37%	1249	420	34%
1990	7522	7139	95%	7815	6403	82%	1713	385	22%
1991	20453	19015	93%	12731	11626	91%	4665	2782	60%
1992	37416	33332	89%	21998	28640	130%	5657	6141	109%
1993	29827	30007	101%	21473	22661	106%	6409	4198	66%
1994	7362	7404	101%	10963	11488	105%	1946	738	38%
1995	14365	15595	109%	24223	30533	126%	13947	16857	121%
1996	1987	1319	66%	1837	332	18%	828	364	44%

Comparison of Upstream and Downstream Flows
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Jul-up	Jul-down	Percent	Aug-up	Aug-down	Percent
1937	3612	1720	48%	1931	330	17%
1938	2235	1060	47%	1344	0	0%
1939	1594	1570	98%	1740	1350	78%
1940	1887	1040	55%	2311	670	29%
1950	1202	50	4%	933	10	1%
1953	1485	149	10%	1406	286	20%
1954	1562	3320	213%	1261	1490	118%
1955	1644	4124	251%	6186	6095	99%
1956	920	22	2%	970	1956	202%
1957	1757	377	21%	7407	11185	151%
1958	1340	0	0%	2182	512	23%
1959	971	253	26%	2691	8248	307%
1960	1457	0	0%	1574	613	39%
1961	1839	35	2%	3522	3659	104%
1962	1822	29	2%	1293	12	1%
1963	1053	0	0%	2366	719	30%
1964	1562	34	2%	2087	1597	77%
1965	1871	1415	76%	1792	1599	89%
1966	1544	163	11%	1734	3399	196%
1967	1657	2915	176%	6803	11507	169%
1968	2273	874	38%	4148	6663	161%
1969	2095	1002	48%	3267	5597	171%
1970	3018	1922	64%	4089	3084	75%
1971	1829	260	14%	2889	3502	121%
1972	889	40	4%	1491	692	46%
1973	2976	2242	75%	2245	974	43%
1974	1236	306	25%	1596	976	61%
1975	2689	3093	115%	1893	3226	170%
1976	1412	424	30%	1608	2860	178%
1977	1683	1662	99%	2679	1959	73%
1978	1188	0	0%	1386	10	1%
1979	3340	6189	185%	2594	2957	114%
1980	1473	237	16%	1703	201	12%
1981	1605	1616	101%	1511	513	34%
1982	1493	443	30%	2600	4638	178%
1983	2776	1107	40%	4558	3781	83%
1984	2115	1216	57%	2352	2469	105%
1985	3867	2086	54%	2883	2524	88%
1986	4821	5860	122%	3515	1920	55%
1987	2255	5630	250%	2629	1480	56%
1988	2325	2050	88%	5409	5400	100%
1989	2129	1700	80%	2426	2620	108%
1990	2717	3632	134%	2356	2513	107%
1991	3768	4978	132%	5679	8477	149%
1992	2077	857	41%	2641	2143	81%
1993	1879	693	37%	2471	1891	77%
1994	1023	1614	158%	2321	7004	302%
1995	4081	2250	55%	2990	1605	54%
1996	622	2098	337%	1130	1705	151%

Comparison of Upstream and Downstream Flows (Corrected)
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Apr-up	Apr-down	Percent	May-up	May-dow	Percent	Jun-up	Jun-down	Percent
1937	33959	32880	97%						
1938	10755	10120	94%	13894	11760	85%	2994	2360	79%
1939	15175	14150	93%	5946	3480	59%	1206	70	6%
1940	9213	7440	81%	5754	3290	57%	1707	370	22%
1950	5071	3470	68%	1968	210	11%			
1953	3762	1310	35%	3243	523	16%	1139	21	2%
1954	6504	4580	70%	4174	3030	73%			
1955	2574	948	37%	3520	1587	45%			
1956	6116	3848	63%	3303	984	30%			
1957	5627	4786	85%	11926	9909	83%	5564	3235	58%
1958	57075	47803	84%	38400	31263	81%			
1959									
1960	20467	20147	98%	8502	6984	82%	2384	1230	52%
1961	23354	22387	96%	14650	10743	73%	2570	308	12%
1962	28237	24842	88%	10720	7548	70%	1931	276	14%
1963	7168	4753	66%	2483	492	20%			
1964	6245	4980	80%	4550	2451	54%	1127	75	7%
1965	13668	11180	82%	15197	13400	88%	4520	3926	87%
1966	10148	8412	83%	5877	3623	62%	2008	470	23%
1967	2738	1280	47%	1382	580	42%			
1968	16422	15380	94%	22584	18401	81%	4308	2246	52%
1969	19986	17135	86%	17066	16147	95%			
1970	9221	6784	74%	11050	8247	75%	4004	1740	43%
1971	4146	2830	68%	2635	1150	44%			
1972	2705	828	31%				1398	32	2%
1973	29021	25118	87%	68619	34692	51%	12597	7980	63%
1974	5762	4119	71%	4091	2506	61%			
1975				31565	29960	95%	6894	6045	88%
1976	4617	4446	96%	4615	4061	88%	1269	40	3%
1977				2796	2187	78%	762	276	36%
1978									
1979	36078	35398	98%	36226	32361	89%			
1980	21376	20463	96%				7530	5998	80%
1981	7423	6687	90%	5356	4049	76%	2346	880	38%
1982	13593	13107	96%				3641	1881	52%
1983									
1984				19873	18959	95%	4368	1801	41%
1985				37711	35213	93%	7356	6189	84%
1986	13838	11740	85%	11183	9360	84%	5287	4390	83%
1987	37869	35420	94%	24400	20250	83%			
1988	13044	12200	94%	10187	6790	67%	2996	1840	61%
1989				2924	1080	37%	1249	420	34%
1990	7522	7139	95%	7815	6403	82%	1713	385	22%
1991	20453	19015	93%	12731	11626	91%	4665	2782	60%
1992	37416	33332	89%						
1993							6409	4198	66%
1994							1946	738	38%
1995									
1996	1987	1319	66%	1837	332	18%	828	364	44%
Sum	570335	501776		490753	375631		108716	62566	
Ave	15009	13205	88%	12915	9885	77%	3507	2018	58%

Comparison of Upstream and Downstream Flows
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Sep-up	Sep-down	Percent	Oct-up	Oct-down	Percent
1937	1768	250	14%	2235	1660	74%
1938	6544	7830	120%	3762	3440	91%
1939	1701	420	25%	1883	850	45%
1940	1653	350	21%	1754	810	46%
1950	1393	2040	146%		200	
1953	770	0	0%	1113	52	5%
1954	1095	1640	150%	1354	1870	138%
1955	1441	48	3%	1045	0	0%
1956	662	0	0%	887	0	0%
1957	1754	94	5%	5594	10944	196%
1958	2422	1310	54%	1826	1200	66%
1959	1115	11	1%	1707	1409	83%
1960	1045	0	0%	2344	5601	239%
1961	1942	534	27%	2028	1372	68%
1962	1295	302	23%	1780	1321	74%
1963	1477	423	29%	1295	741	57%
1964	1085	163	15%	1059	15	1%
1965	1493	1232	83%	1533	675	44%
1966	1198	10	1%	1075	144	13%
1967	2861	5865	205%	1558	212	14%
1968	1354	26	2%	1344	20	1%
1969	3592	2751	77%	4851	10784	222%
1970	3120	1321	42%	2295	750	33%
1971	1907	640	34%	5039	5963	118%
1972	2865	3011	105%	4425	2450	55%
1973	1841	1266	69%	1754	278	16%
1974	893	48	5%	2109	2993	142%
1975	2459	5358	218%	1348	384	28%
1976	1265	290	23%	1358	420	31%
1977	1348	210	16%	1174	84	7%
1978	1028	0	0%	1374	96	7%
1979	1404	112	8%	1283	352	27%
1980	1366	430	31%	1533	308	20%
1981	2651	1545	58%	2127	1924	90%
1982	2538	4948	195%	1744	993	57%
1983	2014	708	35%	2323	1641	71%
1984	1471	245	17%	3091	3831	124%
1985	3083	4434	144%	3909	4500	115%
1986	3744	6190	165%	6688	9400	141%
1987	1717	290	17%	1889	490	26%
1988	5465	8600	157%	2602	3250	125%
1989	2111	260	12%	2414		
1990	3649	2624	72%	2263	1071	47%
1991	5693	9044	159%	2200	1054	48%
1992	1671	444	27%	1669	716	43%
1993	2039	834	41%	1719	686	40%
1994	1729	1817	105%	2388	2732	114%
1995	1954	608	31%	1931	829	43%
1996	1157	560	48%	1115	1667	150%

Comparison of Upstream and Downstream Flows (Corrected)
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Jul-up	Jul-down	Percent	Aug-up	Aug-down	Percent
1937	3612	1720	48%	1931	330	17%
1938	2235	1060	47%			
1939	1594	1570	98%	1740	1350	78%
1940	1887	1040	55%	2311	670	29%
1950	1202	50	4%	933	10	1%
1953	1485	149	10%	1406	286	20%
1954						
1955				6186	6095	99%
1956	920	22	2%			
1957	1757	377	21%			
1958				2182	512	23%
1959	971	253	26%			
1960				1574	613	39%
1961	1839	35	2%			
1962	1822	29	2%	1293	12	1%
1963				2366	719	30%
1964	1562	34	2%	2087	1597	77%
1965	1871	1415	76%	1792	1599	89%
1966	1544	163	11%			
1967						
1968	2273	874	38%			
1969	2095	1002	48%			
1970	3018	1922	64%	4089	3084	75%
1971	1829	260	14%			
1972	889	40	4%	1491	692	46%
1973	2976	2242	75%	2245	974	43%
1974	1236	306	25%	1596	976	61%
1975						
1976	1412	424	30%			
1977	1683	1662	99%	2679	1959	73%
1978				1386	10	1%
1979						
1980	1473	237	16%	1703	201	12%
1981				1511	513	34%
1982	1493	443	30%			
1983	2776	1107	40%	4558	3781	83%
1984	2115	1216	57%			
1985	3867	2086	54%	2883	2524	88%
1986				3515	1920	55%
1987				2629	1480	56%
1988	2325	2050	88%			
1989	2129	1700	80%			
1990						
1991						
1992	2077	857	41%	2641	2143	81%
1993	1879	693	37%	2471	1891	77%
1994						
1995	4081	2250	55%	2990	1605	54%
1996						
Sum	65927	29288		64188	37546	
Ave	1998	888	44%	2377	1391	59%

Comparison of Upstream and Downstream Flows (Corrected)
Up = Station 2 Down = Station 3
Flow in Acre Feet

Year	Sep-up	Sep-down	Percent	Oct-up	Oct-down	Percent
1937	1768	250	14%	2235	1660	74%
1938				3762	3440	91%
1939	1701	420	25%	1883	850	45%
1940	1653	350	21%	1754	810	46%
1950						
1953				1113	52	5%
1954						
1955	1441	48	3%			
1956						
1957	1754	94	5%			
1958	2422	1310	54%	1826	1200	66%
1959	1115	11	1%	1707	1409	83%
1960						
1961	1942	534	27%	2028	1372	68%
1962	1295	302	23%	1780	1321	74%
1963	1477	423	29%	1295	741	57%
1964	1085	163	15%	1059	15	1%
1965	1493	1232	83%	1533	675	44%
1966	1198	10	1%	1075	144	13%
1967				1558	212	14%
1968	1354	26	2%	1344	20	1%
1969	3592	2751	77%			
1970	3120	1321	42%	2295	750	33%
1971	1907	640	34%			
1972				4425	2450	55%
1973	1841	1266	69%	1754	278	16%
1974	893	48	5%			
1975				1348	384	28%
1976	1265	290	23%	1358	420	31%
1977	1348	210	16%	1174	84	7%
1978				1374	96	7%
1979	1404	112	8%	1283	352	27%
1980	1366	430	31%	1533	308	20%
1981	2651	1545	58%	2127	1924	90%
1982				1744	993	57%
1983	2014	708	35%	2323	1641	71%
1984	1471	245	17%			
1985						
1986						
1987	1717	290	17%	1889	490	26%
1988						
1989	2111	260	12%			
1990	3649	2624	72%	2263	1071	47%
1991				2200	1054	48%
1992	1671	444	27%	1669	716	43%
1993	2039	834	41%	1719	686	40%
1994						
1995	1954	608	31%	1931	829	43%
1996	1157	560	48%			
Sum	58868	20359		60361	28447	
Ave	1784	617	35%	1829	862	47%

Appendix F

Backup Information for Water Budget Calculations

Calculation of Net Evaporation Rate

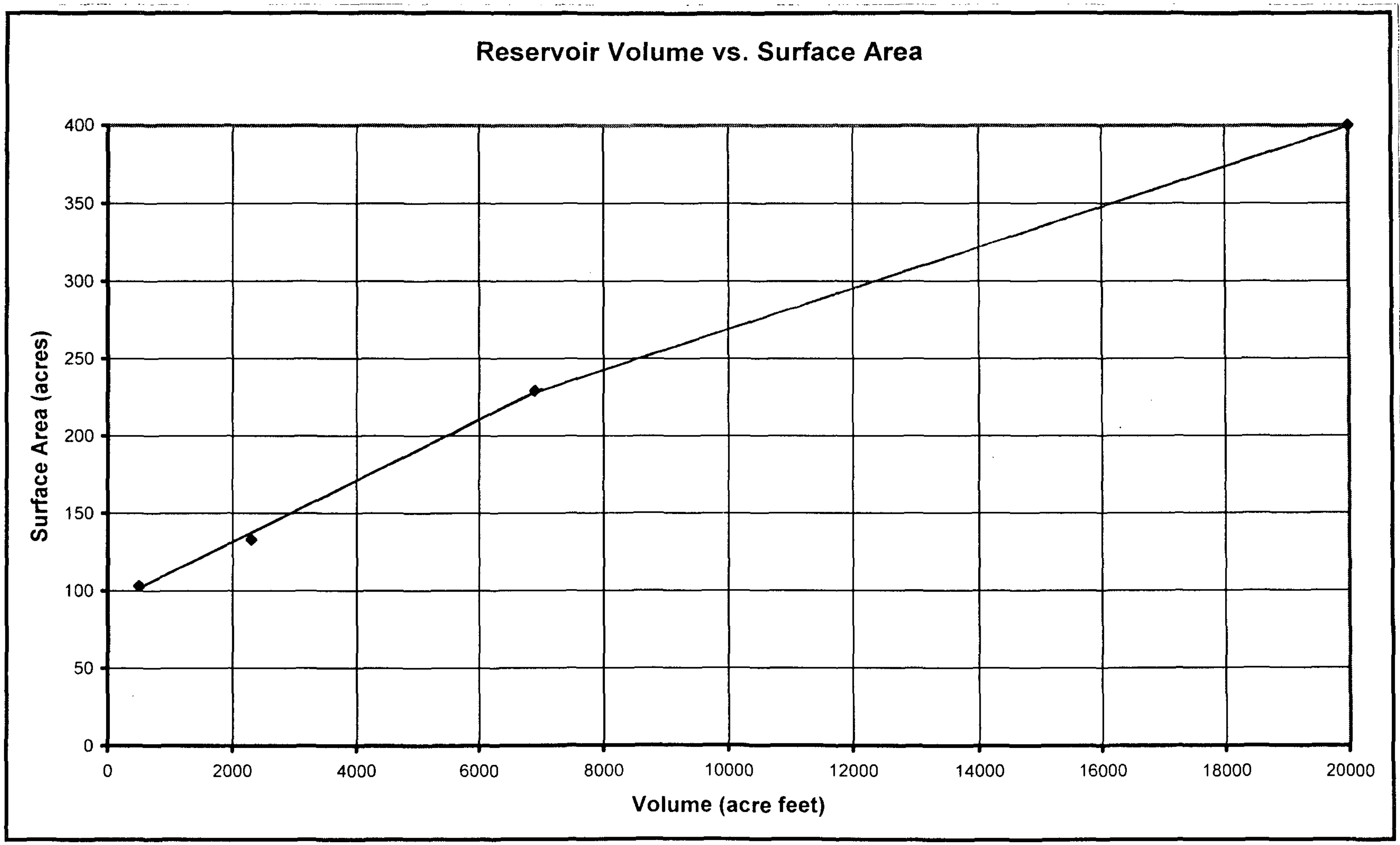
Month	Evap inches	Evap feet	Pan Coeff	Gross Rate feet	Rainfall inches	Rainfall feet	Net Evap Rate feet
Apr	9.73	0.81	0.70	0.57	0.46	0.04	0.53
May	12.67	1.06	0.70	0.74	0.64	0.05	0.69
Jun	14.48	1.21	0.70	0.84	0.55	0.05	0.80
Jul	13.74	1.15	0.70	0.80	1.38	0.12	0.69
Aug	11.68	0.97	0.70	0.68	1.58	0.13	0.55
Sep	9.50	0.79	0.70	0.55	1.19	0.10	0.46
Oct	6.88	0.57	0.70	0.40	1.04	0.09	0.31

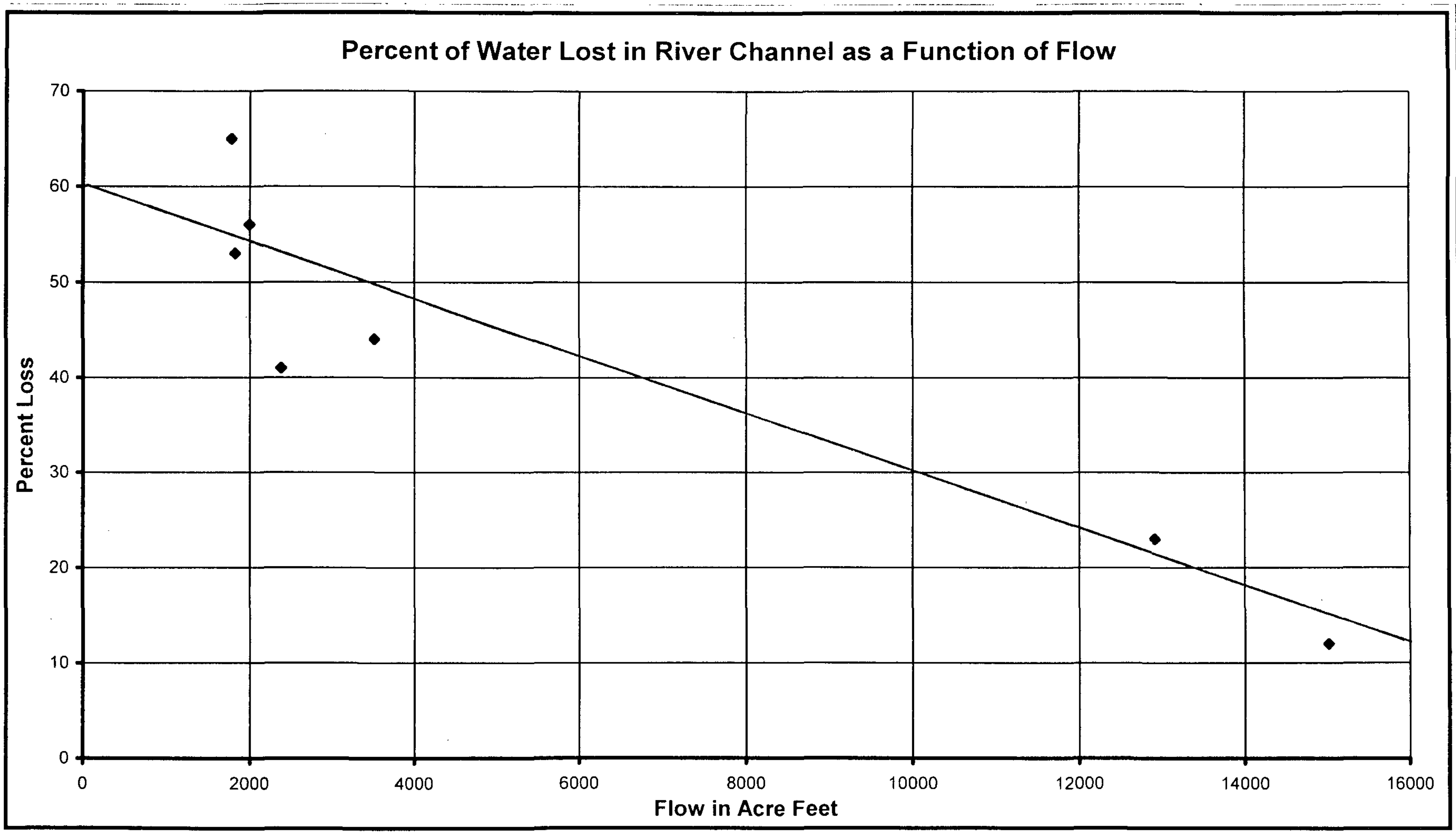
JEMEZ CANYON DAM
MONTHLY EVAPORATION IN INCHES (1954-1990)

YR	APR	MAY	JUN	JUL	AUG	SEP	OCT	SUM
54	10.87	12.13	15.71	14.28	12.14	10.32	7.93	83.38
55	10.43	11.64	16.19	12.45	10.40	10.50	8.71	80.32
56	10.88	14.28	17.09	15.44	13.67	13.33	8.90	93.59
57	8.93	10.80	15.63	13.06	11.25	10.81	5.30	75.78
58	8.48	12.32	14.18	14.71	12.53	8.24	6.08	76.54
59	8.69	13.06	14.00	14.90	10.76	10.91	6.02	78.34
60	10.62	12.73	13.89	13.93	13.60	10.90	6.59	82.26
61	10.06	14.40	14.05	14.30	11.65	9.36	7.68	81.50
62	10.48	14.38	15.00	12.36	13.03	8.78	6.60	80.63
63	12.05	13.28	13.62	15.79	10.75	8.70	6.46	80.65
64	9.22	12.68	15.01	13.69	12.37	8.07	7.88	78.92
65	9.50	12.23	12.04	13.67	11.76	8.77	6.84	74.81
66	10.28	14.82	13.68	12.48	11.00	8.51	7.41	78.18
67	10.91	13.65	11.86	12.57	9.61	8.75	7.60	74.95
68	9.01	12.49	14.57	12.97	10.12	10.05	7.59	77.25
69	10.67	11.76	14.24	13.84	12.89	8.76	6.53	78.69
70	9.82	12.37	11.64	13.15	11.74	9.63	5.90	74.25
71	9.07	12.75	15.93	13.86	10.71	9.94	4.09	76.35
72	11.10	13.39	13.40	14.31	11.74	8.73	4.65	77.32
73	5.26	11.01	13.93	12.28	12.38	8.25	7.29	70.40
74	11.96	14.49	16.19	11.88	10.65	9.05	4.83	79.05
75	8.38	11.51	15.73	12.44	11.71	7.47	7.10	74.34
76	8.92	12.20	15.36	12.62	12.20	8.47	7.62	77.39
77	6.61	13.30	13.97	14.03	12.54	9.50	7.79	77.74
78	12.12	12.07	16.03	15.66	13.49	10.17	8.96	88.50
79	9.30	10.91	12.65	13.55	11.18	9.30	8.96	75.85
80	7.75	11.16	15.39	16.00	12.96	8.88	7.76	79.90
81	9.59	12.98	16.62	13.71	11.59	10.25	7.06	81.80
82	10.86	12.03	16.42	14.30	11.02	8.44	6.17	79.24
83	9.84	12.36	13.81	13.55	11.69	10.91	6.20	78.36
84	10.14	15.22	12.47	15.12	10.85	9.67	4.89	78.36
85	9.18	10.93	12.43	13.57	12.08	9.61	5.96	73.76
86	10.15	12.46	12.82	11.73	11.95	9.28	5.56	73.95
87	8.57	8.06	13.63	13.77	11.01	10.08	7.79	72.91
88	8.60	13.63	12.31	12.99	9.87	8.53	6.89	72.82
89	12.35	16.14	17.22	15.91	12.09	10.28	7.22	91.21
90	9.45	13.28	16.97	13.53	11.33	9.89	7.86	82.31
AVG	9.73	12.67	14.48	13.74	11.68	9.50	6.88	78.69
MAX	12.35	16.14	17.22	16.00	13.67	13.33	8.96	93.59
MIN	5.26	8.06	11.64	11.73	9.61	7.47	4.09	70.40

JEMEZ CANYON DAM
MONTHLY AND ANNUAL PRECIPITATION IN INCHES (1953-1990)

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
53												0.02	
54	0.48	0.59	0.12	0.51	0.40	0.75	0.00	0.65	0.92	1.79	0.27	0.80	7.28
55	0.17	0.09	0.10	0.39	0.09	0.00	0.23	1.01	0.25	2.16	2.28	0.21	6.98
56	0.00	0.00	0.12	0.76	0.42	0.00	0.00	0.20	0.05	0.34	0.51	0.00	2.40
57	0.25	0.00	0.04	0.22	0.79	0.78	0.43	0.86	0.00	1.72	2.28	0.04	7.41
58	2.05	1.15	0.22	0.41	0.32	1.65	0.55	0.09	0.01	0.15	1.07	1.99	9.75
59	0.69	0.50	0.82	0.00	0.02	0.40	0.63	0.40	0.08	0.33	4.37	0.05	8.29
60	2.11	0.03	1.19	0.46	0.53	1.10	0.05	0.55	0.67	0.64	1.65	0.38	9.36
61	3.64	0.32	0.60	0.52	0.06	0.39	0.34	0.00	0.48	0.54	2.04	0.53	9.46
62	0.60	0.64	0.84	0.50	0.24	0.10	0.06	0.02	0.19	2.12	0.71	1.41	7.43
63	1.24	1.52	0.48	0.32	0.57	0.53	0.18	0.19	0.55	0.53	3.25	0.90	10.26
64	0.53	0.22	0.00	0.00	1.39	0.14	0.51	0.31	0.10	1.25	0.97	1.14	6.56
65	0.09	0.24	0.60	0.61	0.68	0.35	0.44	0.81	1.53	0.97	0.41	1.04	7.77
66	1.06	0.28	0.99	0.26	0.22	0.00	0.02	0.30	0.74	0.55	1.87	0.73	7.02
67	0.04	0.04	0.08	0.03	0.33	0.08	0.01	0.15	0.40	0.71	2.01	0.89	4.77
68	0.15	0.34	0.60	0.09	0.62	1.47	0.37	0.86	0.01	0.80	3.22	0.05	8.58
69	0.39	0.36	0.47	0.16	0.23	0.12	1.20	2.30	0.77	1.48	1.57	2.13	11.18
70	2.68	0.14	0.60	0.00	0.16	0.46	0.08	0.76	1.07	3.88	0.48	1.29	11.60
71	0.64	0.34	0.10	0.60	0.20	0.10	0.90	0.10	0.00	3.00	0.90	1.30	8.18
72	1.49	0.51	1.01	0.30	0.03	0.12	0.00	0.68	0.49	0.63	1.86	2.23	9.35
73	3.70	0.37	0.56	0.50	0.22	1.37	0.85	0.44	0.30	1.66	0.87	1.65	12.49
74	0.38	0.11	0.00	0.81	0.28	0.84	0.03	0.45	0.14	2.09	1.05	1.17	7.35
75	2.73	0.34	0.23	0.48	0.07	0.61	0.23	0.35	0.12	3.18	1.27	2.90	13.14
76	0.00	0.23	0.18	0.00	0.09	0.05	0.60	0.40	0.19	1.37	2.24	1.70	7.05
77	0.04	0.10	0.03	0.36	0.00	0.20	0.81	0.27	0.21	0.19	1.10	0.49	3.80
78	0.03	0.83	0.24	0.53	0.66	0.65	0.24	1.48	0.80	0.32	0.96	0.53	7.27
79	0.94	1.47	0.69	1.37	0.12	0.26	0.48	2.24	1.55	0.39	1.58	0.84	11.93
80	0.47	1.45	0.40	0.94	0.82	0.18	0.16	0.72	0.11	0.63	1.57	1.75	9.20
81	0.04	0.08	0.20	0.00	0.21	0.26	0.47	1.79	0.52	2.69	1.23	0.58	8.07
82	1.06	0.30	0.00	0.31	0.29	0.52	0.03	0.82	0.05	1.91	2.33	4.59	12.21
83	0.40	0.90	0.53	0.48	0.49	0.54	0.04	0.42	1.34	1.59	0.61	0.84	8.18
84	1.40	0.20	0.60	0.13	0.00	0.66	0.36	0.00	0.49	0.52	3.13	0.84	8.33
85	2.39	0.49	1.33	0.65	0.35	1.31	2.10	0.72	0.57	1.42	0.56	1.99	13.88
86	2.31	0.36	0.10	0.07	0.60	0.24	0.31	0.67	2.88	1.35	0.98	1.15	11.02
87	2.04	1.96	0.90	0.40	0.38	0.05	0.37	1.27	0.41	0.77	1.96	0.02	10.53
88	0.65	0.65	0.42	0.19	0.06	0.01	2.44	0.42	1.86	1.67	2.06	3.60	14.03
89	0.37	0.25	0.00	0.63	0.35	0.23	0.00	0.14	0.11	2.75	1.39	0.27	6.49
90	1.33	0.00	0.11	0.21	0.44	0.43	1.56	0.68	0.46	3.09	1.74	2.03	12.06
AVG	1.04	0.47	0.42	0.38	0.36	0.46	0.46	0.64	0.55	1.38	1.58	1.19	8.94
MAX	3.70	1.96	1.33	1.37	1.39	1.65	2.44	2.30	2.88	3.88	4.37	4.59	14.03
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.27	0.00	2.40


Reservoir Volume vs. Surface Area
Surface Area (acres)
400
350
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Volume (acre feet)


Percent of Water Lost in River Channel as a Function of Flow
Percent Loss
70
60
50
40
30
20
10
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Flow in Acre Feet