*"Evaluating middle Rio Grande flow alteration at a river network scale to enhance water management opportunities"*

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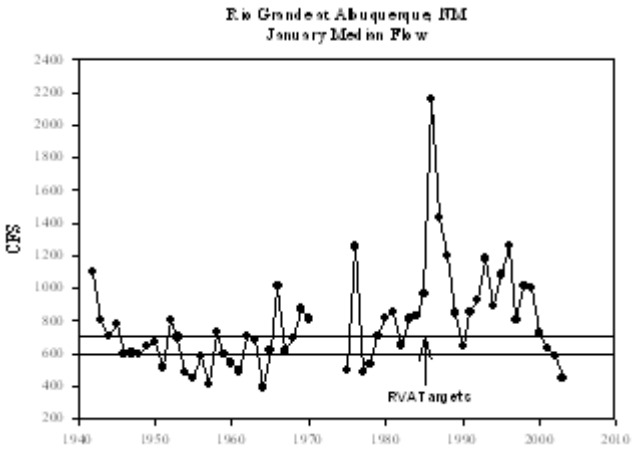


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## EXECUTIVE SUMMARY

Our objective has been to investigate stream flow alteration within the middle Rio Grande (MRG) using the Indicators of Hydrologic Alteration (IHA) approach to quantitatively evaluate the degree to which the flow regime has changed over time in response to major 20th century water development actions. We first identified fourteen U. S. Geological Survey stream flow gaging stations distributed from the Colorado-New Mexico border downstream to Elephant Butte Reservoir with sufficient period-of-record for analysis. Six of these gage stations were located along the mainstem within the designated critical habitat for the Rio Grande silvery minnow (RGSM, *Hybognathus amarus*). Based upon development history, we divided the available record into three time periods: 1) pre-MRGCD, 2) pre-Cochiti Dam, and 3) post-Cochiti Dam, with at least 20 years of record in each period to mitigate possible discrepancies due to climatic variability. We then applied the IHA method to compare 33 different hydrologic parameters between gage stations and time periods. Four stations had sufficient record to allow comparison of the pre-MRGCD and post-Cochiti Dam periods, while at 10 stations we were able to compare pre-Cochiti and post-Cochiti Dam periods. Four secondary stations, either with shorter periods-of-record or located on tributary streams, were also analyzed.

When we compared the pre-MRGCD with the post-Cochiti Dam period, we found overall hydrologic alteration (HA) was low to moderate and quite consistent between stations, with highest HA at the Lobatos, CO gage. At the San Marcial station within the critical habitat, overall alteration was low, with only two of 33 parameters highly altered, the 1-day maximum flow and the flow rise rate. The stream flow target ranges we present for these highly altered parameters could provide guidance for future water management. Also, we found the median date of the annual maximum flow occurred 30 days earlier during the post-Cochiti Dam period, raising concerns regarding the effects of cooler water temperatures on RGSM reproduction.

When we compared the pre-Cochiti with the post-Cochiti Dam periods, we found median monthly stream flows and other parameters describing both high and low flow characteristics were consistently higher during the more recent period. Overall HA was consistently low to moderate and tended to increase in a downstream direction. High alteration of several parameters was found within the RGSM critical habitat, all the result of flow augmentation during the post-Cochiti Dam period. Based upon recently developed relations between RGSM catch rates and flow regime characteristics (Dudley et al, 2005), the enhanced flows of the post-Cochiti Dam period should have lead to increases, not declines, in RGSM numbers.

Our findings indicate stream flow alteration through the MRG over the past century has been modest and the degree of alteration observed is within the range of other western rivers where endangered fish recovery programs are achieving some success. Over the past 29 years, the flow regime through the critical habitat has been substantially enhanced and many flow parameters returned to conditions more characteristic of the early 1900's. However, these enhanced flow conditions have not resulted in RGSM gains, suggesting other factors may limit species recovery. Further flow regime enhancements, other than those mandated in the 2003 Biological Opinion, would not appear prudent at this time until other potential limiting factors are evaluated.

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## INTRODUCTION

Conservation of the Rio Grande silvery minnow (*Hybognathus amarus*) (RGSM) in the middle Rio Grande (MRG) will require creative and flexible water management strategies which enhance species habitat conditions while providing for existing and future water uses within the basin. The March 2003 Biological Opinion (BO; U. S. Fish and Wildlife Service, 2003) strongly implicates recent water management activities with the decline of the species by altering the magnitude, frequency, duration, timing, and variability of river flows. Such alterations in the flow regime that lessen mimicry of the historic hydrograph have been deemed detrimental to the RGSM through the disruption of natural reproductive processes, the reduction in river dynamics and the associated functions of habitat creation and maintenance, and the amplification of river drying events. While the BO identifies water management actions as a principal cause for species declines, quantitative evaluation of the degree of hydrologic alteration has not been conducted. Such an evaluation is needed if water management is to evolve and provide enhanced opportunity for species recovery while protecting historic water uses.

Current ecological thought espouses the view that maintenance of historic hydrologic variability is essential in conserving native riverine biota and ecosystem integrity (Richter et al., 1996; Stanford et al., 1996; Poff et al., 1997). The further the hydrologic regime deviates from the historic condition in terms of stream flow magnitude, frequency, duration, timing, and variability, the greater the probability of modification to the river ecosystem. Based upon these concepts, and the recognition that stream flow regime is a controlling factor of aquatic habitat quantity and quality, The Nature Conservancy (TNC) developed a diagnostic tool for evaluating such deviation from the historic condition. Termed the "Indicators of Hydrologic Alteration" (IHA) approach, the method is first applied to assess the degree of hydrograph alteration that has occurred temporally and spatially within a river system. Second, range of variability analysis (RVA) is then used to establish preliminary target flow ranges which, if met by water managers, will begin to restore the hydrologic regime of the system and provide a solid basis for the development of testable hypotheses regarding species-habitat-flow relations (Richter et al., 1996; Richter et al., 1997). The IHA approach is currently being applied both nationally and internationally as part of ecologically sustainable water management efforts in the Appalachicola-Chattahoochee-Flint basin of the southeastern U. S., the San Pedro River of Arizona, and the river systems within South Africa's Kruger National Park (Richter et al, 2003). Within New Mexico, the approach has recently been used to assist in the evaluation of San Juan River instream flow recommendations (Wesche, 2003).

The goal of our study has been to investigate hydrologic alteration within the MRG using the IHA approach, thereby providing MRG Endangered Species Act Collaborative Program (Program) participants with 1) a quantitative evaluation of the degree to which the MRG flow regime has been changed by major water development actions, 2) "common ground" for discussing future water management opportunities, 3) preliminary stream flow target ranges to help guide future water management decisions, and 4) a template from which Program scientists can develop testable hypotheses to investigate RGSM population-habitat-flow relations and draw insight regarding key limiting factors. To achieve this goal, our specific objectives have been to:

1. Measure and evaluate temporal hydrologic alteration within the MRG due to more recent water development and management actions;

2. Apply a network approach to describe spatial hydrologic alteration within the MRG;

3. For hydrologic parameters identified as highly altered, develop preliminary stream flow target ranges for consideration by Program participants in resolution of water management issues critical to RGSM recovery and present/future water use.

## METHODS

### Description of the IHA Approach

The IHA approach first defines a series of biologically-relevant hydrologic attributes that characterize intra-annual variation in water flow conditions and then uses an analysis of the inter-annual variation in these attributes as the basis for comparing hydrologic regimes before versus after a river has been altered by significant human activities (Richter et al., 1996). The method is statistically based, software driven, and for river applications, the basic data unit is mean daily discharge. Stream flow data are typically obtained from U. S. Geological Survey (USGS) (or other appropriate sources) gage records. Application of the method includes four general steps:

1. The data series is defined for pre- and post-impact periods in the river system of interest, with the period-of-record for each series recommended to be at least 20 years, thereby accounting for natural climatic variability.

2. Values for each of 33 ecologically-relevant hydrologic attributes are calculated for each year in each data series.

3. Inter-annual statistics are computed by calculating measures of central tendency and dispersion for the 33 attributes in each data series, based on the values obtained in Step 2.

4. Values of the Indicators of Hydrologic Alteration are calculated by comparing the 66 inter-annual statistics between the pre-and post- impact data series, and each result is presented as a deviation of one time period relative to the other. The method can be used to compare the state of one river system to itself over time (e.g. temporal comparisons, pre- versus post-impact); or it can be used to compare the state of one system to another (e.g. spatial comparisons, a highly altered system to a less altered, reference system).

The 33 attributes evaluated by the IHA are based upon five fundamental characteristics of hydrologic regimes:

1. ***Flow Magnitude:*** The magnitude of the flow at any given time is a measure of the availability or suitability of the habitat.

2. ***Flow Timing:*** The timing of particular flow conditions can determine whether certain life cycle requirements are met, or influence the degree of stress or mortality associated with extreme events such as floods or droughts.

3. ***Flow Frequency:*** The frequency of occurrence of specific flow conditions such as floods or droughts may be tied to reproduction or mortality events, thereby influencing population dynamics.

4. ***Flow Duration:*** The length of time over which a specific flow condition exists may determine whether a particular life cycle phase can be completed or the degree to which stressful effects such as inundation or desiccation can accumulate.

5. ***Flow Rate of Change:*** The rate of change in flow conditions may be tied to the stranding of certain organisms in ponded depressions or along the water's edge.

The 33 biologically-relevant hydrologic attributes comprising the IHA method are divided into five major groups for purposes of analysis. These groups are:

1. ***IHA Group #1; Magnitude of Monthly Flow Conditions:*** This group includes 12 attributes, the mean or median flow value for each calendar month.

2. ***IHA Group #2; Magnitude and Duration of Annual Extreme Water Conditions:*** This group is comprised of 12 attributes, including the 1-, 3-, 7-, 30-, and 90-day annual flow minima and maxima, the number of zero flow days, and base flow (7-day minimum flow divided by the mean flow for the year).

3. ***IHA Group #3; Timing of Annual Extreme Water Conditions:*** This group includes 2 attributes, the Julian date of the 1-day annual minimum flow condition and the Julian date of the 1-day annual maximum flow condition.

4. ***IHA Group #4; Frequency and Duration of High and Low Flow Pulses:*** The 4 attributes in this group include two which measure the number of annual occurrences during which the flow magnitude exceeds an upper threshold or remains below a lower threshold, respectively, and two which measure the mean duration of such high and low flow pulses. Pulses are defined as those periods within a year in which the mean daily flow rises above the $75^{th}$ percentile (high pulse) or drops below the $25^{th}$ percentile (low pulse) of all daily values for the pre-impact time period.

5. ***IHA Group #5; Rate and Frequency of Flow Change:*** The four attributes in this group measure the number and mean rate of both positive and negative flow changes from one day to the next.

RVA builds upon the IHA analysis described above by using the range of historic (pre-development) variability in the 33 different hydrologic attributes as the basis for setting water

management targets (Richter et al., 1997). The RVA target range for each attribute is normally based upon selected percentile levels or a simple multiple of the parameter standard deviations for the more natural, or pre-development, streamflow regime. The management objective is not to have the river attain the targeted range every year, but to attain the targeted range at the same frequency as occurred in the more natural or pre-development flow regime. For example, attainment of an RVA target range defined by the 75$^{th}$ and 25$^{th}$ percentile values of a particular attribute would be expected in only 50% of years, while a range defined by (+) or (-) one standard deviation would be expected to be attained in about 68% of years, assuming normally distributed data. The degree to which the RVA target range is not attained is a measure of "hydrologic alteration", calculated as:

((Observed - Expected)/Expected) * 100

when expressed as a percentage, where "observed" is the count of years in which the observed value of the hydrologic parameter fell within the targeted range and "expected" is the count of years for which the value is expected to fall within the targeted range. Hydrologic alteration is equal to zero when the observed frequency of post-development annual values falling within the RVA target range equals the expected frequency. A positive deviation indicates the target range is being attained more often than expected, while a negative value indicates attainment less frequently than expected.

## Description of Project Area

The project area is the mainstem Rio Grande from the Colorado-New Mexico state line downstream to the headwaters of Elephant Butte Reservoir, including several major tributaries (Figure 1). Within this area, irrigation by native cultures began perhaps as early as the 1400's, while in more recent times, a diversity of water storage, water diversion, flood control, sediment control, and interbasin transfer projects have been developed to address the hydrologic extremes along the MRG (Tetra Tech EM Inc., 2003). Major water developments brought on-line during the 20$^{th}$ century include:

1916 - Elephant Butte Reservoir on MRG
1935 - San Acacia, Isleta and Angostura diversion dams on MRG
1935 - El Vado Reservoir on Rio Chama
1954 - Jemez Canyon Reservoir on Jemez River
1959 - Low Flow Conveyance Channel (LFCC) on MRG
1963 - Abiquiu Reservoir on Rio Chama
1970 - Galisteo Reservoir on Galisteo Creek
1971 - San Juan-Chama trans-basin diversion
1971 - Heron Reservoir on Rio Chama
1973 - Cochiti Reservoir on MRG

Also within this time frame, municipal wastewater discharges have increased with burgeoning population growth, the most significant being that of the City of Albuquerque, now estimated to be about 60,000 acre-ft per year (Tetra Tech EM Inc., 2003).

Accelerated water development and use within the MRG during the 20th century fostered the development of an extensive stream gaging network by the USGS and other agencies within the project area. These surface water records have been vital to water management and provide the basic stream flow data necessary for our study. USGS gage stations, with their periods-of-record, utilized for IHA analyses included (Figure 1):

- Rio Grande near Lobatos, CO (#08251500); 1899 - present
- Rio Grande near Cerro, NM (#08263500); 1948 - present
- Rio Grande below Taos Junction Bridge near Taos, NM (#08276500); 1925 - present
- Rio Grande at Embudo, NM (#08279500); 1899 - present
- Rio Chama near Chamita, NM (#08290000); 1912 - present
- Rio Grande at Otowi Bridge, NM (#08313000); 1895 - 1905, 1909 - present
- Rio Grande at Cochiti, NM (#08314500); 1926 - 1970
- Rio Grande below Cochiti Dam, NM (#08317400); 1970 - present
- Rio Grande at San Felipe, NM (#08319000); 1925 - present
- Jemez River below Jemez Canyon Dam, NM (#08329000); 1936 - 1938, 1943 - present
- Rio Grande at Albuquerque, NM (#08330000); 1941 - present
- Rio Grande Floodway near Bernardo, NM (#08332010); 1939 - present
- Rio Puerco near Bernardo, NM (#08353000); 1939 - present
- Rio Grande Floodway at San Acacia, NM (#08354900); 1936 - 1958 (pre-LFCC), 1958 - 1964 (LFCC included), 1964 - present (LFCC not included)
- Rio Grande Floodway at San Marcial, NM (#08358400) 1895 - 1964 (total river flow), 1964 - present (floodway only)

## Application of IHA to the Middle Rio Grande

Surface water records for the 15 U. S. Geological Survey (USGS) stream gages analyzed in our study were obtained from the USGS Daily Stream Flow for New Mexico database (http://waterdata.usgs.gov/nm/nwis/discharge). These records were carefully reviewed and data files created for each station and time period as input to the IHA-RVA computer software program (Version 5.0.0) developed and maintained for TNC by Smythe Scientific Software, Boulder, CO (csmythe@webaccess.net). We had anticipated using the most recent upgrade of this software for our analysis, but this version was delayed until late spring 2005 following completion of all model runs. Following the recommendation of TNC and Smythe Scientific Software (2001), non-parametric statistics were used for computing IHA parameters. The coefficient of dispersion (CD) was defined as equal to (75th percentile - 25th percentile)/ 50th percentile, while the high and low pulse thresholds were set as the median plus or minus 25 percent. RVA category boundaries were established as the median plus or minus 17 percent (i.e. between the 33rd and 67th percentiles). HA values were classified as low (-0.33 to +0.33), moderate (-0.34 to - 0.67 and +0.34 to +0.67), or high (< -0.67 and > +0.67) following the guidance of Richter et al, 1998 based upon their analysis of another large, highly variable southwestern river, the Colorado. Absolute values were used to calculate all HA means. The Wilcoxon Signed Rank Test (the non-parametric alternative to the Paired T Test) was used to compare HA values between sites ($p = 0.05$; Analytic Software, 2003).

The time periods analyzed for each stream gage station were based upon the complete years of record available for the station (minimum of 20 years recommended for each period considered to account for climatic variability), the location of the station (with priority given to stations within the RGSM critical habitat) and the water development history of the MRG. Based upon the development chronology provided above, we separated the 1895 to 2003 period into three general analysis periods, as follows:

1) Pre-MRGCD, pre-1935;
2) Pre-Cochiti Dam, 1936 to 1970;
3) Post-Cochiti Dam, 1975 to 2003.

Water years 1971 to 1974 were deleted from analysis to reflect the influence of Cochiti Dam construction and filling, as well as the completion of Heron Reservoir and the San Juan-Chama trans-basin diversion. Based upon the importance of the Albuquerque Reach for recovery (U. S. Fish and Wildlife Service, 2003), the 1942 to 1970 period was commonly used to represent the Pre-Cochiti Dam period, thereby allowing equitable comparisons to be made with the Albuquerque gage (period-of-record 1942 to present). As the activation of the Low Flow Conveyance Channel in 1959 confounded portions of the published record for both the San Acacia and San Marcial gages, the 1936 to 1958 period was used to represent the Pre-Cochiti period at these locations. Similarly, the extensive record at the Bernardo gage was confounded by the inclusion of flows from multiple channels into the published record over several years, thereby limiting the Pre-Cochiti analysis period to less than 20 years.

Based upon these temporal, spatial, and analytic considerations, our primary comparisons of mainstem hydrologic alteration between the Pre-MRGCD and Post-Cochiti Dam periods were for the Rio Grande gage stations near Lobatos, at Embudo, at Otowi Bridge, and at San Marcial. Our primary comparisons between the Pre- and Post-Cochiti Dam periods were for the Rio Grande near Lobatos (1942-70 vs 1975-2003), near Cerros (1949-70 vs 1975-2003), below Taos Junction Bridge (1942-70 vs 1975-2003), at Embudo (1942-70 vs 1975-2003), at Otowi Bridge (1942-70 vs 1975-2003), at/below Cochiti (1942-70 vs 1975-2003), at San Felipe (1942-70 vs 1975-2003), at Albuquerque (1942-70 vs 1975-2003), at San Acacia (1936-58 vs 1975-2003), and at San Marcial (1936-58 vs 1975-2003). Additional comparisons of hydrologic alteration were made for tributary streams including the Rio Puerco, Rio Chama, and Jemez River.

## RESULTS

### Comparison of Pre-MRGCD and Post-Cochiti Periods

Rio Grande stream flows at the four gages having pre-MRGCD records were generally characterized by reduced spring runoff and slightly elevated late season and winter low flows during the post-Cochiti period (Figure 2). Inter-annual variability for the monthly median flows was similar between periods, with highest variability typically observed in the late summer and early fall (Figure 2). Flows were most stable during the winter period.

Overall hydrologic alteration was low to moderate and quite consistent between the four stations (Tables 1 to 5; Figure 3), with no significant differences ($p <= 0.05$) observed between gages based upon paired parameter comparisons (Table 6). Overall HA was highest at the Lobatos, CO gage (0.39) and constant between the remaining three stations (0.33). Among the IHA parameter groups, Group 5 (rate and frequency of flow change) was consistently the most highly altered. Five of the 33 evaluated parameters were highly altered at both Lobatos and Otowi, three at Embudo and two at San Marcial.

The two highly altered parameters observed at San Marcial within the RGSM critical habitat were the 1-day maximum flow and the rise rate, both characteristics commonly dampened by upstream water development and management activity. The 1-day maximum flow was found to be moderately altered at both the Lobatos and Embudo stations, while rise rate was highly altered at Lobatos and moderately altered at Otowi (Figure 4). Comparisons of the annual values for these parameters at San Marcial for the pre-MRGCD and post-Cochiti periods in relation to the RVA target ranges are provided in Figure 5. To reduce the degree of alteration from high to moderate for each parameter would require three additional years during the post-Cochiti period to have fallen within the RVA target range.

Overall, 16 parameters at the San Marcial station fell into the low alteration category when the pre-MRGCD and post-Cochiti periods were compared (Table 5). Many of these parameters were associated with the low flow characteristics of the station (e.g., 1-, 3-, 7-, and 30-day minimums, zero flow days, base flow, and date of minimum, among others). However, the 7- and 30-day maximum flows were also only minimally altered, as were the March, April and July median flows.

**Comparison of Pre-Cochiti and Post-Cochiti Periods**

Median monthly stream flows at the ten Rio Grande stations analyzed were consistently higher throughout the water year during the post-Cochiti period, with the largest increases observed during the spring runoff period throughout the RGSM critical habitat (Figure 6). Inter-annual variability for the monthly median flows tended to be higher during the pre-Cochiti period, with the greatest variability typically observed during the summer period. Flows were most stable during the winter period.

Overall hydrologic alteration was low to moderate in the post-Cochiti period with a gradual increasing trend in the downstream direction (Tables 7 to 17; Figure 7). Overall HA was highest at San Acacia (0.47) and lowest at Lobatos (0.21). Several significant differences ($p < 0.05$) were observed between stations based upon the paired parameter comparisons (Table 18). Hydrologic alteration at Otowi differed from both the Lobatos and Embudo stations, while the Albuquerque gage record was also more highly altered than Lobatos. The San Acacia and San Marcial stations differed from most gages upstream of Otowi, although some of this variation may be due to the differences in the pre-Cochiti period-of-record analyzed at these stations.

Sixteen different hydrologic parameters were highly altered during the post-Cochiti period at one or more stations within the RGSM critical habitat (Table 7). The spatial HA trend for most of

these parameters is generally increasing in a downstream direction (Figure 8) and for the most part reflects the augmented flow regime through the critical habitat during the post-Cochiti period. For example, the 1, 3, 7, 30 and 90-day maximum flow parameters at both San Acacia and San Marcial were highly altered, but the HA values were positive, indicating high flows were occurring more frequently within the RVA target range than would be expected based upon the pre-Cochiti period (Figures 9 to 13). Likewise, several low flow parameters (e.g. December and January medians, 3, 7, and 30-day minimums) were found to be highly altered at several sites within the critical habitat (Figure 8). In these cases, HA values were negative due to post-Cochiti flows too frequently exceeding RVA target ranges (Figure 9 to 13), again reflecting flow augmentation during this recent period.

**Comparisons at Secondary Stations**

IHA analyses were performed at four additional stream gage stations located either on major tributaries of the MRG or on the mainstem but not having sufficient period-of-record to meet the 20 year requirement. These stations included the RG Floodway near Bernardo (1958 - 1970 vs 1975 - 2003), the Rio Puerco near Bernardo (1942 - 1970 vs 1975 - 2003), the Rio Chama near Chamita (1913 - 1935 vs 1975 - 2003), and the Jemez River below Jemez Canyon Dam (1937 - 1953 vs 1955 - 2003). The location of these stations is shown on Figure 1.

Hydrologic alteration at the RG Floodway near Bernardo was moderate, with an overall mean of 0.57, the highest measured at any station during the course of this study (Table 19). As we observed elsewhere through the RGSM critical habitat, the source of much of this alteration was the augmentation of stream flows during the 1975 to 2003 period. Median monthly flows increased from a range of 0 to 963 cfs in the pre-Cochiti period to a range of 228 to 2857 cfs in the post-Cochiti period. The median number of zero flow days declined from 257.0 to 1.0 per year, while most minimum and maximum flow values in Group #2 increased substantially. Overall, 16 of 33 parameters were highly altered as a result of augmentation.

Overall hydrologic alteration at the Rio Puerco station was low, with a mean score of 0.31 (Table 20). As there are no major water storage facilities on the stream, most median monthly flow values increased only slightly during the relatively wet post-Cochiti period, while intermittency remained common with a median value of 195 zero flow days per year. Group 2 minimum flow values remained constant at zero while maximums tended to decline slightly. Overall, while only 5 of 33 parameters were highly altered during the post-Cochiti period, the Rio Puerco flow regime did not experience the augmentation observed throughout the RGSM critical habitat.

Hydrologic alteration on the Rio Chama near Chamita, located downstream of both El Vado and Abiquiu Reservoirs, was moderate with an overall mean HA of 0.47 (Table 21). August, September, December and March median flows were substantially higher during the post-Cochiti period resulting in high HA values. Likewise, all minimum flow values in Group 2 as well as base flow were augmented extensively leading to elevated HA's, while maximum flows also increased but remained within the low alteration category. Overall, 10 of 33 parameters were highly altered.

Hydrologic alteration on the Jemez River following construction of the Jemez Canyon Dam was

moderate, with an overall HA of 0.37 (Table 22). While most median monthly flows increased in the post-dam period, only April and September were highly altered. Within Group 2, only the 3 and 7-day maximum flows were enhanced sufficiently to result in a high degree of alteration, while the number of zero flow days declined substantially from a median value of 104 days per year to only 17 per year. Of the 33 parameters evaluated, 5 were highly altered, 10 were moderately altered, and 18 fell into the low HA category.

### Comparison of Hydrologic Alteration on the Rio Grande with Other Western Rivers

IHA analysis has been conducted on several major western river systems where endangered fish recovery programs are underway. In a case study of the Colorado and Green Rivers, Richter et al (1998) identified six of the 33 IHA parameters as those most greatly affected by reservoir development and operation, including the one-day maxima, 30-day minima, dates of annual maxima and minima, high pulse duration, and number of hydrograph reversals. More recently, Wesche (2003) conducted a spatial comparison of hydrologic alteration on the San Juan River with results reported for the Colorado and Green by Richter et al (1998).

Hydrologic alteration on the Rio Grande through the RGSM critical habitat tends to be near the mid-range when compared with stations from the Colorado, Green and San Juan Rivers (Table 23). Based on the averages of the six parameters across all stations, the overall RG mean of 0.46 ranked it as the second least impaired of the four streams, more altered than the San Juan but less altered than the Green and Colorado. The RG had the highest mean HA value for the 1-day maximum, 0.81, due primarily to the frequency of occurrence of higher flow events within the RVA target ranges during the post-Cochiti period. The RG was the least impaired of the four streams for high pulse duration and 30-day minima, and intermediate for the remaining three parameters.

## DISCUSSION

Overall, stream flow alteration since the 1890's on the Rio Grande through the designated RGSM critical habitat from Cochiti Dam downstream to Elephant Butte Reservoir can be described as low to moderate. While the lack of records prior to this time precludes a more historic quantitative analysis, the available stream gage record covers a period of substantial water development and use expansion and is of sufficient length in most cases (20+ years) to overcome discrepancies associated with climatic variability. Likewise, the available records span the general time period over which RGSM were first considered common, then declining, and finally by the 1990's, endangered. Our goal has been to evaluate flow regime change within the context of this biologic chronology to assist in the identification of potential limiting factors and aid species recovery. Consideration of possible related changes in ground water regime and channel morphology are outside the scope of this study, but are certainly valid research topics.

Hydrologic alteration between the pre-MRGCD and post-Cochiti periods was fairly consistent and generally low from the Colorado-New Mexico border downstream through the critical habitat. Both the Otowi station just upstream of the critical habitat and the San Marcial station

near the downstream boundary experienced little change in most IHA parameters describing the low flow regime. No zero flow days were experienced at Otowi during either period, while the median number of zero flow days at San Marcial declined. Most minimum flow frequency parameters at both stations were unaltered, with the exception of several that reflected enhanced flows during the post-Cochiti period. The number and timing of low flow events were also little altered, while the majority of median monthly flows during typical non-runoff periods (July to February) were greater during the post-Cochiti period, again reflecting only low to moderate alteration. Assuming a direct, positive linkage between low flow regime and aquatic habitat, these results suggest the availability and suitability of riverine habitat was stable between these two time periods.

Most IHA parameters comparing the high flow regime of the pre-MRGCD and post-Cochiti Dam periods were also characterized as having low to moderate alteration. Within the RGSM critical habitat, only the 1-day maximum flow rate and the rise rate at the San Marcial station were highly altered, with the median 1-day maximum flow declining from 10,300 to 4520 cfs and the median rise rate falling from 296 to 131 cfs/day. As both flow volume and rate of rise have been linked to the effectiveness of flushing flows for channel and habitat maintenance purposes (Wesche, 1991), these reductions have potentially contributed to the channel encroachment and narrowing documented in this reach (Tetra Tech EM Inc., 2003). However, such flow reductions may also be of potential benefit to RGSM by lessening the stress of excessive water velocities on adults and juveniles in the narrowed channel and decreasing the distance downstream eggs and larvae are transported. The ecological significance of these highly altered parameters within the context of current and future channel conditions could be the basis for further investigation. The RVA target ranges presented (Figure 5) could provide guidance for future water management.

Other high flow parameters at San Marcial were substantially less altered, including the 3-, 7-, 30- and 90-day maximums, the median monthly flows during the typical runoff period (March through June), and high pulse count and duration. The reduced level of alteration observed in these parameters contributes to the natural shape and variability which remains in the San Marcial hydrograph. One additional high flow parameter of interest is the timing of the annual peak. While alteration was found to be moderate, the median Julian date of the annual maximum flow was 30 days earlier in the post-Cochiti period than in the pre-MRGCD period (Table 5). We hypothesize such a timing shift could potentially affect RGSM reproduction due to cooler water temperatures, reduced egg production, prolonged incubation periods, and slower growth. Future research could investigate the ecological significance of this alteration.

Stream flow regimes throughout the RGSM critical habitat have been substantially enhanced during the post-Cochiti Dam period when compared to the pre-Cochiti period, with 95 percent of median monthly flows being higher during the more recent period. Such augmentation accounts for most of the hydrologic alteration observed between these time periods within the critical habitat. For example, high alteration at the Albuquerque station for the January median flow was the result of too many monthly values exceeding the RVA target range, while for the low pulse count parameter, the occurrence of too few low flow events led to high alteration (Figure 11; Table 15). Likewise, at the San Felipe, San Acacia, and San Marcial stations the 1-day maximum flow parameters were highly altered, again the result of too many values falling within the target

ranges, not too few (Figures 10, 12, and 13). Such trends for both high and low flow parameters were spatially consistent throughout the RGSM critical habitat during the post-Cochiti period. These results suggest improved habitat conditions over the past 29 years, although the potential effects of elevated stream flows in the altered MRG channel could be a research issue.

Recent attempts to link RGSM catch rates to flow characteristics suggest the enhanced regime through the critical habitat during the post-Cochiti Dam period should benefit recovery. At Albuquerque, the relationship that explained the most variation in mean catch rate was the number of days flow exceeded 3000 cfs during the spring, while in the San Acacia reach there was a strong negative correlation between low flow days less than 100 cfs and mean October catch rate (Dudley et al, 2005). During the post-Cochiti period, we found that median monthly spring flows at Albuquerque were substantially enhanced and that both May and June median monthly flows exceeded 3000 cfs. Also, the median 1-, 3-, 7-, 30- and 90-day maximum flow events far exceeded the 3000 cfs criterion and the median 1-, 3-, 7-, 30-, and 90-day minimum monthly flows, as well as all median monthly flows, exceeded the 100 cfs criterion. Downstream at the San Acacia station during the post-Cochiti period, the median 1-, 3-, 7-, and 30-day maximum flows exceeded the 3000 cfs criterion, while all median monthly flows as well as the median 30- and 90-day minimum flows exceeded the 100 cfs criterion. If these RGSM catch rate-flow relations demonstrate a cause-effect relationship, our findings suggest the enhanced flow regime during the post-Cochiti Dam period should have lead to an increasing, not declining, RGSM population. More rigorous evaluation of these relations appears necessary.

Our results indicate stream flow alteration through the middle Rio Grande over the past century has been modest and the degree of alteration observed is within the range of other western rivers where endangered fish recovery programs are achieving some success. While the lack of stream flow data precludes analysis prior to the 1890's and consideration of related changes in ground water regimes and channel morphology are outside our study scope, the available USGS surface water records span the accelerated development of the mid-20$^{th}$ century when status of the RGSM deteriorated from common, to declining and endangered. The temporal pattern of hydrologic alteration however, does not mimic this biologic trend. Over the past 29 years the flow regime throughout the critical habitat has been substantially enhanced and many flow parameters returned to conditions more characteristic of the early 1900's. However, these enhanced hydrologic conditions have not resulted in measurable RGSM gains, suggesting other factors are limiting recovery. Further flow regime enhancements, other than those mandated in the 2003 BO, would not appear prudent at this time until other potential limiting factors are evaluated.

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Table 1. Summary of hydrologic alteration at four Rio Grande USGS gage stations comparing pre-MRGCD and post-Cochiti Dam periods.

| Station | Overall HA | Group 1 HA | Group 2 HA | Group 3 HA | Group 4 HA | Group 5 HA | Highly Altered Parameters |
|---|---|---|---|---|---|---|---|
| RG nr Lobatos, CO (1900-35) | 0.39 | 0.33 (0.07-0.55) | 0.37 (0.0-0.76) | 0.14 (0.03-0.24) | 0.44 (0.07-0.86) | 0.86 (0.69-1.0) | 30-day min; Low pulse duration; rise rate; fall rate; # reversals |
| RG at Embudo, NM | 0.33 | 0.30 (0.03-0.79) | 0.32 (0.0-0.55) | 0.18 (0.07-0.28) | 0.36 (0.04-0.63) | 0.49 (0.24-0.90) | Jan median; March median; # reversals |
| RG at Otowi Bridge | 0.33 | 0.44 (0.07-0.85) | 0.19 (0.0-0.90) | 0.24 (0.17-0.32) | 0.30 (0.04-0.71) | 0.58 (0.32-0.82) | Oct median; July median; Base Q; high pulse duration; # reversals |
| RG at San Marcial | 0.33 | 0.29 (0.03-0.55) | 0.24 (0.03-0.90) | 0.38 (0.22-0.55) | 0.41 (0.20-0.59) | 0.67 (0.48-0.90) | 1-day maximum; rise rate |

Table 2. Indicator of Hydrologic Alteration analysis for Rio Grande near Lobatos, Colorado, for the pre-MRGCD period (1900-1935) compared to post-Cochiti Dam period (1975-2003).

| | Pre - MRGCD Period 1900-35 | | | | Post-Cochiti Period 1975-2003 | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range Limits | | | | Range Limits | | | | |
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | **(cfs)** | | **(cfs)** | **(cfs)** | **(cfs)** | | **(cfs)** | **(cfs)** | **(cfs)** | **(cfs)** | |
| October | 197.1 | 3.02 | 21.7 | 3141.9 | 87.7 | 2.13 | 18.0 | 1203.2 | 121.11 | 435.67 | -0.17 |
| November | 335.1 | 0.97 | 19.2 | 1100.2 | 216.8 | 1.40 | 73.8 | 948.1 | 266.46 | 432.37 | -0.38 |
| December | 343.6 | 0.48 | 26.8 | 655.5 | 274.4 | 0.59 | 88.1 | 654.3 | 300.00 | 381.88 | -0.43 |
| January | 301.5 | 0.42 | 25.0 | 500.0 | 279.7 | 0.49 | 114.7 | 521.5 | 272.58 | 369.59 | 0.34 |
| February | 373.8 | 0.54 | 25.0 | 672.7 | 327.9 | 0.46 | 180.5 | 595.4 | 290.13 | 435.17 | 0.45 |
| March | 519.0 | 0.49 | 33.9 | 1244.8 | 432.8 | 0.69 | 157.1 | 884.0 | 407.18 | 556.88 | -0.48 |
| April | 508.6 | 1.01 | 32.3 | 2889.8 | 484.8 | 1.47 | 59.0 | 2325.8 | 412.55 | 757.57 | -0.07 |
| May | 1855.0 | 1.35 | 21.5 | 5691.0 | 861.4 | 1.35 | 31.2 | 4958.4 | 1512.62 | 2538.45 | -0.48 |
| June | 1868.2 | 1.79 | 20.3 | 7217.3 | 1063.3 | 1.75 | 19.8 | 4417.7 | 1118.82 | 2848.46 | 0.03 |
| July | 404.1 | 2.00 | 10.9 | 5440.0 | 326.3 | 1.90 | 10.0 | 2754.1 | 163.54 | 761.91 | 0.45 |
| August | 222.2 | 1.98 | 9.7 | 1740.6 | 153.9 | 1.03 | 7.7 | 1281.0 | 74.27 | 353.37 | 0.55 |
| Septembe | 157.8 | 2.27 | 16.1 | 2362.3 | 63.2 | 2.13 | 13.1 | 938.4 | 83.75 | 362.54 | -0.17 |
| **Parameter Group #2** | **(cfs)** | | **(cfs)** | **(cfs)** | **(cfs)** | | **(cfs)** | **(cfs)** | **(cfs)** | **(cfs)** | |
| 1-day minimum | 45.0 | 1.89 | 6.0 | 475.0 | 31.0 | 0.94 | 4.1 | 100.0 | 23.68 | 75.79 | 0.66 |
| 3-day minimum | 46.8 | 1.81 | 6.0 | 500.0 | 32.3 | 0.95 | 4.4 | 106.0 | 26.05 | 79.30 | 0.55 |
| 7-day minimum | 56.6 | 1.61 | 6.3 | 500.0 | 36.1 | 1.00 | 4.9 | 115.1 | 26.99 | 84.36 | 0.66 |
| 30-day minimum | 77.9 | 1.97 | 8.7 | 500.0 | 43.8 | 1.12 | 7.0 | 154.8 | 39.21 | 116.28 | 0.76 |
| 90-day minimum | 175.8 | 1.14 | 12.2 | 475.1 | 74.0 | 1.31 | 9.9 | 328.6 | 73.12 | 237.65 | 0.45 |
| 1-day maximum | 4640.0 | 1.19 | 497.0 | 13100.0 | 2070.0 | 1.22 | 279.0 | 6660.0 | 3517.30 | 6944.90 | -0.38 |
| 3-day maximum | 4575.0 | 1.18 | 490.0 | 12833.3 | 1893.3 | 1.32 | 255.7 | 6453.3 | 3238.40 | 6705.63 | -0.28 |
| 7-day maximum | 4255.0 | 1.22 | 489.7 | 12342.9 | 1704.3 | 1.40 | 226.1 | 6008.6 | 2942.91 | 6280.92 | -0.07 |
| 30-day maximum | 2905.5 | 1.28 | 409.6 | 9985.7 | 1516.3 | 1.10 | 197.5 | 5237.7 | 2082.34 | 4180.38 | -0.38 |
| 90-day maximum | 1760.1 | 1.29 | 359.9 | 5311.4 | 915.8 | 1.04 | 172.8 | 3572.8 | 1191.93 | 2720.12 | -0.07 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median | 0.1 | 0.92 | 0.0 | 0.3 | 0.1 | 1.00 | 0.0 | 0.2 | 0.06 | 0.11 | 0.14 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 229.0 | 0.20 | 70.0 | 364.0 | 263.0 | 0.08 | 213.0 | 358.0 | 210.21 | 259.32 | 0.24 |
| Date of maximum | 154.0 | 0.07 | 53.0 | 275.0 | 157.0 | 0.11 | 54.0 | 340.0 | 146.42 | 165.79 | 0.03 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 3.0 | 0.92 | 0.0 | 18.0 | 4.0 | 1.25 | 1.0 | 13.0 | 2.00 | 4.00 | -0.21 |
| Low Pulse Duration (days) | 12.0 | 2.73 | 0.0 | 100.0 | 14.3 | 1.37 | 1.5 | 89.5 | 7.53 | 33.84 | 0.86 |
| High Pulse Count | 4.0 | 1.00 | 0.0 | 12.0 | 3.0 | 1.17 | 0.0 | 10.0 | 2.21 | 5.00 | 0.62 |
| High Pulse Duration (days) | 21.9 | 0.92 | 0.0 | 78.3 | 16.3 | 1.71 | 0.0 | 84.0 | 12.05 | 26.26 | -0.07 |
| The low pulse threshold is (cfs) | 190.0 | | | | | | | | | | |
| The high pulse level is (cfs | 670.8 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 129.3 | 0.73 | 13.4 | 389.9 | 44.1 | 0.87 | 7.3 | 97.1 | 98.55 | 162.33 | -1.00 |
| Fall rate (cfs/day) | -112.4 | -0.80 | -289.8 | -9.7 | -43.0 | -0.91 | -93.3 | -6.8 | -132.34 | -81.71 | -0.69 |
| Number of reversals | 67.0 | 0.63 | 18.0 | 123.0 | 107.0 | 0.24 | 74.0 | 139.0 | 50.68 | 81.58 | -0.90 |

Table 3. Indicator of Hydrologic Alteration analysis for Rio Grande near Embudo, New Mexico, for the pre-MRGCD period (1899-1935) compared to post-Cochiti Dam period (1975-2003).

| | Pre - MRGCD Period 1899-1935 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 420.1 | 0.81 | 230.6 | 1888.4 | 368.3 | 0.54 | 200.5 | 1535.5 | 339.79 | 571.93 | 0.24 |
| November | 501.4 | 0.59 | 230.8 | 1335.0 | 509.0 | 0.61 | 267.1 | 1338.0 | 475.67 | 670.37 | 0.03 |
| December | 503.7 | 0.37 | 264.2 | 901.6 | 528.3 | 0.36 | 281.3 | 956.1 | 478.48 | 564.23 | -0.07 |
| January | 477.1 | 0.30 | 280.0 | 668.6 | 545.4 | 0.38 | 326.3 | 786.8 | 455.03 | 534.94 | -0.69 |
| February | 536.8 | 0.34 | 290.0 | 786.4 | 611.4 | 0.34 | 395.5 | 887.7 | 485.15 | 640.80 | -0.07 |
| March | 752.3 | 0.25 | 280.0 | 1103.6 | 770.8 | 0.49 | 395.5 | 1290.0 | 680.74 | 774.98 | -0.79 |
| April | 864.7 | 0.77 | 280.0 | 3773.3 | 857.3 | 1.23 | 273.6 | 3288.0 | 662.58 | 1200.97 | -0.07 |
| May | 2584.0 | 0.93 | 280.0 | 6576.1 | 1865.5 | 1.05 | 188.6 | 6650.3 | 1255.69 | 3076.32 | 0.24 |
| June | 2408.3 | 1.27 | 249.3 | 8971.3 | 1637.6 | 1.67 | 179.8 | 6180.7 | 1550.91 | 3282.75 | -0.17 |
| July | 594.4 | 1.69 | 158.1 | 3466.1 | 621.7 | 1.12 | 162.7 | 3540.1 | 415.54 | 1075.10 | 0.55 |
| August | 429.1 | 1.11 | 172.7 | 1742.3 | 409.3 | 0.74 | 151.3 | 1551.0 | 284.10 | 553.30 | 0.45 |
| September | 372.7 | 0.71 | 228.3 | 2253.6 | 305.8 | 0.85 | 172.6 | 1178.1 | 314.16 | 503.83 | -0.28 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 245.0 | 0.29 | 130.0 | 450.0 | 239.0 | 0.31 | 145.0 | 376.0 | 223.69 | 265.00 | -0.34 |
| 3-day minimum | 248.7 | 0.34 | 138.3 | 475.0 | 245.0 | 0.30 | 145.7 | 385.0 | 228.81 | 275.93 | -0.17 |
| 7-day minimum | 254.7 | 0.38 | 140.0 | 512.9 | 253.1 | 0.30 | 146.7 | 435.0 | 233.25 | 278.27 | -0.17 |
| 30-day minimum | 275.2 | 0.40 | 154.3 | 591.3 | 269.5 | 0.35 | 150.5 | 421.9 | 251.80 | 334.30 | 0.14 |
| 90-day minimum | 356.3 | 0.49 | 193.5 | 623.0 | 306.7 | 0.45 | 160.8 | 653.3 | 289.45 | 424.86 | 0.34 |
| 1-day maximum | 5300.0 | 1.07 | 500.0 | 15900.0 | 2930.0 | 1.51 | 619.0 | 9120.0 | 2310.50 | 7210.10 | 0.55 |
| 3-day maximum | 5118.3 | 1.09 | 500.0 | 15300.0 | 2883.3 | 1.49 | 604.3 | 8866.7 | 2292.57 | 7029.07 | 0.55 |
| 7-day maximum | 4660.7 | 1.11 | 500.0 | 14285.7 | 2798.6 | 1.39 | 578.0 | 8285.7 | 2152.49 | 6597.10 | 0.55 |
| 30-day maximum | 3584.3 | 0.99 | 492.7 | 10353.7 | 2372.0 | 1.31 | 510.9 | 6875.0 | 1692.81 | 4503.47 | 0.45 |
| 90-day maximum | 2132.4 | 1.04 | 497.6 | 5920.1 | 1760.8 | 1.08 | 422.0 | 5108.2 | 1208.52 | 3057.06 | 0.45 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median) | 0.3 | 0.52 | 0.1 | 0.8 | 0.3 | 0.75 | 0.1 | 0.6 | 0.24 | 0.32 | -0.17 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 235.0 | 0.21 | 40.0 | 366.0 | 269.0 | 0.08 | 220.0 | 289.0 | 222.46 | 257.31 | -0.28 |
| Date of maximum | 153.5 | 0.07 | 48.0 | 332.0 | 146.0 | 0.06 | 55.0 | 275.0 | 146.46 | 163.93 | -0.07 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 4.0 | 1.25 | 0.0 | 14.0 | 5.0 | 0.70 | 2.0 | 15.0 | 2.00 | 6.77 | 0.63 |
| Low Pulse Duration (days) | 9.9 | 1.82 | 0.0 | 100.7 | 12.3 | 1.29 | 1.0 | 61.0 | 7.74 | 17.21 | 0.14 |
| High Pulse Count | 4.0 | 1.00 | 0.0 | 11.0 | 3.0 | 0.67 | 0.0 | 9.0 | 3.00 | 5.00 | -0.04 |
| High Pulse Duration (days) | 18.7 | 1.13 | 0.0 | 68.0 | 23.5 | 1.40 | 0.0 | 110.0 | 15.75 | 25.49 | -0.62 |
| The low pulse threshold is (cfs) | 400.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 890.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 94.2 | 0.94 | 12.6 | 166.1 | 53.2 | 1.00 | 10.7 | 119.5 | 60.35 | 123.89 | 0.24 |
| Fall rate (cfs/day) | -82.0 | -0.84 | -191.7 | -15.9 | -48.5 | -0.93 | -93.7 | -8.5 | -105.27 | -50.11 | 0.34 |
| Number of reversals | 94.0 | 0.32 | 9.0 | 131.0 | 118.0 | 0.17 | 93.0 | 150.0 | 83.69 | 100.77 | -0.90 |

Table 4. Indicator of Hydrologic Alteration analysis for Rio Grande at Otowi Bridge, New Mexico, for the pre-MRGCD period (1899-1935) compared to post-Cochiti Dam period (1975-2003).

| | Pre - MRGCD Period 1899-1935 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 570.4 | 1.22 | 279.0 | 5474.5 | 731.9 | 0.64 | 361.1 | 2224.5 | 420.43 | 887.96 | 0.85 |
| November | 616.9 | 0.63 | 309.0 | 3210.0 | 810.5 | 0.94 | 367.6 | 2034.3 | 549.31 | 797.47 | -0.42 |
| December | 632.2 | 0.56 | 312.6 | 3210.0 | 763.0 | 0.66 | 425.7 | 1959.0 | 526.34 | 716.80 | -0.42 |
| January | 637.9 | 0.43 | 350.0 | 3210.0 | 730.6 | 0.50 | 436.1 | 1757.4 | 580.74 | 729.52 | -0.51 |
| February | 747.6 | 0.36 | 350.0 | 3210.0 | 798.3 | 0.51 | 498.1 | 2641.4 | 675.82 | 839.82 | -0.42 |
| March | 1221.0 | 0.50 | 350.0 | 3251.0 | 1348.7 | 0.59 | 610.1 | 3126.8 | 986.39 | 1380.86 | -0.51 |
| April | 2332.3 | 0.84 | 350.0 | 6189.7 | 2078.4 | 1.06 | 488.7 | 6412.0 | 1612.92 | 2682.37 | -0.32 |
| May | 5639.4 | 0.81 | 350.0 | 12770.6 | 3679.7 | 0.98 | 638.6 | 8390.0 | 3081.41 | 6618.57 | 0.36 |
| June | 3210.0 | 1.28 | 274.1 | 11926.7 | 3086.0 | 1.13 | 844.1 | 7914.0 | 2196.84 | 4411.92 | -0.13 |
| July | 992.6 | 1.89 | 178.6 | 5691.9 | 1336.2 | 0.41 | 734.6 | 4548.1 | 633.74 | 1482.72 | 0.85 |
| August | 675.7 | 1.07 | 164.8 | 2637.1 | 967.7 | 0.39 | 633.2 | 2131.9 | 431.35 | 961.72 | 0.36 |
| September | 579.8 | 1.19 | 257.6 | 3411.3 | 976.3 | 0.52 | 414.6 | 1553.0 | 444.20 | 830.29 | 0.07 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 245.0 | 0.79 | 60.0 | 650.0 | 330.0 | 0.58 | 195.0 | 821.0 | 191.20 | 321.52 | 0.36 |
| 3-day minimum | 256.7 | 0.72 | 61.7 | 663.3 | 401.7 | 0.47 | 212.7 | 874.3 | 200.44 | 324.11 | -0.03 |
| 7-day minimum | 260.7 | 0.63 | 65.7 | 692.9 | 431.9 | 0.63 | 259.3 | 916.9 | 231.60 | 336.68 | -0.13 |
| 30-day minimum | 314.0 | 0.68 | 108.2 | 758.3 | 515.7 | 0.44 | 352.0 | 1154.4 | 269.41 | 382.96 | -0.61 |
| 90-day minimum | 412.4 | 0.54 | 213.8 | 820.0 | 592.7 | 0.48 | 388.6 | 1258.2 | 360.80 | 543.60 | 0.07 |
| 1-day maximum | 8000.0 | 0.98 | 1000.0 | 22200.0 | 5030.0 | 1.13 | 1650.0 | 12000.0 | 6908.00 | 11372.00 | -0.03 |
| 3-day maximum | 7740.0 | 0.93 | 1806.7 | 20700.0 | 4840.0 | 1.15 | 1520.0 | 11833.3 | 6479.60 | 10191.87 | -0.03 |
| 7-day maximum | 7231.4 | 0.90 | 1698.6 | 20357.1 | 4564.3 | 1.16 | 1312.9 | 11528.6 | 5443.60 | 9346.80 | 0.07 |
| 30-day maximum | 6131.7 | 0.93 | 1195.5 | 15526.7 | 4205.0 | 1.08 | 1164.1 | 9206.0 | 4168.87 | 7342.80 | 0.07 |
| 90-day maximum | 3682.0 | 0.98 | 923.6 | 8922.0 | 3466.9 | 0.93 | 894.6 | 7192.7 | 2860.70 | 5187.18 | -0.03 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median | 0.2 | 0.60 | 0.1 | 0.7 | 0.3 | 0.61 | 0.1 | 0.6 | 0.15 | 0.20 | -0.90 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 246.0 | 0.17 | 1.0 | 353.0 | 275.0 | 0.18 | 30.0 | 351.0 | 226.48 | 267.72 | -0.32 |
| Date of maximum | 144.0 | 0.10 | 105.0 | 327.0 | 141.0 | 0.06 | 103.0 | 366.0 | 138.80 | 156.64 | 0.17 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 4.0 | 1.50 | 0.0 | 21.0 | 4.0 | 1.50 | 0.0 | 14.0 | 3.00 | 8.00 | -0.25 |
| Low Pulse Duration (days) | 10.3 | 1.19 | 0.0 | 72.8 | 3.3 | 1.46 | 0.0 | 34.3 | 4.91 | 12.81 | -0.22 |
| High Pulse Count | 4.0 | 0.75 | 0.0 | 8.0 | 4.0 | 0.63 | 0.0 | 10.0 | 3.00 | 6.00 | -0.04 |
| High Pulse Duration (days) | 14.3 | 1.04 | 0.0 | 63.0 | 17.0 | 1.47 | 0.0 | 63.7 | 12.56 | 19.39 | -0.71 |
| The low pulse threshold is (cfs) | 500.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1720.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 198.3 | 0.61 | 53.9 | 444.7 | 103.1 | 0.47 | 44.9 | 188.9 | 149.60 | 245.73 | -0.61 |
| Fall rate (cfs/day) | -154.2 | -0.70 | -330.2 | -44.6 | -95.7 | -0.48 | -159.3 | -45.9 | -189.61 | -127.52 | -0.32 |
| Number of reversals | 103.0 | 0.23 | 10.0 | 142.0 | 129.0 | 0.18 | 100.0 | 159.0 | 97.56 | 109.00 | -0.82 |

Table 5. Indicator of Hydrologic Alteration analysis for Rio Grande Floodway at San Marcial, New Mexico, for the pre-MRGCD period (1899-1935) compared to post-Cochiti Dam period (1975-2003).

| | Pre - MRGCD Period 1899-1935 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 265.6 | 3.99 | 0.0 | 6631.3 | 144.2 | 1.57 | 0.0 | 1510.6 | 81.57 | 555.88 | 0.55 |
| November | 457.0 | 1.32 | 41.0 | 1730.0 | 718.4 | 0.83 | 0.0 | 2065.1 | 257.16 | 675.97 | 0.03 |
| December | 573.6 | 0.63 | 164.2 | 1730.0 | 661.1 | 0.83 | 0.0 | 1812.3 | 451.69 | 716.06 | 0.03 |
| January | 636.4 | 0.45 | 165.6 | 997.4 | 688.8 | 0.59 | 0.0 | 2050.0 | 545.02 | 730.01 | -0.17 |
| February | 689.5 | 0.45 | 166.7 | 1524.1 | 774.0 | 0.48 | 0.0 | 3109.6 | 633.73 | 768.78 | -0.38 |
| March | 788.8 | 0.89 | 129.4 | 3543.9 | 652.6 | 1.35 | 0.0 | 2518.1 | 640.58 | 1038.58 | -0.28 |
| April | 1665.2 | 1.40 | 90.7 | 5292.0 | 1310.1 | 1.42 | 17.4 | 4763.5 | 726.31 | 2218.08 | 0.24 |
| May | 4121.8 | 1.22 | 72.5 | 15656.1 | 2352.9 | 1.27 | 0.0 | 5322.9 | 2006.20 | 5174.77 | 0.34 |
| June | 2750.3 | 1.83 | 3.8 | 12014.7 | 2132.4 | 1.51 | 0.0 | 5338.3 | 1220.94 | 4524.55 | 0.45 |
| July | 707.5 | 3.05 | 0.0 | 5346.5 | 343.1 | 3.41 | 23.9 | 4654.5 | 382.62 | 1720.75 | -0.17 |
| August | 565.7 | 1.68 | 0.0 | 4467.5 | 413.5 | 1.34 | 1.2 | 2438.4 | 189.12 | 848.96 | 0.45 |
| September | 214.7 | 2.65 | 0.0 | 5177.7 | 294.0 | 1.75 | 0.0 | 1340.5 | 102.86 | 447.48 | 0.34 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.0 | 0.00 | 0.0 | 685.0 | 0.0 | 0.00 | 0.0 | 43.0 | 0.00 | 0.00 | -0.05 |
| 3-day minimum | 0.0 | 0.00 | 0.0 | 701.7 | 0.0 | 0.00 | 0.0 | 53.7 | 0.00 | 0.00 | -0.05 |
| 7-day minimum | 0.0 | 0.00 | 0.0 | 797.9 | 0.0 | 0.00 | 0.0 | 104.6 | 0.00 | 0.00 | -0.06 |
| 30-day minimum | 9.0 | 7.35 | 0.0 | 929.5 | 18.4 | 3.66 | 0.0 | 175.6 | 3.41 | 45.64 | -0.07 |
| 90-day minimum | 122.2 | 2.37 | 1.5 | 916.6 | 149.5 | 2.12 | 0.0 | 693.7 | 72.68 | 198.41 | -0.48 |
| 1-day maximum | 10300.0 | 0.72 | 470.0 | 33000.0 | 4520.0 | 0.65 | 1030.0 | 8110.0 | 7276.70 | 11654.00 | -0.90 |
| 3-day maximum | 7605.0 | 0.95 | 458.3 | 27066.7 | 4040.0 | 0.81 | 609.7 | 7886.7 | 5482.67 | 11074.80 | -0.59 |
| 7-day maximum | 7090.0 | 1.07 | 430.0 | 26500.0 | 3697.1 | 0.88 | 425.3 | 7437.1 | 4643.49 | 9808.80 | -0.17 |
| 30-day maximum | 5285.2 | 1.09 | 378.8 | 19116.7 | 2839.0 | 1.03 | 361.7 | 6571.3 | 3876.33 | 6919.33 | 0.14 |
| 90-day maximum | 3524.7 | 1.23 | 333.1 | 10934.0 | 2033.3 | 1.15 | 339.1 | 5044.6 | 2161.45 | 4621.94 | 0.34 |
| Number of zero days (#) | 28.0 | 1.61 | 0.0 | 92.0 | 22.0 | 2.77 | 0.0 | 197.0 | 11.23 | 42.54 | 0.03 |
| Base flow (7-day min/median) | 0.0 | 0.00 | 0.0 | 0.3 | 0.0 | 0.00 | 0.0 | 0.1 | 0.00 | 0.00 | -0.06 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 261.0 | 0.16 | 154.0 | 361.0 | 275.0 | 0.20 | 82.0 | 330.0 | 231.84 | 275.00 | -0.22 |
| Date of maximum | 189.0 | 0.31 | 110.0 | 345.0 | 159.0 | 0.17 | 2.0 | 260.0 | 148.46 | 234.40 | 0.55 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 5.0 | 0.85 | 0.0 | 10.0 | 7.0 | 0.50 | 2.0 | 13.0 | 4.00 | 6.00 | -0.20 |
| Low Pulse Duration (days) | 12.6 | 0.48 | 0.0 | 140.5 | 13.6 | 0.74 | 2.9 | 64.5 | 8.90 | 13.44 | -0.59 |
| High Pulse Count | 7.0 | 0.57 | 0.0 | 16.0 | 5.0 | 1.30 | 0.0 | 12.0 | 5.00 | 8.00 | -0.48 |
| High Pulse Duration (days) | 12.8 | 0.79 | 0.0 | 33.8 | 11.0 | 1.31 | 0.0 | 48.0 | 9.60 | 15.66 | -0.38 |
| The low pulse threshold is (cfs) | 200.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1320.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 296.4 | 0.62 | 3.1 | 847.9 | 131.0 | 0.70 | 27.7 | 288.7 | 228.15 | 366.15 | -0.90 |
| Fall rate (cfs/day) | -219.3 | -0.64 | -630.4 | -2.2 | -103.3 | -0.74 | -222.3 | -21.6 | -261.91 | -167.50 | -0.48 |
| Number of reversals | 101.0 | 0.40 | 21.0 | 158.0 | 119.0 | 0.22 | 53.0 | 161.0 | 76.23 | 105.00 | -0.62 |

Table 6. P-values for Wilcoxon Signed Rank Tests comparing hydrologic alteration between four Rio Grande USGS gage stations for the pre-MRGCD and post-Cochiti Dam periods.

| **P-Value** | | | |
|---|---|---|---|
| | **At Embudo** | **At Otowi** | **At San Marcial** |
| Nr Lobatos | 0.376 | 0.224 | 0.249 |
| At Embudo | - | 0.969 | 0.953 |
| At Otowi | - | - | 0.957 |

Table 7. Summary of hydrologic alteration at ten Rio Grande USGS gage stations comparing pre-Cochiti Dam and post-Cochiti Dam periods.

| Station | Overall HA | Group 1 HA | Group 2 HA | Group 3 HA | Group 4 HA | Group 5 HA | Highly Altered Parameters |
|---|---|---|---|---|---|---|---|
| RG nr Lobatos, CO | 0.21 | 0.28 (0.0-0.58) | 0.14 (0.0-0.36) | 0.22 (0.0-0.45) | 0.30 (0.07-0.57) | 0.16 (0.09-0.29) | None |
| RG nr Cerros, NM (1949-70) | 0.27 | 0.37 (0.21-0.80) | 0.11 (0.0-0.21) | 0.38 (0.08-0.67) | 0.38 (0.21-0.51) | 0.23 (0.02-0.48) | Oct median |
| RG blw Taos Jct Bridge | 0.26 | 0.35 (0.0-0.64) | 0.13 (0.0-0.36) | 0.17 (0.17-0.17) | 0.34 (0.25-0.47) | 0.33 (0.09-0.73) | # reversals |
| RG at Embudo | 0.26 | 0.34 (0.09-0.55) | 0.20 (0.0-0.36) | 0.08 (0.08-0.09) | 0.37 (0.17-0.50) | 0.12 (0.08-0.18) | None |
| RG at Otowi Bridge | 0.35 | 0.35 (0.0-1.0) | 0.35 (0.0-0.73) | 0.44 (0.33-0.55) | 0.32 (0.09-0.64) | 0.32 (0.27-0.36) | January median |
| RG at Cochiti | 0.30 | 0.29 (0.0-0.73) | 0.32 (0.0-0.82) | 0.43 (0.36-0.50) | 0.21 (0.08-0.45) | 0.23 (0.09-0.42) | Jan median; 7day min |
| RG at San Felipe | 0.32 | 0.29 (0.0-0.73) | 0.35 (0.0-0.91) | 0.34 (0.33-0.36) | 0.36 (0.27-0.54) | 0.24 (0.09-0.36) | Aug median; 30day min; 1day max |
| RG at Albuquerque | 0.34 | 0.31 (0.0-0.73) | 0.36 (0.0-0.70) | 0.58 (0.42-0.73) | 0.31 (0.0-0.77) | 0.30 (0.09-0.73) | Jan median; 3-day min; date maximum; low pulse count; # reversals |
| RG at San Acacia (1937-58) | 0.47 | 0.47 (0.04-0.90) | 0.63 (0.28-1.09) | 0.48 (0.23-0.72) | 0.20 (0.09-0.33) | 0.15 (0.04-0.26) | Dec, Jan & May medians; 1-,3-,7-, 30-, 90-day max; date of min |
| RG at San Marcial (1936-58) | 0.42 | 0.34 (0.03-0.82) | 0.57 (0.14-1.17) | 0.17 (0.10-0.24) | 0.35 (0.05-0.66) | 0.45 (0.34-0.55) | Dec median; 1-,3-,7-, 30- & 90-day max |

Table 8. Indicator of Hydrologic Alteration analysis for Rio Grande near Lobatos, Colorado, for the pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 81.7 | 0.73 | 12.9 | 1401.0 | 87.7 | 2.13 | 18.0 | 1203.2 | 65.25 | 96.25 | -0.36 |
| November | 241.6 | 1.01 | 59.6 | 1199.3 | 216.8 | 1.40 | 73.8 | 948.1 | 172.56 | 349.72 | -0.18 |
| December | 249.0 | 0.48 | 61.7 | 762.6 | 274.4 | 0.59 | 88.1 | 654.3 | 216.62 | 301.63 | -0.18 |
| January | 244.2 | 0.45 | 75.7 | 386.1 | 279.7 | 0.49 | 114.7 | 521.5 | 218.47 | 280.98 | -0.27 |
| February | 293.6 | 0.37 | 102.1 | 510.4 | 327.9 | 0.46 | 180.5 | 595.4 | 240.93 | 316.04 | -0.27 |
| March | 320.9 | 0.71 | 66.0 | 657.8 | 432.8 | 0.69 | 157.1 | 884.0 | 238.53 | 399.03 | -0.18 |
| April | 276.8 | 1.46 | 59.3 | 2006.9 | 484.8 | 1.47 | 59.0 | 2325.8 | 168.63 | 442.07 | -0.45 |
| May | 646.5 | 1.87 | 42.9 | 3651.0 | 861.4 | 1.35 | 31.2 | 4958.4 | 174.52 | 1092.03 | 0.00 |
| June | 386.0 | 4.07 | 19.8 | 4311.1 | 1063.3 | 1.75 | 19.8 | 4417.7 | 251.45 | 1206.44 | -0.36 |
| July | 109.2 | 2.57 | 1.3 | 1997.1 | 326.3 | 1.90 | 10.0 | 2754.1 | 50.41 | 203.15 | -0.45 |
| August | 64.1 | 1.73 | 3.2 | 842.1 | 153.9 | 1.03 | 7.7 | 1281.0 | 33.26 | 83.75 | -0.58 |
| September | 46.8 | 1.86 | 1.9 | 599.7 | 63.2 | 2.13 | 13.1 | 938.4 | 37.80 | 84.55 | -0.09 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 25.0 | 1.22 | 0.0 | 55.0 | 31.0 | 0.94 | 4.1 | 100.0 | 5.84 | 33.00 | 0.15 |
| 3-day minimum | 26.3 | 1.16 | 0.0 | 58.3 | 32.3 | 0.95 | 4.4 | 106.0 | 6.38 | 33.07 | 0.36 |
| 7-day minimum | 28.1 | 1.22 | 0.0 | 62.7 | 36.1 | 1.00 | 4.9 | 115.1 | 9.43 | 36.84 | 0.09 |
| 30-day minimum | 38.3 | 1.15 | 0.2 | 98.5 | 43.8 | 1.12 | 7.0 | 154.8 | 19.01 | 49.81 | 0.09 |
| 90-day minimum | 63.0 | 1.04 | 3.6 | 237.0 | 74.0 | 1.31 | 9.9 | 328.6 | 36.95 | 72.40 | -0.18 |
| 1-day maximum | 1750.0 | 1.72 | 280.0 | 9110.0 | 2070.0 | 1.22 | 279.0 | 6660.0 | 985.00 | 2676.00 | 0.00 |
| 3-day maximum | 1656.7 | 1.74 | 273.0 | 8503.3 | 1893.3 | 1.32 | 255.7 | 6453.3 | 905.63 | 2523.00 | 0.00 |
| 7-day maximum | 1351.6 | 1.86 | 249.1 | 7770.0 | 1704.3 | 1.40 | 226.1 | 6008.6 | 771.93 | 2240.71 | -0.09 |
| 30-day maximum | 861.0 | 2.27 | 215.6 | 5940.3 | 1516.3 | 1.10 | 197.5 | 5237.7 | 430.48 | 1786.17 | 0.36 |
| 90-day maximum | 644.3 | 2.01 | 159.0 | 3111.7 | 915.8 | 1.04 | 172.8 | 3572.8 | 349.43 | 1002.65 | -0.09 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 34.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.12 |
| Base flow (7-day min/median | 0.1 | 1.13 | 0.0 | 0.2 | 0.1 | 1.00 | 0.0 | 0.2 | 0.05 | 0.09 | -0.09 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 248.0 | 0.16 | 192.0 | 288.0 | 263.0 | 0.08 | 213.0 | 358.0 | 223.70 | 268.60 | 0.45 |
| Date of maximum | 151.0 | 0.13 | 44.0 | 333.0 | 157.0 | 0.11 | 54.0 | 340.0 | 132.00 | 165.60 | 0.00 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 5.0 | 0.90 | 1.0 | 11.0 | 2.0 | 1.25 | 0.0 | 8.0 | 4.00 | 7.00 | -0.57 |
| Low Pulse Duration (days) | 15.0 | 1.01 | 0.0 | 42.5 | 10.0 | 1.76 | 0.0 | 87.0 | 7.70 | 17.69 | -0.27 |
| High Pulse Count | 4.0 | 1.25 | 0.0 | 11.0 | 5.0 | 1.10 | 0.0 | 15.0 | 2.00 | 6.00 | 0.07 |
| High Pulse Duration (days) | 14.7 | 1.65 | 0.0 | 66.5 | 20.6 | 1.08 | 0.0 | 137.0 | 7.87 | 24.08 | 0.27 |
| The low pulse threshold is (cfs) | 71.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 370.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 41.3 | 1.19 | 9.0 | 132.1 | 44.1 | 0.87 | 7.3 | 97.1 | 25.92 | 58.10 | 0.09 |
| Fall rate (cfs/day) | -33.0 | -1.40 | -102.5 | -7.3 | -43.0 | -0.91 | -93.3 | -6.8 | -48.40 | -21.50 | -0.09 |
| Number of reversals | 101.0 | 0.20 | 79.0 | 127.0 | 107.0 | 0.24 | 74.0 | 139.0 | 96.00 | 111.00 | -0.29 |

Table 9. Indicator of Hydrologic Alteration analysis for Rio Grande near Cerro, New Mexico, for the pre-Cochiti Dam period (1949-7( compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1949-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 114.9 | 0.44 | 52.7 | 720.0 | 134.8 | 1.40 | 56.0 | 1309.6 | 96.37 | 125.12 | -0.80 |
| November | 238.0 | 1.14 | 88.1 | 866.7 | 277.5 | 1.22 | 105.6 | 1073.4 | 159.02 | 373.18 | -0.21 |
| December | 257.1 | 0.61 | 100.5 | 522.5 | 307.4 | 0.55 | 121.0 | 774.1 | 215.19 | 301.37 | -0.41 |
| January | 249.1 | 0.49 | 115.8 | 400.9 | 335.4 | 0.47 | 152.3 | 565.8 | 220.24 | 278.72 | -0.51 |
| February | 300.1 | 0.45 | 140.0 | 516.3 | 386.8 | 0.46 | 216.6 | 657.1 | 270.49 | 344.56 | -0.51 |
| March | 330.7 | 0.57 | 109.8 | 692.0 | 530.9 | 0.62 | 197.3 | 1010.0 | 251.94 | 404.33 | -0.31 |
| April | 289.6 | 1.33 | 106.9 | 1108.4 | 526.2 | 1.53 | 104.1 | 2335.5 | 153.19 | 428.45 | -0.51 |
| May | 474.7 | 1.80 | 84.1 | 2916.8 | 913.3 | 1.26 | 75.5 | 4576.8 | 164.89 | 829.21 | -0.21 |
| June | 407.0 | 3.23 | 64.7 | 4400.3 | 1022.7 | 1.68 | 58.1 | 4285.3 | 281.88 | 937.27 | -0.31 |
| July | 130.4 | 2.73 | 51.5 | 2161.3 | 406.1 | 1.50 | 49.4 | 2180.7 | 74.47 | 249.17 | -0.21 |
| August | 94.5 | 2.89 | 48.1 | 957.0 | 193.6 | 0.96 | 44.5 | 1272.9 | 72.54 | 180.88 | -0.21 |
| Septembe | 88.8 | 1.21 | 44.8 | 658.1 | 110.2 | 1.52 | 49.4 | 970.3 | 74.55 | 148.95 | 0.28 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 61.0 | 0.51 | 44.0 | 102.0 | 68.5 | 0.59 | 40.0 | 131.0 | 51.00 | 72.23 | 0.05 |
| 3-day minimum | 62.2 | 0.53 | 44.0 | 103.7 | 70.0 | 0.58 | 40.3 | 148.7 | 51.86 | 71.47 | 0.08 |
| 7-day minimum | 64.8 | 0.52 | 44.0 | 104.7 | 75.5 | 0.58 | 42.3 | 150.9 | 52.28 | 72.52 | -0.12 |
| 30-day minimum | 72.3 | 0.53 | 44.6 | 129.1 | 82.6 | 0.68 | 44.6 | 185.1 | 56.53 | 88.08 | 0.18 |
| 90-day minimum | 83.1 | 0.87 | 47.3 | 254.7 | 116.5 | 0.65 | 47.5 | 369.5 | 73.97 | 118.21 | -0.02 |
| 1-day maximum | 1305.0 | 1.61 | 326.0 | 9440.0 | 2055.0 | 1.09 | 303.0 | 6370.0 | 753.60 | 2338.20 | 0.18 |
| 3-day maximum | 1243.3 | 1.61 | 316.7 | 8773.3 | 1920.0 | 1.18 | 274.7 | 6283.3 | 711.88 | 2244.60 | 0.18 |
| 7-day maximum | 1068.3 | 1.80 | 285.1 | 8027.1 | 1716.4 | 1.27 | 253.6 | 5728.6 | 666.46 | 1989.40 | 0.18 |
| 30-day maximum | 744.6 | 2.16 | 245.4 | 4796.7 | 1435.7 | 1.06 | 229.5 | 4920.3 | 414.96 | 1359.90 | -0.02 |
| 90-day maximum | 571.2 | 1.61 | 195.1 | 2511.9 | 1032.7 | 0.88 | 209.9 | 3546.1 | 340.21 | 921.42 | -0.21 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median | 0.2 | 0.75 | 0.1 | 0.4 | 0.2 | 0.96 | 0.1 | 0.4 | 0.18 | 0.29 | -0.12 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 250.0 | 0.16 | 199.0 | 309.0 | 267.0 | 0.10 | 215.0 | 359.0 | 233.59 | 273.82 | 0.08 |
| Date of maximum | 155.0 | 0.17 | 44.0 | 321.0 | 155.5 | 0.09 | 54.0 | 341.0 | 130.77 | 172.82 | 0.67 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 5.0 | 1.00 | 1.0 | 14.0 | 2.0 | 1.50 | 0.0 | 10.0 | 3.00 | 7.00 | -0.41 |
| Low Pulse Duration (days) | 9.9 | 1.54 | 0.0 | 37.6 | 7.9 | 3.21 | 0.0 | 105.0 | 5.21 | 18.31 | -0.21 |
| High Pulse Count | 5.0 | 1.30 | 0.0 | 12.0 | 4.5 | 1.28 | 0.0 | 15.0 | 2.00 | 7.41 | 0.41 |
| High Pulse Duration (days) | 15.1 | 1.32 | 0.0 | 61.0 | 24.3 | 1.02 | 0.0 | 99.0 | 6.53 | 18.23 | -0.51 |
| The low pulse threshold is (cfs) | 106.0 | | | | | | | | | | |
| The high pulse level is (cfs | 384.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 34.2 | 1.09 | 9.7 | 97.0 | 40.4 | 0.84 | 8.5 | 91.5 | 23.21 | 49.78 | 0.18 |
| Fall rate (cfs/day) | -27.6 | -1.22 | -92.3 | -7.9 | -35.8 | -0.92 | -85.6 | -7.4 | -41.74 | -17.41 | -0.02 |
| Number of reversals | 102.5 | 0.16 | 88.0 | 123.0 | 113.5 | 0.20 | 74.0 | 138.0 | 100.00 | 111.23 | -0.48 |

Table 10. Indicator of Hydrologic Alteration analysis for Rio Grande below Taos Junction Bridge near Taos, New Mexico, for the pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 287.3 | 0.31 | 170.8 | 1674.8 | 312.8 | 0.57 | 190.3 | 1501.0 | 272.11 | 321.47 | -0.45 |
| November | 427.7 | 0.52 | 223.5 | 1532.0 | 453.1 | 0.67 | 244.0 | 1310.2 | 387.75 | 526.03 | -0.45 |
| December | 461.6 | 0.33 | 243.1 | 1018.0 | 479.7 | 0.38 | 265.7 | 930.5 | 422.86 | 531.84 | -0.09 |
| January | 464.3 | 0.27 | 262.8 | 747.6 | 499.0 | 0.40 | 304.1 | 763.8 | 409.94 | 515.63 | 0.00 |
| February | 519.1 | 0.36 | 290.4 | 756.5 | 574.5 | 0.34 | 373.6 | 864.7 | 472.79 | 558.14 | -0.64 |
| March | 555.1 | 0.46 | 258.6 | 903.7 | 740.5 | 0.46 | 359.5 | 1194.7 | 493.37 | 624.46 | -0.45 |
| April | 657.3 | 0.77 | 277.2 | 3020.1 | 755.0 | 1.23 | 249.8 | 2907.4 | 438.70 | 747.40 | -0.45 |
| May | 1135.2 | 1.36 | 258.6 | 5979.4 | 1551.0 | 1.12 | 204.6 | 6055.5 | 515.73 | 1794.95 | -0.18 |
| June | 757.2 | 2.63 | 221.4 | 5203.0 | 1654.7 | 1.43 | 181.2 | 5495.3 | 615.79 | 1680.70 | -0.45 |
| July | 330.2 | 1.02 | 185.4 | 2579.4 | 602.8 | 1.22 | 176.5 | 3444.9 | 292.42 | 524.61 | -0.45 |
| August | 293.0 | 0.65 | 184.4 | 1462.7 | 364.1 | 0.72 | 162.7 | 1520.3 | 249.05 | 329.53 | -0.45 |
| September | 260.0 | 0.61 | 161.0 | 824.1 | 274.0 | 0.86 | 177.4 | 1174.1 | 243.74 | 329.71 | -0.18 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 211.0 | 0.32 | 159.0 | 251.0 | 220.0 | 0.29 | 158.0 | 344.0 | 192.90 | 238.20 | 0.18 |
| 3-day minimum | 214.3 | 0.31 | 159.0 | 252.7 | 222.7 | 0.30 | 158.7 | 350.0 | 195.90 | 238.53 | 0.09 |
| 7-day minimum | 219.6 | 0.31 | 159.0 | 257.1 | 226.6 | 0.31 | 159.1 | 360.3 | 196.44 | 239.43 | -0.09 |
| 30-day minimum | 229.3 | 0.29 | 161.0 | 317.2 | 241.0 | 0.35 | 162.6 | 385.8 | 212.77 | 257.43 | -0.09 |
| 90-day minimum | 266.8 | 0.34 | 169.8 | 422.8 | 279.1 | 0.43 | 171.6 | 605.9 | 232.15 | 300.58 | 0.09 |
| 1-day maximum | 2090.0 | 1.61 | 563.0 | 9730.0 | 2670.0 | 1.48 | 588.0 | 8120.0 | 1345.00 | 3395.00 | -0.18 |
| 3-day maximum | 1973.3 | 1.72 | 551.3 | 9363.3 | 2556.7 | 1.51 | 542.0 | 7920.0 | 1228.33 | 3318.67 | -0.18 |
| 7-day maximum | 1761.4 | 1.91 | 542.0 | 8617.1 | 2355.7 | 1.50 | 522.4 | 7435.7 | 1067.49 | 3045.14 | -0.09 |
| 30-day maximum | 1257.2 | 2.11 | 414.4 | 6977.7 | 2072.3 | 1.33 | 480.9 | 6350.7 | 744.35 | 2603.77 | 0.18 |
| 90-day maximum | 977.2 | 1.86 | 357.6 | 4794.3 | 1526.4 | 1.09 | 397.5 | 4568.0 | 600.44 | 1573.47 | 0.00 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median) | 0.4 | 0.77 | 0.1 | 0.7 | 0.3 | 0.77 | 0.2 | 0.6 | 0.32 | 0.47 | -0.36 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 258.0 | 0.11 | 131.0 | 309.0 | 273.0 | 0.08 | 172.0 | 360.0 | 243.80 | 274.00 | -0.17 |
| Date of maximum | 150.0 | 0.09 | 45.0 | 315.0 | 147.0 | 0.08 | 52.0 | 290.0 | 133.00 | 158.10 | 0.17 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 5.0 | 0.60 | 1.0 | 13.0 | 3.0 | 1.33 | 0.0 | 12.0 | 3.00 | 5.00 | -0.47 |
| Low Pulse Duration (days) | 12.8 | 0.66 | 0.0 | 29.8 | 10.7 | 1.46 | 0.0 | 106.0 | 9.39 | 17.00 | -0.33 |
| High Pulse Count | 5.0 | 1.20 | 0.0 | 12.0 | 5.0 | 0.80 | 0.0 | 12.0 | 1.90 | 6.00 | 0.25 |
| High Pulse Duration (days) | 14.5 | 1.41 | 0.0 | 282.0 | 23.0 | 1.05 | 0.0 | 122.0 | 8.00 | 22.38 | -0.33 |
| The low pulse threshold is (cfs) | 295.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 630.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 48.7 | 1.21 | 14.1 | 165.9 | 47.8 | 1.00 | 9.1 | 110.7 | 34.16 | 59.89 | -0.09 |
| Fall rate (cfs/day) | -39.2 | -1.44 | -120.5 | -12.2 | -46.2 | -0.96 | -90.6 | -7.9 | -51.33 | -27.94 | -0.18 |
| Number of reversals | 103.0 | 0.14 | 84.0 | 120.0 | 123.0 | 0.17 | 90.0 | 141.0 | 97.70 | 107.10 | -0.73 |

Table 11. Indicator of Hydrologic Alteration analysis for Rio Grande at Embudo, New Mexico, for the pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 302.0 | 0.37 | 181.5 | 1795.0 | 368.3 | 0.54 | 200.5 | 1535.5 | 292.07 | 364.15 | -0.55 |
| November | 448.7 | 0.53 | 243.4 | 1610.8 | 509.0 | 0.61 | 267.1 | 1338.0 | 430.76 | 567.46 | -0.45 |
| December | 481.4 | 0.36 | 269.4 | 1052.2 | 528.3 | 0.36 | 281.3 | 956.1 | 451.41 | 560.65 | -0.27 |
| January | 492.8 | 0.27 | 300.2 | 799.4 | 545.4 | 0.38 | 326.3 | 786.8 | 441.55 | 549.24 | -0.36 |
| February | 553.4 | 0.34 | 323.0 | 802.6 | 611.4 | 0.34 | 395.5 | 887.7 | 500.42 | 613.15 | -0.45 |
| March | 603.5 | 0.43 | 285.5 | 989.4 | 770.8 | 0.49 | 395.5 | 1290.0 | 544.05 | 685.40 | -0.36 |
| April | 822.5 | 0.67 | 292.2 | 3543.8 | 857.3 | 1.23 | 273.6 | 3288.0 | 514.33 | 948.32 | -0.18 |
| May | 1384.3 | 1.31 | 311.1 | 7185.5 | 1865.5 | 1.05 | 188.6 | 6650.3 | 725.37 | 2104.13 | -0.09 |
| June | 828.3 | 2.83 | 233.1 | 5781.3 | 1637.6 | 1.67 | 179.8 | 6180.7 | 644.64 | 1886.60 | -0.36 |
| July | 358.8 | 1.03 | 188.0 | 2687.4 | 621.7 | 1.12 | 162.7 | 3540.1 | 328.54 | 572.92 | -0.55 |
| August | 325.5 | 0.77 | 185.6 | 1698.8 | 409.3 | 0.74 | 151.3 | 1551.0 | 287.24 | 402.25 | -0.27 |
| September | 282.6 | 0.72 | 170.5 | 845.0 | 305.8 | 0.85 | 172.6 | 1178.1 | 252.13 | 376.08 | 0.18 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 227.0 | 0.22 | 165.0 | 268.0 | 239.0 | 0.31 | 145.0 | 376.0 | 195.80 | 238.20 | -0.36 |
| 3-day minimum | 228.3 | 0.24 | 165.0 | 271.0 | 245.0 | 0.30 | 145.7 | 385.0 | 198.83 | 239.37 | -0.36 |
| 7-day minimum | 233.7 | 0.27 | 165.9 | 274.4 | 253.1 | 0.30 | 146.7 | 435.0 | 204.83 | 245.41 | -0.36 |
| 30-day minimum | 250.2 | 0.30 | 170.5 | 344.4 | 269.5 | 0.35 | 150.5 | 421.9 | 222.19 | 277.79 | -0.09 |
| 90-day minimum | 288.3 | 0.40 | 177.2 | 448.4 | 306.7 | 0.45 | 160.8 | 653.3 | 244.64 | 324.45 | 0.09 |
| 1-day maximum | 2160.0 | 1.88 | 565.0 | 10500.0 | 2930.0 | 1.51 | 619.0 | 9120.0 | 1856.00 | 4051.00 | -0.27 |
| 3-day maximum | 2070.0 | 1.97 | 548.3 | 10303.3 | 2883.3 | 1.49 | 604.3 | 8866.7 | 1689.67 | 3905.33 | -0.27 |
| 7-day maximum | 1937.1 | 2.05 | 539.2 | 9328.6 | 2798.6 | 1.39 | 578.0 | 8285.7 | 1497.00 | 3615.14 | -0.18 |
| 30-day maximum | 1397.6 | 2.18 | 504.3 | 7955.0 | 2372.0 | 1.31 | 510.9 | 6875.0 | 970.72 | 3090.30 | 0.00 |
| 90-day maximum | 1111.4 | 1.83 | 446.1 | 5576.7 | 1760.8 | 1.08 | 422.0 | 5108.2 | 642.50 | 1820.30 | 0.09 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median | 0.3 | 0.75 | 0.1 | 0.6 | 0.3 | 0.75 | 0.1 | 0.6 | 0.30 | 0.46 | -0.36 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 261.0 | 0.09 | 212.0 | 281.0 | 269.0 | 0.08 | 220.0 | 289.0 | 245.80 | 274.10 | -0.09 |
| Date of maximum | 148.0 | 0.08 | 92.0 | 333.0 | 146.0 | 0.06 | 55.0 | 275.0 | 133.00 | 153.40 | 0.08 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 5.0 | 0.90 | 1.0 | 12.0 | 3.0 | 1.33 | 0.0 | 14.0 | 4.00 | 7.10 | -0.50 |
| Low Pulse Duration (days) | 12.3 | 0.77 | 0.0 | 20.0 | 7.7 | 1.90 | 0.0 | 110.0 | 7.40 | 14.68 | -0.36 |
| High Pulse Count | 5.0 | 1.00 | 0.0 | 10.0 | 4.0 | 1.13 | 0.0 | 9.0 | 3.00 | 6.10 | 0.17 |
| High Pulse Duration (days) | 13.2 | 1.44 | 0.0 | 93.7 | 25.4 | 1.42 | 0.0 | 175.0 | 8.39 | 19.04 | -0.45 |
| The low pulse threshold is (cfs) | 327.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 697.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 51.6 | 1.13 | 16.9 | 193.1 | 53.2 | 1.00 | 10.7 | 119.5 | 34.70 | 62.44 | -0.09 |
| Fall rate (cfs/day) | -41.7 | -1.29 | -130.9 | -14.6 | -48.5 | -0.93 | -93.7 | -8.5 | -53.48 | -28.17 | -0.18 |
| Number of reversals | 110.0 | 0.17 | 87.0 | 128.0 | 118.0 | 0.17 | 93.0 | 150.0 | 102.90 | 118.00 | 0.08 |

Table 12. Indicator of Hydrologic Alteration analysis for Rio Grande near Otowi Bridge, New Mexico, for the Pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 401.1 | 0.97 | 167.6 | 2685.5 | 731.9 | 0.64 | 361.1 | 2224.5 | 353.02 | 598.33 | 0.00 |
| November | 646.6 | 1.60 | 281.0 | 2420.7 | 810.5 | 0.94 | 367.6 | 2034.3 | 547.50 | 1229.94 | 0.09 |
| December | 610.9 | 1.11 | 355.0 | 1902.9 | 763.0 | 0.66 | 425.7 | 1959.0 | 553.80 | 750.71 | -0.36 |
| January | 629.0 | 0.24 | 401.9 | 985.9 | 730.6 | 0.50 | 436.1 | 1757.4 | 569.51 | 677.17 | -1.00 |
| February | 712.8 | 0.42 | 454.3 | 2191.1 | 798.3 | 0.51 | 498.1 | 2641.4 | 676.07 | 853.59 | -0.45 |
| March | 915.0 | 0.54 | 477.3 | 2217.1 | 1348.7 | 0.59 | 610.1 | 3126.8 | 710.63 | 1046.97 | -0.36 |
| April | 1203.0 | 1.25 | 366.1 | 7328.7 | 2078.4 | 1.06 | 488.7 | 6412.0 | 1032.05 | 1774.29 | -0.45 |
| May | 2490.6 | 1.17 | 578.5 | 10990.6 | 3679.7 | 0.98 | 638.6 | 8390.0 | 1442.74 | 3761.00 | -0.09 |
| June | 1481.8 | 2.25 | 288.2 | 7354.0 | 3086.0 | 1.13 | 844.1 | 7914.0 | 1079.91 | 2953.53 | -0.09 |
| July | 596.0 | 1.11 | 211.9 | 4332.6 | 1336.2 | 0.41 | 734.6 | 4548.1 | 510.13 | 1022.67 | -0.45 |
| August | 823.2 | 0.81 | 259.8 | 3307.7 | 967.7 | 0.39 | 633.2 | 2131.9 | 500.47 | 981.98 | 0.45 |
| September | 490.7 | 1.00 | 191.0 | 1771.4 | 976.3 | 0.52 | 414.6 | 1553.0 | 392.38 | 698.50 | -0.36 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 220.0 | 0.45 | 106.0 | 735.0 | 330.0 | 0.58 | 195.0 | 821.0 | 174.10 | 257.10 | -0.45 |
| 3-day minimum | 222.3 | 0.47 | 111.3 | 812.0 | 401.7 | 0.47 | 212.7 | 874.3 | 179.53 | 264.67 | -0.50 |
| 7-day minimum | 228.9 | 0.52 | 118.9 | 856.3 | 431.9 | 0.63 | 259.3 | 916.9 | 192.93 | 274.47 | -0.73 |
| 30-day minimum | 293.7 | 0.51 | 150.2 | 768.2 | 515.7 | 0.44 | 352.0 | 1154.4 | 249.33 | 367.78 | -0.73 |
| 90-day minimum | 417.4 | 0.62 | 214.3 | 718.2 | 592.7 | 0.48 | 388.6 | 1258.2 | 346.64 | 512.74 | -0.27 |
| 1-day maximum | 4200.0 | 1.23 | 1360.0 | 15600.0 | 5030.0 | 1.13 | 1650.0 | 12000.0 | 3027.00 | 5986.00 | -0.18 |
| 3-day maximum | 4110.0 | 1.26 | 1226.7 | 15000.0 | 4840.0 | 1.15 | 1520.0 | 11833.3 | 2774.00 | 5554.00 | -0.27 |
| 7-day maximum | 3885.7 | 1.23 | 1198.6 | 13700.0 | 4564.3 | 1.16 | 1312.9 | 11528.6 | 2523.86 | 5449.14 | -0.27 |
| 30-day maximum | 3065.0 | 1.35 | 1009.0 | 11639.0 | 4205.0 | 1.08 | 1164.1 | 9206.0 | 1929.40 | 4877.80 | -0.09 |
| 90-day maximum | 1976.4 | 1.58 | 800.6 | 8668.6 | 3466.9 | 0.93 | 894.6 | 7192.7 | 1349.50 | 3312.27 | -0.27 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median) | 0.2 | 0.55 | 0.1 | 0.5 | 0.3 | 0.61 | 0.1 | 0.6 | 0.19 | 0.27 | -0.45 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 267.0 | 0.14 | 6.0 | 315.0 | 275.0 | 0.18 | 30.0 | 351.0 | 243.90 | 275.00 | -0.33 |
| Date of maximum | 146.0 | 0.12 | 39.0 | 333.0 | 141.0 | 0.06 | 103.0 | 366.0 | 131.70 | 152.20 | 0.55 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 7.0 | 0.86 | 0.0 | 17.0 | 4.0 | 1.50 | 0.0 | 14.0 | 5.90 | 9.10 | -0.36 |
| Low Pulse Duration (days) | 7.3 | 0.70 | 0.0 | 20.3 | 3.4 | 1.47 | 0.0 | 15.8 | 5.88 | 8.90 | -0.64 |
| High Pulse Count | 4.0 | 1.25 | 1.0 | 12.0 | 9.0 | 0.72 | 2.0 | 17.0 | 3.90 | 6.10 | -0.09 |
| High Pulse Duration (days) | 14.6 | 1.21 | 1.0 | 157.0 | 13.7 | 1.67 | 1.5 | 58.0 | 10.97 | 21.84 | 0.18 |
| The low pulse threshold is (cfs) | 490.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1310.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 107.8 | 0.59 | 45.9 | 336.3 | 103.1 | 0.47 | 44.9 | 188.9 | 90.23 | 123.25 | -0.36 |
| Fall rate (cfs/day) | -90.0 | -0.83 | -270.5 | -40.7 | -95.7 | -0.48 | -159.3 | -45.9 | -114.67 | -70.74 | 0.27 |
| Number of reversals | 122.0 | 0.12 | 86.0 | 146.0 | 129.0 | 0.18 | 100.0 | 159.0 | 112.00 | 124.10 | -0.33 |

Table 13. Indicator of Hydrologic Alteration analysis for Rio Grande at Cochiti Dam, New Mexico, for the Pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 311.8 | 1.19 | 75.9 | 2863.5 | 508.5 | 0.75 | 213.9 | 2044.5 | 291.00 | 479.31 | -0.09 |
| November | 665.7 | 1.63 | 273.4 | 2797.7 | 820.4 | 0.81 | 330.8 | 1878.3 | 528.29 | 1246.92 | 0.36 |
| December | 625.6 | 1.08 | 357.3 | 1861.0 | 763.7 | 0.67 | 418.6 | 1787.4 | 579.99 | 834.28 | -0.27 |
| January | 653.8 | 0.24 | 393.6 | 1031.8 | 758.7 | 0.46 | 428.3 | 2244.8 | 586.81 | 708.11 | -0.73 |
| February | 742.2 | 0.42 | 449.9 | 2161.8 | 819.4 | 0.51 | 444.1 | 3639.3 | 672.45 | 875.76 | -0.27 |
| March | 872.6 | 0.58 | 388.8 | 2172.5 | 1189.9 | 0.63 | 437.6 | 2868.4 | 658.39 | 972.59 | -0.36 |
| April | 1096.3 | 1.46 | 267.1 | 7387.0 | 1852.2 | 1.06 | 280.8 | 6320.3 | 909.83 | 1775.24 | -0.45 |
| May | 2501.6 | 1.18 | 486.7 | 10679.7 | 3375.8 | 0.95 | 432.0 | 6101.0 | 1347.76 | 3627.26 | 0.00 |
| June | 1415.7 | 2.43 | 192.9 | 6971.7 | 3123.3 | 1.23 | 717.1 | 6204.7 | 922.04 | 3028.90 | -0.18 |
| July | 495.1 | 1.42 | 127.3 | 4276.5 | 1112.3 | 1.19 | 539.2 | 5643.2 | 425.75 | 908.01 | 0.09 |
| August | 746.7 | 0.86 | 191.1 | 3217.4 | 779.1 | 0.54 | 446.8 | 3683.2 | 426.59 | 904.03 | 0.64 |
| September | 399.8 | 1.20 | 116.3 | 1706.8 | 732.2 | 0.70 | 237.9 | 1635.0 | 336.16 | 679.96 | -0.09 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 97.0 | 1.06 | 4.4 | 760.0 | 140.0 | 1.63 | 0.5 | 765.0 | 64.50 | 132.60 | -0.27 |
| 3-day minimum | 105.7 | 0.95 | 9.7 | 821.7 | 164.3 | 1.39 | 12.5 | 773.0 | 74.97 | 141.00 | -0.45 |
| 7-day minimum | 140.0 | 0.79 | 48.3 | 871.1 | 234.9 | 1.24 | 39.0 | 804.3 | 125.53 | 180.69 | -0.82 |
| 30-day minimum | 220.7 | 0.70 | 56.8 | 717.3 | 331.7 | 0.75 | 93.2 | 768.0 | 189.91 | 279.78 | -0.55 |
| 90-day minimum | 342.6 | 0.73 | 138.9 | 684.8 | 487.9 | 0.49 | 267.6 | 782.1 | 315.29 | 498.22 | 0.36 |
| 1-day maximum | 4460.0 | 1.21 | 1420.0 | 14900.0 | 4950.0 | 0.68 | 1310.0 | 8664.0 | 2822.00 | 6807.00 | 0.55 |
| 3-day maximum | 4266.7 | 1.18 | 1310.0 | 14333.3 | 4550.0 | 0.71 | 1273.3 | 8133.3 | 2716.67 | 5678.00 | 0.18 |
| 7-day maximum | 3964.3 | 1.19 | 1185.7 | 13114.3 | 4464.3 | 0.85 | 1190.0 | 7968.6 | 2488.57 | 5488.43 | 0.09 |
| 30-day maximum | 3014.0 | 1.31 | 938.3 | 11236.3 | 3856.6 | 0.98 | 918.7 | 7435.3 | 1922.96 | 4839.83 | 0.00 |
| 90-day maximum | 1871.5 | 1.64 | 680.4 | 8452.6 | 3306.2 | 0.93 | 664.7 | 5903.4 | 1247.97 | 3293.21 | -0.27 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median) | 0.2 | 0.77 | 0.0 | 0.4 | 0.2 | 0.85 | 0.0 | 0.6 | 0.11 | 0.19 | -0.36 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 266.0 | 0.15 | 182.0 | 322.0 | 264.0 | 0.25 | 12.0 | 359.0 | 236.30 | 275.00 | -0.50 |
| Date of maximum | 139.0 | 0.11 | 39.0 | 333.0 | 145.0 | 0.06 | 53.0 | 219.0 | 131.80 | 154.60 | 0.36 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 7.0 | 1.14 | 0.0 | 19.0 | 4.0 | 2.13 | 0.0 | 25.0 | 6.00 | 11.10 | -0.08 |
| Low Pulse Duration (days) | 7.3 | 0.83 | 0.0 | 16.4 | 5.0 | 1.52 | 0.0 | 14.7 | 5.05 | 9.03 | -0.45 |
| High Pulse Count | 5.0 | 0.60 | 2.0 | 13.0 | 6.0 | 0.83 | 1.0 | 13.0 | 4.00 | 6.00 | -0.13 |
| High Pulse Duration (days) | 15.2 | 1.26 | 2.0 | 77.5 | 18.0 | 0.93 | 1.3 | 71.8 | 10.77 | 21.00 | -0.18 |
| The low pulse threshold is (cfs) | 448.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1247.5 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 115.7 | 0.59 | 55.9 | 315.0 | 103.6 | 0.44 | 26.0 | 184.7 | 96.35 | 139.72 | 0.09 |
| Fall rate (cfs/day) | -96.4 | -0.67 | -242.5 | -53.8 | -103.4 | -0.57 | -203.3 | -31.1 | -126.56 | -82.51 | 0.18 |
| Number of reversals | 122.0 | 0.15 | 90.0 | 152.0 | 113.0 | 0.15 | 84.0 | 138.0 | 117.00 | 129.20 | -0.42 |

Table 14. Indicator of Hydrologic Alteration analysis for Rio Grande at San Felipe, New Mexico, for the Pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 381.2 | 1.00 | 123.0 | 3328.0 | 675.8 | 0.50 | 289.0 | 2164.2 | 318.16 | 578.35 | -0.09 |
| November | 665.3 | 1.59 | 279.4 | 3018.7 | 798.7 | 0.77 | 388.9 | 2072.3 | 573.84 | 1264.74 | 0.55 |
| December | 652.3 | 1.06 | 350.7 | 1886.1 | 797.3 | 0.58 | 481.9 | 1968.7 | 589.82 | 842.09 | 0.00 |
| January | 638.5 | 0.29 | 399.5 | 1168.7 | 778.6 | 0.52 | 461.6 | 2163.2 | 585.62 | 702.65 | -0.64 |
| February | 766.4 | 0.45 | 484.3 | 2241.4 | 834.8 | 0.47 | 504.2 | 3694.6 | 686.70 | 870.85 | -0.27 |
| March | 905.3 | 0.49 | 439.1 | 2124.2 | 1262.6 | 0.59 | 545.7 | 3053.5 | 690.44 | 1048.26 | -0.09 |
| April | 1178.5 | 1.34 | 335.7 | 7133.0 | 1884.7 | 1.07 | 377.8 | 6126.0 | 929.07 | 1817.87 | -0.55 |
| May | 2493.2 | 1.21 | 514.7 | 10368.4 | 3446.1 | 0.96 | 521.3 | 6160.3 | 1384.58 | 3630.94 | 0.00 |
| June | 1554.3 | 2.16 | 255.4 | 6892.3 | 3397.3 | 1.13 | 746.4 | 6534.0 | 1077.95 | 3285.87 | -0.27 |
| July | 549.8 | 1.38 | 163.2 | 4300.0 | 1222.2 | 1.14 | 621.6 | 5979.0 | 483.19 | 947.30 | -0.27 |
| August | 807.1 | 0.86 | 251.6 | 3464.5 | 941.1 | 0.40 | 596.0 | 3666.8 | 560.48 | 1052.52 | 0.73 |
| September | 466.6 | 1.28 | 141.1 | 1760.3 | 872.5 | 0.47 | 358.9 | 1780.8 | 362.24 | 755.99 | 0.00 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 149.0 | 0.65 | 54.0 | 900.0 | 290.0 | 0.93 | 67.0 | 715.0 | 118.50 | 190.00 | -0.50 |
| 3-day minimum | 164.3 | 0.59 | 64.7 | 909.0 | 303.7 | 0.92 | 97.0 | 742.0 | 144.10 | 203.80 | -0.45 |
| 7-day minimum | 189.0 | 0.62 | 85.3 | 978.6 | 337.9 | 0.87 | 134.7 | 758.0 | 165.30 | 234.39 | -0.55 |
| 30-day minimum | 268.5 | 0.68 | 95.5 | 918.9 | 466.6 | 0.58 | 178.3 | 846.8 | 233.94 | 319.02 | -0.73 |
| 90-day minimum | 409.8 | 0.67 | 176.6 | 799.8 | 607.9 | 0.40 | 408.6 | 866.1 | 338.79 | 524.55 | -0.09 |
| 1-day maximum | 4770.0 | 1.34 | 1420.0 | 17200.0 | 4560.0 | 0.80 | 1520.0 | 8100.0 | 2956.00 | 7423.00 | 0.91 |
| 3-day maximum | 4423.3 | 1.20 | 1290.0 | 14400.0 | 4520.0 | 0.89 | 1343.3 | 7966.7 | 2852.67 | 6141.00 | 0.18 |
| 7-day maximum | 3838.6 | 1.25 | 1214.3 | 12857.1 | 4458.6 | 0.93 | 1190.0 | 7897.1 | 2628.71 | 5733.86 | 0.18 |
| 30-day maximum | 3098.0 | 1.29 | 1000.6 | 10958.7 | 4011.3 | 1.01 | 1001.0 | 7386.7 | 1991.94 | 4880.17 | 0.09 |
| 90-day maximum | 1995.3 | 1.51 | 693.8 | 8238.6 | 3408.1 | 0.88 | 815.1 | 5991.3 | 1247.52 | 3444.63 | 0.00 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Base flow (7-day min/median | 0.2 | 0.63 | 0.1 | 0.5 | 0.3 | 0.78 | 0.1 | 0.6 | 0.16 | 0.23 | -0.55 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 254.0 | 0.17 | 49.0 | 315.0 | 292.0 | 0.28 | 6.0 | 359.0 | 229.40 | 275.00 | -0.33 |
| Date of maximum | 149.0 | 0.13 | 39.0 | 333.0 | 149.0 | 0.09 | 53.0 | 273.0 | 128.90 | 160.90 | 0.36 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 7.0 | 0.93 | 0.0 | 23.0 | 4.0 | 1.63 | 0.0 | 23.0 | 6.00 | 10.20 | -0.54 |
| Low Pulse Duration (days) | 7.3 | 0.81 | 0.0 | 12.9 | 4.0 | 1.25 | 0.0 | 14.3 | 4.49 | 8.72 | -0.27 |
| High Pulse Count | 4.0 | 1.38 | 1.0 | 17.0 | 5.0 | 0.70 | 1.0 | 15.0 | 4.00 | 8.00 | 0.29 |
| High Pulse Duration (days) | 13.0 | 1.14 | 1.0 | 76.0 | 16.5 | 1.21 | 2.0 | 73.0 | 10.46 | 16.18 | -0.36 |
| The low pulse threshold is (cfs) | 486.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1330.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 124.2 | 0.61 | 60.4 | 394.9 | 103.9 | 0.42 | 32.6 | 187.3 | 99.94 | 152.30 | 0.09 |
| Fall rate (cfs/day) | -105.2 | -0.65 | -324.6 | -47.2 | -101.6 | -0.47 | -205.8 | -29.5 | -130.60 | -83.86 | 0.36 |
| Number of reversals | 127.0 | 0.16 | 100.0 | 152.0 | 124.0 | 0.18 | 95.0 | 148.0 | 118.70 | 130.20 | -0.27 |

Table 15. Indicator of Hydrologic Alteration analysis for Rio Grande at Albuquerque, New Mexico, for the Pre-Cochiti Dam period (1942-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 123.2 | 2.99 | 0.0 | 1403.5 | 408.1 | 0.93 | 38.4 | 1801.6 | 79.61 | 283.68 | -0.45 |
| November | 599.6 | 1.64 | 66.1 | 2211.0 | 904.3 | 0.78 | 144.8 | 2302.3 | 410.41 | 1145.95 | 0.64 |
| December | 667.5 | 0.99 | 270.4 | 2053.5 | 845.3 | 0.51 | 441.5 | 2276.5 | 536.35 | 784.64 | -0.09 |
| January | 640.1 | 0.31 | 391.6 | 1100.0 | 845.6 | 0.48 | 443.4 | 2158.7 | 594.37 | 701.57 | -0.73 |
| February | 790.2 | 0.47 | 453.3 | 2145.5 | 811.9 | 0.41 | 479.8 | 3562.1 | 659.01 | 874.35 | 0.00 |
| March | 749.6 | 0.74 | 167.2 | 2102.9 | 1166.0 | 0.81 | 480.0 | 2790.3 | 501.57 | 850.75 | -0.18 |
| April | 1013.2 | 1.71 | 54.7 | 8570.7 | 2086.1 | 0.95 | 137.2 | 6342.6 | 630.53 | 1782.23 | -0.36 |
| May | 2103.9 | 1.61 | 112.0 | 11236.1 | 3176.8 | 1.12 | 148.3 | 6203.2 | 995.60 | 3571.16 | -0.09 |
| June | 1034.3 | 4.11 | 11.6 | 6993.0 | 3042.0 | 1.21 | 336.4 | 6113.0 | 588.26 | 2668.47 | -0.27 |
| July | 282.9 | 2.04 | 0.0 | 4182.9 | 858.3 | 1.73 | 333.4 | 5438.7 | 175.18 | 511.77 | -0.64 |
| August | 459.3 | 1.37 | 28.4 | 3687.1 | 650.8 | 0.68 | 278.3 | 3451.9 | 330.92 | 620.40 | 0.18 |
| September | 164.0 | 2.60 | 12.9 | 1614.5 | 558.6 | 1.00 | 69.6 | 1554.0 | 104.14 | 442.92 | -0.09 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 6.0 | 6.17 | 0.0 | 395.0 | 166.0 | 1.78 | 0.0 | 515.0 | 0.00 | 19.60 | -0.60 |
| 3-day minimum | 7.3 | 5.32 | 0.0 | 433.0 | 180.3 | 1.80 | 0.0 | 532.3 | 0.00 | 20.53 | -0.70 |
| 7-day minimum | 10.0 | 5.78 | 0.0 | 503.3 | 187.1 | 1.82 | 0.0 | 576.0 | 0.95 | 22.61 | -0.55 |
| 30-day minimum | 43.6 | 2.59 | 0.0 | 528.0 | 242.6 | 1.10 | 13.2 | 661.6 | 10.56 | 91.99 | -0.64 |
| 90-day minimum | 205.1 | 1.36 | 5.2 | 582.0 | 458.2 | 0.63 | 129.3 | 758.6 | 107.19 | 312.98 | -0.36 |
| 1-day maximum | 4380.0 | 1.43 | 1080.0 | 20600.0 | 4670.0 | 0.67 | 1240.0 | 8650.0 | 2813.00 | 6752.00 | 0.55 |
| 3-day maximum | 4180.0 | 1.21 | 970.0 | 16400.0 | 4550.0 | 0.74 | 1065.7 | 8400.0 | 2424.00 | 5686.00 | 0.18 |
| 7-day maximum | 3867.1 | 1.25 | 901.3 | 13628.6 | 4424.3 | 0.80 | 839.6 | 8172.9 | 2076.43 | 5354.43 | 0.00 |
| 30-day maximum | 2950.3 | 1.37 | 670.8 | 11791.7 | 3692.7 | 0.92 | 594.6 | 7552.3 | 1771.47 | 4697.57 | 0.00 |
| 90-day maximum | 1829.5 | 1.72 | 555.9 | 9062.6 | 3137.6 | 0.96 | 557.1 | 5886.4 | 1176.25 | 3243.30 | 0.00 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 68.0 | 0.0 | 0.00 | 0.0 | 8.0 | 0.00 | 4.10 | 0.40 |
| Base flow (7-day min/median | 0.0 | 5.65 | 0.0 | 0.3 | 0.2 | 1.48 | 0.0 | 0.7 | 0.00 | 0.04 | -0.36 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 269.0 | 0.17 | 172.0 | 319.0 | 275.0 | 0.18 | 151.0 | 345.0 | 245.00 | 275.10 | -0.42 |
| Date of maximum | 149.0 | 0.19 | 39.0 | 333.0 | 145.0 | 0.08 | 53.0 | 231.0 | 129.90 | 169.20 | 0.73 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 8.0 | 1.06 | 0.0 | 20.0 | 2.0 | 2.25 | 0.0 | 16.0 | 5.90 | 12.00 | -0.77 |
| Low Pulse Duration (days) | 7.3 | 0.96 | 0.0 | 26.7 | 4.0 | 1.55 | 0.0 | 29.0 | 4.93 | 9.78 | 0.00 |
| High Pulse Count | 7.0 | 0.57 | 0.0 | 16.0 | 7.0 | 0.71 | 1.0 | 14.0 | 5.00 | 7.00 | -0.38 |
| High Pulse Duration (days) | 12.4 | 1.29 | 0.0 | 74.0 | 16.2 | 0.62 | 1.0 | 97.3 | 8.07 | 16.77 | 0.09 |
| The low pulse threshold is (cfs) | 241.3 | | | | | | | | | | |
| The high pulse level is (cfs) | 1100.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 128.8 | 0.79 | 50.7 | 657.9 | 128.5 | 0.43 | 43.6 | 214.1 | 107.67 | 152.59 | 0.09 |
| Fall rate (cfs/day) | -106.9 | -0.76 | -619.0 | -41.6 | -112.8 | -0.55 | -194.5 | -36.6 | -144.46 | -93.40 | 0.09 |
| Number of reversals | 137.0 | 0.14 | 92.0 | 159.0 | 134.0 | 0.10 | 109.0 | 159.0 | 128.90 | 143.10 | 0.73 |

Table 16. Indicator of Hydrologic Alteration analysis for Rio Grande Floodway at San Acacia, New Mexico, for the Pre-Cochiti Dam period (1937-58) compare post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1937-58 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 278.6 | 2.71 | 0.0 | 3385.8 | 282.0 | 1.42 | 4.9 | 1891.8 | 138.43 | 496.09 | 0.42 |
| November | 357.3 | 1.76 | 3.5 | 2701.3 | 846.7 | 1.33 | 1.6 | 2644.7 | 237.13 | 643.78 | -0.62 |
| December | 747.0 | 0.49 | 157.5 | 1595.8 | 867.5 | 1.23 | 0.1 | 2209.0 | 634.24 | 820.01 | -0.72 |
| January | 723.6 | 0.21 | 372.0 | 1117.7 | 829.5 | 1.34 | 0.3 | 2626.5 | 665.04 | 768.55 | -0.81 |
| February | 792.9 | 0.52 | 508.5 | 1971.3 | 817.4 | 1.37 | 0.2 | 3848.6 | 677.93 | 970.25 | -0.53 |
| March | 648.9 | 1.58 | 112.5 | 2086.8 | 709.4 | 1.74 | 5.0 | 3105.8 | 484.09 | 1023.50 | -0.24 |
| April | 798.7 | 2.40 | 4.5 | 7615.0 | 1041.6 | 2.01 | 15.8 | 5760.9 | 309.48 | 1768.30 | 0.04 |
| May | 1991.2 | 2.75 | 29.9 | 16372.3 | 2607.7 | 1.35 | 12.6 | 6085.5 | 691.99 | 5120.19 | 0.90 |
| June | 1383.4 | 3.17 | 6.8 | 10015.3 | 2312.9 | 1.50 | 6.0 | 5452.7 | 185.04 | 4083.70 | 0.61 |
| July | 430.4 | 3.32 | 3.2 | 4084.2 | 451.2 | 2.91 | 17.6 | 4311.9 | 300.18 | 972.49 | -0.05 |
| August | 627.3 | 0.95 | 90.4 | 3123.4 | 425.7 | 1.49 | 6.3 | 2794.9 | 416.91 | 773.57 | -0.34 |
| September | 173.1 | 1.57 | 10.5 | 827.2 | 558.1 | 1.46 | 60.3 | 1820.7 | 81.24 | 273.05 | -0.34 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.0 | 0.00 | 0.0 | 28.0 | 0.3 | 44.29 | 0.0 | 78.0 | 0.00 | 1.00 | -0.28 |
| 3-day minimum | 0.1 | 60.00 | 0.0 | 49.3 | 5.2 | 8.08 | 0.0 | 169.7 | 0.00 | 1.14 | -0.60 |
| 7-day minimum | 0.3 | 20.44 | 0.0 | 106.3 | 11.5 | 6.49 | 0.0 | 197.1 | 0.00 | 2.68 | -0.54 |
| 30-day minimum | 18.1 | 6.89 | 0.0 | 266.0 | 101.3 | 2.46 | 0.1 | 404.9 | 2.62 | 74.28 | -0.34 |
| 90-day minimum | 207.5 | 1.31 | 9.5 | 550.0 | 264.3 | 2.11 | 0.2 | 1044.5 | 87.00 | 290.27 | -0.53 |
| 1-day maximum | 7595.0 | 0.76 | 2490.0 | 23700.0 | 5240.0 | 0.40 | 2020.0 | 9420.0 | 4543.00 | 9381.90 | 0.80 |
| 3-day maximum | 6151.7 | 1.10 | 1966.7 | 23366.7 | 4726.7 | 0.64 | 1818.3 | 9103.3 | 3903.80 | 8925.90 | 0.71 |
| 7-day maximum | 5288.6 | 1.39 | 1162.7 | 22371.4 | 4078.6 | 0.80 | 1024.6 | 8442.9 | 2411.69 | 8509.73 | 1.09 |
| 30-day maximum | 3905.7 | 1.66 | 760.3 | 17496.7 | 3484.0 | 0.97 | 332.3 | 7530.7 | 1491.88 | 6174.38 | 0.90 |
| 90-day maximum | 2583.1 | 1.28 | 558.5 | 10304.9 | 2419.4 | 1.15 | 169.1 | 5330.8 | 892.38 | 3966.52 | 0.71 |
| Number of zero days (#) | 4.5 | 4.72 | 0.0 | 43.0 | 0.0 | 0.00 | 0.0 | 43.0 | 0.00 | 19.41 | 0.42 |
| Base flow (7-day min/median | 0.0 | 10.10 | 0.0 | 0.1 | 0.0 | 2.98 | 0.0 | 0.2 | 0.00 | 0.00 | -0.65 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 249.0 | 0.07 | 174.0 | 294.0 | 247.0 | 0.22 | 27.0 | 363.0 | 245.59 | 255.41 | -0.72 |
| Date of maximum | 154.0 | 0.21 | 40.0 | 250.0 | 163.0 | 0.28 | 93.0 | 271.0 | 141.36 | 203.05 | 0.23 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 8.0 | 0.91 | 3.0 | 20.0 | 7.0 | 0.86 | 1.0 | 24.0 | 6.00 | 11.41 | -0.09 |
| Low Pulse Duration (days) | 7.1 | 1.07 | 2.7 | 17.8 | 6.5 | 2.48 | 1.0 | 48.0 | 4.91 | 9.64 | -0.24 |
| High Pulse Count | 11.5 | 0.74 | 2.0 | 21.0 | 9.0 | 0.94 | 2.0 | 18.0 | 8.18 | 12.00 | -0.33 |
| High Pulse Duration (days) | 7.7 | 1.25 | 1.7 | 57.0 | 8.6 | 1.86 | 1.5 | 56.0 | 4.02 | 10.16 | -0.15 |
| The low pulse threshold is (cfs) | 126.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1050.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 230.0 | 0.55 | 95.9 | 512.3 | 153.2 | 0.43 | 49.7 | 242.5 | 171.75 | 255.54 | -0.15 |
| Fall rate (cfs/day) | -202.4 | -0.58 | -452.2 | -79.1 | -135.0 | -0.47 | -216.7 | -41.2 | -224.60 | -138.62 | 0.04 |
| Number of reversals | 147.5 | 0.17 | 107.0 | 167.0 | 146.0 | 0.12 | 112.0 | 179.0 | 137.13 | 152.00 | 0.26 |

Table 17. Indicator of Hydrologic Alteration analysis for Rio Grande Floodway at San Marcial, New Mexico, for the Pre-Cochiti Dam perio (1936-58) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1936-58 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | HA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 229.1 | 2.74 | 0.0 | 3587.7 | 144.2 | 1.57 | 0.0 | 1510.6 | 111.85 | 521.15 | 0.45 |
| November | 371.4 | 1.84 | 0.0 | 2871.3 | 718.4 | 0.83 | 0.0 | 2065.1 | 179.84 | 582.23 | -0.26 |
| December | 636.3 | 0.76 | 0.0 | 1550.6 | 661.1 | 0.83 | 0.0 | 1812.3 | 564.77 | 779.84 | -0.17 |
| January | 650.5 | 0.38 | 0.0 | 1180.2 | 688.8 | 0.59 | 0.0 | 2050.0 | 586.60 | 680.81 | -0.82 |
| February | 770.4 | 0.63 | 0.0 | 1861.5 | 774.0 | 0.48 | 0.0 | 3109.6 | 663.83 | 906.35 | 0.03 |
| March | 652.8 | 1.45 | 0.0 | 1934.3 | 652.6 | 1.35 | 0.0 | 2518.1 | 540.75 | 1152.57 | 0.03 |
| April | 766.1 | 2.75 | 0.0 | 7257.3 | 1310.1 | 1.42 | 17.4 | 4763.5 | 173.80 | 1485.24 | 0.24 |
| May | 1274.1 | 3.92 | 0.0 | 16158.7 | 2352.9 | 1.27 | 0.0 | 5322.9 | 384.05 | 3546.13 | 0.55 |
| June | 568.6 | 7.59 | 0.0 | 10231.7 | 2132.4 | 1.51 | 0.0 | 5338.3 | 85.24 | 3410.83 | 0.66 |
| July | 275.6 | 4.47 | 0.0 | 4004.5 | 343.1 | 3.41 | 23.9 | 4654.5 | 93.48 | 660.20 | 0.55 |
| August | 403.8 | 1.28 | 0.0 | 3493.9 | 413.5 | 1.34 | 1.2 | 2438.4 | 208.97 | 609.40 | -0.07 |
| September | 201.1 | 2.67 | 0.0 | 1516.2 | 294.0 | 1.75 | 0.0 | 1340.5 | 98.88 | 294.76 | -0.28 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.4 | 81.25 | 0.0 | 221.0 | 0.0 | 0.00 | 0.0 | 43.0 | 0.00 | 14.50 | 0.34 |
| 3-day minimum | 0.6 | 69.26 | 0.0 | 249.0 | 0.0 | 0.00 | 0.0 | 53.7 | 0.00 | 24.25 | 0.40 |
| 7-day minimum | 2.1 | 24.39 | 0.0 | 404.4 | 0.0 | 0.00 | 0.0 | 104.6 | 0.00 | 31.71 | 0.34 |
| 30-day minimum | 15.5 | 12.41 | 0.0 | 528.3 | 18.4 | 3.66 | 0.0 | 175.6 | 0.00 | 115.80 | 0.29 |
| 90-day minimum | 143.4 | 2.63 | 0.0 | 519.0 | 149.5 | 2.12 | 0.0 | 693.7 | 35.48 | 276.00 | 0.14 |
| 1-day maximum | 4930.0 | 1.41 | 0.0 | 25100.0 | 4520.0 | 0.65 | 1030.0 | 8110.0 | 2550.00 | 9100.00 | 1.17 |
| 3-day maximum | 4538.3 | 1.59 | 0.0 | 23133.3 | 4040.0 | 0.81 | 609.7 | 7886.7 | 2420.00 | 8675.83 | 0.93 |
| 7-day maximum | 4080.0 | 1.77 | 0.0 | 22671.4 | 3697.1 | 0.88 | 425.3 | 7437.1 | 1915.04 | 8138.21 | 1.17 |
| 30-day maximum | 3327.5 | 1.91 | 0.0 | 17770.0 | 2839.0 | 1.03 | 361.7 | 6571.3 | 1330.43 | 5421.25 | 0.97 |
| 90-day maximum | 2235.5 | 1.34 | 0.0 | 10369.1 | 2033.3 | 1.15 | 339.1 | 5044.6 | 893.12 | 3471.44 | 0.76 |
| Number of zero days (#) | 1.5 | 57.00 | 0.0 | 366.0 | 22.0 | 2.77 | 0.0 | 197.0 | 0.00 | 54.00 | 0.14 |
| Base flow (7-day min/median | 0.0 | 16.95 | 0.0 | 0.1 | 0.0 | 0.00 | 0.0 | 0.1 | 0.00 | 0.02 | 0.19 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 242.5 | .27 1 | 14.0 | 305.0 | 275.0 | 0.20 | 82.0 | 330.0 | 218.25 | 275.00 | -0.10 |
| Date of maximum | 147.5 | 0.21 | 42.0 | 359.0 | 159.0 | 0.17 | 2.0 | 260.0 | 132.25 | 172.00 | 0.24 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 3.0 | 1.25 | 0.0 | 8.0 | 5.0 | 0.50 | 1.0 | 14.0 | 2.00 | 5.00 | -0.05 |
| Low Pulse Duration (days) | 7.5 | 2.64 | 0.0 | 56.5 | 9.4 | 1.16 | 0.0 | 27.4 | 3.63 | 13.91 | 0.66 |
| High Pulse Count | 9.0 | 0.56 | 0.0 | 20.0 | 8.0 | 0.88 | 1.0 | 18.0 | 5.00 | 10.00 | -0.23 |
| High Pulse Duration (days) | 7.8 | 1.64 | 0.0 | 124.0 | 11.0 | 1.12 | 1.0 | 99.7 | 5.52 | 13.56 | 0.45 |
| The low pulse threshold is (cfs) | 47.8 | | | | | | | | | | |
| The high pulse level is (cfs) | 970.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 166.6 | 1.05 | 0.0 | 458.1 | 131.0 | 0.70 | 27.7 | 288.7 | 121.44 | 242.86 | 0.55 |
| Fall rate (cfs/day) | -131.1 | -4.03 | 35.2 | 0.0 | -103.3 | -0.74 | -222.3 | -21.6 | -174.20 | -88.04 | 0.34 |
| Number of reversals | 122.5 | 0.34 | 0.0 | 150.0 | 119.0 | 0.22 | 53.0 | 161.0 | 100.75 | 130.75 | 0.45 |

Table 18. P-values for Wilcoxon Signed Rank Tests comparing hydrologic alteration between ten Rio Grande USGS gage stations for the pre-Cochiti Dam and post-Cochiti Dam periods. Values in bold are significant at $p \leq 0.05$.

| **P-Value** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Nr Lobatos** | **Nr Cerros** | **Blw Taos** | **At Emudo** | **At Otowi** | **At Cochiti** | **At San Felipe** | **At Albuquerque** | **At San Acacia** |
| Nr Cerro | 0.224 | - | - | - | - | - | - | - | - |
| Blw Taos | 0.274 | 0.789 | - | - | - | - | - | - | - |
| At Embudo | 0.172 | 0.930 | 0.609 | - | - | - | - | - | - |
| At Otowi | **0.012** | 0.074 | 0.142 | **0.043** | - | - | - | - | - |
| At Cochiti | 0.072 | 0.474 | 0.534 | 0.388 | 0.084 | - | - | - | - |
| At San Felipe | 0.068 | 0.349 | 0.295 | 0.157 | 0.347 | 0.609 | - | - | - |
| At Albuquerque | **0.017** | 0.158 | 0.104 | 0.074 | 1.000 | 0.346 | 0.554 | - | - |
| At San Acacia | **0.001** | **0.009** | **0.009** | **0.002** | 0.106 | **0.012** | 0.071 | 0.116 | - |
| At San Marcial | **0.004** | 0.0529 | **0.049** | **0.026** | 0.580 | 0.161 | 0.224 | 0.588 | 0.555 |

Table 19. Indicator of Hydrologic Alteration analysis for Rio Grande Floodway near Bernardo, New Mexico, for the Pre-Cochiti Dam perio (1958-70) compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1958-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 0.0 | 0.00 | 0.0 | 1075.5 | 227.7 | 1.77 | 0.0 | 1843.5 | 0.00 | 0.00 | -0.96 |
| November | 3.1 | 102.21 | 0.0 | 1972.5 | 950.3 | 0.71 | 167.5 | 2134.3 | 0.00 | 194.78 | -0.90 |
| December | 0.0 | 0.00 | 0.0 | 1023.3 | 880.7 | 0.68 | 442.1 | 2090.0 | 0.00 | 51.04 | -1.00 |
| January | 0.0 | 0.00 | 0.0 | 778.1 | 877.2 | 0.55 | 445.4 | 2265.8 | 0.00 | 24.65 | -1.00 |
| February | 0.1 | 4681.56 | 0.0 | 945.1 | 925.5 | 0.44 | 362.5 | 3707.1 | 0.00 | 45.65 | -1.00 |
| March | 0.0 | 0.00 | 0.0 | 1064.8 | 984.6 | 1.24 | 163.3 | 2761.3 | 0.00 | 64.58 | -1.00 |
| April | 238.9 | 6.18 | 0.0 | 3845.6 | 1571.1 | 1.24 | 29.6 | 5159.6 | 0.01 | 591.21 | -0.01 |
| May | 963.4 | 2.29 | 0.0 | 7860.0 | 2857.1 | 1.17 | 0.7 | 5746.1 | 320.00 | 1632.19 | -0.64 |
| June | 107.7 | 13.05 | 0.0 | 4435.3 | 2638.5 | 1.62 | 0.0 | 6177.7 | 13.38 | 1177.18 | -0.19 |
| July | 0.0 | 0.00 | 0.0 | 1204.1 | 597.2 | 2.57 | 0.0 | 5260.6 | 0.00 | 0.05 | -0.95 |
| August | 2.2 | 122.48 | 0.0 | 1321.2 | 342.2 | 1.22 | 0.0 | 2918.7 | 0.00 | 128.51 | -0.75 |
| September | 0.0 | 0.00 | 0.0 | 278.3 | 284.0 | 2.27 | 0.0 | 1409.2 | 0.00 | 2.18 | -0.95 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.0 | 0.00 | 0.0 | 11.0 | 0.0 | 0.00 | 0.0 | 150.0 | 0.00 | 0.00 | -0.44 |
| 3-day minimum | 0.0 | 0.00 | 0.0 | 11.7 | 0.8 | 85.45 | 0.0 | 160.3 | 0.00 | 0.00 | -0.48 |
| 7-day minimum | 0.0 | 0.00 | 0.0 | 12.6 | 1.1 | 98.13 | 0.0 | 184.6 | 0.00 | 0.00 | -0.55 |
| 30-day minimum | 0.0 | 0.00 | 0.0 | 7.9 | 84.7 | 2.38 | 0.0 | 403.3 | 0.00 | 0.00 | -0.78 |
| 90-day minimum | 0.0 | 0.00 | 0.0 | 38.6 | 269.4 | 1.43 | 0.1 | 789.3 | 0.00 | 0.00 | -1.00 |
| 1-day maximum | 3460.0 | .89 1 | 2.0 | 11600.0 | 4520.0 | 0.91 | 630.0 | 8950.0 | 2182.80 | 4168.40 | -0.46 |
| 3-day maximum | 3053.3 | 0.81 | 48.0 | 11333.3 | 4226.7 | 0.97 | 599.3 | 8653.3 | 2029.27 | 3598.20 | -0.73 |
| 7-day maximum | 2618.6 | 0.88 | 20.6 | 10445.7 | 4131.4 | 0.98 | 496.4 | 8174.3 | 1893.58 | 3194.74 | -0.82 |
| 30-day maximum | 1766.9 | 1.16 | 4.8 | 8423.3 | 3619.7 | 1.01 | 474.4 | 6988.0 | 711.69 | 2426.64 | -0.46 |
| 90-day maximum | 824.4 | 1.65 | 1.6 | 5457.4 | 2872.3 | 1.00 | 455.8 | 5741.1 | 349.83 | 1540.05 | -0.10 |
| Number of zero days (#) | 257.0 | 0.34 | 0.0 | 363.0 | 1.0 | 34.00 | 0.0 | 134.0 | 238.02 | 290.36 | -1.00 |
| Base flow (7-day min/median | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 75.24 | 0.0 | 0.3 | 0.00 | 0.00 | -0.55 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 275.0 | .00 2 | 13.0 | 275.0 | 248.0 | 0.21 | 113.0 | 277.0 | 275.00 | 275.00 | -0.74 |
| Date of maximum | 153.0 | 0.12 | 43.0 | 347.0 | 150.0 | 0.14 | 53.0 | 359.0 | 131.72 | 156.90 | -0.01 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Low Pulse Duration (days) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| High Pulse Count | 4.0 | 1.00 | 0.0 | 10.0 | 5.0 | 1.10 | 1.0 | 12.0 | 2.62 | 5.38 | -0.01 |
| High Pulse Duration (days) | 18.2 | 1.78 | 0.0 | 109.0 | 24.5 | 2.15 | 0.5 | 362.0 | 11.15 | 24.04 | -0.28 |
| The low pulse threshold is (cfs) | 0.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 132.8 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 241.4 | 0.93 | 24.9 | 1211.8 | 127.1 | 0.61 | 34.9 | 276.2 | 142.40 | 290.11 | -0.01 |
| Fall rate (cfs/day) | -182.2 | -3.81 | 56.4 | -24.5 | -116.6 | -0.63 | -201.9 | -24.0 | -214.66 | -119.31 | 0.08 |
| Number of reversals | 39.0 | 0.85 | 1.0 | 136.0 | 130.0 | 0.14 | 94.0 | 149.0 | 29.00 | 47.56 | -1.00 |

Table 20. Indicator of Hydrologic Alteration analysis for Rio Puerco near Bernardo, New Mexico, for the Pre-Cochiti Dam period (1942-7 compared to post-Cochiti Dam period (1975-2003).

| | Pre - Cochiti Period 1942-70 Range Limits | | | | Post-Cochiti Period 1975-2003 Range Limits | | | | RVA Targets | | HA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 12.8 | 3.71 | 0.0 | 586.0 | 4.0 | 6.48 | 0.0 | 165.9 | 2.22 | 15.14 | -0.64 |
| November | 0.0 | 0.00 | 0.0 | 79.2 | 0.3 | 22.08 | 0.0 | 100.2 | 0.00 | 0.78 | -0.20 |
| December | 0.0 | 0.00 | 0.0 | 1.8 | 0.0 | 762.00 | 0.0 | 26.6 | 0.00 | 0.00 | -0.42 |
| January | 0.0 | 0.00 | 0.0 | 4.5 | 0.9 | 2.79 | 0.0 | 70.0 | 0.00 | 0.00 | -0.72 |
| February | 0.0 | 0.00 | 0.0 | 57.1 | 2.8 | 10.03 | 0.0 | 141.6 | 0.00 | 0.12 | -0.65 |
| March | 0.0 | 0.00 | 0.0 | 208.1 | 5.3 | 3.31 | 0.0 | 101.2 | 0.00 | 0.47 | -0.55 |
| April | 0.0 | 0.00 | 0.0 | 52.2 | 3.5 | 4.38 | 0.0 | 93.2 | 0.00 | 2.92 | -0.30 |
| May | 8.2 | 3.81 | 0.0 | 90.7 | 17.9 | 2.71 | 0.0 | 126.0 | 1.01 | 15.67 | -0.18 |
| June | 1.5 | 19.19 | 0.0 | 166.5 | 5.1 | 5.99 | 0.0 | 88.3 | 0.03 | 5.57 | -0.18 |
| July | 31.1 | 3.28 | 0.0 | 362.4 | 15.8 | 4.02 | 0.0 | 255.8 | 14.71 | 62.74 | -0.36 |
| August | 149.3 | 2.05 | 6.6 | 921.6 | 52.2 | 2.29 | 0.0 | 448.8 | 102.07 | 279.88 | -0.09 |
| September | 36.1 | 3.33 | 0.0 | 481.3 | 53.2 | 1.86 | 0.0 | 311.1 | 15.50 | 72.23 | -0.18 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 3-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 7-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 30-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 1.2 | 0.00 | 0.00 | -0.07 |
| 90-day minimum | 0.0 | 0.00 | 0.0 | 0.4 | 0.0 | 404.56 | 0.0 | 8.5 | 0.00 | 0.00 | -0.42 |
| 1-day maximum | 1830.0 | 1.43 | 430.0 | 5010.0 | 947.0 | 0.80 | 321.0 | 2220.0 | 1534.00 | 3402.00 | -0.45 |
| 3-day maximum | 1185.7 | 1.35 | 298.3 | 3336.7 | 658.0 | 0.91 | 144.7 | 1540.0 | 908.10 | 2133.40 | -0.27 |
| 7-day maximum | 805.0 | 1.00 | 151.6 | 2481.6 | 389.9 | 0.85 | 62.3 | 1073.4 | 524.36 | 1091.70 | -0.18 |
| 30-day maximum | 296.8 | 0.92 | 50.5 | 1052.0 | 170.5 | 0.74 | 26.0 | 527.3 | 207.13 | 425.67 | -0.27 |
| 90-day maximum | 124.4 | 0.95 | 28.6 | 580.0 | 80.2 | 1.01 | 16.2 | 243.4 | 93.49 | 167.49 | -0.18 |
| Number of zero days (#) | 263.0 | 0.16 | 218.0 | 335.0 | 195.0 | 0.54 | 61.0 | 324.0 | 243.50 | 279.00 | -0.75 |
| Base flow (7-day min/median | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 275.0 | 0.01 | 275.0 | 316.0 | 275.0 | 2.00 | 75.0 | 311.0 | 275.00 | 277.10 | 0.05 |
| Date of maximum | 226.0 | 0.14 | 70.0 | 299.0 | 234.0 | 0.13 | 48.0 | 288.0 | 216.00 | 231.80 | -0.58 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Low Pulse Duration (days) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| High Pulse Count | 9.0 | 0.61 | 4.0 | 19.0 | 10.0 | 0.40 | 3.0 | 18.0 | 8.00 | 11.00 | 0.00 |
| High Pulse Duration (days) | 8.9 | 0.44 | 4.2 | 17.2 | 10.5 | 0.74 | 4.4 | 90.0 | 8.07 | 10.36 | -0.45 |
| The low pulse threshold is (cfs) | 0.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 1.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 177.2 | 1.29 | 48.6 | 524.7 | 54.5 | 1.40 | 15.1 | 255.7 | 135.19 | 246.40 | -0.82 |
| Fall rate (cfs/day) | -92.4 | -1.03 | -309.6 | -18.5 | -30.8 | -1.18 | -125.0 | -8.1 | -130.48 | -63.31 | -0.73 |
| Number of reversals | 38.0 | 0.47 | 11.0 | 58.0 | 62.0 | 0.50 | 22.0 | 111.0 | 35.00 | 51.00 | -0.67 |

Table 21. Indicator of Hydrologic Alteration analysis for Rio Chama near Chamita, New Mexico, for the period 1913-35 compared to 1975-2003.

| | Pre - Cochiti Period 1913-35 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | HA |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 104.6 | 1.94 | 22.0 | 705.5 | 257.2 | 1.09 | 37.3 | 1273.0 | 89.60 | 162.66 | -0.63 |
| November | 96.1 | 1.15 | 30.3 | 247.3 | 166.5 | 1.95 | 51.4 | 1224.0 | 73.64 | 135.07 | -0.26 |
| December | 93.5 | 0.62 | 28.2 | 166.8 | 179.2 | 1.69 | 63.4 | 1291.0 | 78.88 | 115.23 | -0.72 |
| January | 100.5 | 0.46 | 45.0 | 150.0 | 152.7 | 0.96 | 63.5 | 876.2 | 73.51 | 113.96 | -0.26 |
| February | 132.4 | 0.64 | 70.0 | 363.9 | 141.6 | 1.26 | 56.1 | 1676.8 | 111.46 | 178.51 | -0.63 |
| March | 341.8 | 0.54 | 112.9 | 1039.4 | 443.8 | 0.90 | 85.1 | 1705.2 | 262.93 | 380.13 | -0.72 |
| April | 1082.6 | 1.49 | 524.1 | 4129.3 | 1150.3 | 1.04 | 120.3 | 2533.7 | 745.61 | 1788.06 | -0.08 |
| May | 2160.0 | 0.80 | 297.0 | 4983.5 | 1743.5 | 0.82 | 328.0 | 2741.0 | 1624.81 | 2757.92 | 0.56 |
| June | 1117.4 | 1.22 | 70.9 | 3678.7 | 1109.3 | 1.12 | 117.2 | 2346.0 | 615.25 | 1430.30 | 0.01 |
| July | 330.1 | 1.24 | 24.7 | 2120.0 | 639.1 | 0.59 | 257.7 | 1477.2 | 197.03 | 430.20 | -0.36 |
| August | 176.6 | 1.13 | 10.5 | 2120.0 | 441.8 | 0.59 | 95.5 | 1114.5 | 103.53 | 224.93 | -0.91 |
| September | 120.0 | 2.05 | 5.4 | 2120.0 | 390.0 | 0.78 | 114.2 | 1163.7 | 62.58 | 179.12 | -0.82 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 10.5 | 2.81 | 0.0 | 94.0 | 49.0 | 0.97 | 17.0 | 156.0 | 4.12 | 15.78 | -1.00 |
| 3-day minimum | 11.5 | 2.90 | 0.0 | 96.7 | 50.0 | 1.03 | 18.3 | 220.3 | 8.55 | 17.86 | -1.00 |
| 7-day minimum | 13.4 | 2.62 | 0.0 | 97.0 | 58.4 | 0.95 | 20.0 | 290.3 | 10.44 | 26.11 | -0.91 |
| 30-day minimum | 31.7 | 1.45 | 3.6 | 97.0 | 101.4 | 0.81 | 33.2 | 398.3 | 19.83 | 56.72 | -0.63 |
| 90-day minimum | 58.9 | 0.48 | 17.1 | 100.1 | 136.7 | 1.00 | 60.1 | 397.8 | 51.75 | 71.67 | -0.82 |
| 1-day maximum | 4230.0 | 0.59 | 1330.0 | 7000.0 | 2430.0 | 0.57 | 1020.0 | 3570.0 | 2723.00 | 4550.00 | -0.29 |
| 3-day maximum | 4055.0 | 0.53 | 1310.0 | 6550.0 | 2370.0 | 0.58 | 946.7 | 3480.0 | 2587.17 | 4332.33 | -0.08 |
| 7-day maximum | 3607.9 | 0.52 | 1214.3 | 6251.4 | 2284.3 | 0.54 | 819.1 | 3435.7 | 2440.60 | 3813.27 | 0.01 |
| 30-day maximum | 2762.2 | 0.58 | 754.0 | 5076.7 | 2046.3 | 0.59 | 616.2 | 3042.0 | 2236.31 | 3002.86 | -0.26 |
| 90-day maximum | 1505.3 | 0.78 | 421.2 | 3638.6 | 1328.7 | 0.85 | 491.4 | 2319.1 | 1381.04 | 2108.38 | -0.08 |
| Number of zero days (#) | 0.0 | 0.00 | 0.0 | 27.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.14 |
| Base flow (7-day min/median) | 0.0 | 2.49 | 0.0 | 0.1 | 0.1 | 0.91 | 0.0 | 0.5 | 0.01 | 0.06 | -0.72 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 264.5 | 0.19 | 173.0 | 356.0 | 282.0 | 0.24 | 13.0 | 358.0 | 232.05 | 268.73 | -0.54 |
| Date of maximum | 134.5 | 0.05 | 105.0 | 163.0 | 134.0 | 0.05 | 106.0 | 255.0 | 127.05 | 140.39 | -0.17 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 6.0 | 0.79 | 0.0 | 17.0 | 5.0 | 2.20 | 0.0 | 20.0 | 5.00 | 8.39 | -0.61 |
| Low Pulse Duration (days) | 11.2 | 0.85 | 0.0 | 71.0 | 4.3 | 1.30 | 0.0 | 135.0 | 6.34 | 13.65 | -0.36 |
| High Pulse Count | 4.5 | 0.89 | 2.0 | 10.0 | 8.0 | 0.44 | 2.0 | 16.0 | 4.00 | 8.00 | -0.20 |
| High Pulse Duration (days) | 14.7 | 0.87 | 5.5 | 87.5 | 14.4 | 0.70 | 4.6 | 95.0 | 12.59 | 21.81 | 0.20 |
| The low pulse threshold is (cfs) | 86.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 600.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 102.4 | 0.90 | 41.4 | 261.8 | 68.4 | 0.50 | 37.9 | 107.5 | 81.80 | 133.97 | -0.26 |
| Fall rate (cfs/day) | -81.6 | -0.71 | -172.7 | -34.7 | -60.2 | -0.38 | -89.7 | -33.7 | -101.12 | -58.58 | 0.38 |
| Number of reversals | 95.5 | 0.45 | 66.0 | 133.0 | 132.0 | 0.11 | 110.0 | 157.0 | 78.66 | 109.51 | -1.00 |

Table 22. Indicator of Hydrologic Alteration analysis for Jemez River below Jemez Canyon Dam, New Mexico, for the period 1937-53 compared to 1975-2003.

| | Pre - Cochiti Period 1937-53 | | Range Limits | | Post-Cochiti Period 1975-2003 | | Range Limits | | RVA Targets | | HA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | CD | Low | High | Median | CD | Low | High | Low | High | |
| **Parameter Group 1** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| October | 10.6 | 3.70 | 0.1 | 170.0 | 12.1 | 2.29 | 0.0 | 193.5 | 4.89 | 14.80 | -0.02 |
| November | 15.5 | 1.73 | 4.3 | 170.0 | 23.1 | 1.17 | 2.2 | 179.2 | 10.96 | 29.55 | 0.10 |
| December | 19.6 | 0.94 | 6.8 | 170.0 | 19.9 | 0.80 | 0.2 | 74.4 | 12.33 | 25.39 | 0.47 |
| January | 15.9 | 1.13 | 3.1 | 170.0 | 22.8 | 0.53 | 0.3 | 67.9 | 10.23 | 20.52 | -0.14 |
| February | 23.7 | 0.78 | 14.4 | 170.0 | 27.9 | 0.65 | 0.3 | 75.1 | 20.47 | 31.29 | 0.22 |
| March | 37.3 | 0.85 | 20.2 | 170.0 | 60.0 | 0.98 | 7.8 | 287.7 | 31.30 | 46.95 | -0.33 |
| April | 194.5 | 1.91 | 5.6 | 577.5 | 152.6 | 1.22 | 1.0 | 771.9 | 63.62 | 342.91 | 0.96 |
| May | 105.0 | 2.44 | 3.4 | 390.1 | 120.4 | 2.10 | 0.0 | 967.5 | 38.35 | 236.75 | 0.22 |
| June | 7.6 | 3.17 | 0.0 | 90.8 | 31.3 | 2.51 | 0.0 | 988.4 | 0.68 | 19.73 | -0.14 |
| July | 6.0 | 2.89 | 0.0 | 37.2 | 13.9 | 1.90 | 0.0 | 358.5 | 0.45 | 13.59 | 0.22 |
| August | 14.6 | 1.79 | 0.1 | 87.1 | 32.2 | 1.35 | 0.2 | 246.7 | 6.58 | 21.78 | -0.20 |
| September | 2.3 | 1.77 | 0.0 | 23.1 | 9.1 | 3.05 | 0.0 | 157.4 | 0.87 | 3.92 | -0.71 |
| **Parameter Group #2** | (cfs) | | (cfs) | (cfs) | (cfs) | | (cfs) | (cfs) | (cfs) | (cfs) | |
| 1-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 3.3 | 0.00 | 0.00 | -0.31 |
| 3-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 3.3 | 0.00 | 0.00 | -0.37 |
| 7-day minimum | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 3.4 | 0.00 | 0.00 | -0.43 |
| 30-day minimum | 0.0 | 0.00 | 0.0 | 3.7 | 0.3 | 8.83 | 0.0 | 13.1 | 0.00 | 0.00 | -0.62 |
| 90-day minimum | 2.3 | 2.01 | 0.3 | 11.3 | 6.0 | 1.81 | 0.0 | 24.5 | 1.35 | 4.77 | -0.08 |
| 1-day maximum | 682.0 | 1.14 | 95.0 | 1310.0 | 621.0 | 1.21 | 150.0 | 3640.0 | 382.24 | 859.11 | 0.47 |
| 3-day maximum | 494.3 | 1.58 | 58.7 | 1190.0 | 510.7 | 1.06 | 89.7 | 3403.3 | 268.55 | 758.48 | 0.78 |
| 7-day maximum | 320.9 | 2.13 | 47.9 | 1043.0 | 381.9 | 1.14 | 64.6 | 2982.9 | 182.29 | 654.37 | 0.71 |
| 30-day maximum | 231.9 | 2.01 | 32.8 | 736.9 | 240.8 | 1.04 | 40.0 | 1113.2 | 98.51 | 379.26 | 0.65 |
| 90-day maximum | 162.0 | 1.33 | 24.7 | 340.6 | 146.7 | 1.07 | 27.2 | 625.1 | 51.29 | 196.70 | 0.53 |
| Number of zero days (#) | 104.0 | 0.32 | 56.0 | 143.0 | 17.0 | 4.06 | 0.0 | 174.0 | 99.00 | 114.84 | -0.80 |
| Base flow (7-day min/median | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.1 | 0.00 | 0.00 | -0.43 |
| **Parameter Group #3** | | | | | | | | | | | |
| Date of minimum | 275.0 | 0.22 | 145.0 | 286.0 | 275.0 | 0.26 | 6.0 | 365.0 | 275.00 | 276.00 | -0.43 |
| Date of maximum | 129.0 | 0.32 | 106.0 | 264.0 | 143.0 | 0.33 | 80.0 | 299.0 | 114.58 | 220.39 | 0.29 |
| **Parameter Group #4** | | | | | | | | | | | |
| Low Pulse Count | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| Low Pulse Duration (days) | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| High Pulse Count | 10.0 | 0.75 | 4.0 | 23.0 | 11.0 | 0.55 | 3.0 | 22.0 | 7.58 | 12.71 | 0.22 |
| High Pulse Duration (days) | 6.4 | 0.74 | 1.0 | 15.3 | 8.7 | 0.61 | 2.8 | 20.2 | 4.76 | 7.70 | -0.27 |
| The low pulse threshold is (cfs) | 0.0 | | | | | | | | | | |
| The high pulse level is (cfs) | 40.0 | | | | | | | | | | |
| **Parameter Group #5** | | | | | | | | | | | |
| Rise rate (cfs/day) | 26.5 | 0.73 | 6.0 | 52.9 | 25.4 | 0.79 | 6.0 | 68.7 | 19.70 | 30.63 | -0.33 |
| Fall rate (cfs/day) | -22.8 | -0.84 | -42.7 | -5.7 | -18.9 | -0.68 | -62.1 | -4.4 | -27.34 | -16.69 | 0.29 |
| Number of reversals | 119.0 | 0.22 | 42.0 | 142.0 | 100.0 | 0.36 | 54.0 | 145.0 | 113.29 | 123.71 | -0.63 |

Table 23 . Comparison of Hydrologic Alteration[1] for Colorado, Green , and San Juan Rivers with the Rio Grande. (Colorado and Green River data are from Richter et al., 1998; San Juan River data is from Wesche, 2003).

| Stream Gage Station | 1-day maxima | 30-day minima | Date annual max | Date annual min | High pulse duration | # Hydrograph reversals | Average |
|---|---|---|---|---|---|---|---|
| Colorado River at Hot Sulphur Springs, CO | -0.91 (H)[2] | -0.95 (H) | -0.57 (M) | +0.24 (L) | -0.69 (H) | -0.48 (H) | 0.64 (M) |
| Colorado River near Kremmling, CO | -0.89 (H) | -0.58 (M) | -0.68 (H) | +0.43 (M) | 0.-84 (H) | -0.89 (H) | 0.72 (H) |
| Colorado River at Glenwood Springs, CO | -0.69 (H) | -0.69 (H) | -0.23 (L) | +0.54 (M) | -0.38 (M) | -0.23 (L) | 0.46 (M) |
| Colorado River near Cameo, CO | -0.39 (M) | -0.83 (H) | -0.28 (L) | -0.33 (L) | -0.17 (L) | 0.0 (L) | 0.33 (L) |
| Colorado River near Cisco, UT | -0.68 (H) | -0.43 (M) | -0.60 (M) | -0.52 (M) | -0.43 (M) | -0.19 (L) | 0.48 (M) |
| Colorado River Averages[3] | 0.71 (H) | 0.70 (H) | 0.47 (M) | 0.41 (M) | 0.50 (M) | 0.36 (M) | 0.52 (M) |
| Green River near Greendale, UT | -0.82 (H) | -1.0 (H) | -0.70 (H) | -0.88 (H) | -0.82 (H) | -1.0(H) | 0.87 (H) |
| Green River near Jensen, UT | -0.22 (L) | -1.0(H) | -0.11 (L) | -0.11 (L) | -0.22 (L) | -1.0(H) | 0.44 (M) |
| Green River at Green River, UT | -0.53 (M) | -0.55 (M) | -0.06 (L) | -0.06 (L) | -0.10 (L) | -1.0(H) | 0.38 (M) |
| Green River Averages | 0.52 (M) | 0.81 (H) | 0.29 (L) | 0.35 (M) | 0.38 (M) | 1.0(H) | 0.56 (M) |
| San Juan River near Bluff, UT (1929-61 vs 1965-91) | -0.07 (L) | -0.57 (M) | -0.07 (L) | -0.14 (L) | -0.50 (M) | -0.19 (L) | 0.26 (L) |
| San Juan River near Bluff, UT (1929-61 vs 1992-02) | +0.59 (M) | -0.65 (M) | +0.06 (L) | +0.06 (L) | -0.12 (L) | -0.83 (H) | 0.38 (M) |
| RG at Cochiti (1942-70 vs 1975-2003) | +0.55 (M) | +0.55 (M) | +0.36 (M) | -0.50 (M) | -0.18 (L) | -0.42 (M) | 0.43 (M) |
| RG at San Felipe (1942-70 vs 1975-2003) | +0.91 (H) | -0.73 (H) | +0.36 (M) | -0.33 (L) | -0.36 (M) | -0.27 (L) | 0.49 (M) |
| RG at Albuquerque (1942-70 vs 1975-2003) | +0.55 (M) | -0.64 (M) | +0.73 (H) | -0.42 (M) | +0.09 (L) | +0.73 (H) | 0.53 (M) |
| RG at San Acacia (1937-58 vs 1975-2003) | +0.80 (H) | -0.34 (M) | +0.23 (L) | -0.72 (H) | -0.15 (L) | +0.26 (L) | 0.42 (M) |
| RG at San Marcial (1899-1935 vs 1975-2003) | -0.90 (H) | -0.07 (L) | +0.55 (M) | -0.22 (L) | -0.38 (M) | -0.62 (M) | 0.46 (M) |
| RG at San Marcial (1936-58 vs 1975-2003) | +1.17 (H) | +0.29 (L) | +0.24 (L) | -0.10 (L) | +0.45 (M) | +0.45 (M) | 0.45 (M) |

[1] A positive deviation indicates that annual parameters values fell inside the RVA target window more often than expected (e.g., >50% of post-dam years): negative values indicate that annual values fell within the RVA target window less often than expected (e.g., <50%).

[2] Degree of hydrologic alteration is denoted as H=high, M=medium, and L=low.

[3] Average values are based upon absolute values of each deviation.

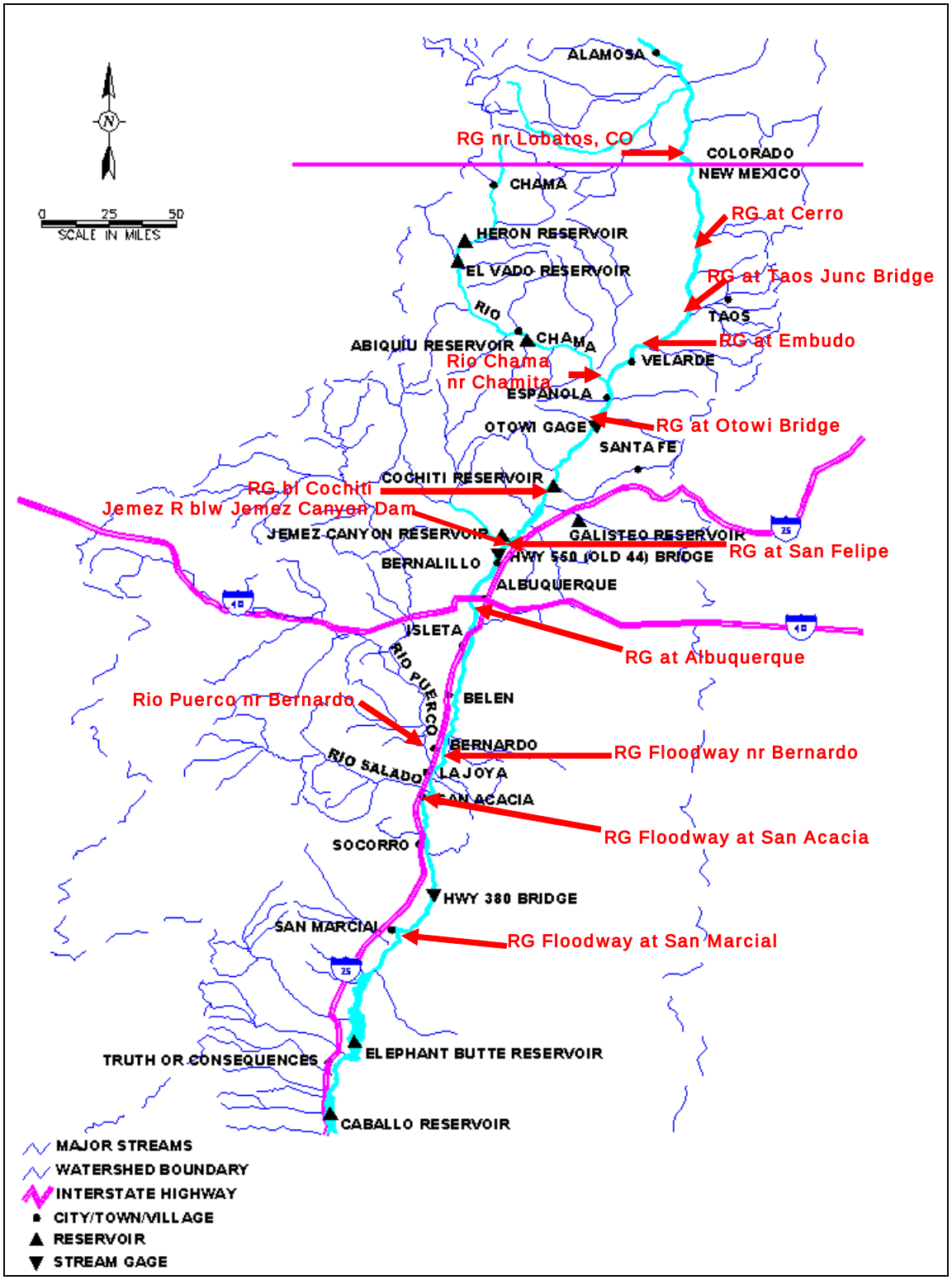



Figure 1. Map of Rio Grande indicating U.S. Geological Survey stream flow gaging stations used for Indicators of Hydrologic Alteration analysis.

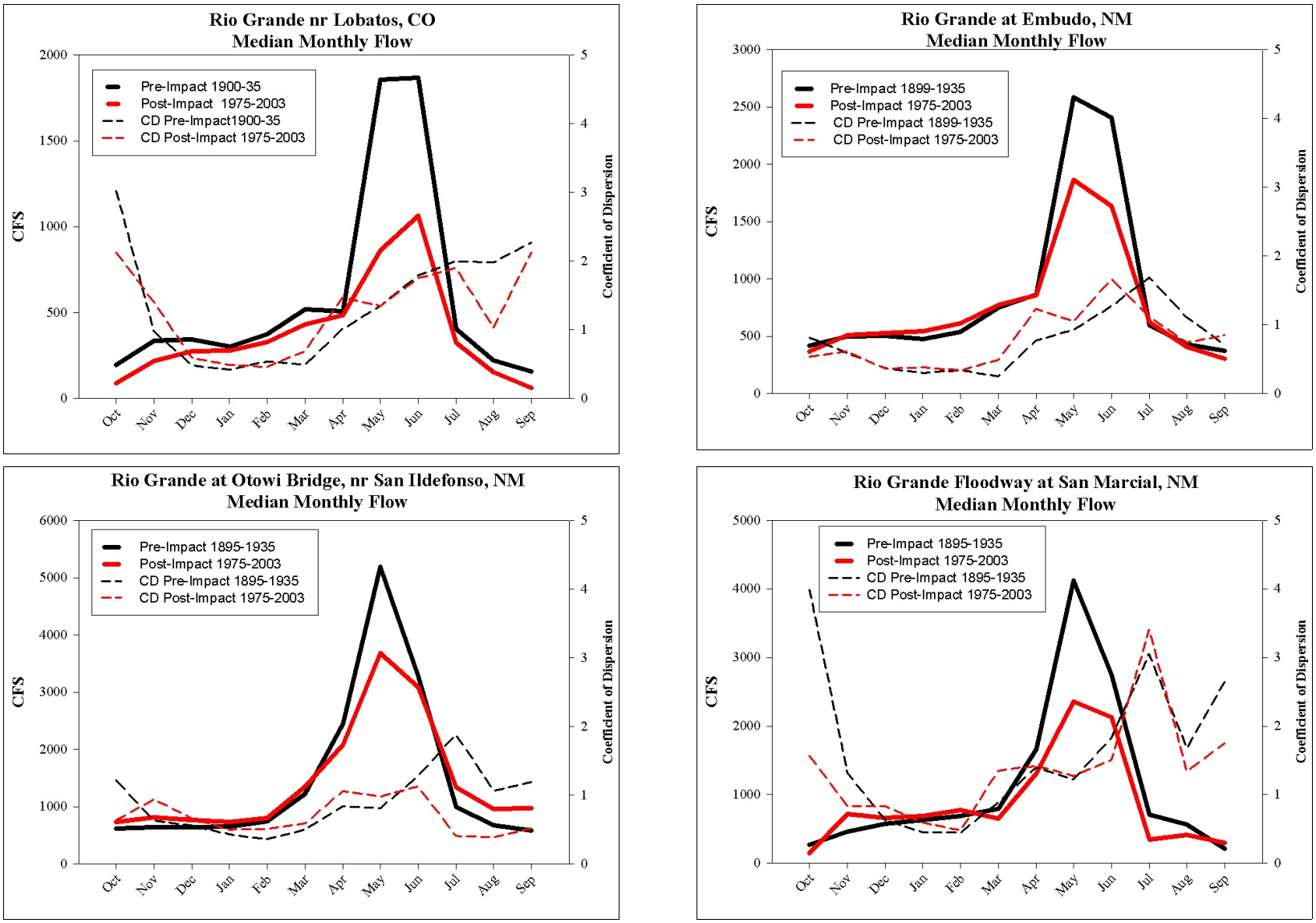



Figure 2. Median monthly stream flow at the Rio Grande near Lobatos, at Embudo, at Otowi, and at San Marcial USGS gage stations for the pre-MRGCD and post-Cochiti Dam periods.

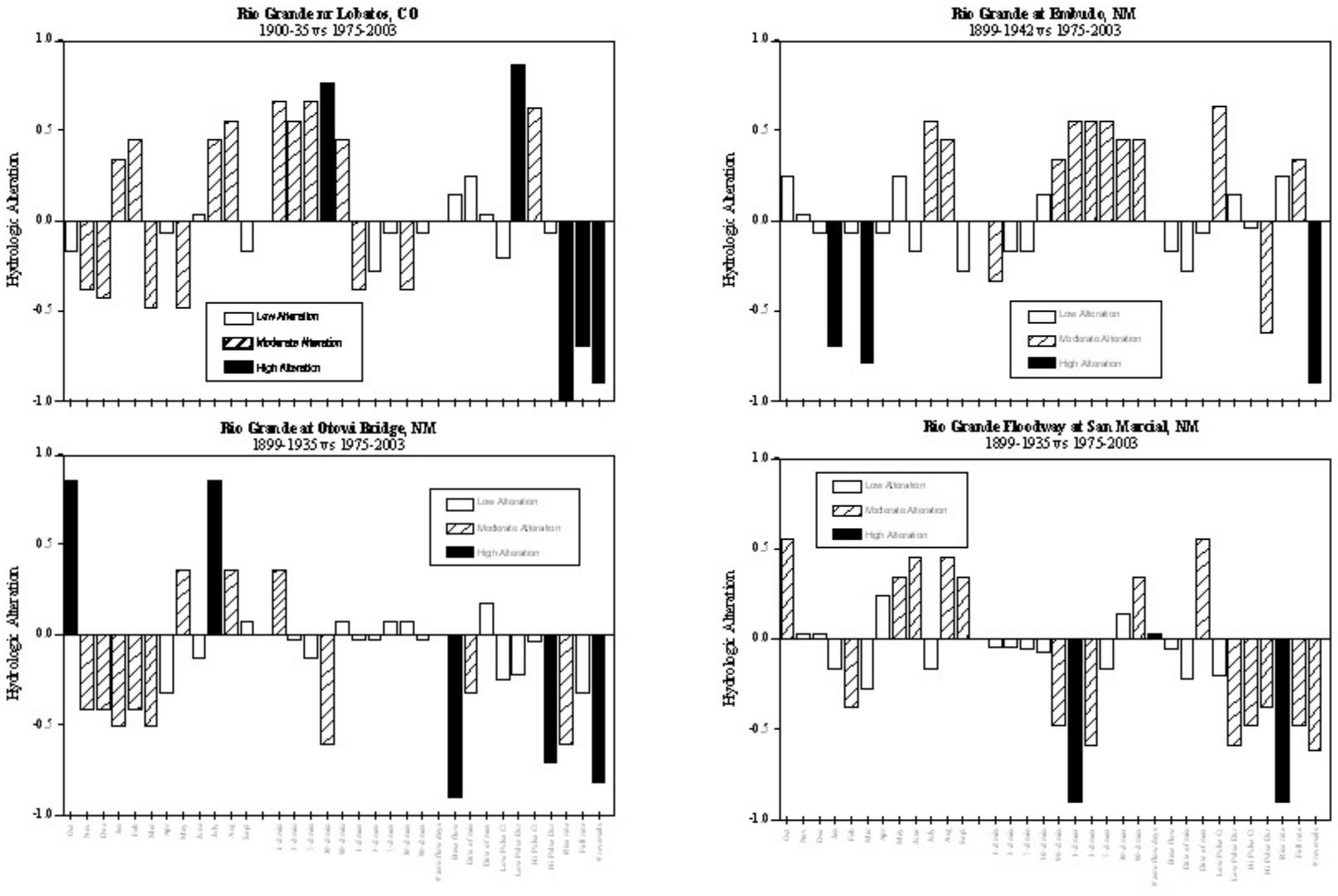



Figure 3. Hydrologic alteration of 33 IHA parameters at four Rio Grande USGS stream gage stations comparing the pre-MRGCD and post-Cochiti Dam periods.

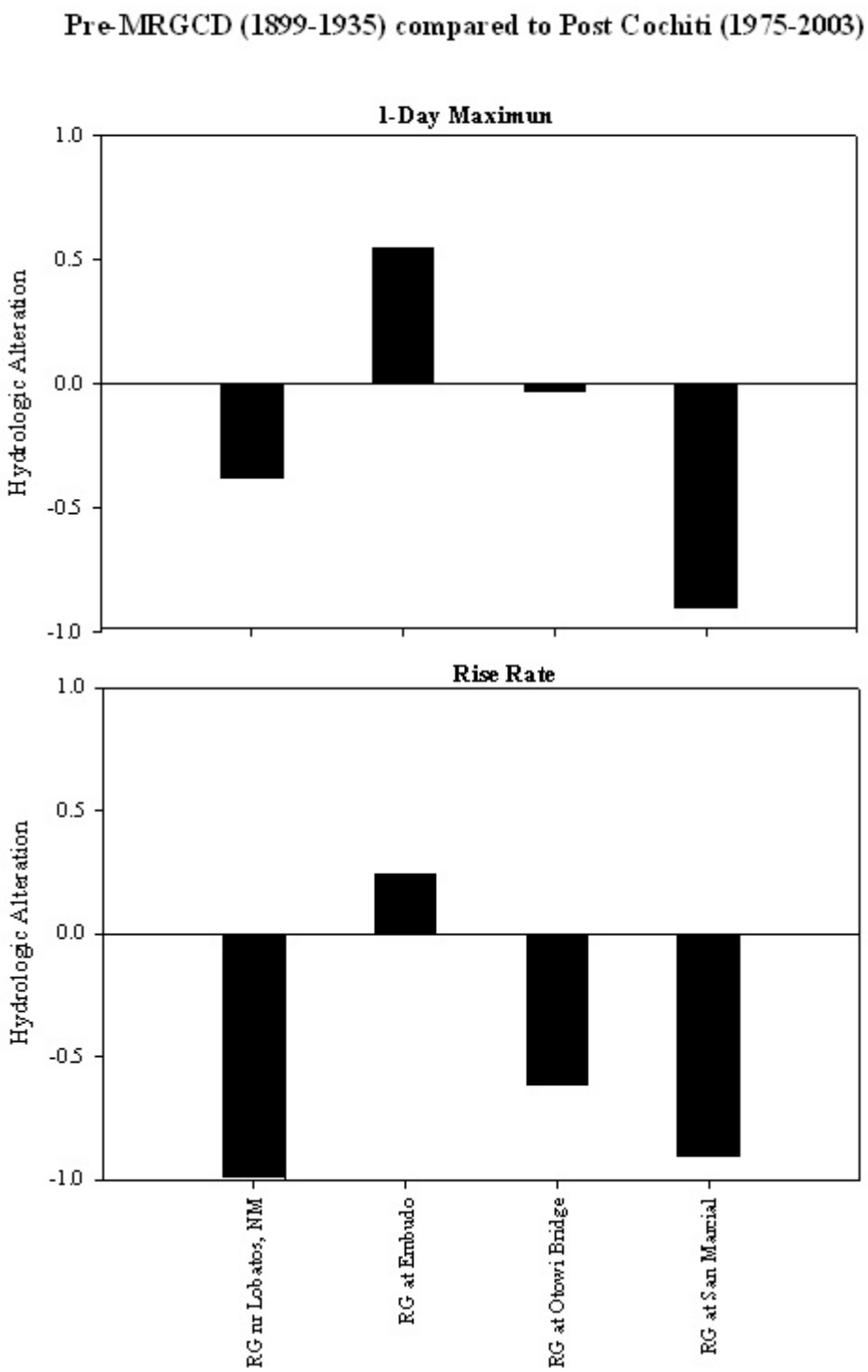



Figure 4. Spatial trend of hydrologic alteration for 1-day maximum and rise rate at four Rio Grande USGS stream gage stations comparing the pre-MRGCD and post-Cochiti Dam periods.

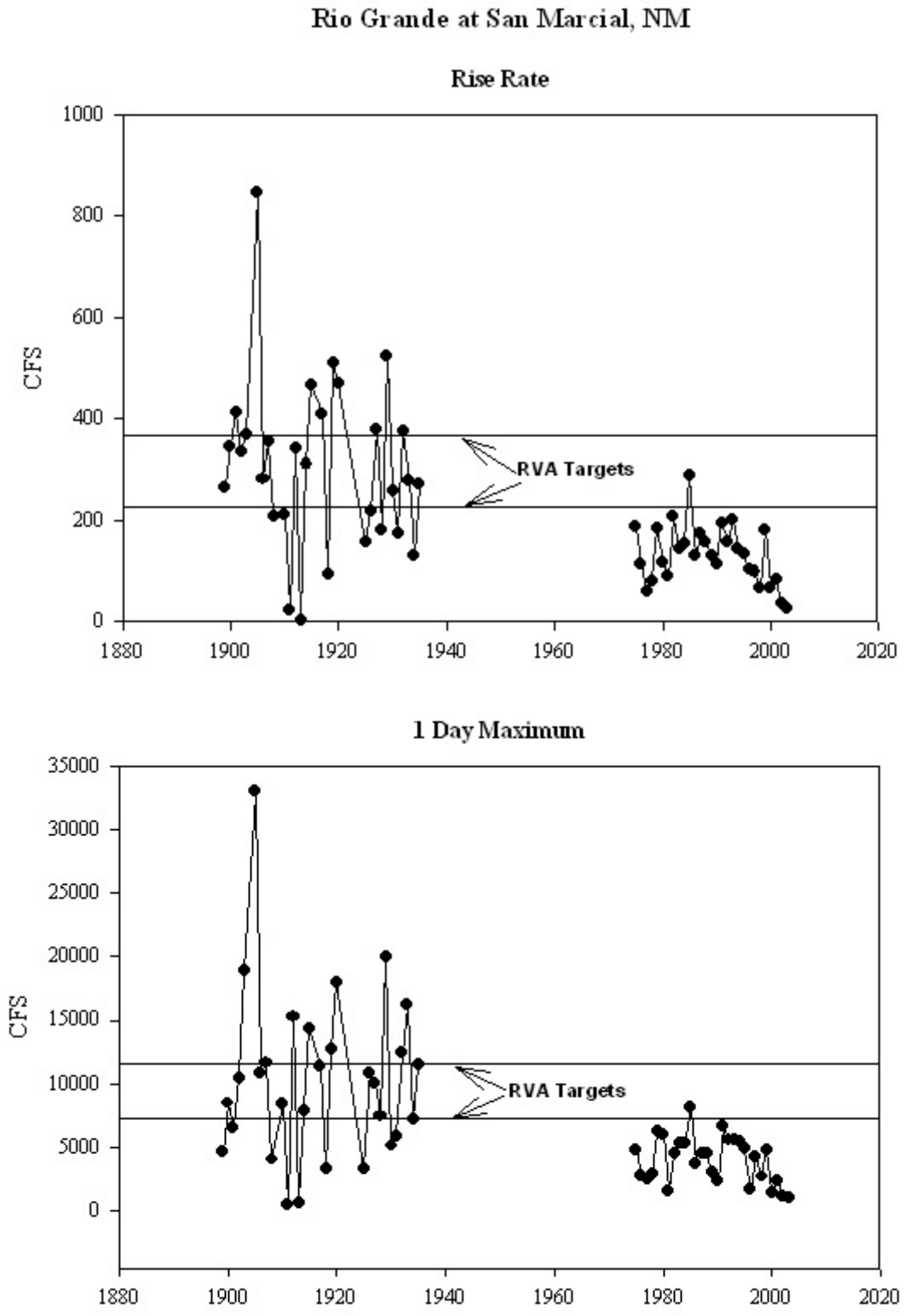



Figure 5. Range of Variability Analysis (RVA) targets for 1-day maxima and rise rate at Rio Grande at San Marcial USGS stream flow gage station comparing pre-MRGCD and post-Cochiti Dam periods.

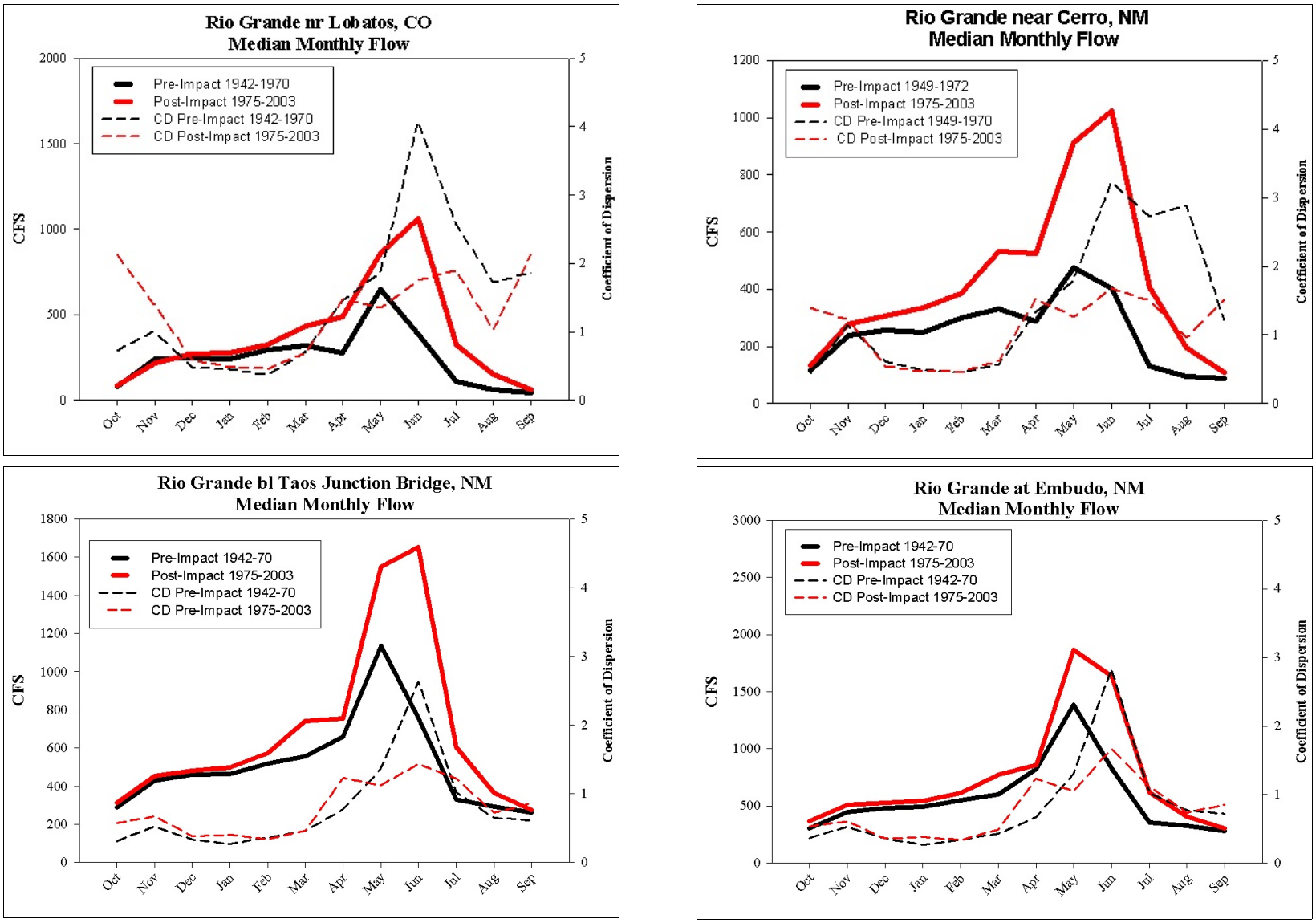
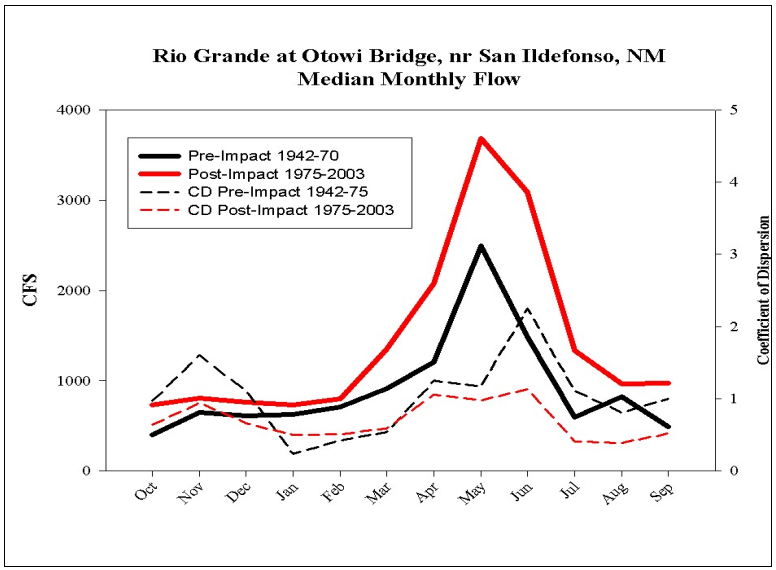
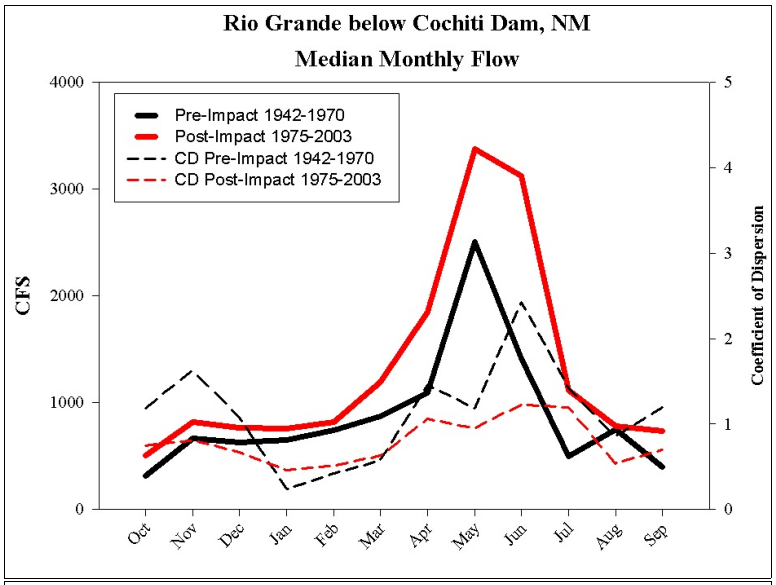
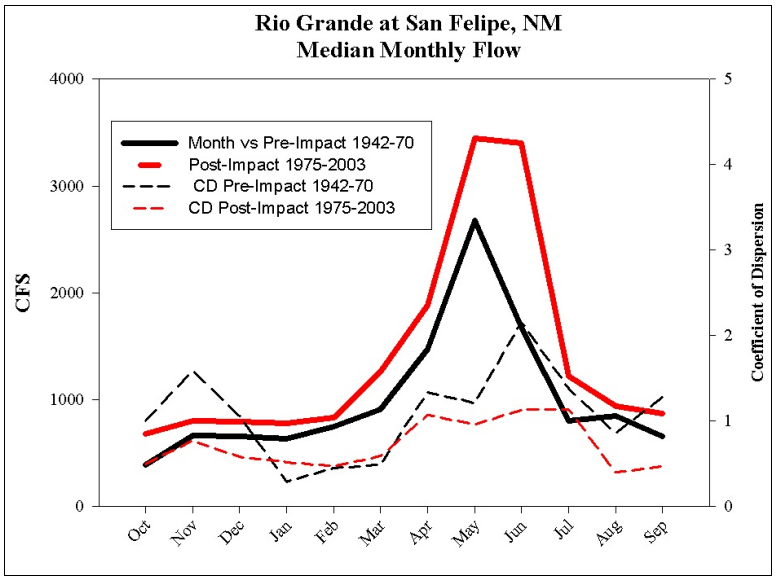



Figure 6. Median monthly stream flow for ten Rio Grande USGS gage stations for the pre-Cochiti Dam and post-Cochiti Dam periods.



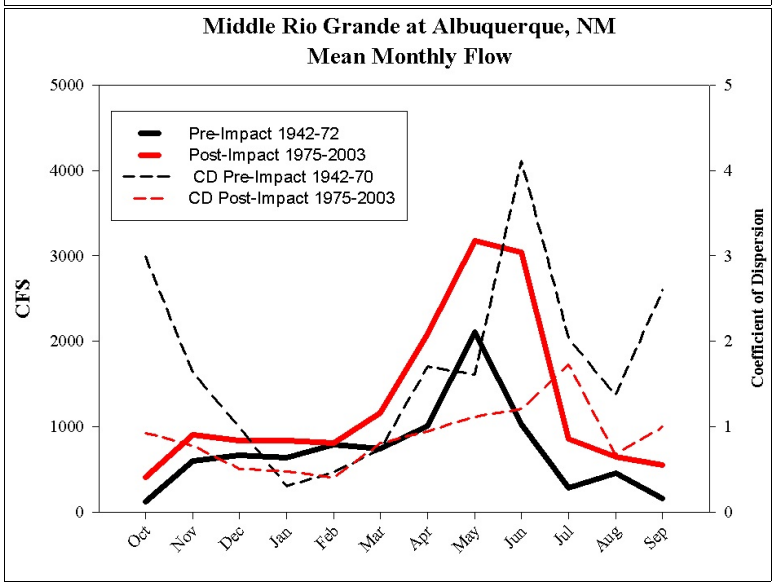
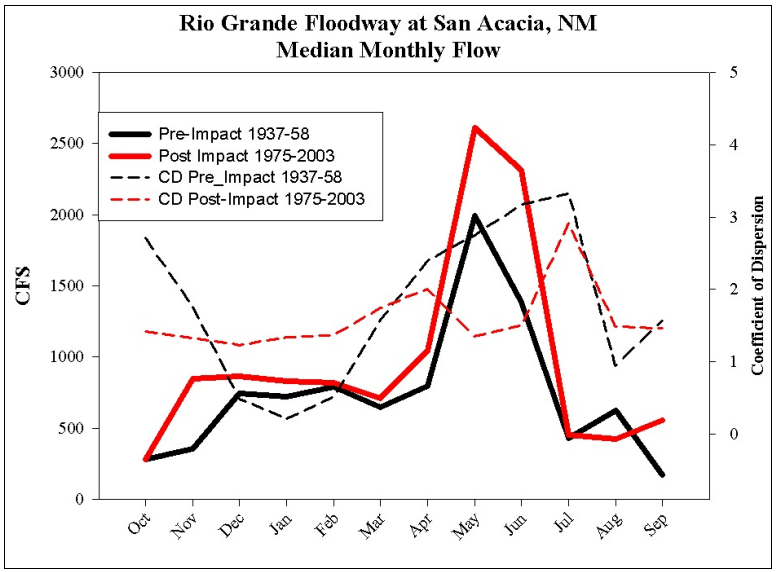




Figure 6 (cont). Median monthly stream flow for ten Rio Grande USGS gage stations for the pre-Cochiti Dam and post-Cochiti Dam periods.



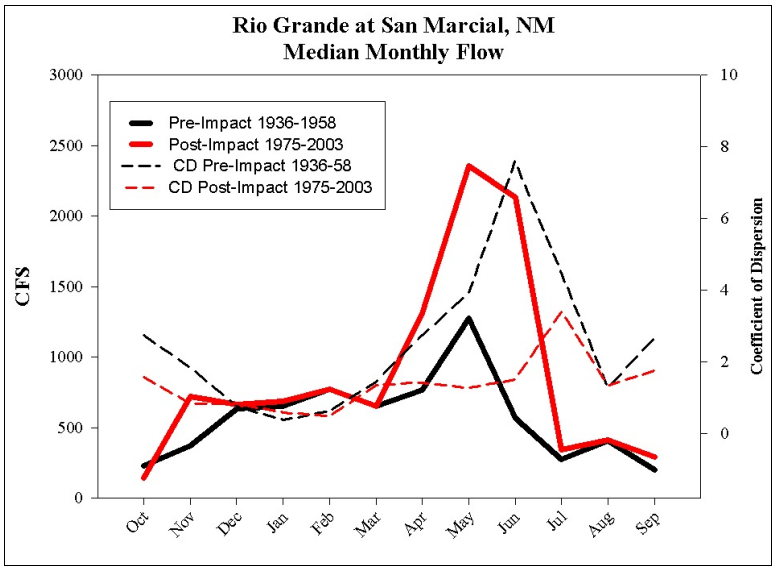




Figure 6 (cont). Median monthly stream flow for ten Rio Grande USGS gage stations for the pre-Cochiti Dam and post-Cochiti Dam periods.

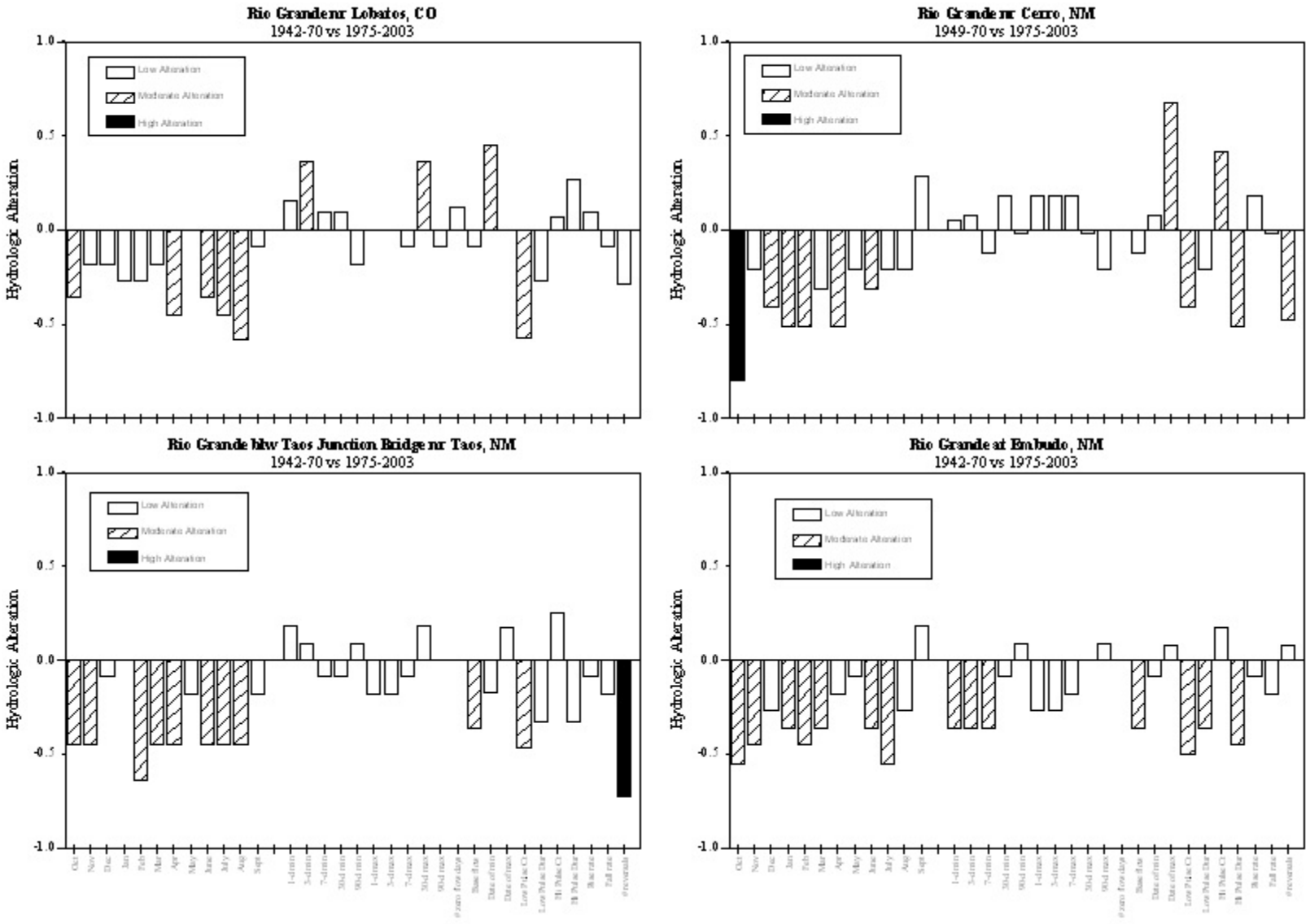



Figure 7. Hydrologic alteration of 33 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

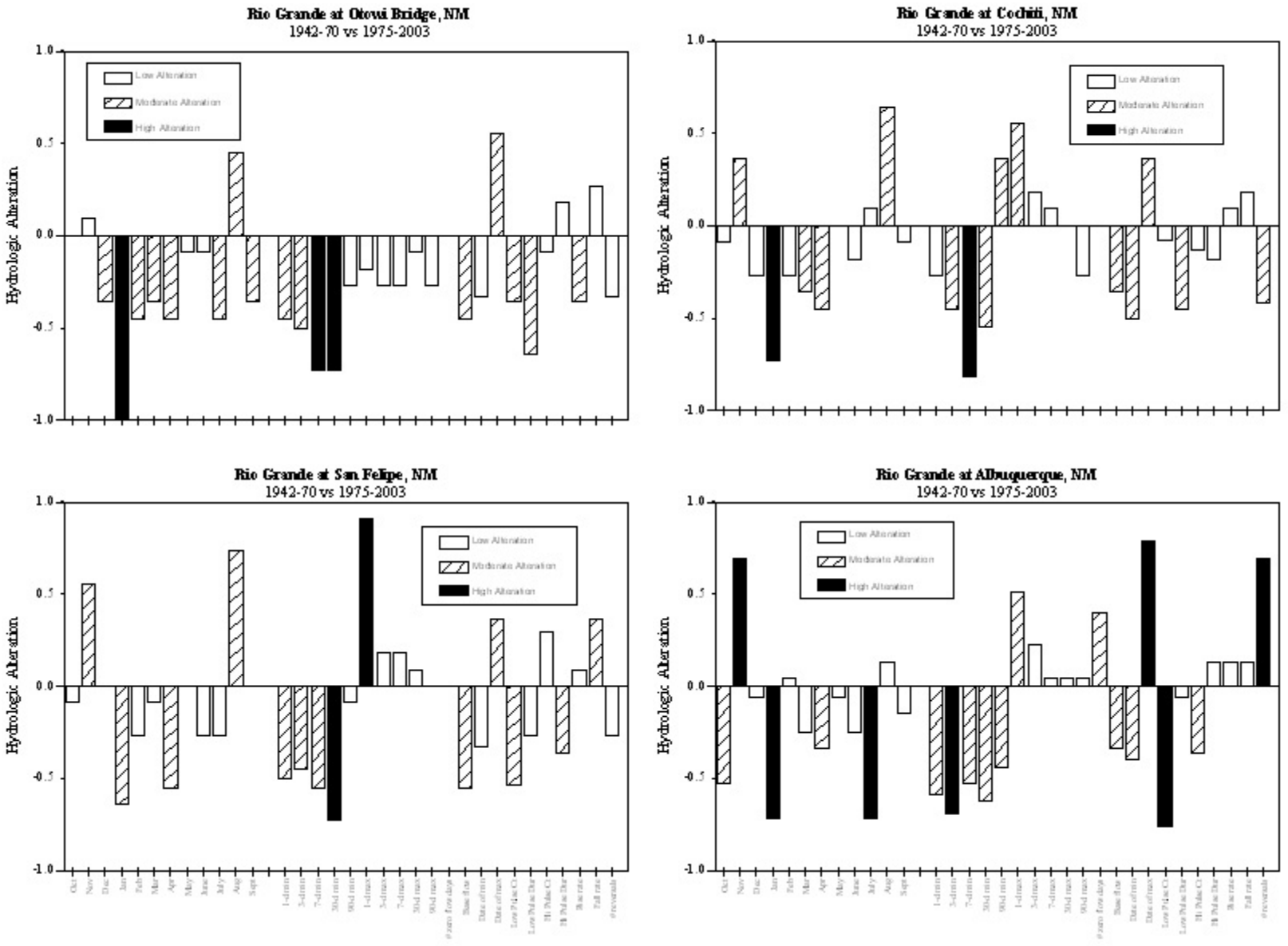
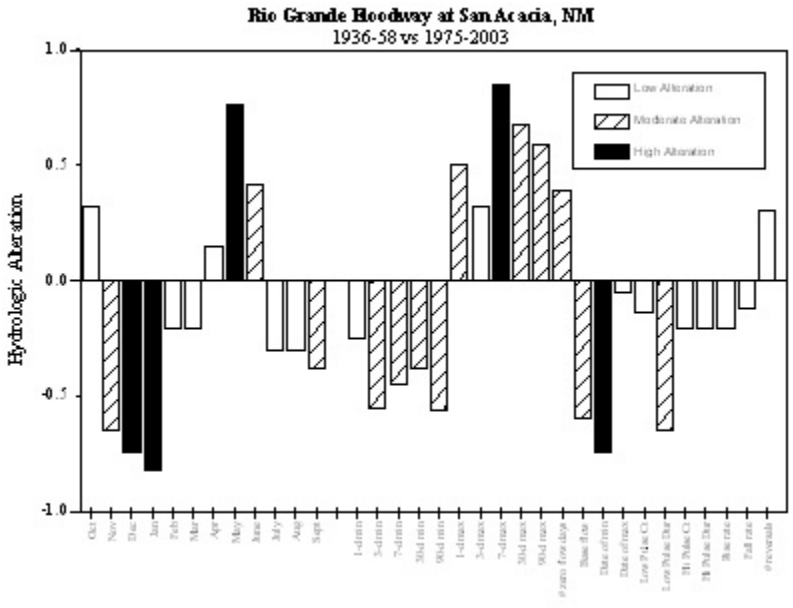



Figure 7 (cont). Hydrologic alteration of 33 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.



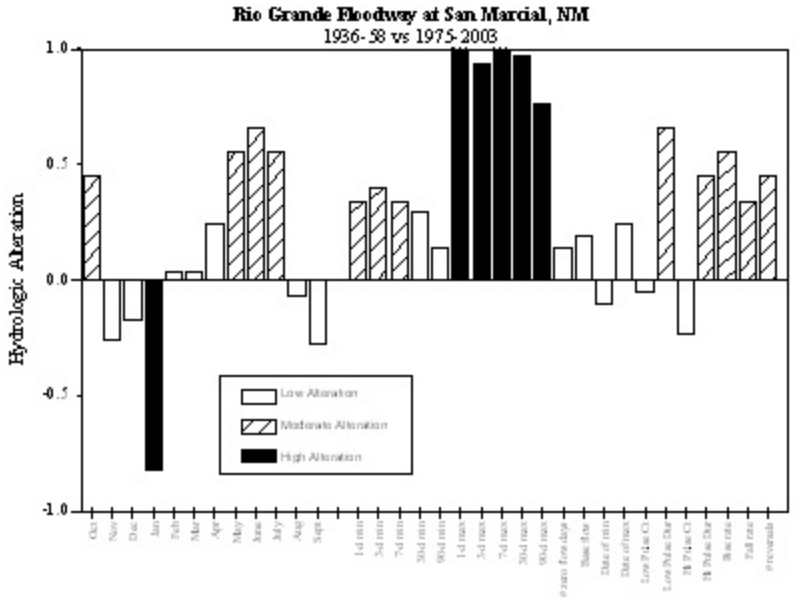




Figure 7 (cont). Hydrologic alteration of 33 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

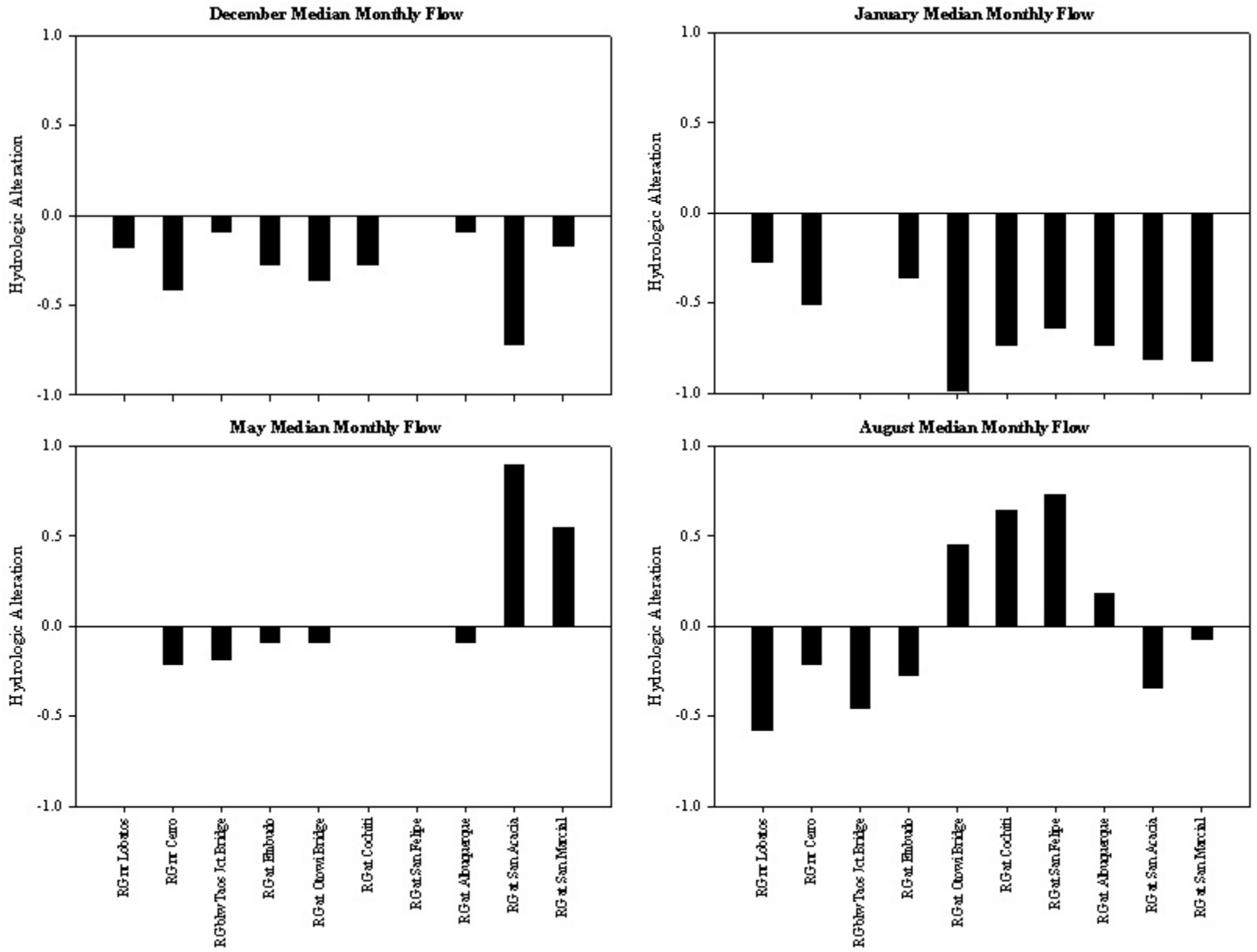



Figure 8. Spatial trends of hydrologic alteration for 16 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

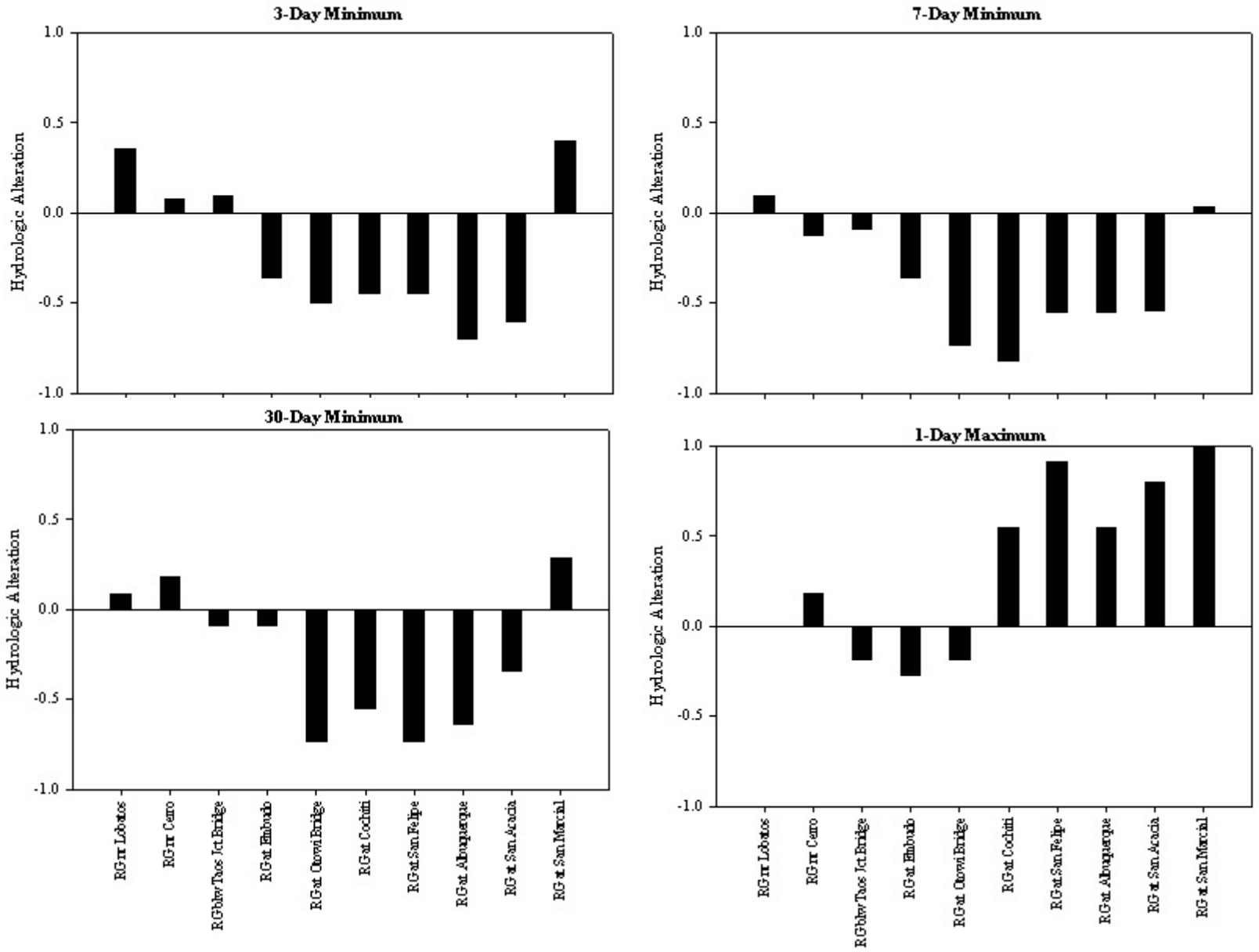



Figure 8 (cont). Spatial trends of hydrologic alteration for 16 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

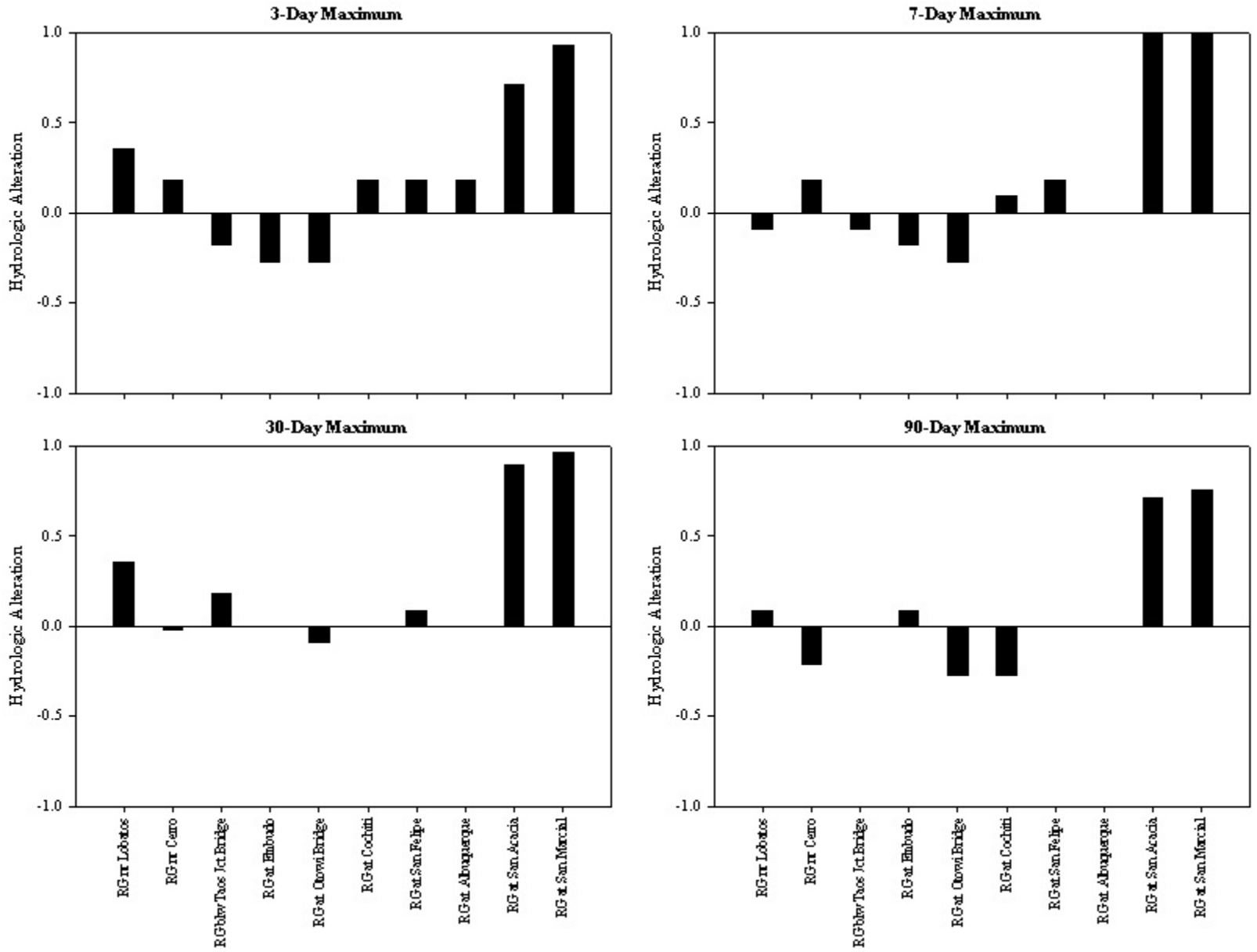



Figure 8 (cont). Spatial trends of hydrologic alteration for 16 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

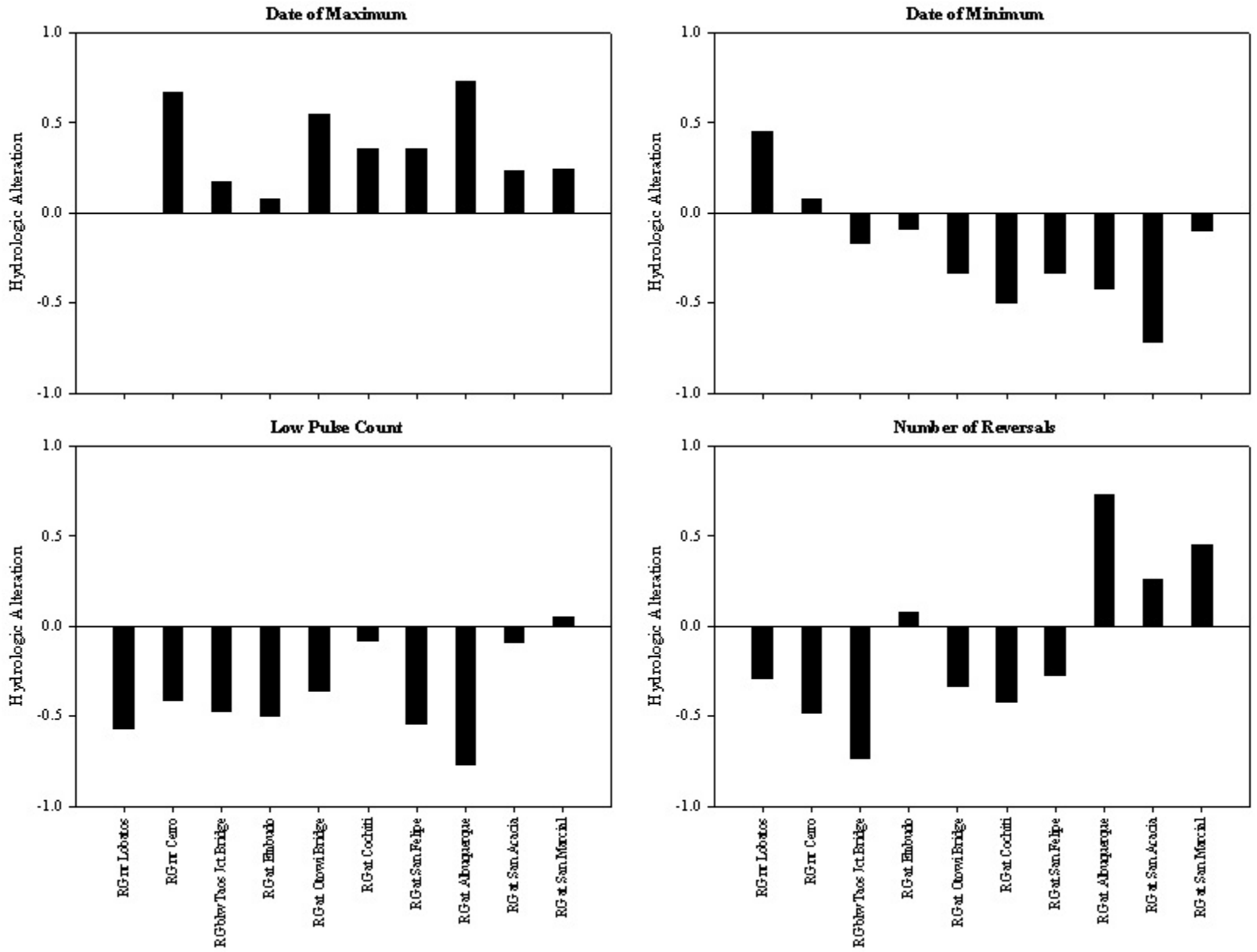



Figure 8 (cont). Spatial trends of hydrologic alteration for 16 IHA parameters at 10 Rio Grande USGS stream gage stations comparing the pre-Cochiti Dam and post-Cochiti Dam periods.

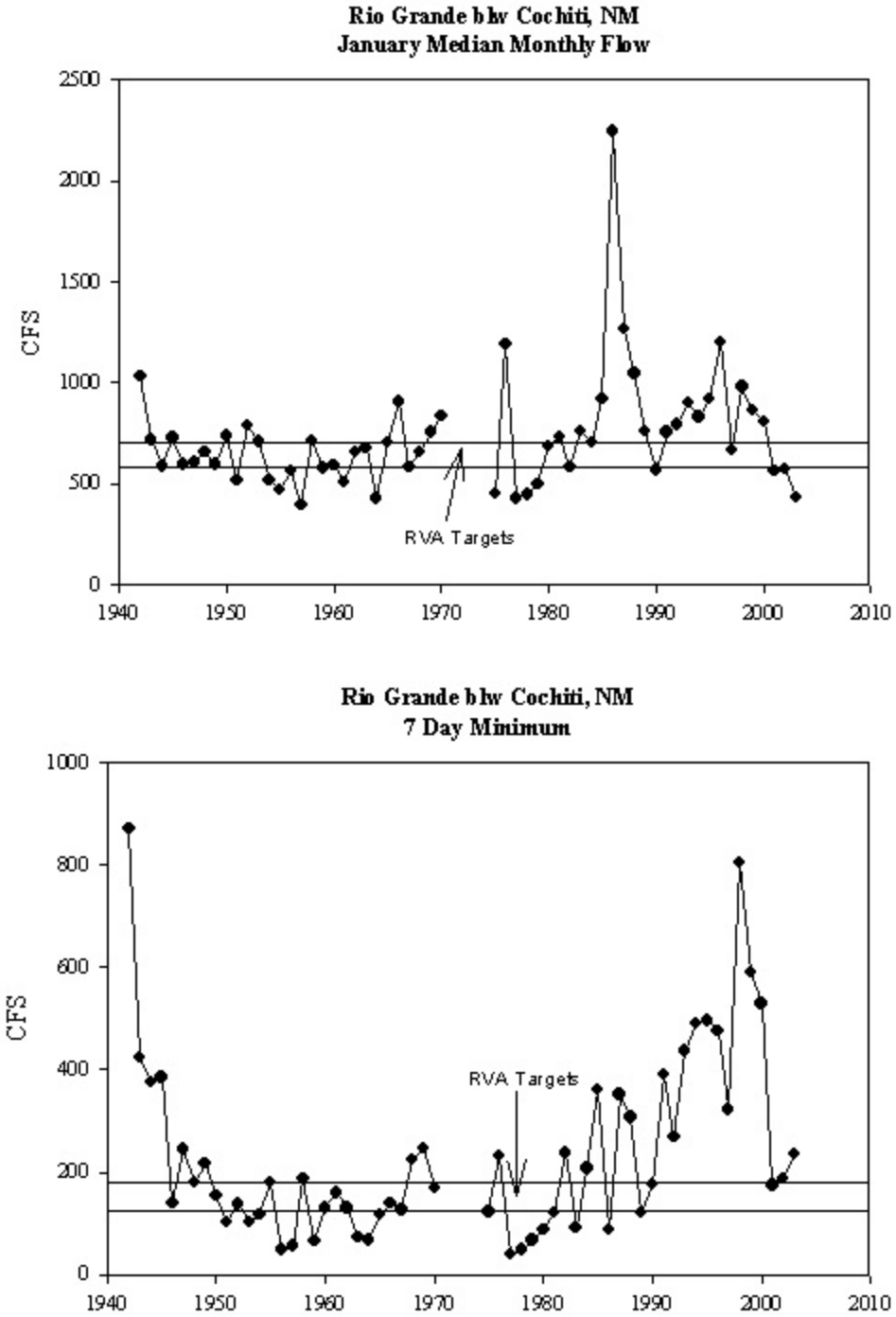



Figure 9. Range of Variability Analysis (RVA) targets for January median monthly flow and 7-day minimum flow at Rio Grande below Cochiti, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

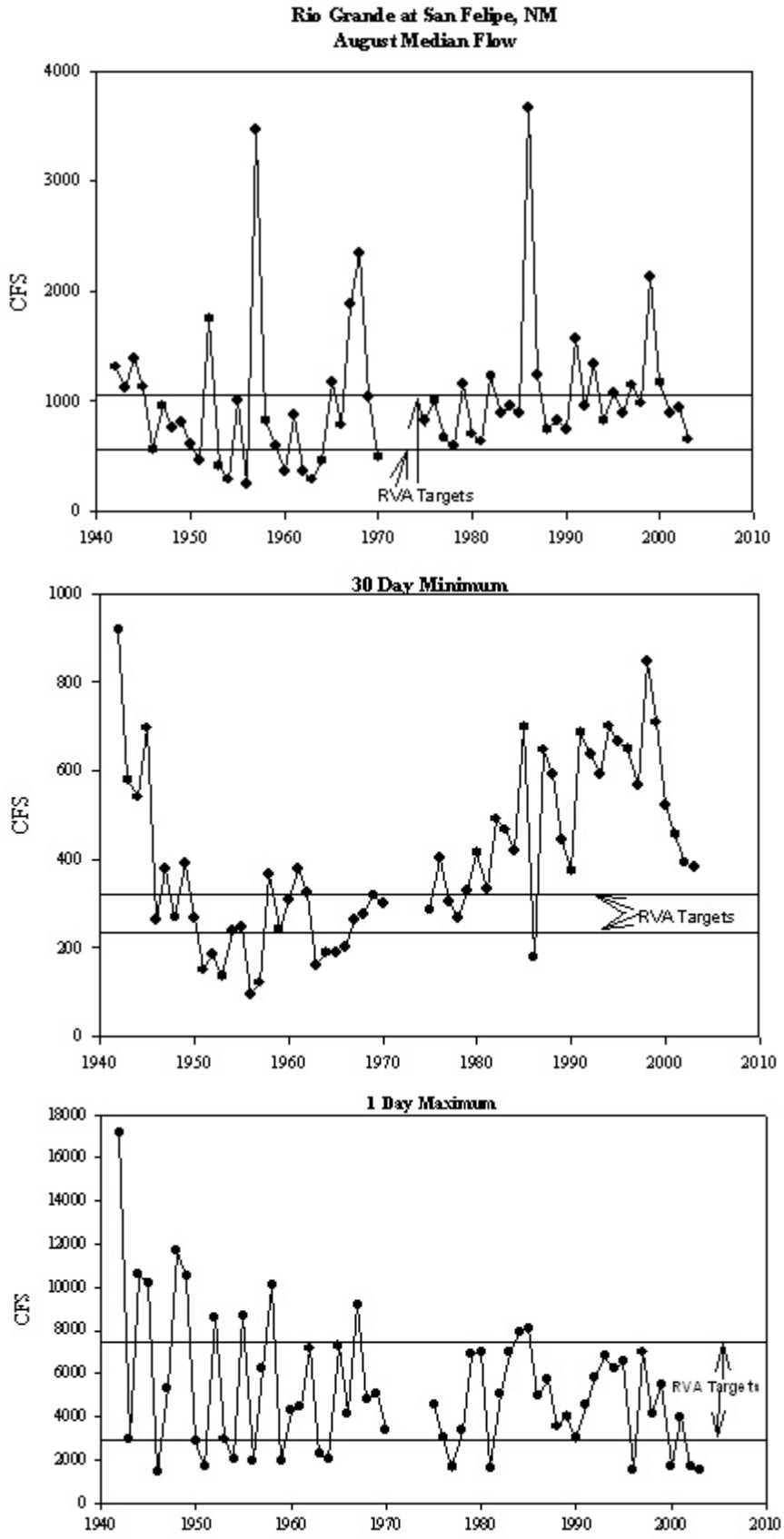



Figure 10. Range of Variability Analysis (RVA) targets for August median flow, 30-day minimum and 1-day maximum flow at Rio Grande at San Felipe, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

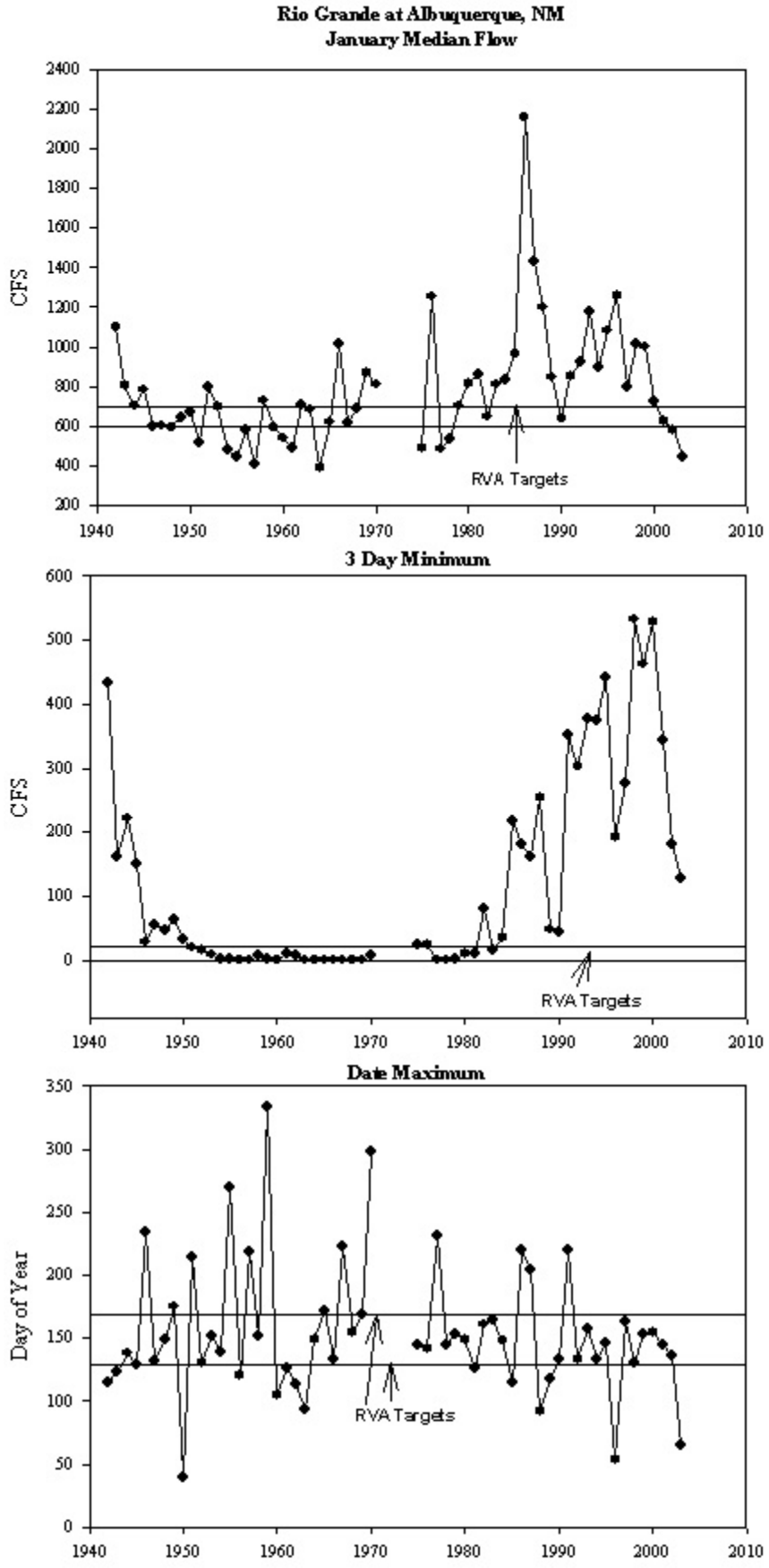



Figure 11. Range of Variability Analysis (RVA) targets for January median flow, 3-day minimum, date of maximum, low pulse count and number of reversals at Rio Grande at Albuquerque, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

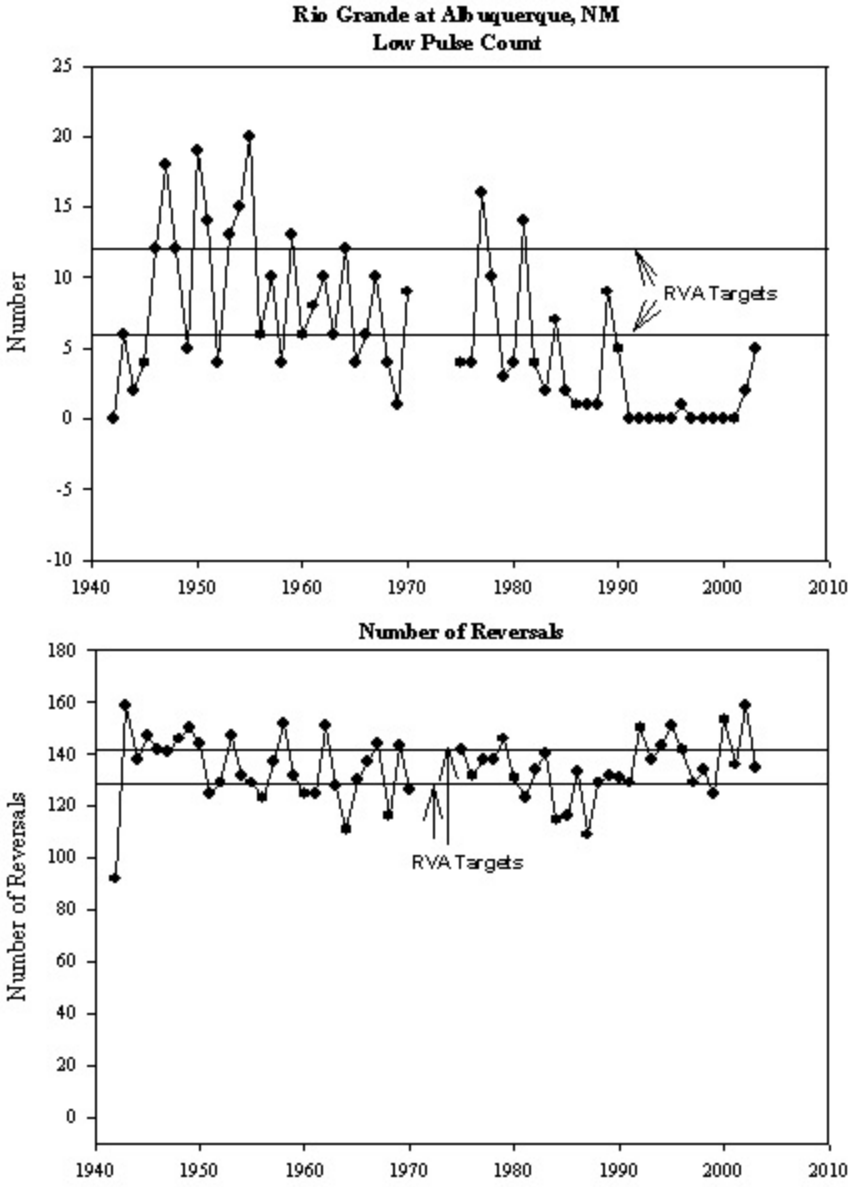



Figure 11 (cont). Range of Variability Analysis (RVA) targets for January median flow, 3-day minimum, date of maximum, low pulse count and number of reversals at Rio Grande at Albuquerque, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

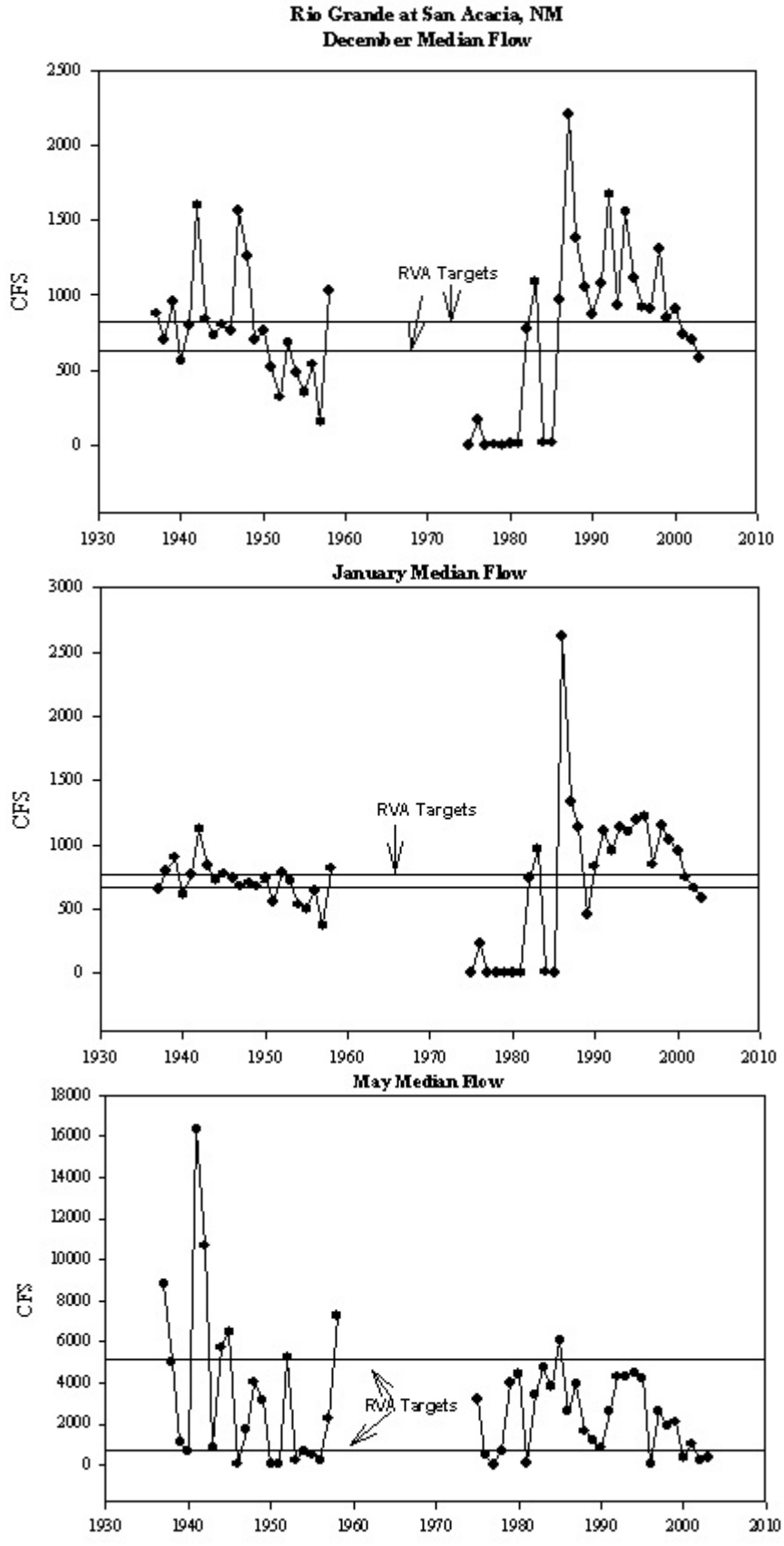



Figure 12. Range of Variability Analysis (RVA) targets for December, January and May median flow, 1-day, 3-day, 7-day, 30-day and 90-day maximum, and date of minimum at Rio Grande at San Acacia, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

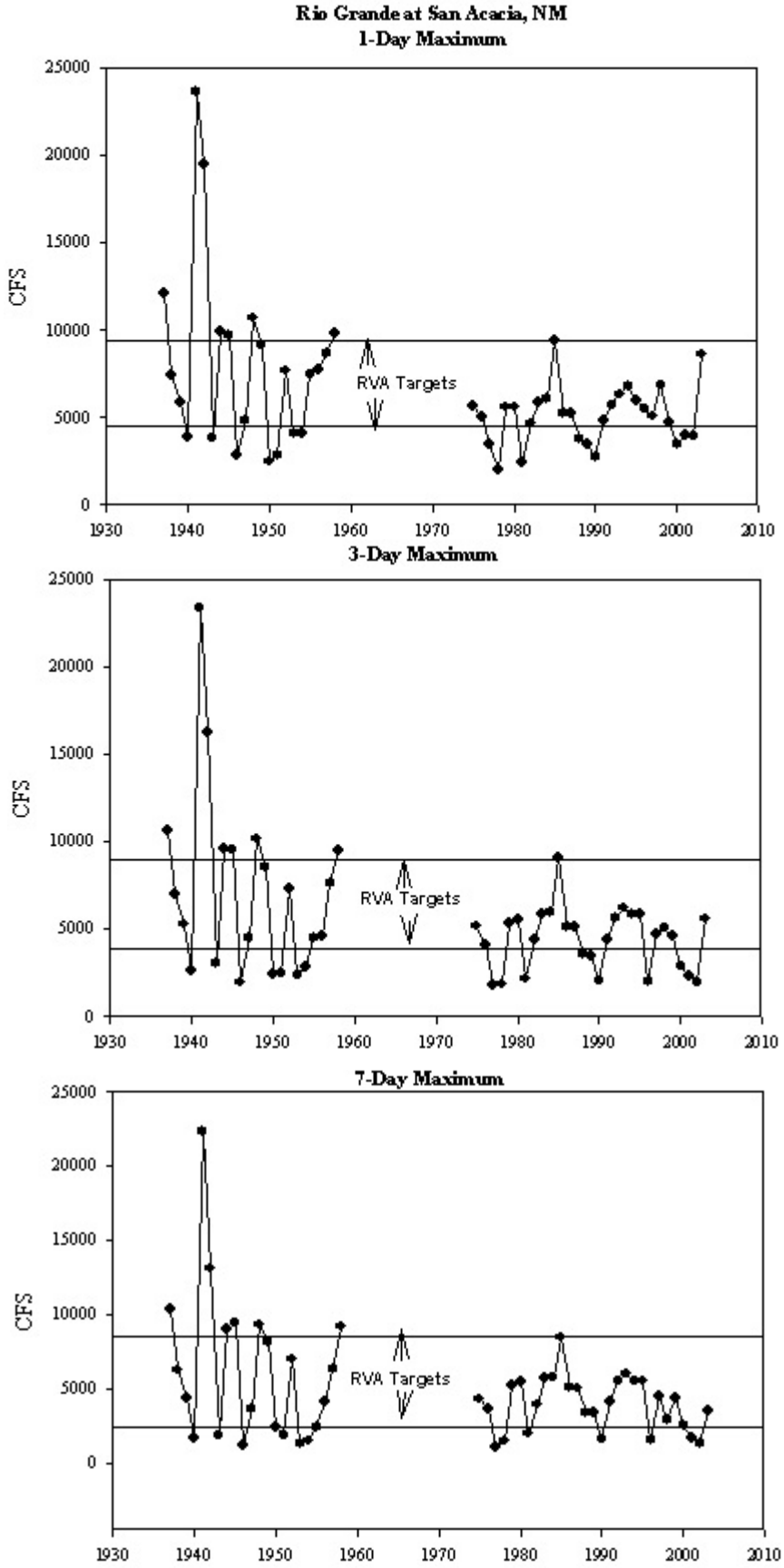



Figure 12 (cont). Range of Variability Analysis (RVA) targets for December, January and May median flow, 1-day, 3-day, 7-day, 30-day and 90-day maximum, and date of minimum at Rio Grande at San Acacia, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

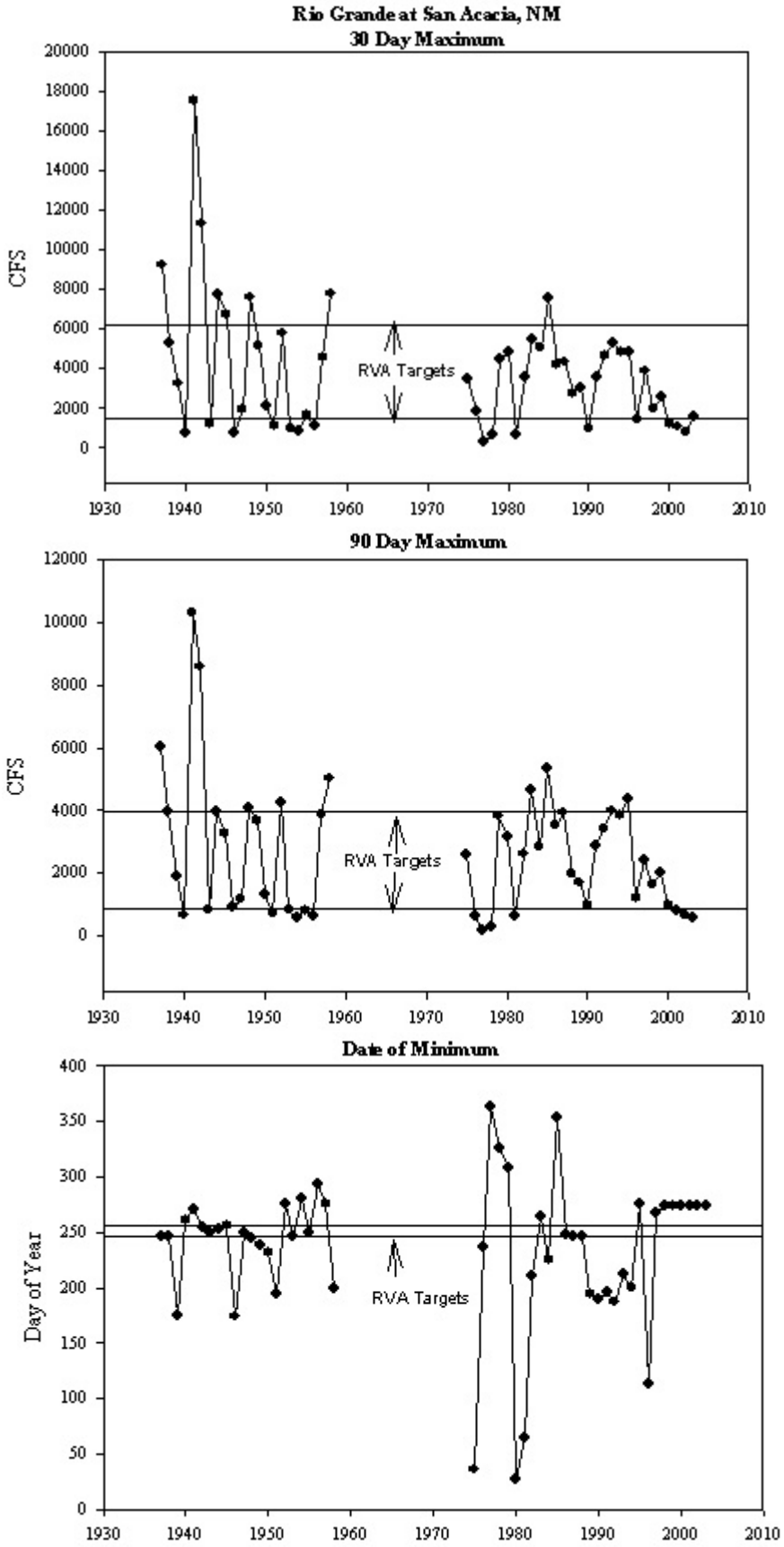



Figure 12 (cont). Range of Variability Analysis (RVA) targets for December, January and May median flow, 1-day, 3-day, 7-day, 30-day and 90-day maximum, and date of minimum at Rio Grande at San Acacia, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

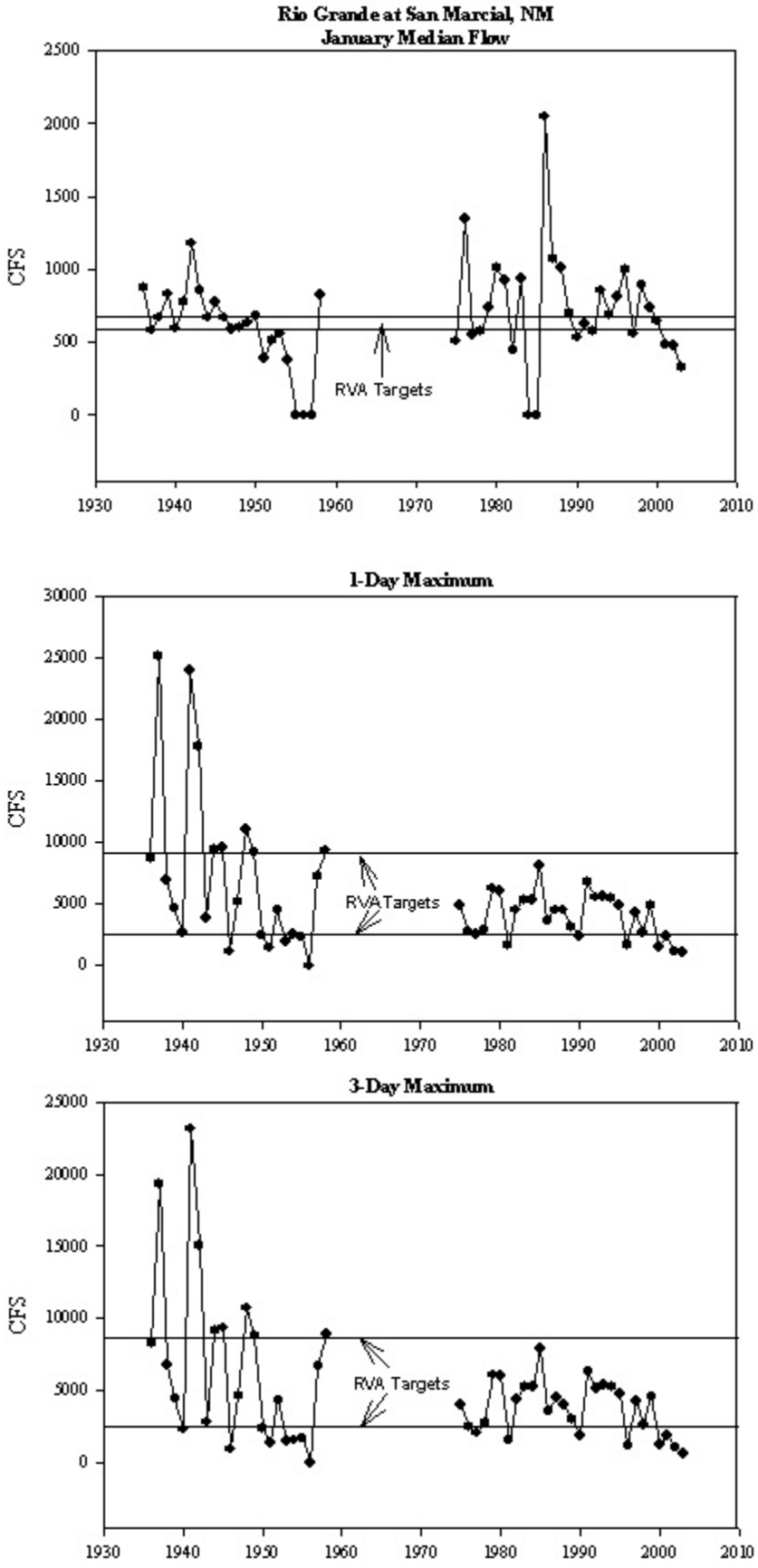



Figure 13. Range of Variability Analysis (RVA) targets for January median flow, 1-day, 3-day, 7-day, 30-day and 90-day maximum at Rio Grande at San Marcial, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.

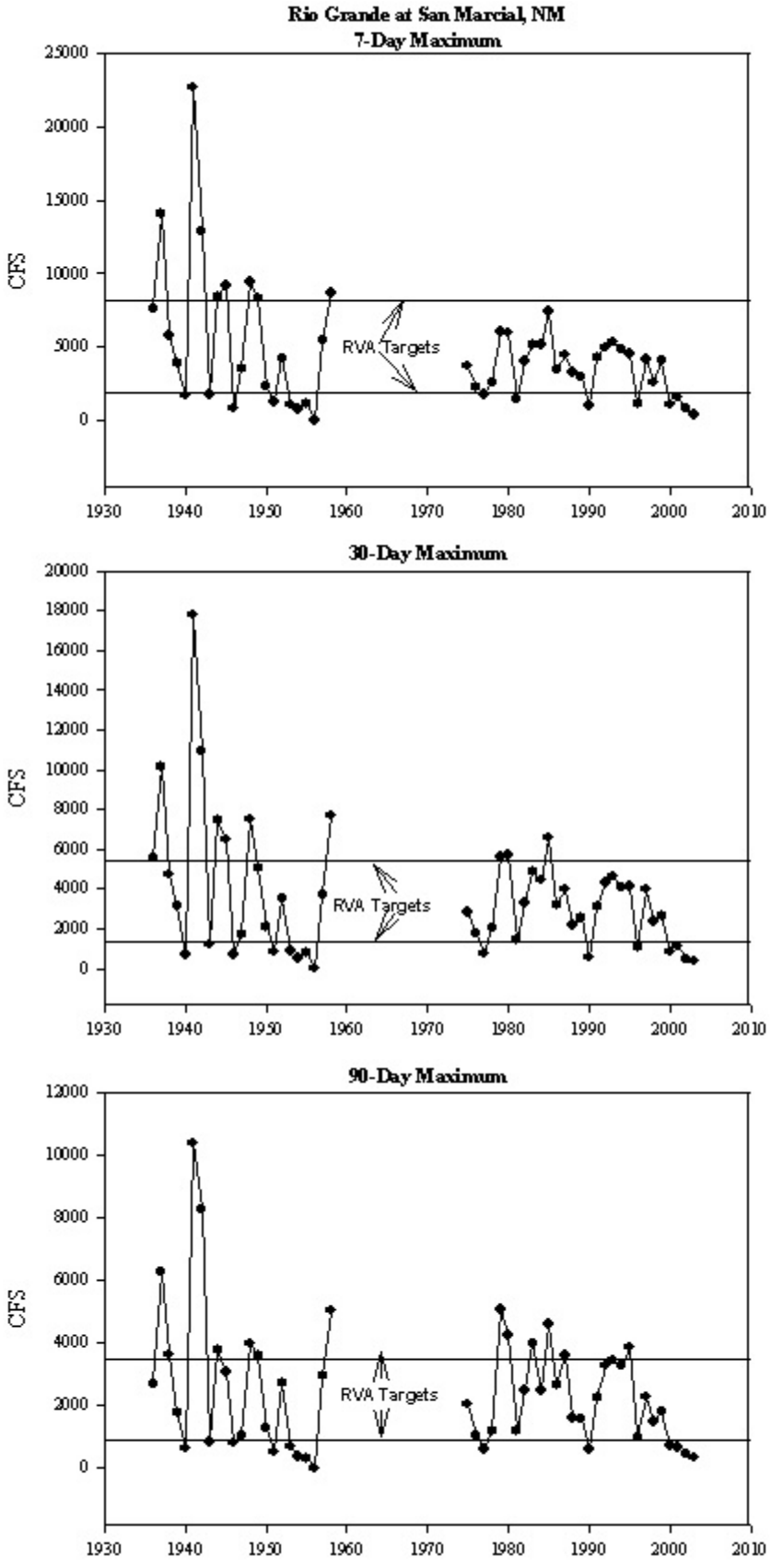



Figure 13 (cont). Range of Variability Analysis (RVA) targets for January median flow, 1-day, 3-day, 7-day, 30-day and 90-day maximum at Rio Grande at San Marcial, NM, USGS stream flow gage station comparing pre- and post-Cochiti Dam periods.