Dolores River Watershed Assessment

Prepared for

Rivers Edge West
U.S. Bureau of Land Management

DRAFT FINAL

Prepared by HDR

March 2, 2020

Table of Contents

Table of Figures

Table of Plots

Table of Tables

List of Acronyms

ac-ft	acre-feet
AEP	Annual Exceedance Probability
AGRC	Utah Automated Geographic Reference Center
BHS	Bluehead Sucker
BOR	Bureau of Reclamation
CDPHE	Colorado Department of Public Health and Environment
CDSS	Colorado's Decision Support Systems
cfs	cubic feet per second
CPW	Colorado Parks and Wildlife
DEM	Digital Elevation Model
DOI	Department of the Interior
DRD	Dolores River Dialogue
DRIP	Dolores River In-stream-flow Partnership
DRRP	Dolores River Restoration Partnership
DWCD	Dolores Water Conservancy District
DWR	Division of Water Resources
EA	Environmental Assessment
EIS	Environmental Impact Statement
FMS	Flannelmouth Sucker
ft	feet
H	High
IHA	Indicators of Hydrologic Alteration
L	Low
M	Medium
M&I	Municipal and Industrial
mm	millimeters
MVIC	Montezuma Valley Irrigation Company
NED	National Elevation Dataset
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
Project	Dolores Project
RTC	Roundtail Chub
RVA	Range of Variability Approach

SMB	Smallmouth Bass
sq. mi.	Square miles
SSURGO	Soil Survey Geographic Database
TNC	The Nature Conservancy
TU	Trout Unlimited
UMUT	Ute Mountain Ute Indian Tribes
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
Watershed	Dolores River Watershed
WBD	Watershed Boundary Dataset

1 Introduction and Background

1.1 Location

The Dolores River flows through the western part of Colorado and the eastern part of Utah. The Dolores River Watershed (Watershed) is located to the west of the San Juan Mountain Range and southwest of the Uncompahgre Plateau in Mesa, Montrose, San Miguel, Dolores, and Montezuma Counties, Colorado, and Grand and San Juan Counties, Utah. Approximately 88 percent of the Watershed is located in Colorado with the other 12 percent falling in Utah. McPhee Reservoir is located on the south side of the Watershed and diverts flow to the San Juan River basin for irrigation. The Watershed location is presented in Figure 1.

1.2 Purpose

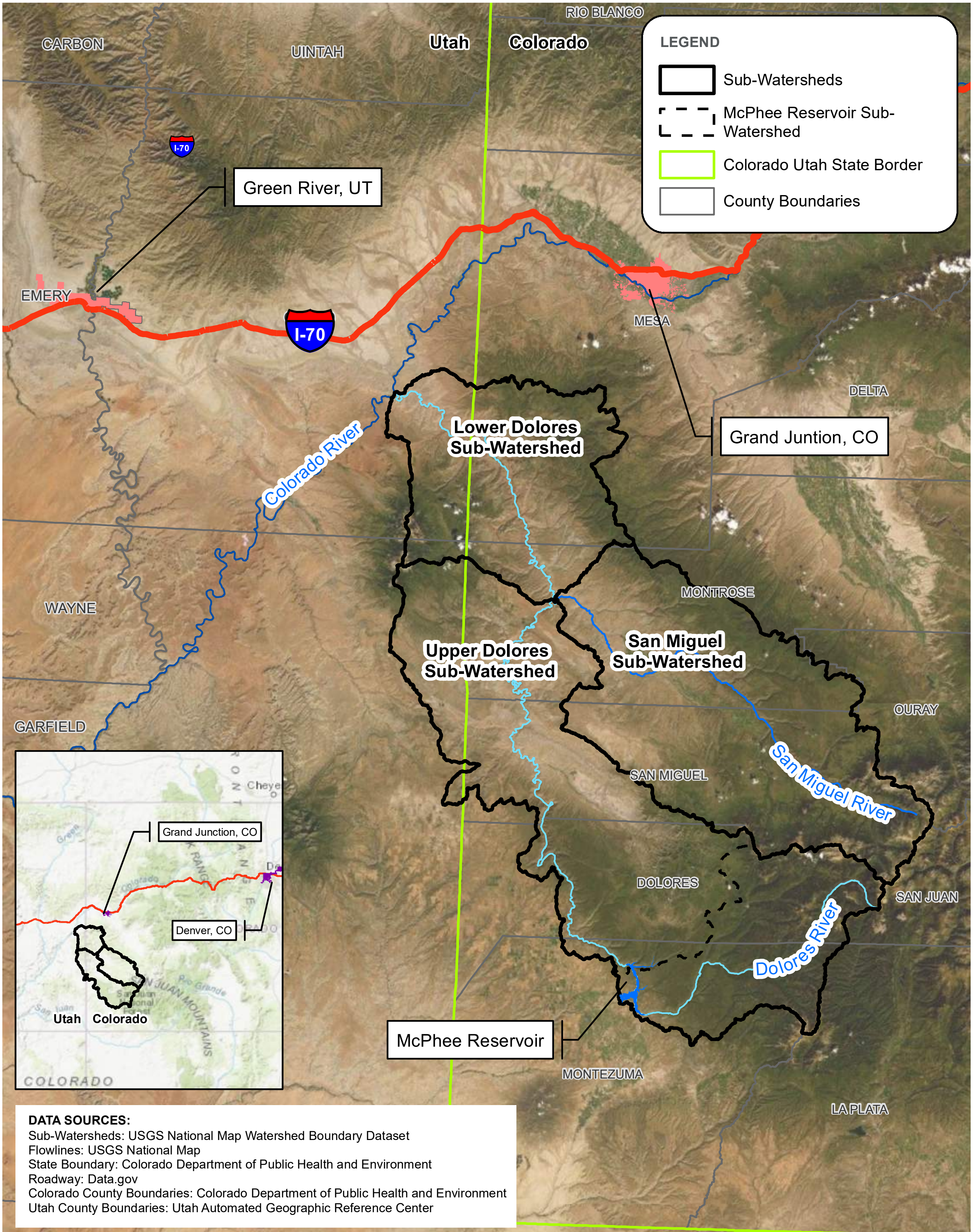
Rivers Edge West (formerly known as the Dolores River Restoration Partnership [DRRP]), is a non-profit organization focused on advancing the restoration of riparian lands through education, collaboration, and technical assistance. Over the past decade, the DRRP has performed extensive restoration efforts which have achieved remarkable results. Much of their efforts have been focused on the removal of Tamarisk and other invasive species that have significant impacts on river systems in the southwestern United States. This, coupled with the modified hydrology of the system, has changed that nature of the Dolores River system.

In 2019, Rivers Edge West, with assistance and support for the Bureau of Land Management (BLM), initiated a project to assess the hydrologic conditions in the Watershed. There were two specified goals for this assessment:

1. Increase the understanding of the historical and current hydrologic regime to better understand and aid in future management and restoration of the Watershed.
2. Produce a watershed summary and planning document to be used as an informational reference for the general public, private landowners, and federal agencies.

At the date of this Report, three components have been developed:

1. A literature of previous studies developed in the Watershed, including: history, hydrology river geomorphology, ecology, water quality, and operations and water rights.
2. A general characterization of the Watershed, including descriptions of: topography, geology, soils, land use, precipitation, and land ownership.
3. A hydrologic assessment aimed at addressing the following questions:
    a. How has the hydrologic regime in the Watershed changed with the construction and operation of McPhee Dam and Reservoir?
    b. What is the influence of San Miguel River on the Dolores River downstream of their confluence and how has the influence of the San Miguel River changed with the construction and operation of McPhee Dam and Reservoir?
    c. How does the current hydrology impact the form and function of the Dolores River?



DATA SOURCES:
Sub-Watersheds: USGS National Map Watershed Boundary Dataset
Flowlines: USGS National Map
State Boundary: Colorado Department of Public Health and Environment
Roadway: Data.gov
Colorado County Boundaries: Colorado Department of Public Health and Environment
Utah County Boundaries: Utah Automated Geographic Reference Center

VICINITY MAP
DOLORES RIVER WATERSHED ASSESSMENT
FIGURE 1

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\VICINITY_MAP.MXD - USER: KRANNEY - DATE: 12/11/2019

1.3 History

The flow regime of the Dolores River is naturally variable, historically contributing between approximately 73,000 to 793,000 acre-feet (ac-ft). Water development has significantly changed river flows over the past 130 years. Significant flows from the Dolores River have been diverted into the San Juan River Watershed for agricultural purposes via trans-basin diversion for over a century. The first diversions, of minimal amount, occurred in 1878 by the Lost Canyon and Montezuma Ditch Companies (Voggesser, 2001). In the 1880's, the Montezuma Water and Land Company (now the Montezuma Valley Irrigation Company [MVIC]) developed two physical trans-basin diversions (Main Canal No. 1 and Main Canal No. 2) to divert flows from the Dolores Basin to irrigable lands in the San Juan River Watershed, as shown in Figure 2. These diverted the majority of flows from the end of the spring runoff until the end of the irrigation season, typically October, up until construction of the Dolores Project (Project) in 1984 (which includes construction of the McPhee Dam and Reservoir). These diversions resulted in a dry riverbed below the two diversions during the late summer (Dolores Watershed Plan, Appendix 2; DRD, 2005; Porter, 2001).

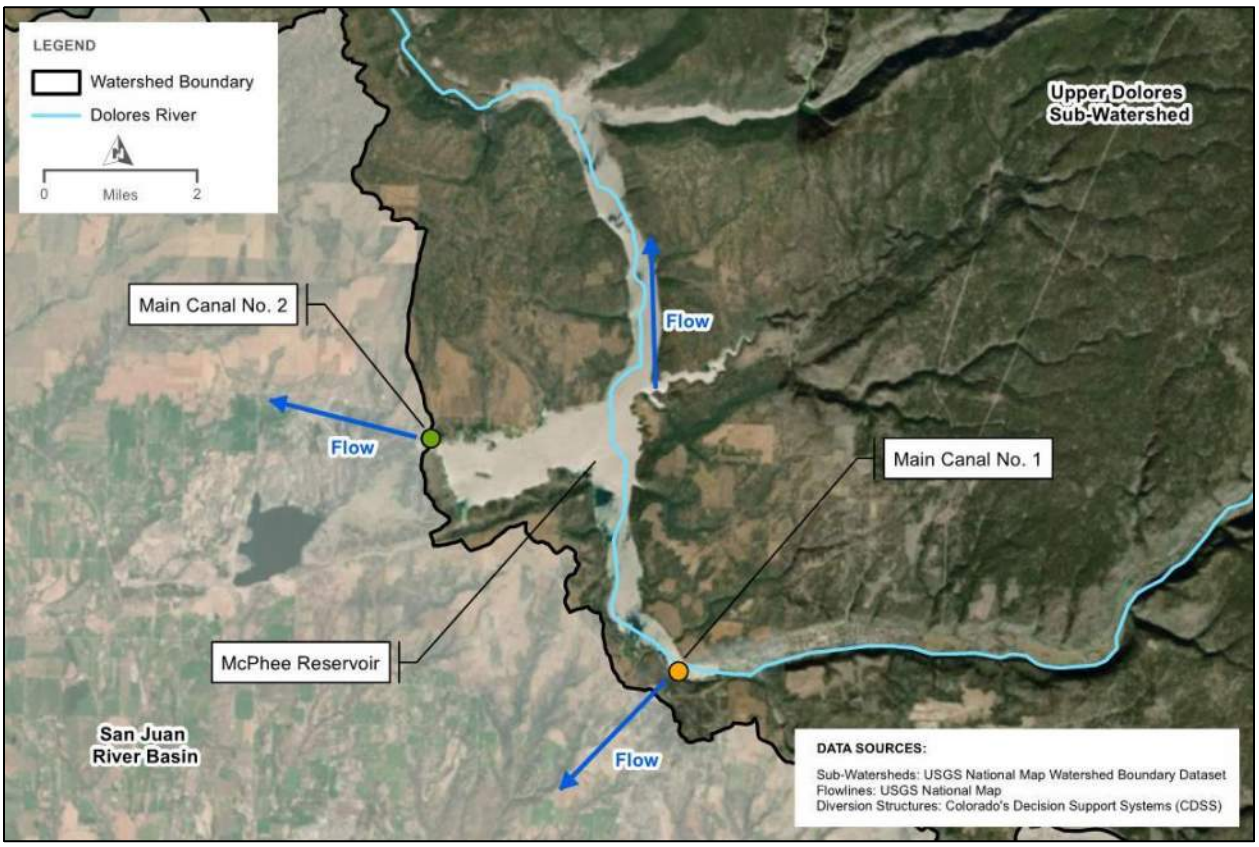


Figure 2. MVIC Diversion Structures

The Dolores Water Conservancy District (DWCD) was created to support, organize, and manage the Project with the United States Bureau of Reclamation (BOR) (Dolores Watershed Plan, Appendix 2). The Project was authorized by the Colorado River Basin Act of September

30, 1968 (Public Law 90-537), with the Environmental Impact Statement (EIS), Definite Plan Report completion, and initial ground breaking in 1977.

The purpose of the Project is to store and regulate flows of the Dolores River primarily for irrigation, municipal and industrial (M&I) use, recreation, fish and wildlife, and production of hydroelectric power. Secondary purposes include flood control and economic redevelopment. Major infrastructure components of the Project include McPhee Dam and Reservoir, the Great Cut Dike, 84 miles of canals (including the Dove Creek Canal, South Canal, Dolores Canal, and Towaoc Canal), 20 miles of pipeline, 84.7 miles of lateral systems, two hydroelectric power plants, and six pumping plants that facilitate the flow of water (BOR). MVIC's Canals 1 and 2 were also improved.

The Project supplies water to farmers for irrigation in the Dolores District in Dolores County, but also supplements farmers in the Montezuma Valley who have received private water from MVIC since the 1880's. It was predicted that average annual flows in the Dolores River would be reduced by 105,200 ac-ft while average annual flows in the San Juan River would be increased by 24,300 ac-ft (BOR, 1977; DRD, 2005a). The Project also satisfies the Ute Mountain Ute Indian Tribes' (UMUT) Winters Doctrine claims to the Mancos River, and a year-round bypass flow for a fishery downstream of the McPhee Dam. Minimum reservoir releases to the Dolores River were established to maintain flow for fish habitat: 78 cubic feet per second (cfs) during wet years, 50 cfs during normal years, and 20 cfs during dry years. (BOR, 1977; DRD, 2005a; Porter, 2001).

Construction of McPhee Dam was completed in 1983 and filling of the McPhee Reservoir was completed in 1987. There was a constant release of 150 cfs until the drought of 1988 to 1992. In accordance with the EIS, March 1, 1990 was classified was a "dry" year. As such, 20 cfs was released from the McPhee Reservoir. Subsequent precipitation that occurred in the Watershed in April would have changed the status to a "normal" year. However, the DWCD and BOR followed the EIS guidelines and maintained a 20 cfs release. By June, it was observed that this "dry" release was having a negative impact on the downstream fishery. This lead to a six year process to change "flow release" to a "managed pool" via an Environmental Assessment (EA) in 1997 (DRD, 2005a; Porter, 2001, DWCD).

Recreational boating on the Dolores River began in the 1930's, and became increasingly popular in the 1970's. The Dolores River remains a popular boating destination when appropriate flows are released from McPhee Reservoir. In 1976, it was found the river was suitable for inclusion under the National Wild and Scenic Rivers System (1986 Wild and Scenic Rivers Act) (BLM, 1976; Dolores Watershed Plan, Appendix 2). However, local opposition stopped formal inclusion into the federal system, and a proposal for a National Conservation Area has been drafted to maintain the Wild and Scenic qualities. Local stakeholders are currently working to pass this legislation.

The decision to change from "flow release" to "managed pool" included a variety of parties working together to create a pool of 36,500 ac-ft of water for the fishery. Previously, only 29,300 ac-ft were allocated downstream for the pool. The additional water needed to increase the pool was obtained from the DWCD, who was compensated for their loss (DRD, 2005a; Porter, 2001).

In 1997, Trout Unlimited (TU) and DWCD provided leadership by creating an ad hoc group called the Dolores River In-stream-flow Partnership (DRIP). This group's main purpose was to "work together to create a [fish] pool of 36,500 ac-ft." However, this fish pool is still short by 4,700 ac-ft at the time of this report.

The drought from 2000 to 2004 caused the DRIP process to be suspended. In the fall of 2003, the San Juan Citizen's Alliance and DWCD formed a collaborative effort known as the Dolores River Dialogue (DRD). This group's main focus is to "*explore management opportunities, build support for and take action to improve the ecological conditions in the Dolores River downstream of McPhee Reservoir while honoring water rights, protecting agricultural and municipal water supplies, and the continued enjoyment of boating and fishing*" (Dolores Watershed Plan, Appendix 2).

1.4 Hydrology

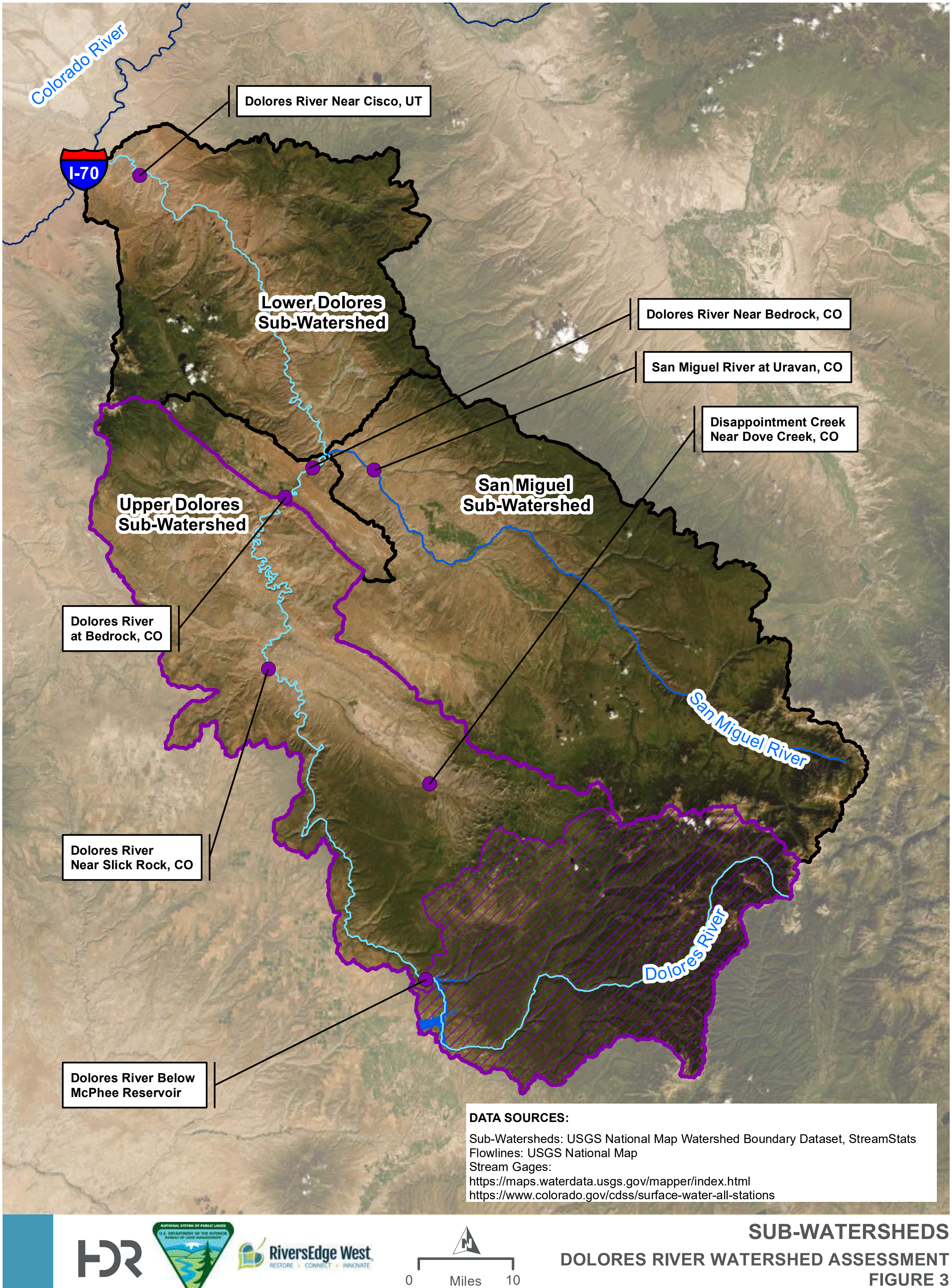
The flow regime of the Dolores River has changed over the past 130 years due to trans-basin diversions to the San Juan River Watershed (Dolores Watershed Plan, Appendix 2). The most significant hydrologic analysis to date was completed by the DRD. The following is a summary of their analyses and results.

The DRD developed a *Hydrology Report* in 2005 with the purpose of describing "*the amount of water expected to flow downstream of McPhee Reservoir through spills and baseflow releases. It also needs to describe the realistic opportunities to manage or enhance those flows.*" This report is still in draft format, and has unfinished sections. The completed portion of the report summarizes two main types of analysis: watershed hydrology and operational hydrology of McPhee Reservoir. The watershed hydrology was analyzed by developing four metrics using data from a variety of streamflow gages located in the Watershed (see Table 1 and Figure 3). Discussion of results was not included in the draft report. These metrics include:

1. Total annual flow and peak flood flow frequency at the Dolores River at Dolores gage.
2. Post-McPhee spill hydrology by reviewing the Dolores River at Dolores vs Dolores River at Bedrock stream gages, reviewing DWCD total out-of-basin diversions, and peak flow frequency below McPhee Reservoir.
3. Analysis of various downstream gages to evaluate total flow and peak flow variability.
4. Development of Indicators of Hydrologic Alteration (IHA) analyses at the Dolores River at Bedrock and Dolores River at Cisco stream gages.

Table 1. Gage Data Reviewed in Draft DRD Hydrology Report

Gage Name	Gage Number
Dolores River at Dolores	USGS 09166500
Dolores River below McPhee Reservoir	DOLBMCCO-DWR
Disappointment Creek near Dove Creek	USGS 09168500
Dolores River at Slickrock	USGS 09168730
Dolores River near Bedrock	USGS 0917110
San Miguel River at Uravan	USGS 09177000
Dolores River at Gateway	USGS 09179500
Dolores River near Cisco, UT	USGS 09180000



DATA SOURCES:

Sub-Watersheds: USGS National Map Watershed Boundary Dataset, StreamStats
Flowlines: USGS National Map
Stream Gages:
https://maps.waterdata.usgs.gov/mapper/index.html
https://www.colorado.gov/cdss/surface-water-all-stations

SUB-WATERSHEDS

DOLORES RIVER WATERSHED ASSESSMENT
FIGURE 3

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\MAP_DOCS\WATERSHED_AREA.MXD - USER: KRANNEY - DATE: 2/26/2020

The analysis of operational hydrology of McPhee Reservoir included the amount of water expected to flow downstream of McPhee Reservoir through baseflow releases and spills. The baseflow release analysis examined the total flow available for downstream release based on a full-allocation year and used patterns reminiscent of recent historical releases to model monthly flows. The spill analysis included hydrologic modeling of the Upper Dolores River and various allocation assumptions. Similar to the watershed hydrology, discussion of results was not included in the draft report.

In 2006, the DRD developed a Correlation Report, which is also still in draft format. The DRD reviewed a variety of hydrologic scenarios along the Dolores River, including:

1. Flows before installation of the MVIC trans-basin diversions.
2. Flows after installation of the MVIC trans-basin diversions.
3. Flows after installation of McPhee Reservoir.

Using this information, the study developed a model of 77 years of flows (1928-2005) on the Dolores River by estimating the frequency and magnitude of spills given actual inflow gage records at Dolores, storage in McPhee Reservoir, and full Project demands. The results of this model are presented in Figure 4. The purpose of this model was to provide an estimate of expected future water availability as a foundation for correlating potential opportunities to manage spills and baseflow releases with expected benefits to the downstream environment.

The annual flow conditions in the Dolores River before installation of the MVIC trans-basin diversions were determined by comparing flows at the Dolores River at Bedrock and Dolores gages. This relationship was analyzed using daily flow data between 1974 and 1985 and adding back in daily diversion records from the MVIC Canals Nos. 1 and 2. This analysis showed that total flow at Bedrock was greater than that at Dolores, which is expected due to their differences in watershed size (see Figure 3). However, during dry periods, flow at the Dolores gage is almost the same as at the Bedrock gage likely due to minimal contributed flow along this section of the Dolores River. During wet periods, the total flow at the downstream Bedrock gage is 50 to 60 percent greater than the upstream Dolores gage. This suggests the flows experienced in the downstream Watershed increase proportionally with the total precipitation in the watershed. Peak flows were also compared. They generally had the same trend, but with greater variability (see Figure 5). *Note: the authors of this Report suspect these flows may have been overestimated as it is assumed losses were not included in analysis.*

This study then reviewed annual flow conditions on the Dolores River for representative dry, average, and wet water years after installation of the MVIC trans-basin diversions. With the exception of bypass flows required to meet senior water demands, MVIC's diversions took all the river's flow for all water conditions. The runoff volumes are presented in Table 2. During the study period, flow-by volume ranged from 22 to 81 percent of the total run-off volume. The volume of water during the driest year (28,000 ac-ft) is close to the fish pool (29,300 ac-ft). *Note: the authors of this Report assume "flow-by" is defined as water released through the McPhee Dam and Reservoir.*

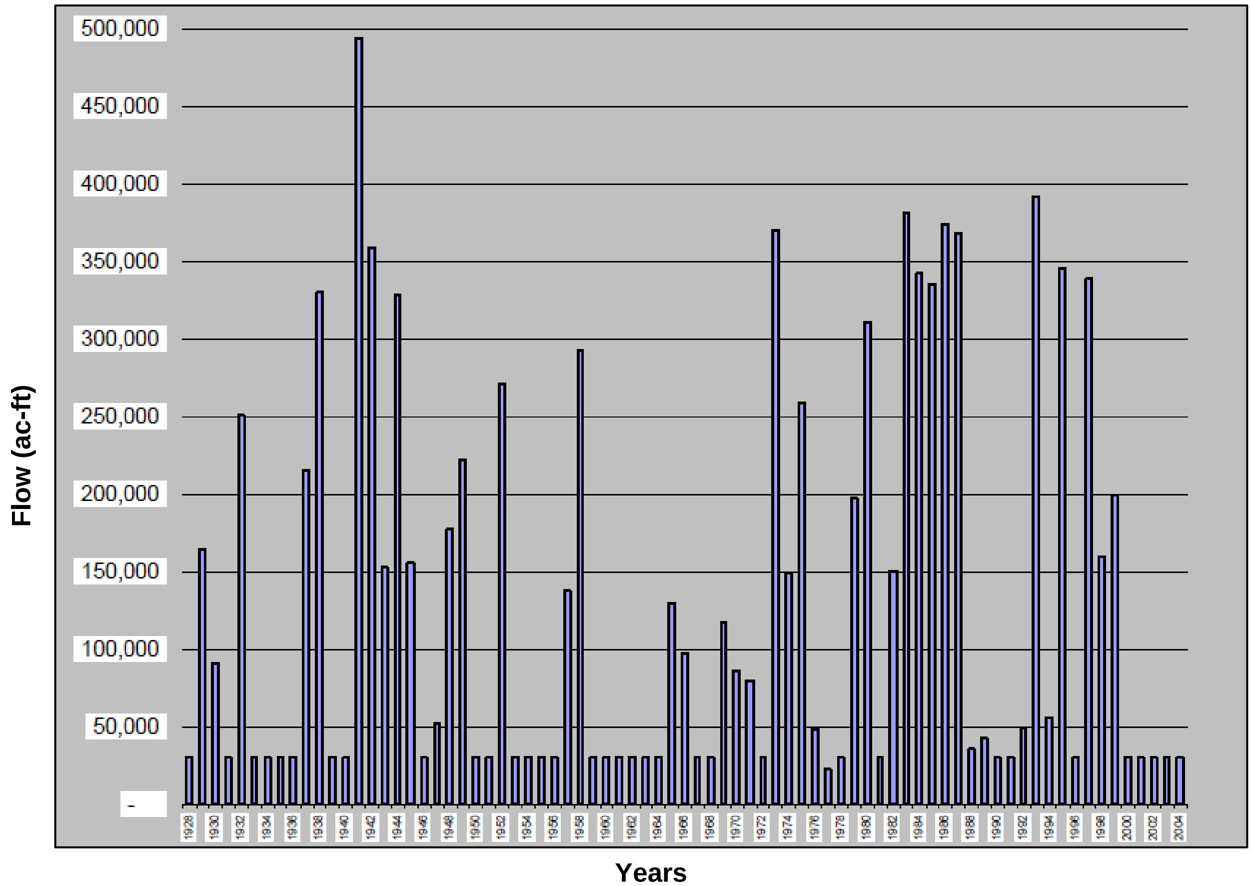


Figure 4. DRD Hydrology Model from 1928 to 2005 (Source: DRD, 2006)

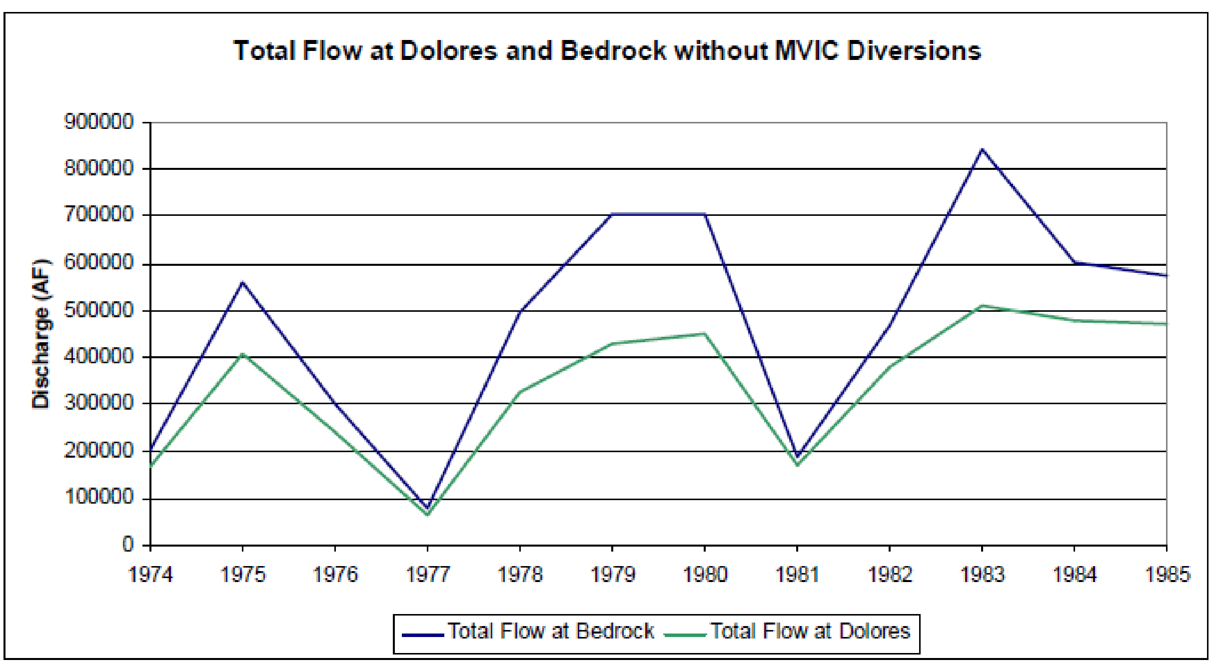


Figure 5. Total annual flow at Bedrock and Dolores gages from 1974-1985 (Source: DRD, 2006)

Table 2. Comparison of Flow-by with MVIC Diversions (Source: DRD, 2006)

1928-1973	Largest *(ac-ft)*	Smallest *(ac-ft)*	Average *(ac-ft)*
Runoff Volume	793,000	130,000	350,000
MVIC Only			
MVIC Diversions	150,000	64,000	131,000
Flow-by (occurs every year)	643,000	28,000	219,000
Flow-by as % of runoff volume	*81%*	*22%*	*63%*

The DRD also developed a Core Science Report in 2005. The following was stated in this report: "*Impacts to the flow regime of the Dolores River occurred before the construction of McPhee Dam. Prior to construction of McPhee Dam, the mean annual flow at Dolores (above McPhee Dam) was 763 cfs and decreased to 465 cfs at Bedrock (94 miles downstream from the dam). The decrease was caused by diversions in place prior to construction of McPhee Dam…. McPhee Dam increased the depletion of the annual flows from 30% to 69% of natural flow... Construction of McPhee Dam in 1984 affected the flow regime of the Dolores River by altering the spring peak flows and the magnitude and variability of the base flow. Between 1986 and 2004, the spring peak was essentially eliminated downstream from the dam for six of the 19 years of record. In an average runoff year, both the magnitude and duration of the spring peak flow are decreased. Correlation of the peak flows above and below the dam show a distinct decrease in the peak flows below the dam.*"

This study developed an Indicators of Hydraulic Alteration (IHA) analysis at both the Dolores River at Bedrock and Cisco stream gages (see Figure 3). At the Bedrock gage, the parameters exhibiting the greatest impact by the dam are the annual maximum flows (approximate 40 percent decrease) and the duration of the high pulse (approximate 60 percent decrease). At the Cisco gage, the impacts of the dam on the flows are not as significant as at the Bedrock gage. The greatest change is in the one and three day maximum flows (approximate 13 percent decrease).

In addition, a variety of studies have reviewed select stream gage data to make statements on how flows have been impacted with the installation of McPhee reservoir. Examples include:

A paper by American Whitewater (Fey, et al., 2014) states that "*with the completion of McPhee Dam and Reservoir in 1987…69 percent of the historic flow of the Dolores River is depleted annually…as opposed to 39 percent before Project construction, attributable to pre- Project allocations to the MVID*." The paper includes a graphic of Dolores River at Bedrock average daily stream flow both pre- and post-impact, shown in Figure 6.

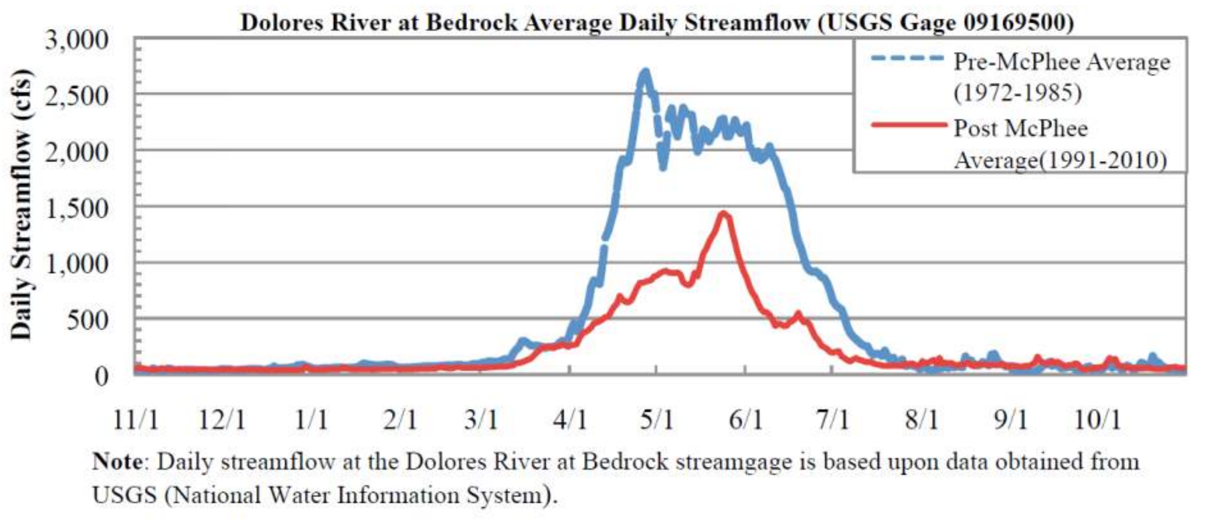


Figure 6. Dolores River at Bedrock Average Daily Streamflow, USGS Gage 09169500 (Source: (Fey, et al., 2014, Figure A)

A paper on "Flow Management and Endangered Fish in the Dolores River, 2012-2017" (BOR, 2018) states that the "*average annual discharge of the Dolores River declined from 504 cfs (as measured at Bedrock, CO) to about 240 cfs after dam construction in 1984….The lowermost reaches of the Dolores River receive considerable flow input…from the San Miguel River on a year-round basis…*"

1.5 River Geomorphology

Both the DRD Core Science Report (2005) and Correlation Report (2006) also reviewed impacts of the McPhee Reservoir on river geomorphology. This is defined as the interaction of sediment transport, flow, geology, and vegetation that impacts the aquatic and riparian life of a river.

The primary limiting factor for the Dolores River geological and ecological processes is flow, and reductions of flow are cause for geomorphic changes in the Dolores River. Some of these changes include: narrowing and reduction of depth in the channel, growth of the lateral and mid-channel bars, reduction in sediment mobility, and encroachment of the riparian vegetation. The channel bed morphology has been simplified, and there is reduced channel-floodplain connectivity along sections of the Dolores (DRD, 2005b).

The DRD Correlation Report (2006) conducted an analysis on the geomorphic conditions for current and expected future water availability. The Dolores River was broken into eight reaches for this analysis, as shown in Figure 7. These reaches were determined based on gradient, sinuosity, chemical parameters, vegetation, and potential limiting factors to stream channel movement and formation. The changes seen in each reach based on the existing and expected geomorphic conditions are presented in Table 3.

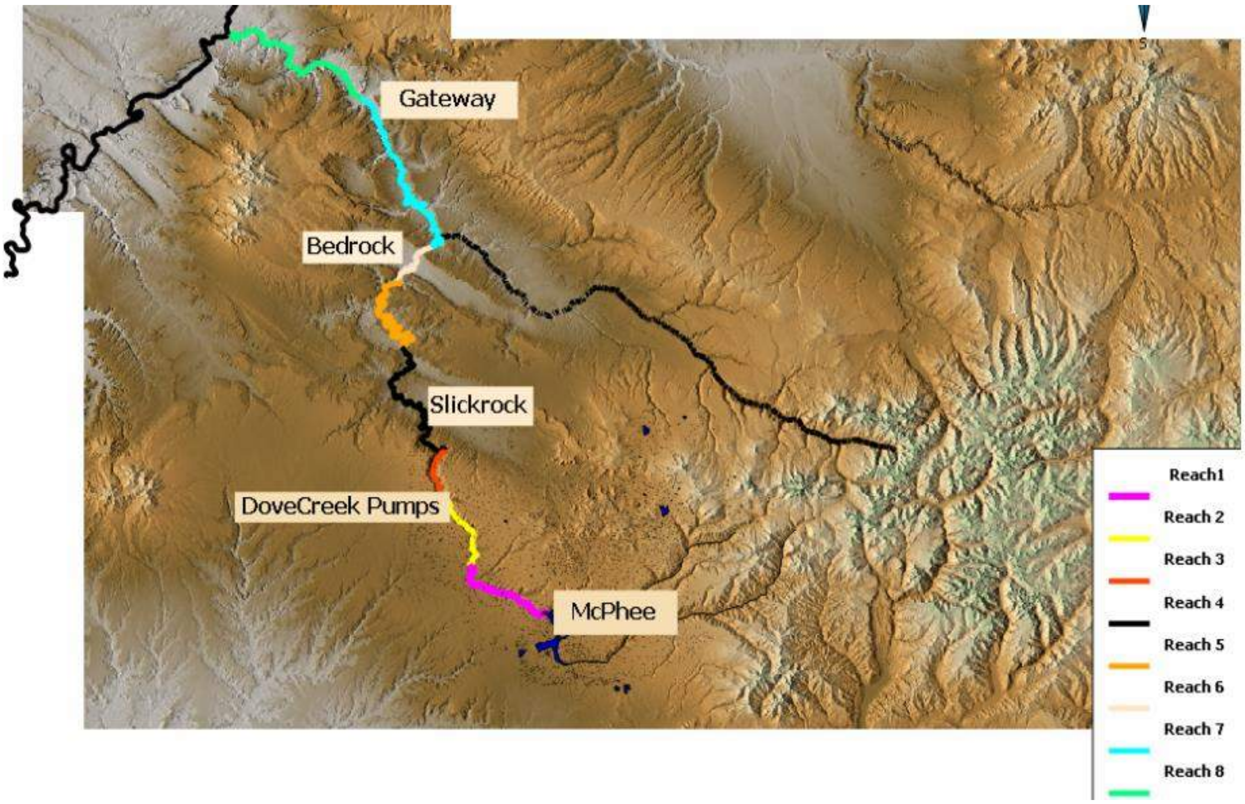


Figure 7. Reach Delineations Doloress River below McPhee Dam (Source: DRD, 2006)

Table 3. Existing and Expected Geomorphic Conditions (Source: DRD, 2006)

Reach[1]	Geomorphic Conditions: Existing	Expected Future Water Availability
1	• Low flows over prolonged drought are unable to perform minimal geomorphic functions. • May not be possible to mobilize embedded riffles. • General goal to enhance natural process of "channel downsizing" to accommodate overall decrease in stream power.	• "Small spill" flows allow for geomorphic work consistent with the channel maintenance objectives. • Impacts of 5,000 cfs on embedded riffles is unknown. Whether or not lateral migration and sedimentation outweighs the benefits of channel scour is unknown. • The natural process of "channel downsizing" is improved with tapered hydrograph on larger spill volumes.
2	• Current flow management maintains geomorphic function of pool scour and sediment transport. • Tributary sediments will accumulate in pools and diminish habitat quality during prolonged dry periods.	• Ecological flow management would maintain current sediment transport. • Larger spill scenarios will improve pool scour and riffle mobilization. • Tributary sediments will accumulate in pools and diminish habitat quality during prolonged dry periods.
3	• Current flow management maintains geomorphic function of pool scour and sediment transport. • Tributary sediments will accumulate in pools and diminish habitat quality during prolonged dry periods.	• Ecological flow management would maintain current sediment transport. • Larger spill scenarios will improve pool scour and riffle mobilization. • Tributary sediments will accumulate in pools and diminish habitat quality during prolonged dry periods.
4	• Current flow management maintains geomorphic function of pool scour above Disappointment Creek. • Significant accumulation of fines below Disappointment Creek. Impairs habitat quality. • Riparian vegetation encroachment on sediment induces "channelization" and reduces floodplain connectivity.	• Ecological flow management will maintain and improve geomorphic function of pool scour. • Riparian vegetation encroachment on sediments will induce channel entrenchment and reduce floodplain connectivity in some alluvial reaches. • Ecological flow management would maximize ability to scour fines, but floodplain dislocation in some reaches may require treatments to improve function. • "Large spill" scenario could induce channel entrenchment, further disconnection from the floodplain.
5	• "Hybrid" between reaches 2-3 upstream and reach 4 affected by significant contribution of sediments. • Lack of regular spills and sediment deposition affects native fish habitat.	• "Hybrid" between reaches 2-3 upstream and reach 4 affected by significant contribution of sediments. • Lack of regular spills and sediment deposition affects native fish habitat. • Ecological flows should improve scouring.
6	• Active channel is entrenched and disconnected from historic floodplain. Current management will perpetuate condition.	• Active channel is entrenched and disconnected from historic floodplain.

Reach[1]	Geomorphic Conditions: Existing	Expected Future Water Availability
	• Specifics on sediment flux are unknown. • Geomorphic character changes between the Paradox Valley and confined canyon above San Miguel River may offer better habitat.	• Ecological management should improve sediment flux. • Geomorphic character changes between the Paradox Valley and confined canyon above San Miguel River may offer better habitat. • Large spills will improve pool scour and habitat availability for native fish species.
[1] Report only provides observations for Reaches 1 through 6		

The DRD 2005 Correlation Report developed steps to restore the Dolores River to pre-impact conditions. The geomorphological goals of this process are:

1. *Scour fine sediment from pools and interstices of riffle substrate (annually, if possible).*
2. *Maintain channel dimensions through alluvial reaches; scour pools of course sediment; sort gravels; mobilize bar sediments and other in-channel depositional features (annually if possible; hydrology modeling suggests 2-4 years likely).*
3. *Inundate floodplains and backwater/remnant channel habitats; deposit fine sediments on floodplain/overbank areas (annually if possible; hydrology modeling suggests 2-4 years likely).*
4. *Occasionally provide the stream power to mobilize riffles, resetting primary productivity within the river; release imbedded channel sediments; scour near channel or low-floodplain surfaces (5-10 year recurrence); induce downstream meander migration in alluvial reaches.*
5. *Investigate the effect of sediment introduced from Disappointment Creek on downstream habitats and geomorphology. In general, investigate sediment flux by reach and ability of river to move sediment contributions from tributaries.*
6. *Refine the notion of bankfull flows for alluvial reaches; compare with hydrologic expectations to discern optimal channel dimensions to meet habitat needs of aquatic communities.*

In 2017, a controlled release of McPhee was conducted due to increased snow pack, water elevations in McPhee, and the predicted precipitation for the 2017 year. Colorado Parks and Wildlife (CPW) conducted pre- and post-release monitoring on the Dolores River at five sites via Wolman pebble counts, cross section surveys, erosion stakes, painted patches, and sediment traps (CPW, 2018).

In general, the high flows released caused minimal bank erosion and riparian vegetation removal due to the highly vegetation banks. However, channel and floodplain interaction occurred, which resulted in observed sediment deposition and scour (CPW, 2018). Additional observations from this release include:

1. *Noticeable evidence of scouring and evacuation of sediment in the channel and substantial deposition of this sediment on the floodplain.*
2. *Evidence of scouring and evacuation of material within surveyed pools at most alluvial ecological monitoring sites. Evidence of floodplain deposition confirming that the controlled release reset the vertical relief and increased the overall pool volume.*
3. *Little bank erosion observed and no increase in the channel width. This suggests that the Lower Dolores River is stabilizing within a narrower, more confined channel.*
4. *Fine sediments (2 millimeters [mm]) were almost completely removed from the survey site at the Slickrock Downstream location. This indicates that higher-energy sites within the active channel were equally coarsened by the managed release, improving breeding and foraging habitat for native fish.*
5. *The median grain size increased from 85 mm to 108 mm on the high energy, low-floodplain environment at the Slickrock Downstream site.*

6. *Erosion stakes on the low-floodplain, high energy site showed substantial scour at the Slickrock Downstream site. Cobble movement was noted, indicating that larger particles were mobilized during the release.*
7. *Minimal lateral bank erosion was noted at the Slickrock Downstream site. However, sediment deposition occurred in the floodplain where the river slowed because of dense willows. Noticeable channel incision was observed in the pre-existing side channel.*
8. *Side channel reactivation was observed at several locations.*

A sample of the bar sample particle sizes pre- and post-spill is shown in Figure 8.

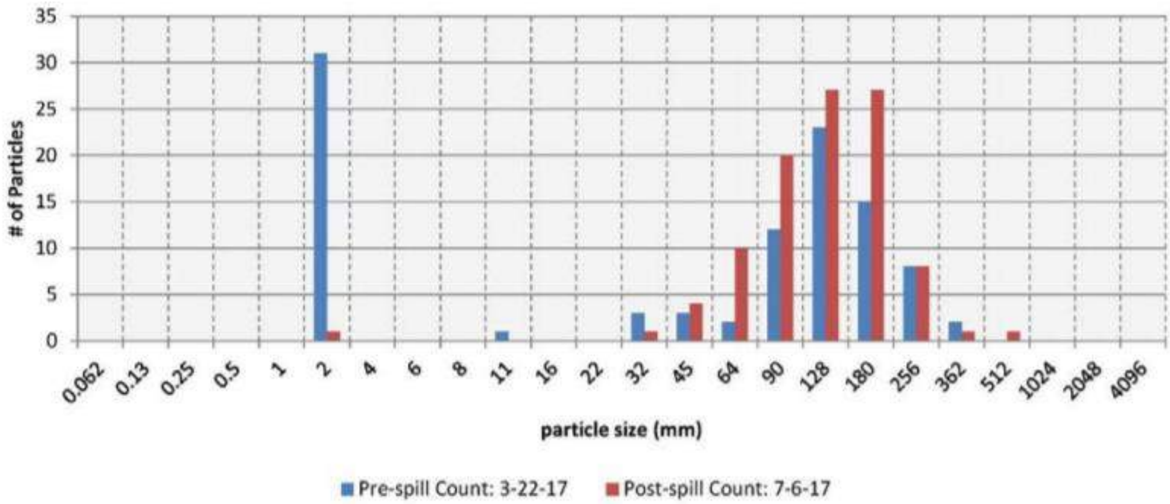


Figure 8. Pre- and Post-spill Bar Sample, Dolores River Below Disappointment Creek (Source: CPW, 2018)

1.6 Ecology

1.6.1 Native Fish

The Dolores River contains a range of fish communities. Cold-water fish species (example: trout) are found at the downstream end of McPhee Reservoir. The Dolores River then transitions to having warm-water fish species as it flows downstream (Speas, 2018). There has been a decline in a variety of warm water fish species in the Colorado River Basin, with three specifically in the Dolores River: Roundtail Chub (RTC, *Gila robusta*), Flannelmouth Sucker (FMS, *Catostomus latipinnis*), and Bluehead Sucker (BHS, *Catostomus discoboulus*) (OSC, 2014; Bestgen, et al., 2011). The current status of these three fish species is presented in Table 4.

In 2011, a report was developed by a team of fish biologists to better understand status and trends of the three fish species and uncover opportunities for population improvements (Bestgen, et al., 2011). Subsequently, the Lower Dolores Working Group, a sub-group of the DRD, completed the "*Lower Dolores Implementation, Monitoring and Evaluation Plan for Native Fish*" in 2014. The plan is constructed to specifically address opportunities presented in the 2011 report (Bestgen, et al., 2011). Native fish protection is of interest to the myriad stakeholders in the Dolores River Basin for the fish themselves, and to protect water rights.

Four additional native fish in the Colorado River Basin are the Humpback Chub, Colorado Pikeminnow, Bonytail, and Razorback Sucker. All are listed as endangered under the Endangered Species Act; these fish are protected by the United States Fish and Wildlife Service (USFWS). The Dolores River is not listed as a critical habitat for these four endangered fish, however, Colorado Pikeminnow, Razorback Sucker, and Bonytail have been shown to historically use the lower reaches, and the presence of Predatory Smallmouth Bass (SMB) in the Dolores is of concern to the USFWS. The Upper Colorado Endangered Fish Recovery Program (UCEFRP) is USFWS-led and is a multi-agency partnership to recover endangered fish in the upper Colorado River basin. The following was recommended by Speas of the UCEFRP (2018) to improve fisheries:

1. *Spill management - Spills from McPhee Reservoir should be managed with flow volumes that correspond to peak flow thresholds for channel maintenance and sediment transport.*
2. *Thermal modification – There should be sufficient flows in March and April to suppress river temperatures and prevent spawning prior to peak flows.*
3. *Sediment transport – There should be an increase in the magnitude and frequency of spill events to restore the pre-impact stream power.*
4. *Baseflow management – The optimum baseflow is 150 to 300 cfs. This is likely not achievable, so the following are recommended: 25 to 35 cfs in the winter, 50 cfs in the spring, 60 to 120 cfs in the summer, and 40 to 60 cfs in the fall.*

Following the 2017 controlled release of McPhee Reservoir, the CPW also conducted fisheries monitoring (CPW, 2018). The main observations following this release were:

- *Slickrock Canyon is still a stronghold for native species, with three native species (FMS, BHS, and RTC) comprising 88% of the total catch out of 591 fish caught. Specifically, FMSs comprised 53% of the catch, RTC 32%, and BHS 3%.*
- *Overall density of native fish is still low in Slickrock Canyon, yet a fair number of suckers are still being caught, particularly flannelmouths.*
- *In Slickrock Canyon, there was a 95% increase in catch per unit effort (CPUE) over 2007 for the three native fish species. In 2017, 0.43 fish per minute were caught, whereas in 2007 only 0.22 fish per minute were caught.*
- *RTC reproduction was evident at most sites, including the Dove Creek Pumps reach, James Ranch Reach, and Big Gypsum Reach. Young-of-the-year bluehead and FMSs were also detected, but at low levels. Findings about 2017 reproduction are preliminary because detection of young-of-year fish is difficult; population surveys in future years will provide a better indication of how much reproduction of native species occurred this year.*
- *Few non-natives were found in Slickrock Canyon.*
- *One white sucker was found in Slickrock Canyon. This species had not previously been documented on the Dolores River below McPhee Dam. White suckers hybridize with native suckers and are a serious threat to the genetic integrity of native suckers.*

- *SMB (non-native predator fish that eat native fish) were found to be persistent in the Pyramid Reach, and more frequent removals of these species is recommended. CPUE was 34.6 SMB/hour in 2017, versus 13.4 in 2007, and 18 in 2011.*
- *No SMB were found downstream of Disappointment Creek, including in Slickrock Canyon.*
- *Removal of non-native fish was only possible because of the combination of the large managed release and the use of approximately 2,800 (ac-ft) of fish pool water.*
- *More catfish, red shiner, and sand shiner were found in 2017 (versus surveys in 2012, 2013, and 2014), which was troubling. Shiner habitat overlaps with the habitat of young native fish, and shiners eat the natives.*
- *As in past years, higher trout biomass was sampled with higher discharge.*

Table 4. Current status of native fish specifies (Source: OSC, 2014)

Reach	General Description	Roundtail Chub	Flannelmouth Sucker	Bluehead Sucker	Non-Native Fishes
Reach 1	• Cold-water release precludes use by native warm-water species.	• Unoccupied • No potential	• Unoccupied • No potential	• Unoccupied • No potential	• Brown trout abundant (80%) and self-sustaining • Rainbow trout common (20%) • Combined trout biomass is about 43% of a typical Rocky Mtn. stream. • Green sunfish rare.
Reach 2	• Cold- to cool-water habitat (thermally transitional waters). • Use by all warm water native fish documented during Ponderosa Canyon surveys in 1993 • FMS/BHS not documented in 2005 or 2007 surveys. • RTC present.	• Relatively low abundance • Difficult to assess • Habitat suitability ebbs and flows with water discharge.	• Status unknown but may be extirpated from reach • limited potential or seasonal occupation only	• Status unknown • Based on juveniles found downstream, at least seasonal occupation during spawning season	• Brown trout relatively low abundance (less than 50 adults per mile) • Fire and drought (warm water) limit population. • Green sunfish status unknown.
Reach 3	• Good habitat (structure and instream cover, riffle-poolrun complexity). • Sedimentation from tributaries • Lack of sediment mobility may affect habitat availability.	• Abundant • Adults show small body size relative to downstream and other river populations.	• Rare • Absent from most DCP surveys • 1 juvenile in 2013 survey • No FMS in seine samples	• Rare • Absent • from most DCP surveys • 8 juvenile in 2013 • No BHS in seine samples	• Brown trout rare to common near Dove Creek pumps (less than 50 fish per mile) and decreasing to rare near Pyramid. • SMB rare to common at Dove Creek pumps and common at Pyramid. • Green sunfish common. • Channel catfish rare.

Reach	General Description	Roundtail Chub	Flannelmouth Sucker	Bluehead Sucker	Non-Native Fishes
Reach 4	• Pyramid to Disappointment – good structure and instream cover; riffle-pool-run complexity (similar to Reach 3) • Disappointment to Big Gypsm Valley – heavy sedimentation, lack of structure, and turbid water. • Reach above Disappointment Ck. has abundant clean cobble used by FMS for spawning.	• Rare but slightly larger than in Reach 3.	• Uncommon but need more data on utilization of Pyramid reach • May be important for spawning. • 2012 seine survey found a few young • Dead picked up after 2013 Disappointment Creek flash flood	• Uncommon • No juveniles in 2012 seine surveys. • Several large adults captured above Disappointment Creek in 2007.	• Brown trout rare to absent. • SMB common to abundant down to Disappointment Creek confluence. • SMB rare below Disappointment Creek. Heavy sediment and flash flooding may limit SMB population expansion. downstream of Disappointment • Creek. • Green sunfish common. • Black bullhead common. • Channel catfish rare.
Reach 5	• Good structure, riffle-runpool complexes, and turbid water. • Native fish made up 79% of catch in 2007 survey.	• Approximately 2 fish per mile caught • Larger fish caught • Spawning or fry use may be linked to tributaries.	• Approximately 2 to 3 fish per mile caught • Larger adults than upstream populations.	• Extremely rare (1 fish caught per 5 miles of canyon) • Larger adults caught.	• SMB, channel catfish, green sunfish, and common carp are rare. • Black bullhead status unknown.
Reach 6	• Salty, channelized, and hot	• No data available	• No data available	• No data available	• No data available
Dolores River below San Miguel confluence	• Good canyon habitats with structure, riffle-pool-run complex, and influenced by San Miguel inflows • Native fish 51% of catch in 2007 survey;	• Uncommon in surveys (approximately 2 to 10 fish per mile) • Smaller size class river miles	• Uncommon (approximately 7 to 10 fish per mile) • Good age structure amongst sampled fish.	• Uncommon (approximately 3 to 10 fish per mile) • Good age structure amongst sampled fish.	• Channel catfish and carp are common (20-30% of fish captures). • Status of green sunfish, black bullhead, white sucker, uncertain.

Reach	General Description	Roundtail Chub	Flannelmouth Sucker	Bluehead Sucker	Non-Native Fishes
	• 76-93% natives in 2010 surveys on 3 reaches.				
Overall	• Habitat intact, mostly contiguous, and lacking hybridization with white sucker • Regional 3-species recovery priority. Flow management/out of basin diversions remain significant challenge for reach between Dove Creek pumps and the San Miguel River confluence (approximately 70 miles)	• Abundant in Reaches 3 and 4 but small • Better age structure but less abundant below Disappointment Creek and San Miguel River.	• Gone or nearly gone from Reaches 1 through 3 • Reach 4 may be an important spawn area. • Juveniles in reach 4. • Good age structure below San Miguel River confluence.	• Gone from Reaches 1 and 2 • Some evidence of reproduction in Reach 3, but less so in Reaches 4 and 5 • Part of the intact native fish assemblage below the confluence with the San Miguel River.	• Brown trout most abundant in first 12 miles, then absent approximately 40 miles downstream of McPhee Reservoir. • SMB common in about 20 miles from Dove Creek pumps to Disappointment Creek. • Channel catfish and carp most common non-native species below San Miguel.

1.6.2 Riparian Ecology

The altered flow regime on the Dolores River caused from the installation of McPhee Reservoir has impacted the riparian vegetation assemblage along the lower Dolores River. A decrease in native cottonwood regeneration has been observed with an increase in tamarisk, a non-native woody species. In the past decade, a large multi-stakeholder effort by the public-private DRRP has removed almost 2,000 acres of tamarisk from along the river. This work is ongoing, and an increase in native coyote willow can now be seen in abundance in the riparian area.

The lower Dolores River includes multiple habitats. These include Narrowleaf Cottonwood communities, Ponderosa Pine dominant communities, Juniper and Piñon communities, and some Tamarisk dominant communities. Willows are present along most reaches of the Dolores River. Cottonwoods are not the dominant woody plant species in the riparian zone. The suspected reason for the reduction is the regulated flows from the McPhee Reservoir (DRD Core Science Report, 2005). A 2016 study reaffirms this reasoning, as a decrease in cottonwood cover in floodplains and an increased willow cover in river banks along the Dolores River was observed since completion of the McPhee Reservoir (Dott, et al., 2016).

Various other studies have shown that flow regulation can impact riparian ecology. Regulated flows can reduce the number of peak flow events while increasing the magnitude and duration of low-flow conditions. These low flows can lead to an increase in vegetation such as tamarisk, which can then lead to bank armoring and channel narrowing by tamarisk and willow (Dott, et al., 2016). Another study suggests that when annual streamflows are less than approximately 162,000 ac-ft per year, then the growth of three riparian tree species (Populus angustifolia, Populus deltoides subsp. wislizenii, Acer negundo) decreases (Coble and Kolb, 2012).

The DRD Correlation Report (2006) also conducted an analysis on the riparian ecology conditions for current and expected future water availability for each study reach. The changes seen in each reach are presented in Table 5.

Table 5. Existing and Expected Ecological Conditions (Source: DRD, 2006)

Reach[1]	Ecological Conditions: Existing	Ecological Conditions: Expected Future Water Availability
1	• Current flow management presents minimal opportunities to encourage sexual reproduction of cottonwoods and may be reducing long-term viability of off-channel wet meadow habitats. • Woody vegetation primary colonizer of "low floodplain" habitat and serving to narrow channel naturally. • Combining riparian plantings with mechanical treatments is a feasible approach.	• Ecological flow management may present opportunities to encourage sexual reproduction of cottonwoods if timing recession feasible with inflow/outflow constraints of higher flow. • Long-term viability of off-channel wet meadow habitats and floodplains improved by more frequent flows near 1800-2000 cfs on small spill years. • Woody vegetation primary colonizer of "low floodplain" habitat and will continue to facilitate channel narrowing. • Combining riparian plantings with mechanical treatments is a feasible approach, but needs to be maintained by supportive flow regime.
2	• Ponderosa pine and oak woodland community is unique in the Dolores River basin. • Current management appears to preserve this community. • The main threat is increasing the non-native forbs in understory. • Non-spill periods encourage development of dense low-flow sedge/grass/willow associations.	• Ponderosa pine and oak woodland community is unique in the Dolores River basin. • Ecological flow management will preserve this community and may diminish threats of non-native forbs in understory. • Non-spill periods encourage development of dense low-flow sedge/grass/willow associations.
3	• Ponderosa pine and oak woodland grades downstream into box-elder, willow, and silver buffaloberry in near-stream environment. • Non-spill periods encourage development of dense near-channel sedge/grass/willow associations. • Current management preserves this community. • Main threat is non-native weeds in understory, potential reduction in historical, higher elevation wet meadow habitats.	• Ponderosa pine and oak woodland grades downstream into box-elder, willow, and silver buffaloberry in near-stream environment. • Non-spill periods encourage development of dense low-flow sedge/grass/willow associations on low streambank. • Ecological flow management would preserve near-stream community, but may increase scour of low-flow streambank. • Main threat is non-native weeds in understory, potential reduction in historical, higher elevation wet meadow habitats. • Ecological flows aimed toward historic bankfull and above should improve conditions of these habitats.
4	• Willow/sedge and silverberry community is relatively stable above Disappointment Creek. • There is channel narrowing below Disappointment Creek. The entrenchment reduces diversity and increasing the tamarisk and understory knapweed threatens native communities.	• Ecological flows will maintain willow/sedge and silverberry community above Disappointment Creek. • Below Disappointment Creek it is possible that an increase in connection of the floodplain to the channel and appropriate recession limb timing could create the conditions for seed propagation of cottonwoods.

Reach[1]	Ecological Conditions: Existing	Ecological Conditions: Expected Future Water Availability
	• Remant gallery cottonwoods not dominant and disconnected from dynamic river processes necessary for proper age class structure. The debate remains whether they were native or induced by settlement.	• Channel narrowing and entrenchment threatens native communities.
5	• Relatively intact riparian community of willow and New Mexico privet above Coyote Wash. • Phragmites act to stabilize channel margins with willow. • Community changes rapidly to tamarisk-knapweed association below Coyote Wash, which may be due to natural salinity, historic land use, or both.	• Relatively intact riparian community of willow and New Mexico privet above Coyote Wash. • Phragmites act to stabilize channel margins with willow. • Community changes rapidly to tamarisk-knapweed association below Coyote Wash, which may be due to natural salinity, historic land use, or both. • Ecological flows will not serve to significantly affect riparian ecology through reach 5, although appropriate reach morphology, peak flow timing, and recession of the hydrograph.
6	• Significant intrusion of tamarisk throughout this reach, aided by this species' high tolerance to salt, giving it a competitive advantage over native woody species. • Any strategy must contemplate significant salt concentration in surface water, groundwater, and soils.	• Significant intrusion of tamarisk throughout this reach, aided by this species' high tolerance to salt, giving it a competitive advantage over native woody species. • Any strategy must contemplate significant salt concentration in surface water, groundwater, and soils. • Very high peak flows could scour sites recently colonized by tamarisk, and if timed with seed-set and appropriate hydrograph recession, could enable cottonwood establishment.

[1] Report only provides observations for Reaches 1 through 6

Following the 2017 controlled release of McPhee, riparian vegetation monitoring was also conducted along ecological monitoring sites and by comparison of historical photographs (CPW, 2018). A summary of findings related to riparian ecology is presented below.

- *A comparison of historic repeat photos demonstrates willow encroachment on point bars and river banks from 2003 to 2017, and appear to also have increased in density from 2003 to 2017 along the river bank at the Big Gypsum site.*
- *There was evidence of floodplain scouring and movement of sediment resulting in deposition and creation of some new small bare areas.*
- *The configuration of the channel has minimally changed.*
- *The density of riparian vegetation (mostly willow) and consequent armoring of river banks resulted in very little bank erosion or thinning/removal of riparian vegetation, creating few new bare areas where cottonwood seedlings could establish.*
- *No new cottonwood seedlings were found on ecological monitoring sites. The most common non-cottonwood seedlings found were willow, occurring at multiple survey areas.*
- *Comparison of historic vegetation transects found average willow stem density did not change between 2010 and 2017, indicating the managed release did not reduce willow density. Willows are serving to armor the river banks, resulting in channel narrowing, and represent one of the biggest changes in recent times on the Lower Dolores.*
- *Percent bare ground was over 40% at the Big Gypsum site, resulting in some seed germination on new seedbeds, but seedlings here were also found to be predominantly willow.*

The solution to riparian habitat improvement has been found through the cooperative efforts of landowners, land managers, and ecologists within the sideboards of operational obligations. In addition, the relatively uncontrolled San Miguel River may provide some guidance for native restoration objectives for the Dolores below McPhee (DRD, 2005b; DRD, 2006).

1.7 Water Quality

The 1977 EIS reported on water quality conditions in the Dolores River before the completion of McPhee Reservoir. Between 1969 and 1975, the Colorado State Department of Health collected 36 water samples along the Dolores River. Based on these samples, the presence of the heavy metals iron, zinc, and mercury as well as arsenic and selenium were found. However, none of these elements exceeded the recommended limit for domestic water, and local water treatment plants have the capability to remove harmful substances. Mining activities, including uranium, have taken place approximately 40 miles upstream of the Town of Dolores, and has historically introduced heavy metals and toxic substances into the Dolores River. The quality of the water improves downstream due to dilution by tributaries. Additionally, the alkalinity of the water decreases the threat heavy metals pose to aquatic organisms.

Turbidity, temperature, dissolved oxygen, and nutrient levels within the Dolores River, before the completion of the McPhee Reservoir, were within normal limits for a healthy and diverse biological system. The 1977 EIS stated that diversions by the MVIC have caused deterioration of the water quality downstream of the reservoir due to flow depletions.

The EIS predicted that water quality of the Dolores River would decrease during the construction period of the reservoir because of increased turbidity and sedimentation. However, the uniformity of the flows would generally improve the water quality downstream by removing high turbidity in spring runoff, while increasing summer flows. Increased summer flows would also dilute ground water and decrease salt concentrations.

Table 6 presents the predicted post-project water quality.

Table 6. Post-Project Expected Water Quality (Source: 1977 EIS)

Table C-2
Project return flow in
local tributaries of San Juan River

Local drainage to San Juan River	Area drained (acres)	Average existing flow (sec.-ft.)	Predicted return flow entering tributaries: Average annual acre-feet	Maximum in September (sec.-ft.)	Minimum in April (sec.-ft.)	Quality of return flow (mg/1) 6/
Monument Creek	1,640	intermittent	790	1.5	0.7	600
Cross Canyon	16,878	intermittent	6,520	12.8	6.2	600
			1/750			500
Hovenweep Canyon	1,642	intermittent	660	1.3	.6	600
Yellow Jacket Canyon	12,900	2/13	3,900	7.9	3.4	1,030
McElmo Creek 3/	21,100	45.9	3,850	8.4	2.6	2,360
			4/3,100			500
Navajo Wash	697	3	450	.9	.4	6,650
			5/500			500
Aztec Wash	590	intermittent	380	.9	.2	8,440
Cowboy Wash	1,091	intermittent	800	1.8	.5	5,700
Coyote Wash	5,126	intermittent	3,300	6.8	2.6	8,510

1/ Municipal and industrial return flow from Dove Creek area.
2/ Flow measured at Colorado-Utah State line. Includes intermittent flows from Hovenweep Canyon.
3/ McElmo Creek at Colorado-Utah State line.
4/ Municipal and industrial return flow from Cortez area.
5/ Municipal and industrial return flow from Towaoc area.
6/ Quality of irrigation return flow shown is estimated to be the highest for project operation and would occur during approximately the fourth year of operations. Quality improves gradually thereafter.

The salinity of the Dolores River is attributed to the presence of Paradox Formation salt domes. In 2014, the USGS developed a report titled *Assessment of Dissolved-Solids Loading to the Colorado River in the Paradox Basin between the Dolores River and Gypsum Canyon, Utah,* which reviewed the salinity issues within the Colorado River. In 1974, Congress enacted the Colorado River Basin Salinity Control Act to enhance and protect the water quality of the Colorado River. In 1995, the USBR was given the task of implementing a basin-wide salinity program. Significant financial investments and salinity control measures on private agricultural lands significantly reduced salt loadings. Nearly 205,000 tons of dissolved solids were discharged into the Dolores River prior to mitigation. Therefore, in 1996 the USBR implemented a series of brine-withdrawal wells in the alluvium along the Dolores River and a deep-injection well to dispose of the brine, to decrease the amount of salt in the river. Within 4 years, these brine-withdrawal wells had intercepted more than 90% of the dissolved solids previously discharged into the Dolores.

This report conducted four synoptic measurements at 20 different locations along the Colorado River. Location 1, USGS Stream Gage 09180500: Colorado River near Cisco, UT, is located just downstream of the confluence of the Colorado and Dolores Rivers. During the measurements, discharge and dissolved-solids concentration were measured.

Table 7 shows the results from synoptic tests 2, 3, and 4 at Location 1. The results suggest that the dissolved-solids loading in the Colorado River is negligible. The four synoptic tests completed between 2003 and 2011 along the confluence of the Colorado and Dolores Rivers indicated the Paradox formation, local salt anticlines, the Intrepid Potash evaporation ponds, and the perennial tributaries did not appear to be significant sources of salinity.

The BOR's withdrawal wells have been connected to recent earthquakes in Paradox Valley, therefore the wells have not been in operation. A draft EIS with four alternatives for salinity mitigation in the Paradox Valley Unit is currently available, and the BOR is anticipating an ROD in summer of 2020.

Table 7. Results from the Synoptic Tests at Location 1

U.S. Geological Survey streamgage Colorado River near Cisco, UT (09180500)			
Measurement date	Discharge (ft³/s)	Specific conductance (μS/cm at 25 °C)	Dissolved-solids concentration (mg/L)
Synoptic 2			
10/3/10	3,540	1,190	758
10/4/10	3,650	1,230	785
10/5/10	3,680	1,220	782
10/6/10	3,800	1,210	772
10/7/10	3,950	1,240	791
10/8/10	3,930	1,170	743
minimum	3,540	1,170	743
maximum	3,950	1,240	791
mean	3,760	1,210	772
Synoptic 3			
10/25/10	5,120	1,200	766
10/26/10	5,670	1,170	748
10/27/10	5,360	1,170	745
10/28/10	5,020	1,170	745
minimum	5,020	1,170	745
maximum	5,670	1,200	766
mean	5,290	1,180	751
Synoptic 4			
9/12/11	5,190	991	621
9/13/11	5,140	990	621
9/14/11	5,090	999	627
9/15/11	5,240	990	621
minimum	5,090	990	621
maximum	5,240	999	627
mean	5,170	992	622

1.8 Operations and Water Rights

The DWCD is the primary entity responsible for operating McPhee Dam and Reservoir, in coordination with the BOR. Water stored in the reservoir provides water for irrigation, M&I uses, controlled flows for downstream fish and wildlife purposes, recreational boating and electrical power generation. The capacity of McPhee Reservoir is 381,000 ac-ft with a maximum active capacity of 229,000 ac-ft. The 30-year average reservoir inflow is 327,000 ac-ft. McPhee Dam and Reservoir are the major storage features of the Project; the system also includes a system of canals, tunnels, and laterals to deliver water to over 61,000 acres of land. Approximately 85 percent of stored water is allocated for irrigation, 11 percent is allocated for the fish pool, and 4 percent is allocated for M&I uses. Specific DWCD Project allocations are presented in Table 8

Water stored in McPhee Reservoir consists of both “Project Water” and “Non-Project Water.” Project Water consists of the storage created when McPhee Dam was built and delivered via the Project delivery systems. These uses and users include: municipal and agricultural water for the Ute Mountain Ute Reservation in Towaoc, Colorado; Full-Service Farmers around Dove Creek; municipal water for Cortez and Dove Creek; and for the downstream fish pool. With the exception of municipal water, all entities are subject to equal shortages when declared by DWCD and BOR rather than adhering to individual water right priority dates.

Non-Project Water consists of historical MVIC water rights up to 150,000 ac-ft a year. A carriage contract between BOR and MVIC allows this storage to occur. Non-Project Water is managed by MVIC, and is therefore not subject to the same shortages or stipulations as Project Water. MVIC is not allowed carry-over storage rights. Water stored in Groundhog Reservoir and Narraguinnep Reservoirs is MVIC Non-Project Water. MVIC’s project water is on average 13,700 ac-ft and is limited to 26,300 irrigable acres rather than the entire MVIC service area.

Multiple statutes, agreements, and environmental assessments drive how water is managed in the Dolores River Basin. These instruments include:

- Colorado River Storage Project Act of 1956
- Colorado River Basin Project Act of 1968
- 1977 Final Environmental Impact Statement
- 1977 Dolores Project Colorado Definite Plan Report
- 1977 Repayment Contract between the United States and the DWCD
- 1986 Colorado Ute Indian Water Rights Final Settlement Agreement
- 1989 Repayment Contract between the United States and the Ute Mountain Ute Tribe\
- 1989 Water Rights and Salinity Control Act
- 1996 Environmental Assessment for the fish pool allocation concept
- 2000 Operating Agreement between the BOR and DWCD
- 2001 DWCD Carriage Contract FEIS
- Annual operating plans
- Other memorandums and agreements.

Table 8. DWCD Project Allocations (DWCD, FAQ)

Allocation Holder	Primary Allocation AF	Adjustments AF	Total AF	Notes
Full Service Farmers	55,282	6,985	62,267	Adjustments include 985 AF re-allocated from downstream water rights +6000 AF from Class B Stock.
Ute Mountain Ute Tribe	23,300	1,217	24,517	The adjustment includes 417 AF from downstream water rights re-allocation + 800 AF in San Juan Basin F&W water. Not counted in the adjustment is past Farm and Ranch leases which have recently averaged 4,000 AF/YR.
Downstream Fishery	29,300	2,498	31,798	Adjustment includes 1,274 AF in senior downstream water rights, plus 524 AF from downstream water rights re-allocation and 700 AF in Paradox Salinity Unit augmentation, released with fish pool.
MVIC	Variable: Approx. 80,000 to 150,400	Variable: Approx. 0 to 60,000	Variable: Approx. 90,000 to 150,400	MVIC Project Water allocation is variable. MVIC has 26,300 acres of land defined in USBR contracts as irrigable and therefore eligible for Project Water. MVIC Project water is calculated by totaling the MVIC non-Project supply, applying this supply toward the full 37,500 acres (per contract) irrigated by MVIC, then making up the difference for the 26,300 irrigable acres so they receive a full supply of 4.01 AF/Acre. Call Water stored in McPhee at no charge is the first water spilled since Project Water gets priority. The active capacity of Groundhog and Narraguinnep Reservoirs is counted as non-Project supply. By contract, MVIC must limit their total non-Project diversions to 150,400 AF for all irrigable and class 6 lands (totaling 37,500 acres) and Project Water can only be applied to the 26,300 irrigable acres. Average annual MVIC Project Water supply per contract was estimated to be 13,700 AF, which is the basis for MVIC's flat rate share of DP O&M charges, regardless of MVIC's actual annual diversions. An additional 3,000 AF of non-Project stock water is available to MVIC under their historic water rights. MVIC's total water supply is a mix of their historic CO water rights, the majority, combined with smaller contractual supply from the DP.
M&I City of Cortez	2,300		2,300	
M&I Town of Dove Creek	280		280	
M&I DWCD	5,120		5,120	
San Juan F&W Water	800		800	Diverted to federal mitigation wetlands and Totten per contract
Totals	267,782	70,700	278,482	Neither MVIC Non-Project nor Project Water is included in these totals, but Class B portion (max. 6,000 AF) is listed under DWCD adjustments.

Yearly operations of McPhee Reservoir are dependent on annual inflow conditions. Operating on a “fill before spill” criteria means that the reservoir must be full before water exceeding Project allocations is released from McPhee Reservoir. Spills occur approximately 50 percent of the time (DRD, 2005). On years with no spills, water managers determine if any Project Water shortages need to occur, or if full allocation is possible. CPW works with water managers to delineate the release pattern of the “fish-pool” allocation. Each spring, DWCD and BOR work with the Colorado River Forecast Center to determine runoff patterns and volume while considering recommendations from the Monitoring and Recommendation Team composed of stakeholders. These stakeholders include: DWCD, BOR, Dolores River Boating Advocates, American Whitewater, CPW, the Nature Conservancy (TNC), MVIC, BLM, and other relevant stakeholders.

BOR is required to consider recreational attributes of the Dolores River, including releasing appropriate volume and duration of water for whitewater boating. The current operational Agreement states McPhee operations should: “… *optimize the amount of available water for Project purposes and benefit whitewater and recreational boating, may necessitate releases from McPhee Reservoir in anticipation of a forecasted spill*” (2000, AOP p. 4).

1.9 Literature Review

References reviewed for this study are presented and summarized in Table 9.

Table 9. References reviewed for literature review

Title	Author	Year	Summary	Classification
Assessment of dissolved-solids loading to the Colorado River in the Paradox Basin between the Dolores River and Gypsum Canyon, Utah	Christopher L. Shope Steven J. Gerner	2014	The purpose of this study was to conduct four synoptic sampling events to quantify the salinity loading throughout the study reach and evaluate the occurrence and impacts of both natural and anthropogenic sources. The results from this study indicate that no significant sources of dissolved-solids loading from tributaries or directly by groundwater discharge, with the exception of the Green River, were identified in the study area.	Water Quality
Climate Change and the Upper Dolores Watershed: A Coldwater-fisheries Adaptive Management Framework.	Trout Unlimited and Mountain Studies Institute	2017	Produced by the Dolores River Anglers, the TU chapter aims to provide a framework to delineate what streams in the Upper Dolores watershed are likely to provide viable trout populations through the end of the 21st century. Further, it suggests relevant management strategies and ecological factors of survivable trout populations in the face of climate change. This report identifies climate change impacts to the Upper Dolores Watershed.	Biology Climate Hydrology
Core Science Report	Dolores River Dialogue	2005	This report included review of literature and previously prepared documents related to the Dolores River, discussion of linkages between flow and ecological and physical processes in the Dolores River, and identification of key data gaps.	Hydrology Geomorphology Ecology
Defining Recreational Streamflow Needs in the Lower Dolores River: Integrating Specific and Overall Evaluations of Flow and Recreation Quality	Nathan Fey Evan Stafford Kristina Wynne	2014	This study used a web-based approach to collect information on whitewater flows in five segments of the Lower Dolores River and organized the data to define flows that provide for certain recreational needs. Results from this study provide resource managers with better information on whitewater flow-needs in the Dolores River basin, which can be used in the development of annual operating plans for McPhee Dam and to improve the scheduling and	Hydrology Water Rights and Operations

Title	Author	Year	Summary	Classification
			prediction program for releases to the Lower Dolores River.	
Dolores Project Colorado: Final Environmental Statement	Bureau of Reclamation	1977	This was EIS for the Project, which evaluated diversion of the Dolores River to the San Juan River Basin via the construction of the McPhee Dam and Reservoir. The document includes a scope of work, summary of environmental impacts and unavoidable adverse effects and alternative options considered, including four modifications of the plan, four alternative uses of water, and non-development.	History Hydrology Ecology Water Rights and Operations
Dolores River Instream Flow Assessment, Project Report	Vandas, Steve.	1990	From the BLM Montrose Office, this study quantifies values associated with the Dolores River including aquatic and riparian habitat, and other stream channel characteristics related to proper channel maintenance. This report documents the post-impact streamflow regimes, present flow dependent resource values and analyzes water management options for securing instream flow protection.	Hydrology Geomorphology Operations Recreation
Dolores River Wild and Scenic Study Report	Colorado Department of Natural Resources	1976	A report compiled by state and federal agencies assessing and recommending various segments of the Dolores River basined on their Wild and Scenic attributes, or “Outstandingly Remarkable Values”	Hydrology Ecology Water Rights and Operations Recreation
Dolores River, Colorado: The River of Sorrows	Bureau of Land Management	Undated	The purpose of this report was to summarize the evaluation of the Dolores River as to its potential for designation under Section 5(d) of the National Wild and Scenic Rivers Act PL 90-542. It described the characteristics of the Dolores River, specifically: the history of the area, hydrological characteristics, and description of surrounding geomorphology. The report concluded that the Dolores River appeared to have qualities for inclusion under the National Wild and Scenic Rivers Act.	History Hydrology Geomorphology
DRAFT Correlation Report: Summary of Hydrologic and Scientific Findings And Resulting Matrix Templates.	Dolores River Dialogue	2006	The purpose of this report was to (1) conduct a water availability analysis, (2) analyze potential downstream environments, (3) create a correlation between the previously mentioned efforts, and (4) create a matrix of doable alternatives with	Hydology Geomorphology Ecology

Title	Author	Year	Summary	Classification
			identifiable consequences to inform potential actions.	
DRAFT Hydrology Report	Dolores River Dialogue	2005	The purpose of this study was to perform a hydrologic analysis to describe the amount of water expected to flow downstream of McPhee Reservoir through spills and baseflow releases. Historical watershed hydrologic data available from gaged stations is described, and a model for McPhee Reservoir operations hydrology was developed.	History Hydrology
Flow Management and Endangered Fish in the Dolores River during 2012-2017: U.S. Bureau of Reclamation	Dave Speas	2018	The purpose of this study is to assess the extent to which flow management on the Dolores River may contribute to endangered fish recovery through the analysis of three lines of hydrologic and ecologic evidence. Through this, the authors found that available information is insufficient to identify linkages between flow management at McPhee Dam and endangered fish recovery.	Hydrology Ecology
History of Dolores River Water Use, the Dolores Project, the Rise of Environmental Consciousness Nationally and Locally, and Stakeholder Collaboration to Promote Conservation of Lower Dolores River Natural Resources			The purpose of this appendix was to provide factual background information that undergirds the DRD purpose statement. It discusses rights to be honored, the nature of a water right under Colorado law, the necessity for agricultural and municipal water supplies, the history of Dolores River water use, the development of the Project, the rise of environmental consciousness nationally and locally, and the recognition of and response to downstream Dolores River ecological impacts.	Ecology Operations and Water Rights
Lower Dolores River 2017 McPhee Reservoir Manages Release Ecological Monitoring and Evaluation	Colorado Parks and Wildlife The Nature Conservancy Colorado Mesa University	2018	The purpose of this report was to summarize the 2014 study, Lower Dolores River Implementation, Monitoring and Evaluation Plan for Native Fish, and describe its recent implementation. During this study, monitoring focused on sensitive native fish and the assessment of in-channel and riparian habitats, and pre- and post-release data were collected.	Geomorphology Ecology
Lower Dolores River Implementation, Monitoring and Evaluation Plan for Native Fish	Dolores River Dialogue	2014	The purpose of this study was to create an IM&E Plan that supported community needs while protecting fisheries, riparian health, and the quality of the boating experience below McPhee Reservoir.	Hydrology Ecology Operations and Water Rights

Title	Author	Year	Summary	Classification
			The Implementation Plan was designed to maintain, protect, and enhance native fish populations in the Dolores River based on habitat conditions such as channel maintenance and optimal base flow.	
Memorandum: Biological Opinion for Dolores Project, Colorado	United States Fish and Wildlife	1980	This biological opinion was prepared in response to a request for formal consultation on the Project by the Upper Colorado Regional Director. This opinion states that the proposed project is not likely to jeopardize the continued existence of the bald eagle, American peregrine falcon, black-footed ferret Uinta Basin hookless cactus, or the Mesa Verce cactus. However, it will likely jeopardize the continued existence of the endangered Colorado squawfish, bonytail chub, and the humpback chub.	Ecology
Native Riparian Tree Establishment Along the Regulated Dolores River, Colorado	Adam P. Coble Thomas E. Kolb	2013	The purpose of this study was to investigate influences of flow regulation of the Dolores River, Colorado, by McPhee Dam on establishment of three native riparian tree species (*Populus angustifolia, Populus deltoides subsp. wislizenii, and Acer negundo*). The results of this study suggest that flow releases form McPhee Dam into the Lower Dolores River between 1985 and 2008 provided appropriate conditions for *Populus* establishment, particularly at low topographic positions within the active channel in recent years, whereas *A. Negundo* may require greater flows to bolster establishment at the higher topographic positions where it often occurs.	Ecology
Operating Agreement, McPhee Dam and Reservoir	United States Bureau of Reclamation	2000	Legal agreement between the U.S. Department of Interior BOR and the DWCD. Signed in 2000, the agreement expires in 2025.	Water Rights and Operations
Riparian Tree Growth Response to Drought and Altered Streamflow along the Dolores River, Colroado	Adam P. Coble Thomas E. Kolb	2012	The purpose of this study was to investigate influences of streamflow regulation by McPhee Dam on the Lower Dolores River, Colorado, on the growth of three riparian tree species (*Populus angustifolia, Populus deltoides subsp. wislizenii, and Acer negundo*). The results of this study provide guidelines for flow releases form McPhee Dam to	Ecology Water Operations

Title	Author	Year	Summary	Classification
			mitigate drought impacts on riparian tree growth along the Lower Dolores River.	
River of Sorrows: The History of the Lower Dolores River Valley	Kendrick, D. Gregory Smith, A. Duane Dishman, Linda Gerhold, Maureen	1981	A National Park Service digital book regarding the history of the Project. Four chapters include: 1) A historical overview of the Dolores River Valley, 2) Ranching and farming in the Lower Dolores River Valley, 3) Eastern Capital and Frontier initiative: The History of the Montezuma Valley Irrigation System; 4) McPhee, Colorado: A 20th Century Lumber Company Town	History
Status and Trends of Flannelmouth Sucker *Catostomus latipinnis*, Bluehead Sucker *Catostomus discobolus*, and Roundtail Chub *Gila robusta*, in the Dolores River, Colroado, and Opportunities for Population Improvement: Phase II Report	Kevin R. Bestgen Phaedra Budy William J. Miller	2011	The purpose of this report was to (1) summarize information that describes status and trends of the three species and to discuss reasons for their decline, and (2) present opportunities for improvement of the native fish community. Through this, the authors determined that RTC are rare in upstream reaches and abundant, but highly fluctuating or declining, in downstream reaches, FMS is rare in upstream reaches and present in variable and declining abundance in the remainder of the study areas, and BHS rare in the entire study area and is declining in most reaches. Although reason for the declines are uncertain, the authors present nine potential management opportunities to improve the native fish community.	Ecology
Temporal and Spatial Variation in Riparian Vegetation and Floodplain Aquifers on the Regulated Dolores River	C.E. Dott G.L. Gianniny M.J. Clutter C. Aanes	2016	The purpose of this study was to compare three long-term study sites above and below McPhee Dam and describe observations of decreased cottonwood cover on floodplains and increased willow cover on river banks since dam completion on the Dolores River. Through this, the authors found that floodplain habitats below dams exist under artificially extreme drought and inform how biologically diverse riparian systems will be impacted by a drying climate.	Ecology
The Dolores Project	Voggesser, Garett.	2001	A BOR history of the Project and water users.	History
The Dolores River Dialogue as an Example	Carolyn Dunmire Ann Oliver Chuck Wanner	2010	The purpose of this report was to describe the formation of the DRD, and how scientific investigation is managed, conducted, and funded by	Hydrology Ecology Water Rights and

Title	Author	Year	Summary	Classification
of Long-term Collaborative Decision-making	Mike Preston Jim Siscoe David Graf Chester Anderson Randy Carver Marsha Porter-Norton		the DRD, as well as examples of recent decisions and actions undertaken by the DRD including: the Lower Dolores River Plan Working Group contributing to the update of BLM's 1990 Dolores River Corridor Management Plan and Dolores River Watershed Plan.	Operations
The River of Sorrow (film)	Rig to Flip	2015	This is an hour-long documentary describing the overall situation of the Dolores River . It is the ideal platform to gain on overall perspective of water rights, stakeholders, and recreational boating on the Dolores River.	Water Rights and Operations
Transbasin Water Transfer Dolores River Southwestern Colorado	John Porter	2001	The purpose of this report was to summarize the history of water diversions from the Dolores River, including commentary on western expansion and development, the BOR's Project, and the Water for Everyone Tomorrow PACKage (WETPACK) project.	History Water Rights and Operations
Vegetative and geomorphic complexity at tributary junctions on the Colorado and Dolores Rivers: a blueprint for riparian restoration	Margaret S. White Brian G. Tavernia Patrick B. Shafroth Teresa B. Chapman John S. Sanderson	2018	The purpose of this study is to investigate spatial patterns and extents of tributary influence on riparian habitat complexity in the near channel zone along regulated reaches of the Colorado and Dolores Rivers in the western United States. The results of this study indicate that tributary junctions deliver critical resource inputs on regulated systems, providing for increased geomorphic and land cover diversity upstream and downstream of tributaries. Additionally, the authors found that response patterns were non-linear and discontinuous, which could potentially be influenced by the degree of mainstream flow regulation.	Geomorphology Ecology

2 Watershed Characterization

2.1 General Watershed Characteristics

The following describes the spatial characteristics of the Dolores Watershed (Watershed) based on publicly available information (as of August 2019). These characteristics include; topography, geology, soils, land use, precipitation, and land ownership. A summary of this data, including publication year and date downloaded, is described in Section 2.2.

2.1.1 Watershed

The Watershed is approximately 4,634 square miles (sq. mi.) based on the United States Geological Survey's (USGS) 2015 Watershed Boundary Dataset (WBD). The Watershed is located in Southwest Colorado, to the northwest of the San Juan mountain range, and southwest of the Uncompahgre Plateau. Approximately 88 percent of the Watershed is located in Colorado with the other 12 percent falling in Utah. The Watershed generally drains from southeast to northwest, with flows draining into either the Dolores River or the San Miguel River, a tributary of the Dolores River. The Dolores River eventually outfalls into the Colorado River near the eastern Utah border.

For this assessment, the watershed was broken into three sub-watersheds based on WBD-HUC8 (see Figure 10). Table 10 presents these sub-watershed characteristics, including: WBD identifier, drainage area, drainage source, and length of the main stem river in the sub-watershed. The length of river is determined from data derived from the 2014 National Hydrography Dataset (NHD).

The contributing drainage area to McPhee Reservoir is located within the Upper Dolores sub-watershed, and is approximately 30 percent of the total Upper Dolores sub-watershed. The McPhee Reservoir primarily diverts flow into the San Juan River basin for irrigation.

Table 10. Sub-Watershed Characteristics

Sub-Watershed	WBD Identifier	Area (sq. mi.)	Drainage Source	River Length (mi)
Lower Dolores	14030004	923	Dolores River	62
Upper Dolores[1]	14030002	2158	Dolores River	178
San Miguel	14030003	1553	San Miguel River	78
[1] Includes 645 sq. mi. above McPhee Reservoir				

2.1.2 Topography

The Watershed ranges in elevation from a high elevation of approximately 14,250 feet (ft) in the southeast portion of the watershed to 4,100 ft at the confluence of the Dolores River with the Colorado River (northwest portion of the watershed), as shown in Figure 11. The highest slopes are found in the mountains in the southeast portion of the Watershed, and along drainages. Table 11 contains a summary of topographic information for each sub-watershed, including minimum and maximum elevation, basin slope, and general sub-watershed trends based on 1/3 arc-second (10 meter) digital elevation model (DEM) data from the 2017-2019 National Elevation Dataset (NED).

Table 11. Sub-Watershed Topographic Information

Sub-Watershed	Maximum Elevation (ft)	Minimum Elevation (ft)	Average Sub-Watershed Slope (percent)[2]	General Trends
Lower Dolores	12,716	4,100	28	Flows drain from both the east and west sides of the sub-watershed to the Dolores River located in the middle of the sub-watershed. Flows are then drained out of the sub-watershed via the Dolores River into the Colorado River. The highest point within the sub-watershed is located on the southwest side.
Upper Dolores[1]	14,256	4,816	21	Flow generally drains from the southeast (mountainous) portion of the sub-watershed towards the north side of the basin via the Dolores River. The steepest slopes are located in the mountainous area.
San Miguel	14,024	4,813	20	Flow generally drains from the southeast (mountainous) portion of the sub-watershed to the northwest via the San Miguel river. Slopes east to west. The steepest slopes are located in the mountainous area.

[1] The McPhee Reservoir Sub-Watershed ranges from 14,256 ft in the southeast portion of the sub-watershed to 6,928 ft at the reservoir.
[2] Calculated based on the results from a slope grid generated from topography

2.1.3 Geology

Geological information was obtained from the 2005 USGS Mineral Resources through the NRCS Data Gateway tool. The geological conditions are presented in Figure 12 and Figure 13. A stratigraphic column located in the Watershed is presented in Figure 9.

The following information is based on a variety of sources (Ake, et al., 2010; NPS, 2018; USGS, 2011).

The Watershed is located in the Colorado Plateau physiographic region in Western Colorado. The Colorado Plateau is comprised of a series of plateaus and mesas located within an immense basin surrounded by highlands. Precambrian basement rock underlies the Plateau with primarily overlying sedimentary rock with igneous deposits in the volcanic areas of the region. Landforms in the region have been formed by intense water and wind erosion.

Rock exposed in the Dolores Canyon consists of Pennsylvanian age limestone to Jurassic age Entrada sandstone. The upper rim of the canyon is capped by Cretaceous age Dakota sandstone forming steep cliffs. The Dolores River is thought to have originally flowed south to join the San Juan River prior to the uplift of Sleeping Ute Mountain in the late Cretaceous, altering the course of the river to its present day location. Near-surface salt deposits up to 14,000-ft thick underlie Paradox Valley in the northern part of the watershed. The Dolores River picks up thousands of tons of salt flowing through the valley each year. As part of the Colorado

River Basin Salinity Control Project, the saline groundwater was collected in wells and injected deep beneath the surface into Precambrian rocks formations. The injection process induces large amounts of earthquakes in the region, most of magnitude 2.5 or lower and undetectable by humans. The saltwater is no longer injected because of this.

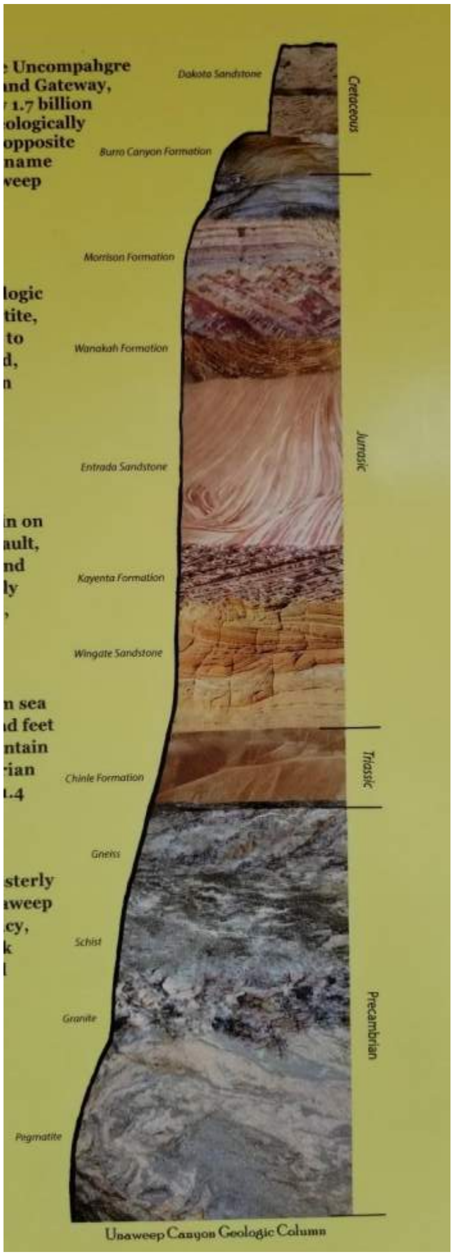


Figure 9. Stratigraphic column located in Watershed

2.1.4 Soils

Soils data were obtained from the Soil Survey Geographic Database (SSURGO) through the United States Department of Agriculture (USDA) National Resources Conservation Service's (NRCS) Web Soil Survey tool (2018 for Colorado, 2013-2015 for Utah). This database contains a variety of soils-related information, including Hydrologic Soil Group (HSG), which is a description of runoff potential when soils are saturated (NRCS, 2007). The HSG for the Watershed is presented in Figure 14.

The Upper Dolores and San Miguel sub-watersheds primarily consist of Hydrologic Soil Group (HSG) C (approximately 45 percent), which is classified as having moderately high runoff potential. It typically has between 20 and 40 percent clay and less than 50 percent sand (NRCS, 2007). The Lower Dolores sub-watershed is primarily unmapped (approximately 32 percent), and the mapped portion consists largely of both HSG C and D (total of approximately 46 percent). HSG D is classified as having high runoff potential when thoroughly wet. It typically has greater than 40 percent clay and less than 50 percent sand (NRCS, 2007). Table 12 shows a summary of the soils data for the sub-watersheds.

Table 12. Sub-Watershed Soils Data Summary

Sub-Watershed	Soil Group A	Soil Group B	Soil Group C	Soil Group D	Unmapped	Other[1]
Lower Dolores	5%	17%	26%	20%	32%	0%
Upper Dolores	2%	21%	44%	23%	9%	1%
San Miguel	3%	14%	45%	22%	16%	0%
[1]Sum of A/D, B/D, and C/D HSG						

2.1.5 Land Use

The 2014 National Land Cover Dataset (NLCD), as shown in Figure 15, was obtained from the USDA NRCS Geospatial Data Gateway tool. The sub-watersheds consist primarily of evergreen forest, shrub/scrub, and deciduous forest, with the primary land use in each sub-basin being the evergreen forest, as described in Table 13.

Table 13. Land Use Data Summary

Sub-Watershed	Primary Land Use	Secondary Land Use	Tertiary Land Use
Lower Dolores	Evergreen Forest 45%	Shrub/Scrub 29%	Deciduous Forest 18%
Upper Dolores	Evergreen Forest 43%	Shrub/Scrub 27%	Deciduous Forest 21%
San Miguel	Evergreen Forest 39%	Deciduous Forest 25%	Shrub/Scrub 19%

Impervious surface data derived from the NLCD was also available from the 2013 National Atlas of the United States, and was obtained using USGS National Map Small-Scale Data Download tool. However, approximately 96 percent of the Watershed is unmapped, and therefore this dataset was not considered in this assessment.

Agriculture data was obtained from the 2017 Colorado Decision Support System (CDSS) Division of Water Resources' (DWR) web portal, as shown in Figure 16. The Watershed is not used extensively for agriculture. Crops are primarily grown on irrigated lands in the San Miguel sub-watershed, with grass pasture being the main crop grown.

2.1.6 Land Ownership

Land ownership parcel data was available from the BLM Colorado Surface Management Agency (SMA), as shown in Figure 17. The sub-watersheds consist primarily of federal land parcels managed by the BLM and the United States Forest Service (USFS), as shown in Table 14. Other land owners include: the State of Colorado, the State of Utah, private, and other.

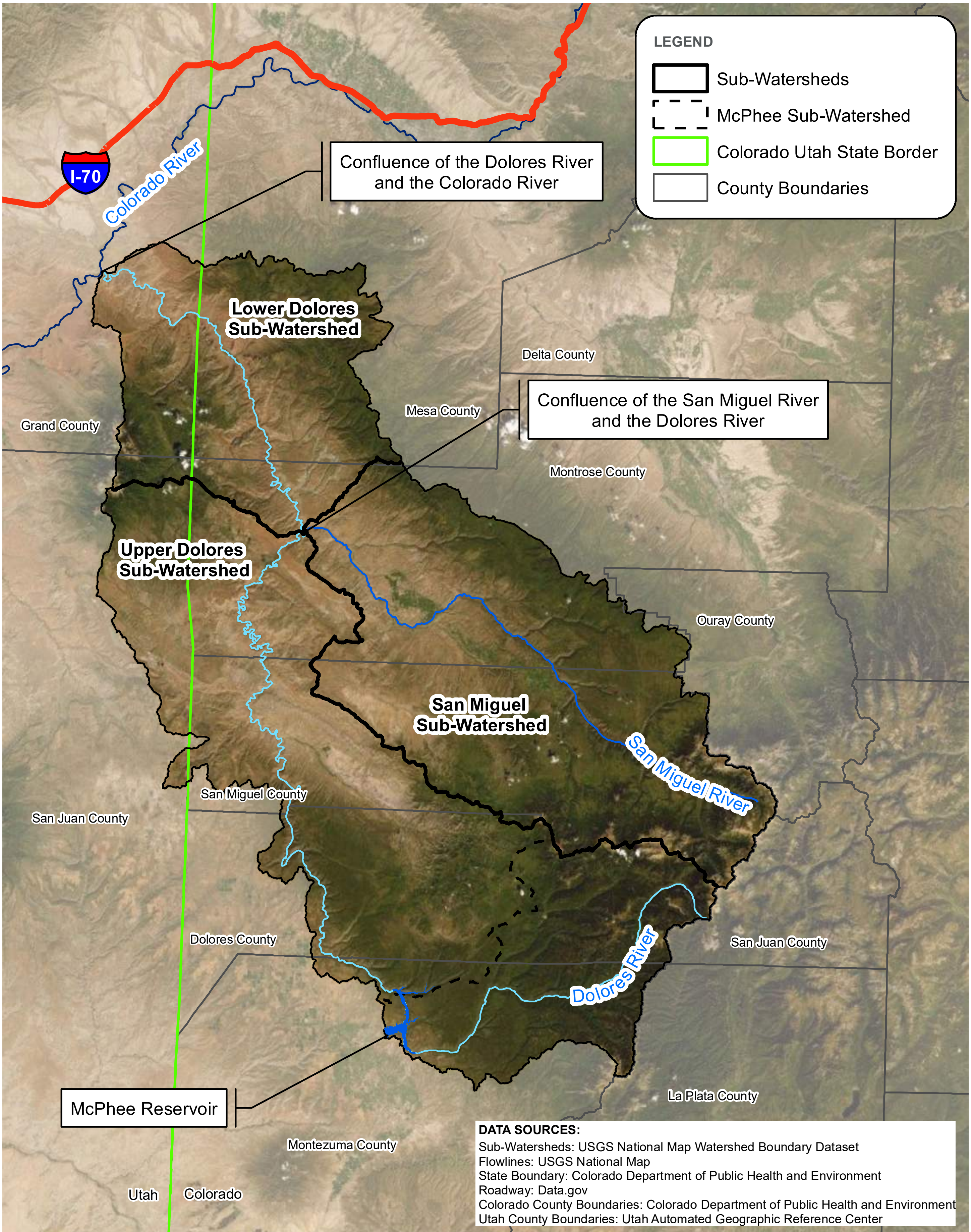
Table 14. Land Ownership Data Summary

Sub-Watershed	Federal		State	Private	Other
	BLM	*USFS*			
Lower Dolores	59%	22%	4%	15%	0%
Upper Dolores	36%	42%	3%	18%	1%
San Miguel[1]	27%	35%	2%	34%	2%
[1] Other includes less than 1% BOR and NPS					

2.1.7 Precipitation

Annual average precipitation data from 1981 to 2010 was available from the PRISM Climate Group, as shown in Figure 18. The greatest amounts of average annual rainfall occurs in locations that correspond to the highest elevations (the mountain range on the southeast portion of the basin, and the high point between the Upper Dolores and Lower Dolores sub-watersheds). The lowest amounts of average annual rainfall occur along the lower halves of the Upper Dolores and San Miguel Sub-Watersheds, in the vicinity of the streams, and along the streams in the Lower Dolores Sub-Watershed.

Frequency-based precipitation data is available from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Estimates tool (2013 for Colorado, 2011 for Utah). There is data available for events ranging from the 1-year to the 1000-year event with durations ranging from 5 minutes to 60 days. This data may be useful for future projects along the stream corridor for design and restoration projects and for compliance with Federal Emergency Management Agency (FEMA) requirements. An example frequency event (the 100-year, 24-hour [hr] data) is presented in Figure 19.



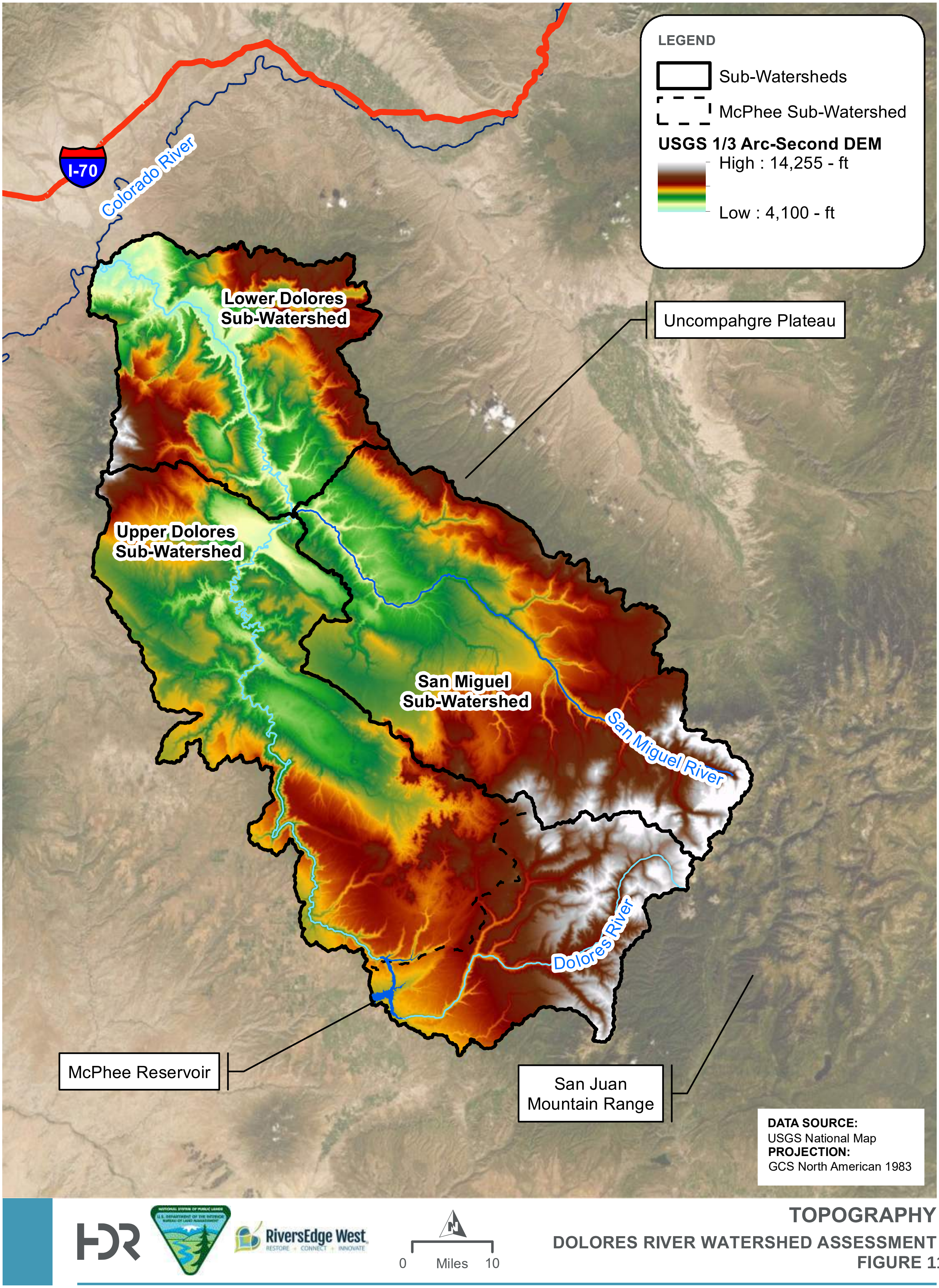
0 Miles 10

SUB-WATERSHEDS

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 10

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\SUBWATERSHEDS.MXD - USER: KRANNEY - DATE: 11/25/2019

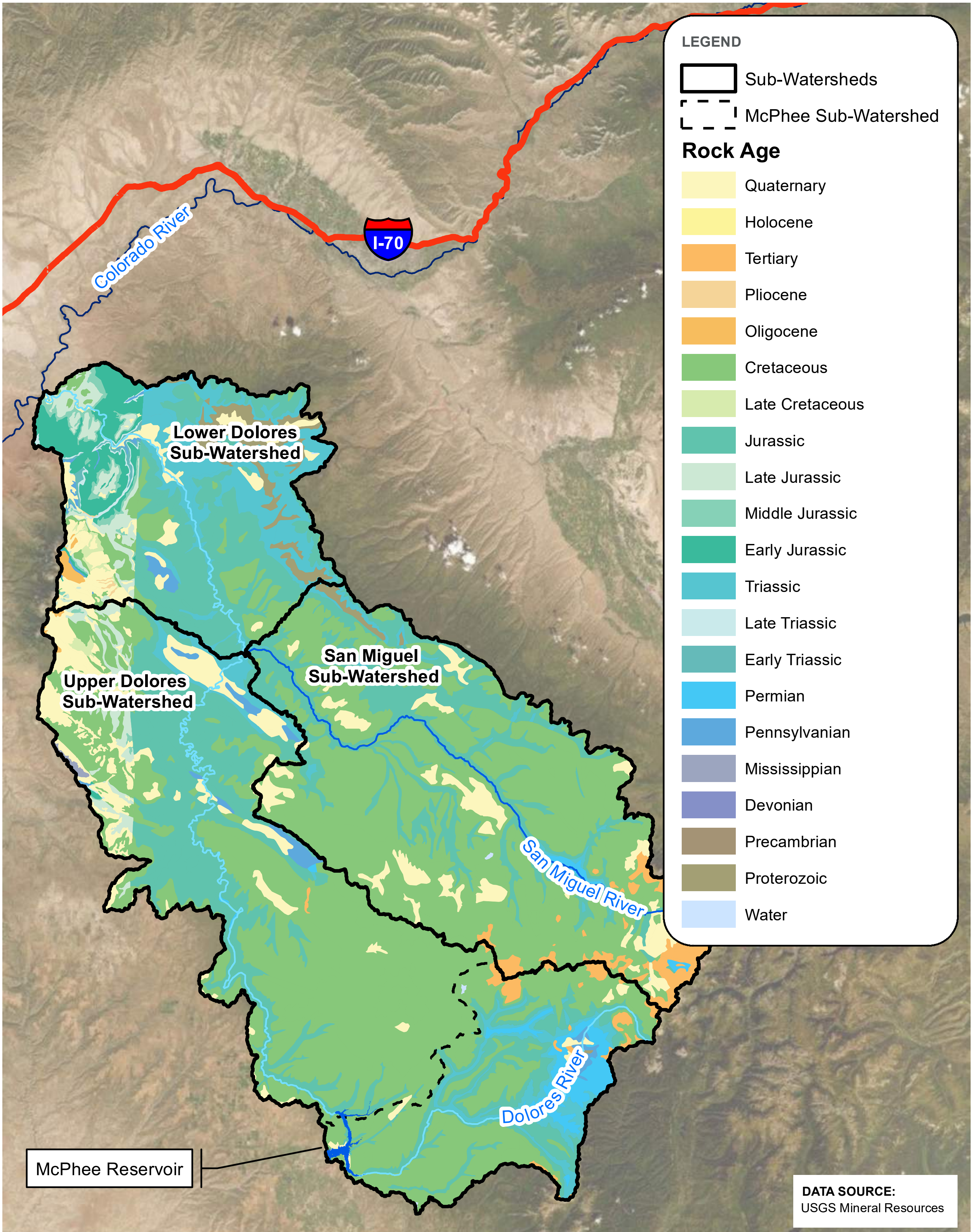


TOPOGRAPHY

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 11

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\TOPOGRAPHY.MXD - USER: MESSELLS - DATE: 2/20/2020

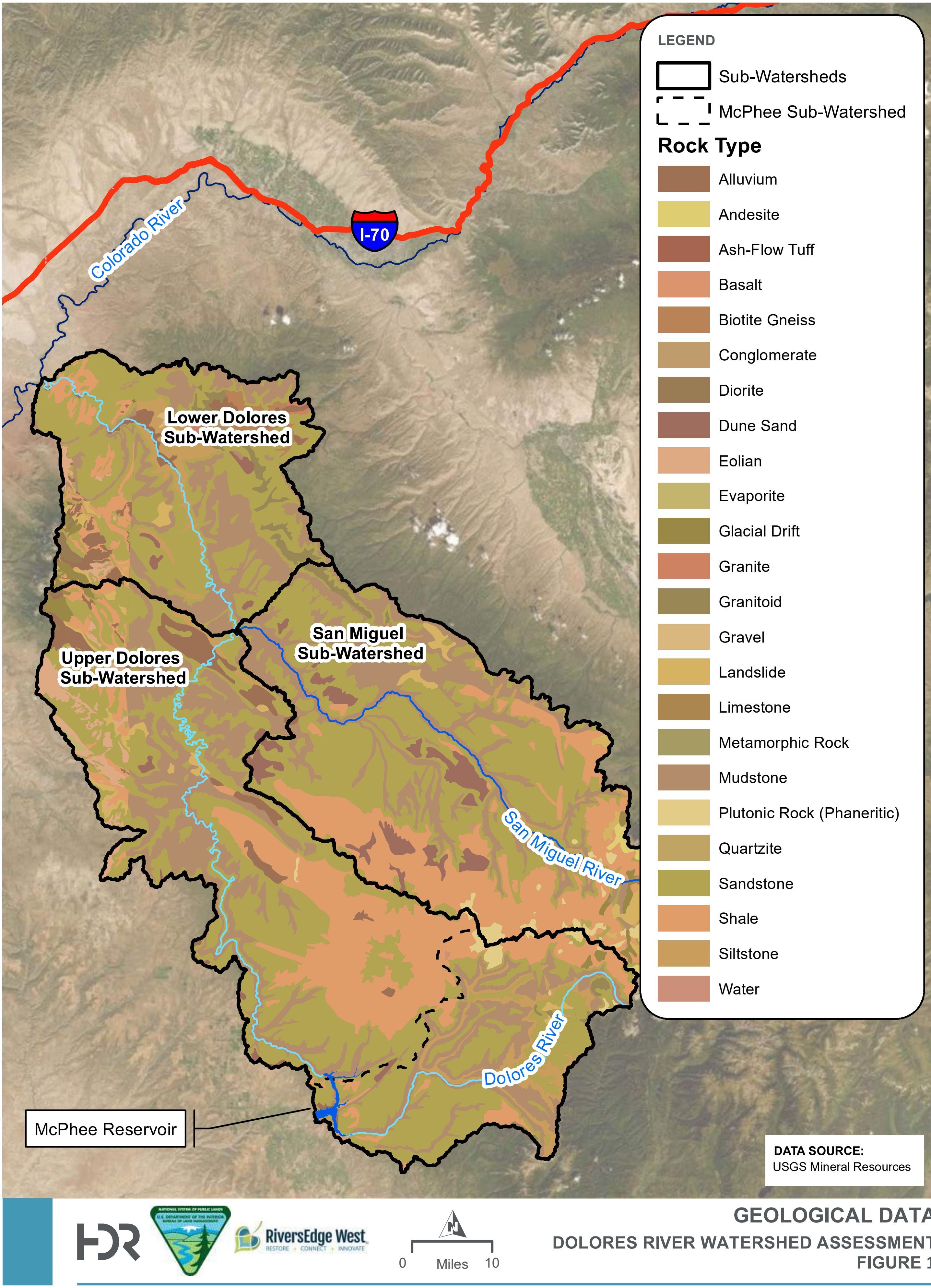


GEOLOGICAL AGE DATA

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 12

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\GEOLOGY_AGE.MXD - USER: KRANNEY - DATE: 11/25/2019

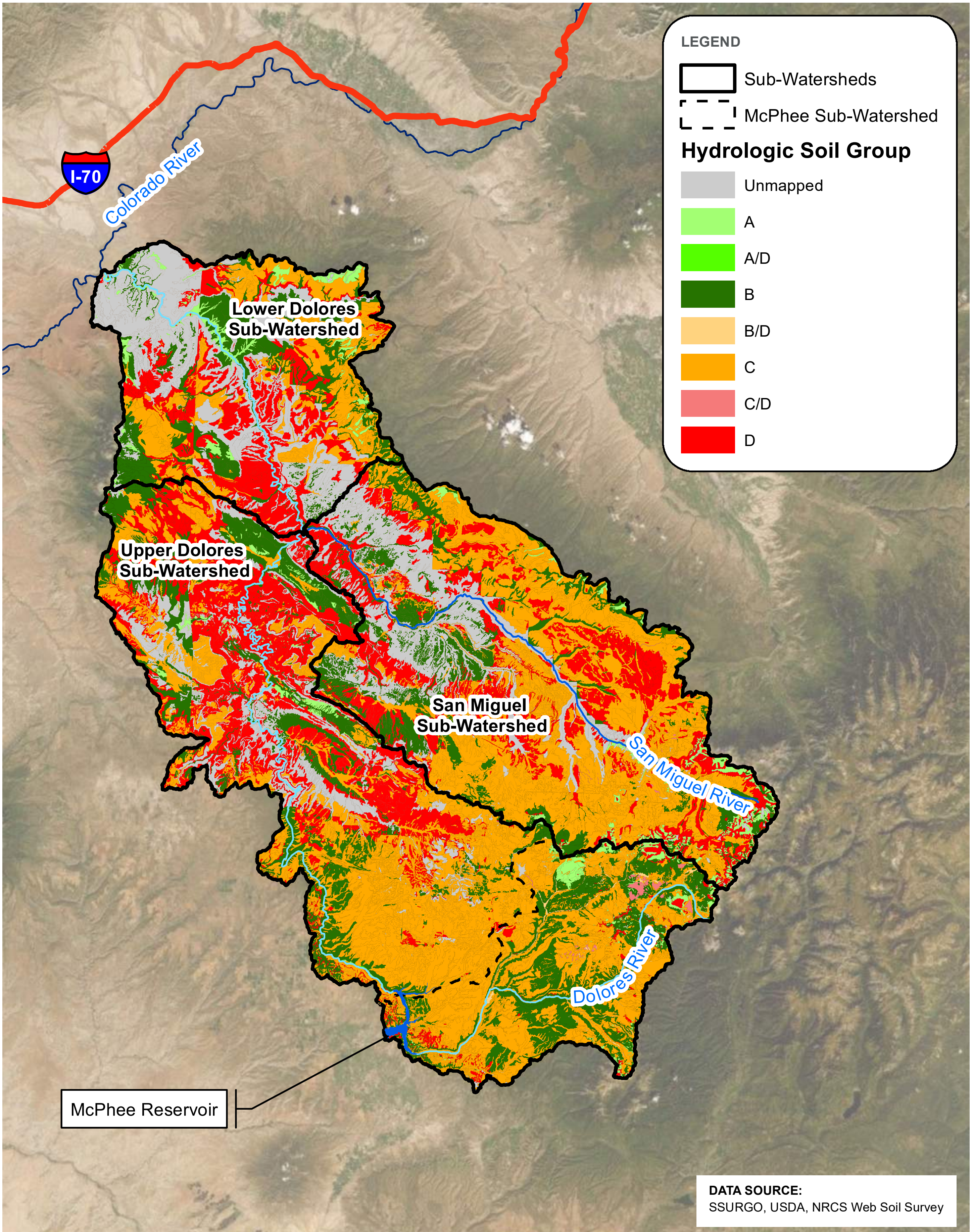


GEOLOGICAL DATA

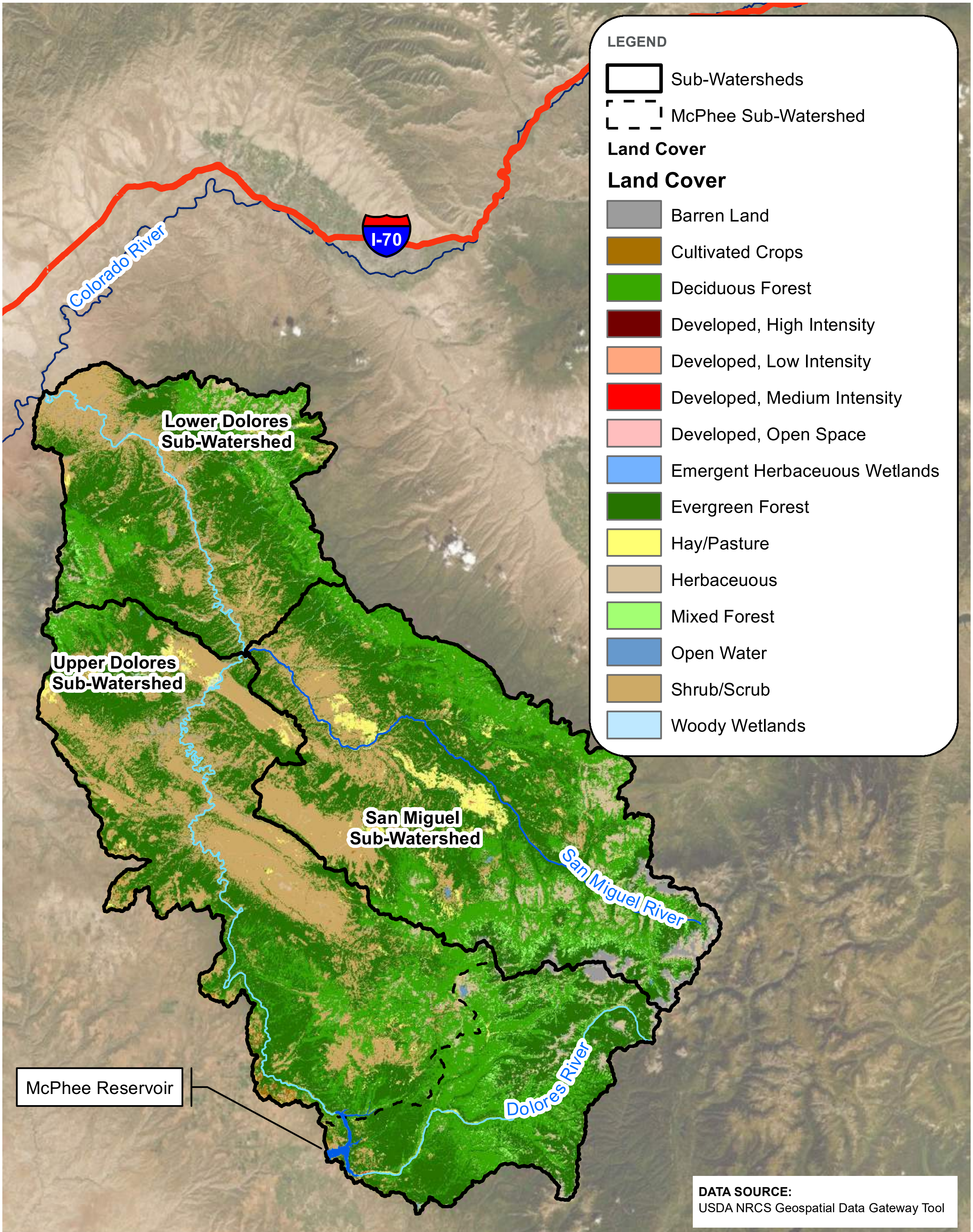
DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 13

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\GEOLOGY_ROCK_TYPE.MXD - USER: KRANNEY - DATE: 11/25/2019



SOILS DATA
DOLORES RIVER WATERSHED ASSESSMENT
FIGURE 14

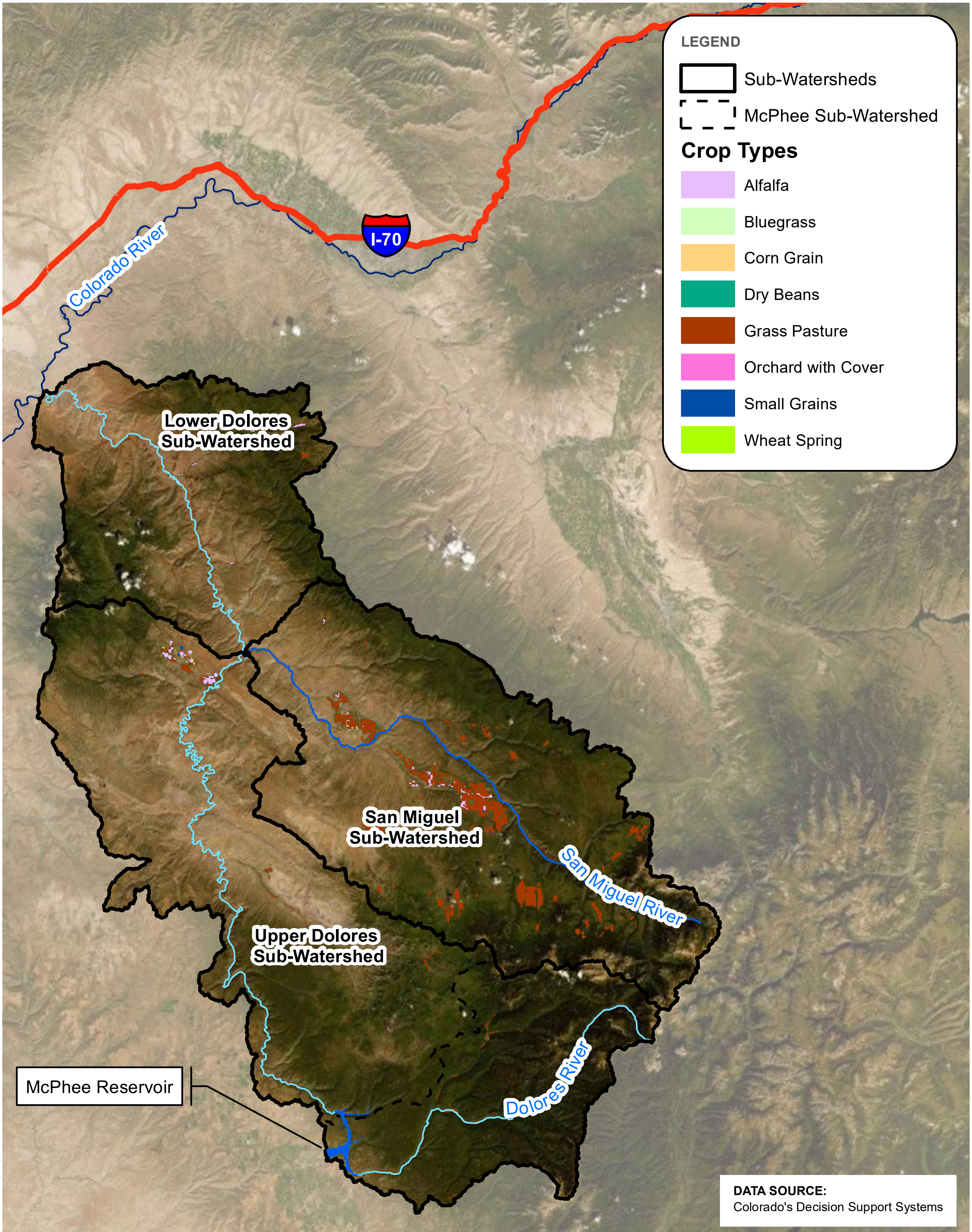


LAND USE

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 15

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\LAND_USE.MXD - USER: KRANNEY - DATE: 11/25/2019



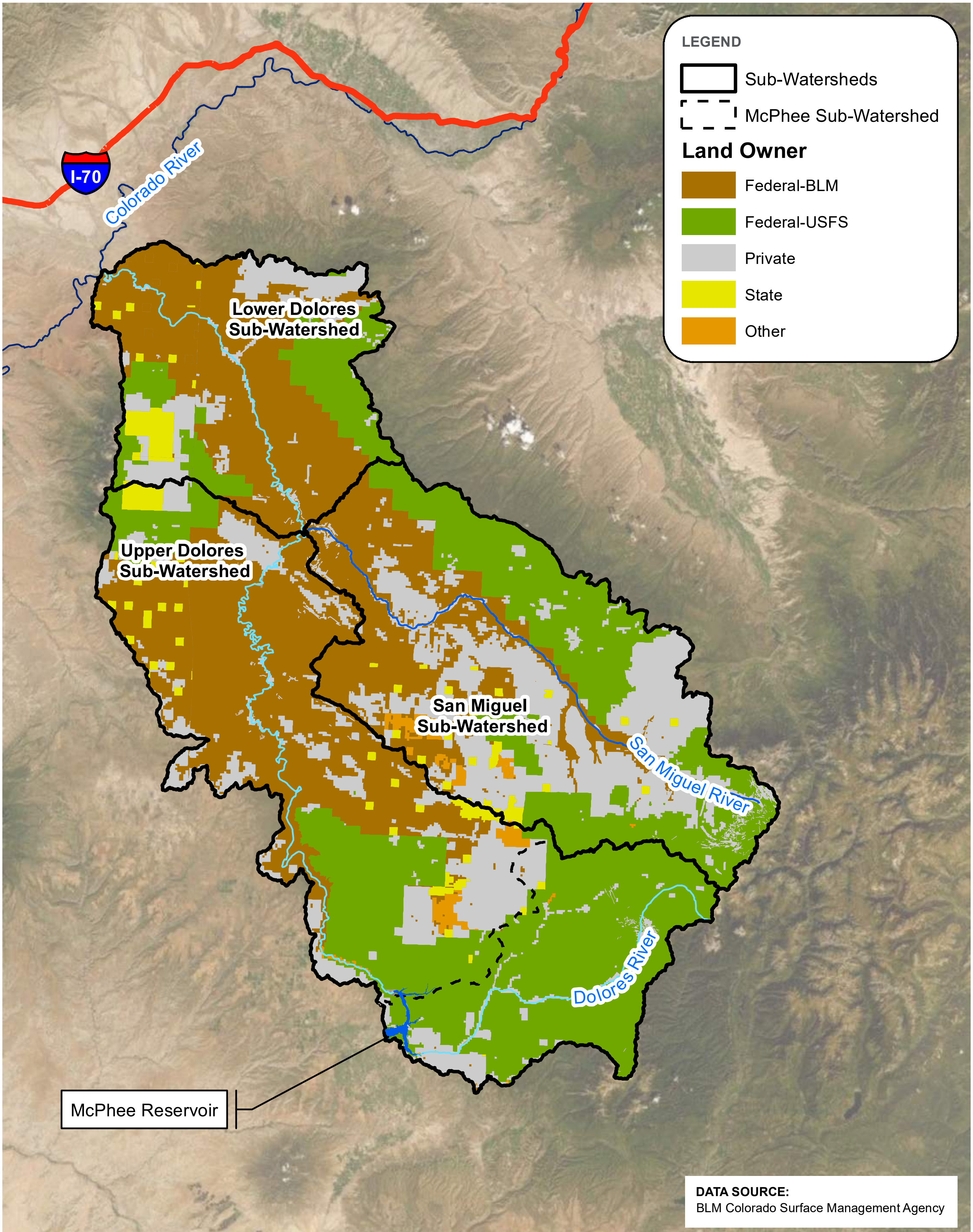
0 Miles 10

CROP TYPES

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 16

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\CROPS.MXD - USER: KRANNEY - DATE: 11/25/2019

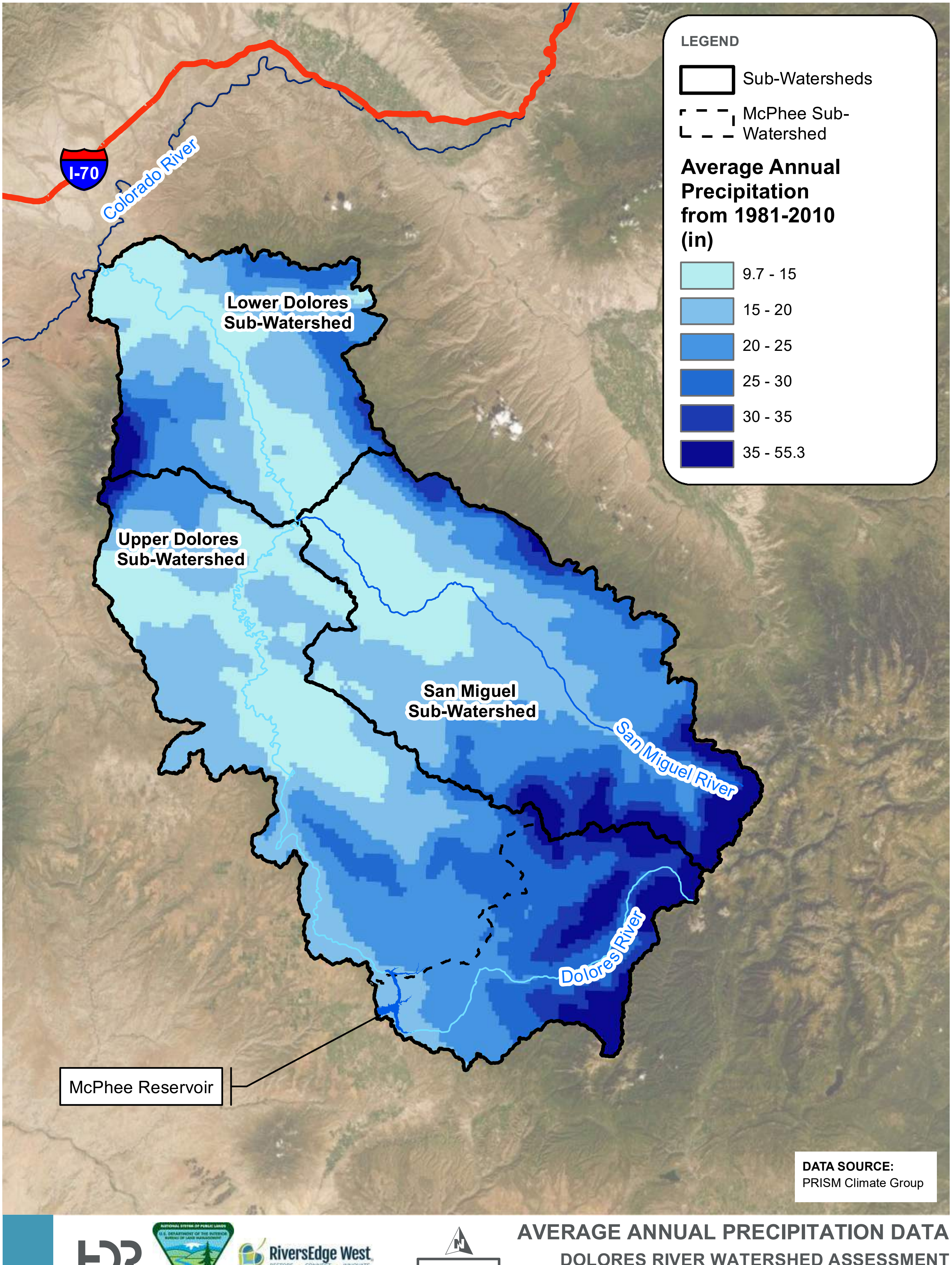


LAND OWNERSHIP

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 17

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\PARCELS.MXD - USER: KRANNEY - DATE: 2/26/2020

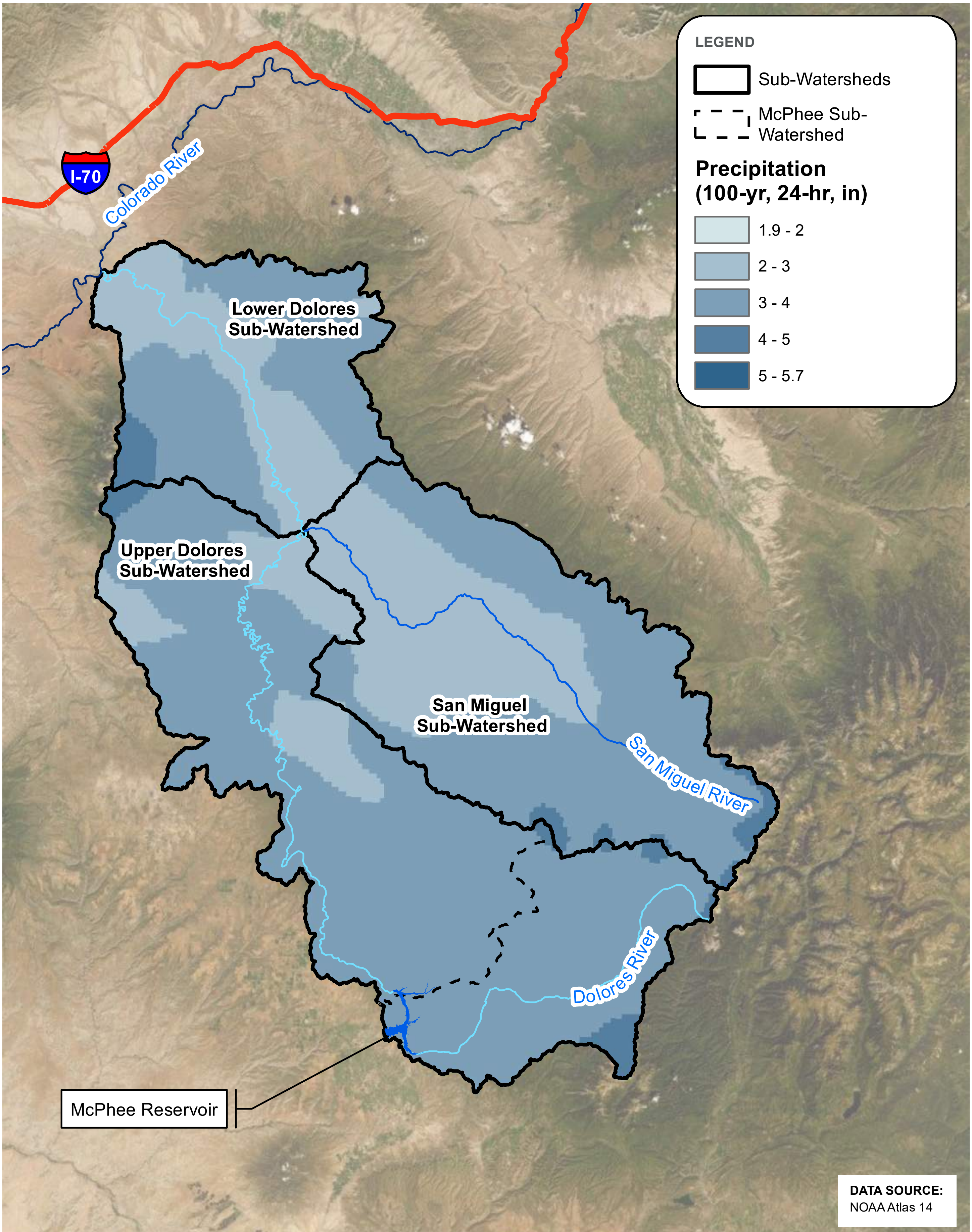


AVERAGE ANNUAL PRECIPITATION DATA

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 18

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\ANNUAL_AVERAGE_PRECIPITATION.MXD - USER: KRANNEY - DATE: 9/24/2019



0 Miles 10

100-YEAR, 24-HOUR PRECIPITATION EVENT

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 19

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\DELIVERABLE\MXD\PRECIPITATION.MXD - USER: KRANNEY - DATE: 2/17/2020

2.2 Data Sources

Table 15 presents a summary of data reviewed at the time of the watershed characterization. Additional data may be available at different sources. Additional information on each dataset is available from their individual metadata.

Table 15. Data Sources

Data Layer	Data Type	Source	Date Published	Date Acquired	Description	Report Use	Link
Sub-Watersheds	ArcGIS Shapefile	WBD; USGS National Map	12/16/2015	8/8/2019	WBDHU8 and WBDHU10 located within the Watershed	Section 2.1	https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View#productSearch
Flowlines	ArcGIS Shapefile	NHD; USGS National Map	06/2014	8/9/2019	Colorado River, Dolores River, and San Miguel River	Section 2.1	https://nationalmap.gov/small_scale/atlasftp.html?openChapters=chpbio%2Cchpwater#chpwater
Topography	Raster	NED; USGS National Map	Varies from 2017 to 2019	8/8/2019	DEM 1/3 Arc-Second resolution.	Section 2.1.2	https://viewer.nationalmap.gov/basic/#productSearch
Geology	ArcGIS Shapefile	USGS Mineral Resources; NRCS Data Gateway	CO: 2005 UT: 2005	8/8/2019	Colorado and Utah	Section 2.1.3	https://datagateway.nrcs.usda.gov/GDGOrder.aspx
Soils	ArcGIS Shapefile	SSURGO; USDA, NRCS Web Soil Survey	CO:9/10/2018 UT: 12/16/2013, 9/21/2015	8/12/2019	Colorado and Utah	Section 2.1.4	https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Land Use	ArcGIS Shapefile	NLCD; NRCS Data Gateway	CO: 3/31/2014 UT: 3/31/2014	8/8/2019	Colorado and Utah	Section 2.1.5	https://datagateway.nrcs.usda.gov/GDGOrder.aspx
Percent Impervious	ArcGIS Shapefile	NLCD; USGS National Map	2/20/2013	8/9/2019	Colorado and Utah	Section 2.1.5	https://nationalmap.gov/small_scale/atlasftp.html?openChapters=chpbio%2Cchpwater#chpwater
Crop Types	ArcGIS Shapefile	Colorado's Decision Support Systems (CWCB/DWR)	Division 4: 5/18/2017 Division 7: 9/20/2017	8/12/2019	Colorado: Divisions 4 and 7	Section 2.1.5	https://www.colorado.gov/pacific/cdss/gis-data
Annual Average Precipitation	Raster	PRISM Climate Group at Oregon State University	7/10/2012	9/24/2019	Average annual precipitation from 1981 to 2010.	Section 2.1.7	http://www.prism.oregonstate.edu/normals/
Frequency Precipitation	Raster	NOAA Precipitation Frequency Data Server	CO:4/15/2013 UT: 4/08/2011	9/3/2019	100-year 24 hour duration storm	Section 2.1.7	https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html
Historic Aerial Imagery	TIFF	USGS Earth Explorer	9/27/2018	8/9/2019	Not downloaded for assessment		https://earthexplorer.usgs.gov/
State Data	ArcGIS Shapefile	Colorado Department of Public Health and Environment (CDPHE)	CO Counties: 2/19/2018 CO City Boundaries: 2/19/2018	8/9/2019	Colorado County and City Boundaries		https://data-cdphe.opendata.arcgis.com/datasets/66c2642209684b90af84afcc559a5a02_5
State Data	ArcGIS Shapefile	Data.gov	2/20/2013	8/9/2019	Colorado Roadways		https://catalog.data.gov/dataset/tiger-line-shapefile-2016-state-colorado-current-county-subdivision-state-based
State Data	ArcGIS Shapefile	Utah Automated Geographic Reference Center (AGRC)	UT Counties: 2/23/2017 UT Cities: 2/23/2017 UT Roadways: 10/26/2017	8/9/2019	Utah County Boundaries, City Boundaries, and Roadways		https://gis.utah.gov/data/
County Data[1]	ArcGIS Shapefile and Raster	Mesa County	3/08/2018	8/8/2019	Mesa County, Colorado: Drainage Basins, Rivers, Watershed Boundaries, Mesa County Boundary, and Roads		https://emap.mesacounty.us/DownloadData/
County Data[1]	ArcGIS Shapefile	Montrose County	2/26/2015	8/9/2019	Montrose County, Colorado: County Roads		https://www.montrosecounty.net/406/Downloadable-Data

Data Layer	Data Type	Source	Date Published	Date Acquired	Description	Report Use	Link
County Data[1]	ArcGIS Shapefile	San Miguel County	6/27/2016	8/9/2019	San Miguel County, Colorado: Roadways		https://www.sanmiguelcountyco.gov/185/MappingGIS
County Data[1]	ArcGIS Shapefile	Montezuma County	6/05/2009	8/9/2019	Montezuma County, Colorado: Roadways		http://montezumacounty.org/web/departments/gis-mapping/gis-download/
FEMA Data	ArcGIS Database	FEMA	6/09/2019	8/8/2019	Colorado FEMA floodplain information		https://msc.fema.gov/portal/home#
FEMA Data	ArcGIS Database	FEMA	7/28/2019	8/8/2019	Utah FEMA floodplain information		https://msc.fema.gov/portal/home#
Parcel Data	ArcGIS Shapefile	BLM	12/27/2019	1/22/2020	Utah land ownership information		https://www.blm.gov/services/geospatial/GISData/utah
Parcel Data	ArcGIS Shapefile	BLM	12/27/2019	1/22/2020	Colorado land ownership information		https://www.blm.gov/site-page/services-geospatial-gis-data-colorado

[1] **Additional data available**

3 Hydrologic Assessment

3.1 Purpose

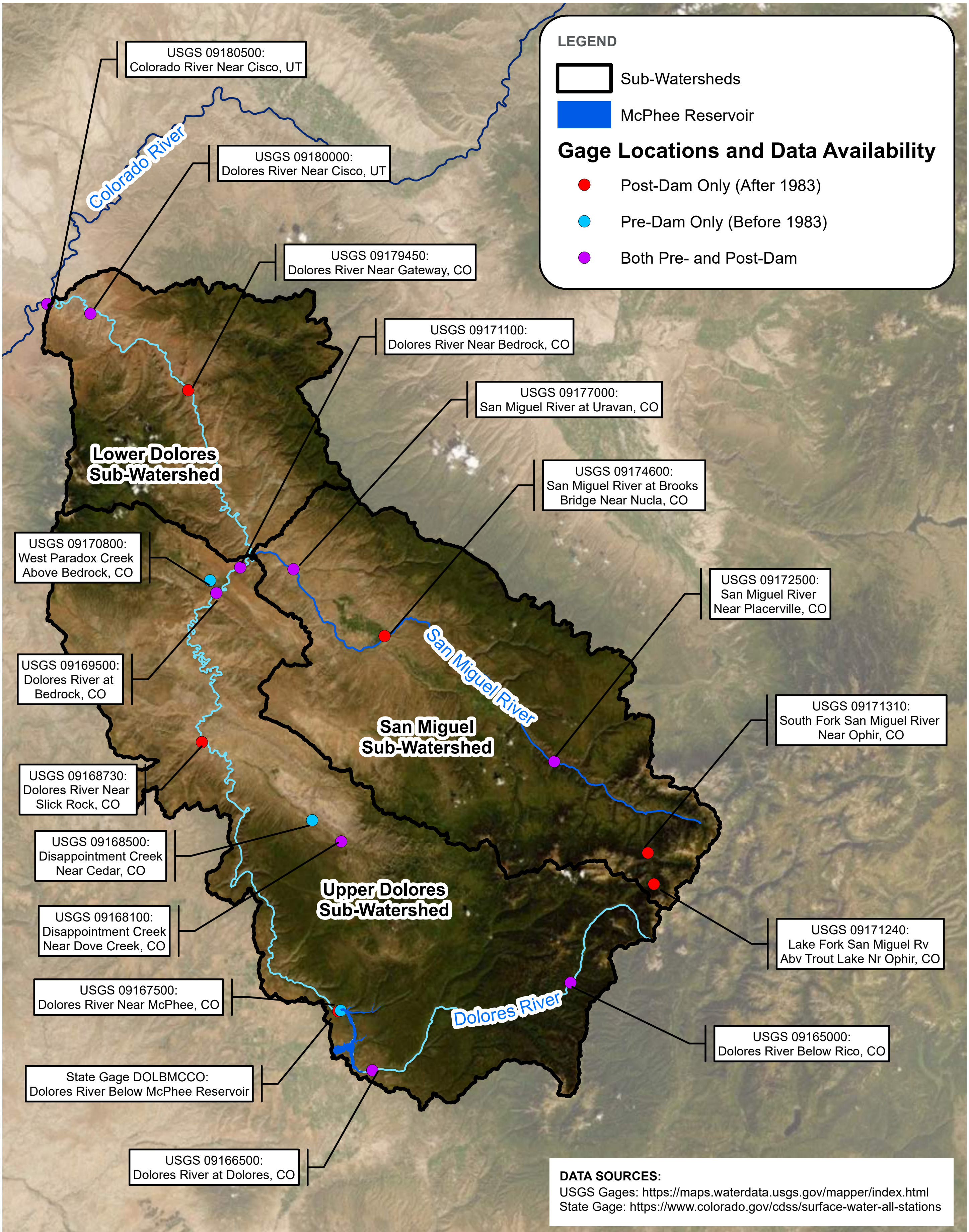
As discussed in Section 1 of this Report, the flow regime of the Dolores River has changed over the past 130 years due to western expansion and development. The first major change occurred in 1880’s when the MVIC began directing water for irrigation. Another significant change in the Watershed occurred in 1983 with the construction of McPhee Dam. The purpose of this Hydrologic Assessment is to evaluate three main hydrologic components:

4. Evaluate the impacts McPhee Dam had on the Watershed’s overall hydrologic regime. This was completed by developing IHA parameters for both pre-impact and post-impact conditions, and then comparing the change of those parameters using the Range of Variability Approach (RVA).
5. Evaluate the influence the San Miguel River has on the Lower Dolores River. This was completed by reviewing and comparing flow duration curves for gages in the Lower Dolores River, Middle Dolores River, and San Miguel River.
6. Understand how the current hydrology impacts the form and function of the Dolores River, and how this information can be used to inform future watershed management.

This analysis evaluates hydrologic impacts pre and post McPhee Reservoir construction. However, impacts began with the MVIC diversions. Analyzing the unaltered hydrology of the system pre-1880’s is outside the scope of this study.

3.2 Summary of Gage Data

There are 17 USGS gages and one State of Colorado gage available in the Watershed on the following watercourses: Dolores River, Disappointment Creek, San Miguel River, West Paradox Creek, and Colorado River. The locations of these gages are shown in Figure 20. A variety of data is available at many of these gages, including: discharge, precipitation, temperature, and other parameters. These parameters are typically available as daily averages or at specific time increments throughout the day. There are also typically daily, monthly, and yearly statistics available for each gage, as well as peak streamflow data. A summary of the available data for each of the gages can be found in Table 16. This table includes links to the specific gages, which can be used to review additional information. *For the purpose of this analysis, the average daily discharge data was obtained.*



0 Miles 10

GAGE LOCATIONS AND DATA AVAILABILITY

DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 19

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\MAP_DOCS\GAGE_LOCATIONS_MAP_V2.MXD - USER: MESSELLS - DATE: 10/22/2019

Table 16. Available USGS and State Gage Information

Gage Name	Gage Number	River Name	Drainage Area (sq mi)	Date Acquired	Start Date	End Date	Available Data	Link
Dolores River Near Cisco, UT	09180000	Dolores River	4,580	8/20/2019	12/1/1950	8/19/2019	Both	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09180000
Dolores River Near Gateway, CO	09179450	Dolores River	4,146	8/20/2019	11/18/2014	8/19/2019	Post-Impact	https://waterdata.usgs.gov/nwis/inventory/?site_no=09179450&agency_cd=USGS
Dolores River Near Bedrock, CO	09171100	Dolores River	2,147	8/20/2019	8/1/1971	8/19/2019	Both	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09171100
Dolores River at Bedrock, CO	09169500	Dolores River	2,025	8/20/2019	10/1/1917	8/19/2019	Both	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09169500
Dolores River Near Slick Rock, CO	09168730	Dolores River	1,434	8/20/2019	5/1/1997	8/19/2019	Post-Impact	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09168730
Dolores River at Dolores, CO	09166500	Dolores River	504	8/20/2019	10/1/1895	8/19/2019	Both	https://waterdata.usgs.gov/nwis/inventory/?site_no=09166500
Dolores River Below Rico, CO	09165000	Dolores River	106	8/20/2019	10/1/1951	8/19/2019	Both	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09165000
Dolores River Near McPhee, CO	09167500	Dolores River	817	8/20/2019	10/1/1938	9/29/1952	Pre-Impact	https://waterdata.usgs.gov/nwis/inventory/?site_no=09167500
Dolores River Below McPhee Reservoir	DOLBMCCO	Dolores River	819	8/27/2019	10/11/1985	9/30/2018	Post-Impact	https://www.colorado.gov/cdss/surface-water-all-stations
San Miguel River at Uravan, CO	09177000	San Miguel River	1,500	8/20/2019	8/1/1954	8/19/2019	Both	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09177000
San Miguel River at Brooks Bridge Near Nucla, CO	09174600	San Miguel River	743	8/20/2019	3/31/1995	8/19/2019	Post-Impact	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09174600
San Miguel River Near Placerville, CO	09172500	San Miguel River	309	8/20/2019	10/1/1910	8/19/2019	Both	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09172500
South Fork San Miguel River Near Ophir, CO	09171310	San Miguel River	41.7	8/20/2019	11/1/2011	8/19/2019	Post-Impact	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09171310&agency_cd=USGS
Lake Fork San Miguel Rv Abv Trout Lake Nr Ophir, CO	09171240	San Miguel River	8.52	8/20/2019	11/1/2011	8/19/2019	Post-Impact	https://waterdata.usgs.gov/nwis/inventory/?site_no=09171240&agency_cd=USGS
West Paradox Creek Above Bedrock, CO	09170800	West Paradox Creek	53.3	8/20/2019	8/1/1971	9/29/1973	Pre-Impact	https://waterdata.usgs.gov/nwis/inventory/?site_no=09170800
Colorado River Near Cisco, UT	09180500	Colorado River	24,100	8/20/2019	10/1/1913	8/19/2019	Both	https://waterdata.usgs.gov/nwis/inventory?site_no=09180500
Disappointment Creek Near Cedar, CO	09168500	Disappointment Creek	167	8/27/2019	3/1/1953	9/29/1956	Pre-Impact	https://waterdata.usgs.gov/co/nwis/inventory/?site_no=09168500&agency_cd=USGS
Disappointment Creek Near Dove Creek, CO	09168100	Disappointment Creek	147	8/27/2019	8/1/1957	9/29/1986	Both	https://waterdata.usgs.gov/nwis/inventory/?site_no=09168100

3.3 Pre- and Post-Impact Hydrologic Analysis

3.3.1 Methodology and Software

The first component of the hydrologic assessment is to evaluate impacts McPhee Dam has had on the Watershed's overall hydrologic regime. This evaluation was completed using an IHA Analysis and RVA methodology and approach, as developed by Richter et al.:

1. *A Method for Assessing Hydrologic Alteration within Ecosystems* (Richter, et al., 1996)
2. *A Spatial Assessment of Hydrologic Alteration within a River Network* (Richter, et at., 1998)

The purpose of these analyses are to statistically characterize the temporal variability in the hydrologic regime using biologically relevant statistics, and to quantify and compare hydrologic regimes from pre-impact to post-impact. Results from this analysis can be used to provide ecosystem managers the appropriate information to restore the river system's integrity to pre-impact conditions.

TNC developed IHA software to characterize natural and altered hydrologic regimes. The IHA software can be used to summarize long periods of daily hydrologic data into manageable series of ecologically relevant hydrologic parameters. It can also be used to analyze how a flow regime has been impacted by an abrupt change. For this analysis, Version 7.1 of the IHA software was used.

3.3.1.1 IHA PARAMETERS

The IHA software uses daily hydrologic gage data to run the statistical analysis and compute a total of 33 IHA parameters. These can be organized into five groups based on hydrologic regime. These are presented in Table 17 and summarized below based on Richter et al. (1996):

1. **Magnitude of Monthly Water Conditions** – This group measures the monthly central tendency of daily water conditions. These parameters can provide a general measure of habitat availability and suitability.
2. **Magnitude and Duration of Annual Extreme Water Conditions** – This group measures the magnitude of extreme annual water conditions of various durations. These parameters can provide measures of environmental stress and disturbance.
3. **Timing of Annual Extreme Water Conditions** – This group determines the date of the minimum and maximum water conditions. Similar to Group 2, these can also measure the seasonal nature of environmental disturbance or stress.
4. **Frequency and Duration of High and Low Pulses** – This group measures the annual frequencies and durations of high and low pulses (i.e. when a water condition exceeds an upper threshold). These parameters can provide a measure of pulsing behavior in a year.
5. **Rate and Frequency of Water Condition Changes** – This group measures the rate changes in water conditions from day to day. These parameters can provide a measure of the rate and frequency of intra-annual environmental change.

The IHA parameters can be calculated using either a parametric or a non-parametric statistical method. The parametric method assumes a normal distribution of the information, while the non-parametric method assumes non-normal distribution. For this analysis, the non-parametric method was performed because of the skewed nature of hydrologic datasets. Non-parametric analyses present the results in medians because the results are presented in terms of percentiles. Table 17 summarizes the IHA parameters calculated and explains their ecosystem influences.

Table 17. IHA Hydrologic Parameters and their Ecosystem Influences (Source: IHA User's Manual, TNC, 2009, Table 1)

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influences
Magnitude of Monthly Water Conditions *(Group 1)*	Mean or median value for each calendar month *Subtotal: 12 Parameters*	• Habitat availability for aquatic organisms • Soil moisture availability for plants • Availability of water for terrestrial animals • Availability of food/cover for fur-bearing mammals • Reliability of water supplies for terrestrial animals • Access by predators to nesting sites • Influences water temperature, oxygen levels, photosynthesis in water column
Magnitude and Duration of Annual Extreme Water Conditions *(Group 2)*	Annual minima, 1-day mean Annual minima, 3-day means Annual minima, 7-day means Annual minima, 30-day means Annual minima, 90-day means Annual maxima, 1-day mean Annual maxima, 3-day means Annual maxima, 7-day means Annual maxima, 30-day means Annual maxima, 90-day means Number of zero-flow days Base flow index: 7-day minimum flow/mean flow for year *Subtotal: 12 Parameters*	• Balance of competitive, ruderal, and stress-tolerant organisms • Creation of sites for plant colonization • Structuring of aquatic ecosystems by abiotic vs. biotic factors • Structuring of river channel morphology and physical habitat conditions • Soil moisture stress in plants • Dehydration in animals • Anaerobic stress in plants • Volume of nutrient exchanges between rivers and floodplains • Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments • Distribution of plant communities in lakes, ponds, floodplains • Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
Timing of Annual Extreme Water Conditions *(Group 3)*	Julian date of each annual 1-day maximum Julian date of each annual 1-day minimum *Subtotal: 2 Parameters*	• Compatibility with life cycles of organisms • Predictability/avoidability of stress for organisms • Access to special habitats during reproduction or to avoid predation • Spawning cues for migratory fish • Evolution of life history strategies, behavioral mechanisms
Frequency and Duration of High and Low Pulses	Number of low pulses within each water year	• Frequency and magnitude of soil moisture stress for plants • Frequency and duration of anaerobic stress for plants

(Group 4)	Mean or median duration of low pulses (days) Number of high pulses (days) Mean or median duration of high pulses (days) *Subtotal: 4 Parameters*	• Availability of floodplain habitats for aquatic organisms • Nutrient and organic matter exchanges between river and floodplain • Soil mineral availability • Access for waterbirds to feeding, resting, reproduction sites • Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
Rate and Frequency of Water Condition Changes *(Group 5)*	Rise rates: Mean or median of all positive differences between consecutive daily values. Fall rates: Mean or median of all negative differences between consecutive daily values Number of hydrologic reversals *Subtotal: 3 Parameters*	• Drought stress on plants (falling levels) • Entrapment of organisms on islands, floodplains (rising levels) • Desiccation stress on low-mobility streamedge (varial zone) organisms

3.3.1.2 RANGE OF VARIABILITY APPROACH

In order to evaluate the impact of an abrupt change in a watershed (i.e. construction of a dam), the IHA software will develop IHA parameters based on "pre-impact" and "post-impact" periods. It then applies the RVA to analyze the hydrologic change between those time periods. The RVA uses the pre-impact natural variation of IHA parameter values as a reference for defining the extent to which natural flow regimes have been altered. The pre-impact variation can also be used as a basis for defining initial environmental flow goals.

The RVA method strives to maintain the natural flow regime by keeping post-impact annual parameters within a targeted range based on pre-impact natural variability. The target range is based on selected percentile levels (based on non-parametric analysis). ***For this analysis, the results from the middle category (range of the 34th percentile to the 67th percentile of pre-impact results) were used as the target range.***

In order to determine the degree of alteration of the IHA parameters, the RVA method will then calculate the Hydrologic Alteration (HA) based on the target range. The results from the HA analysis can be used to understand the deviance the post-impact parameters have from the target range (determined from the pre-impact parameters).

The RVA first calculates the expected frequency with which the post-impact IHA parameters fall. It then computes the frequency with which the post-impact parameters fall. The degree to which the RVA target range is not attained is measured by the HA, which is defined as:

$$\text{Hydrologic Alteration} = \frac{\text{Observed} - \text{Expected}}{\text{Expected}} * 100$$

"Observed" represents the count of the years that fell within the expected range, while "expected" represents the anticipated count of years that would fall within the expected range.

- When the resulting HA is equal to zero, the observed frequency of post-impact annual values falling within the RVA target range equals the expected frequency.
- **A positive deviation** means the annual parameter fell inside the RVA target window more often than expected
- **A negative deviation** means the annual parameter fell inside the RVA target window less often than expected.

In order to further interpret the HA analysis results, the HA results subdivided in terms of percentiles.

- **Low (L)**: HA of 0 to 33 percent; represents little or no alteration
- **Medium (M)**: HA of 34 to 67 percent ; represents moderate alteration
- **High (H)**: HA of 68 to 100; represents a high degree of alteration

It is recommended that a minimum of 20 years of data be used for both pre-impact analysis and post-impact analysis in order to adequately understand the impacts the dam had on the flow regime (TNC, 2009; Richter, et al., 1997). If there are gaps in the daily discharge data used for *the analysis, then the IHA software performs a linear interpolation over the gaps. Therefore, results produced from data with missing pieces should be interpreted with caution.*

3.3.2 Gage Data Used

The discharge data used for this non-parametric analysis was broken into 2 categories: pre-impact and post-impact. The year 1983 was used as the transition year. All discharge data gathered before or during 1983 is classified as pre-impact, while all data gathered from 1984 to present is classified as post-impact. There are four gages within the Watershed that meet the minimum of 20 years of pre-impact and 20 years of post-impact data required for the IHA analysis (see Section 3.3.1.2):

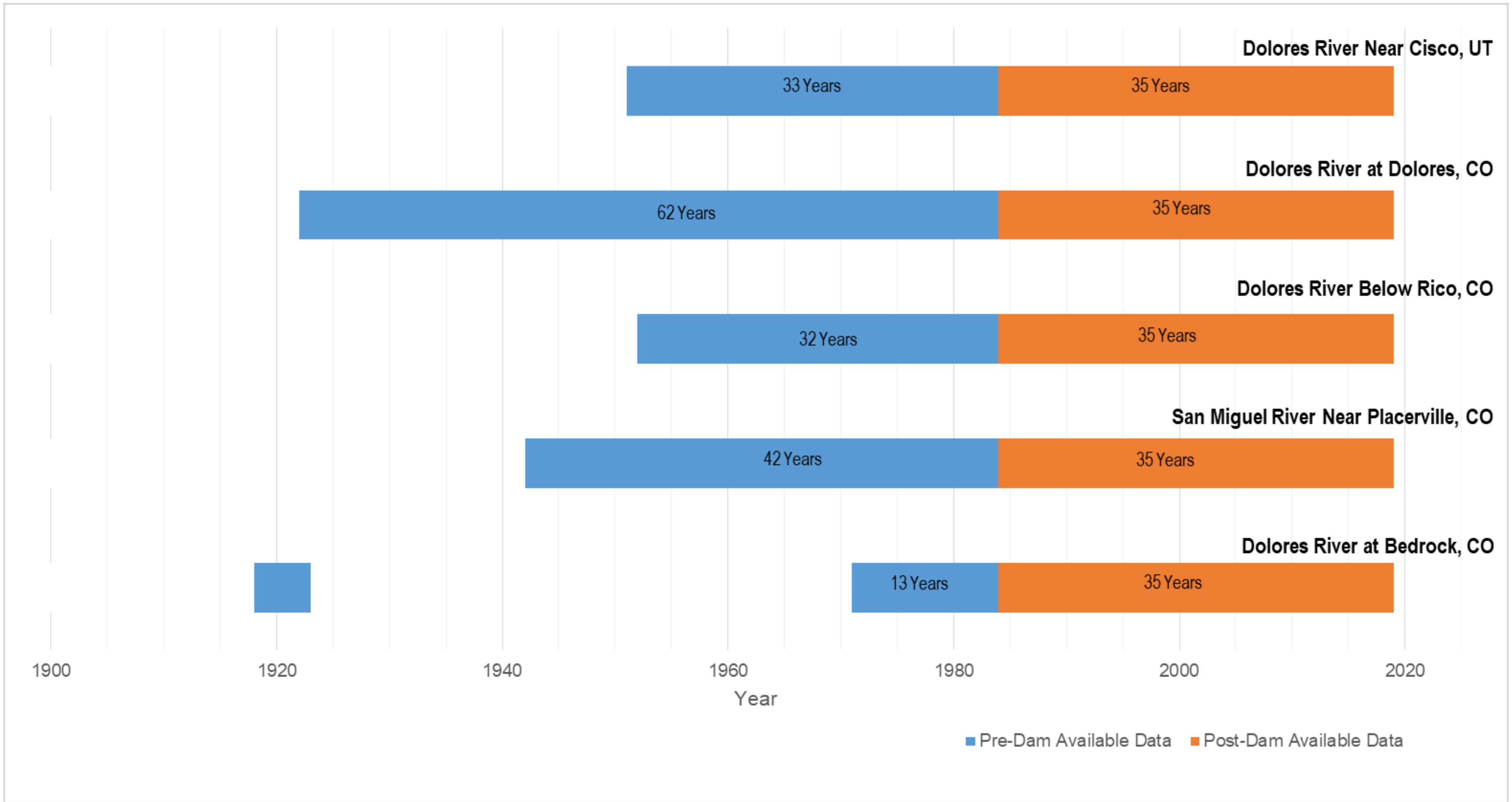
1. Dolores River Near Cisco, UT
2. Dolores River at Dolores, CO
3. Dolores River Below Rico, CO
4. San Miguel River Near Placerville, CO

A summary of the data available for all the gages is shown in Table 18 and Plot 1. As seen in Table 18, both the Dolores River at Dolores, CO and San Miguel River near Placerville, CO had large gaps of missing data. Most of these gaps were from short segments of data before the 1940's. *The IHA software automatically interpolates over gaps in data, and recommends that users should use caution with these results.* In order to avoid this caution and create a more continuous dataset, these short segments were removed to create a generally continuous dataset. The resulting period of record used in the analysis can be seen in Table 18.

The 2005 DRD Draft Hydrology Report also reviewed the Dolores River at Bedrock, CO gage. This gage did not meet the minimum of 20 years of pre-impact requirement and includes a large data gap (between 1922 and 1971). However, in order to be consistent with previous work completed and to gain a better understanding of the impacts the McPhee Reservoir had on the Dolores River, this gage was included in the analysis. *The results of this gage analysis are interpreted with the understanding that the data availability was insufficient.* Each of these five gages are presented in Figure 21.

Table 18. Modified Gage Data

Gage	Original Period of Record	Years of Missing Data	Period of Record Used in Analysis
Dolores River Near Cisco, UT	12/1/1950-8/19/2019	No Missing Data	12/1/1950-8/19/2019
Dolores River at Dolores, CO	10/1/1895-8/19/2019	1903-1910 and 1912-1921	10/1/1921-8/19/2019
Dolores River Below Rico, CO	10/1/1951-8/19/2019	No Missing Data	10/1/1951-8/19/2019
San Miguel River Near Placerville, CO	10/1/1910-8/19/2019	1912-1930 and 1934-1942	4/1/1942-8/19/2019
Dolores River at Bedrock, CO	10/1/1917-8/19/2019	1922-1971	10/1/1917-9/29/1922 and 8/1/1971-10/21/2019



Plot 1. Modified Gage Data

3.3.3 Results and Discussion

The purpose of this analysis is to assess the degree of alteration the Watershed has experienced due to the construction of McPhee Dam and Reservoir in 1984. The Watershed was broken into four stream segments based on stream gage locations for this assessment, as described in Table 19.

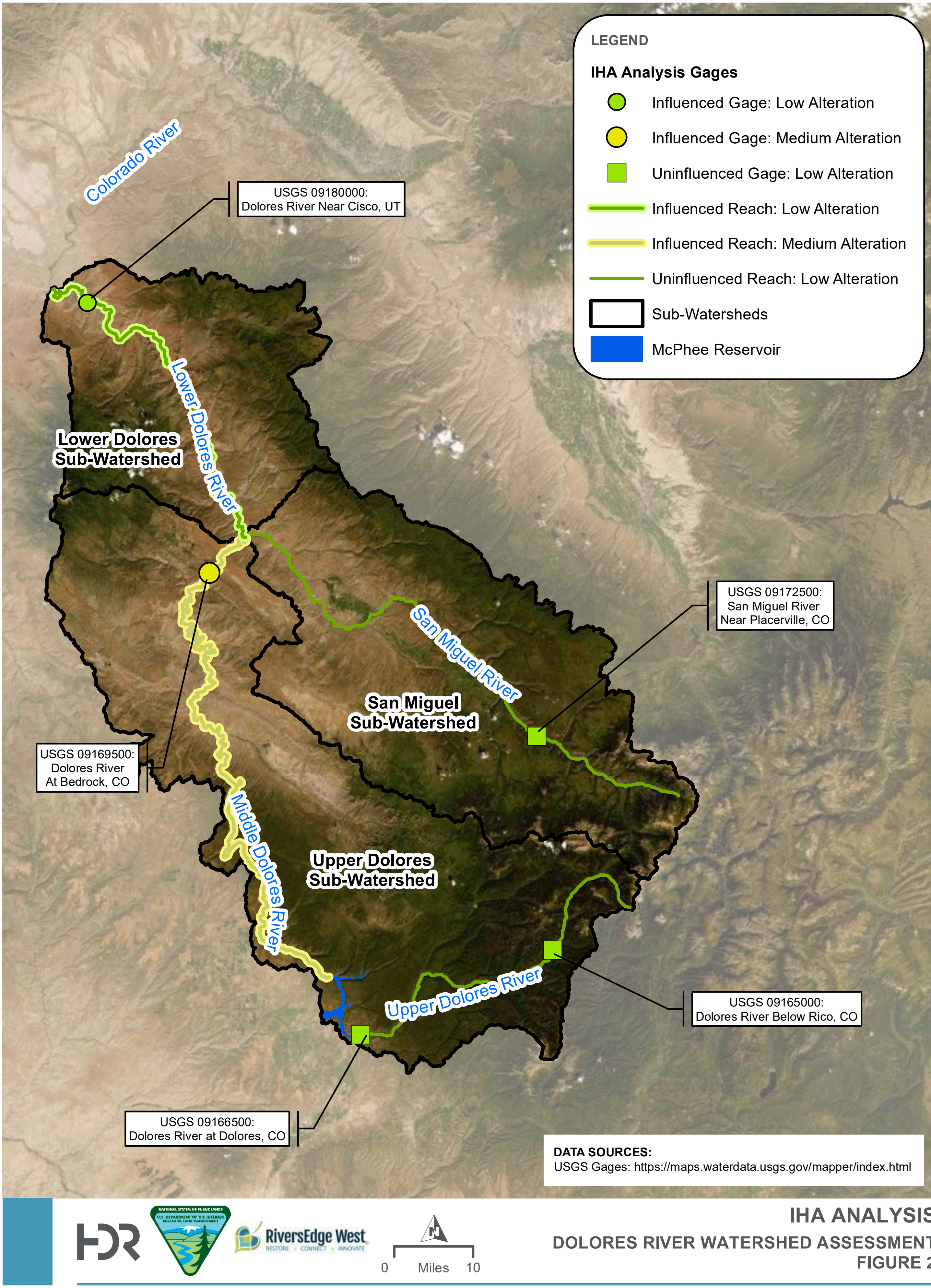
Table 19. Stream Segmentation for IHA Analysis

Stream Segment	Gage	Influenced by McPhee Reservoir?	Description
Upper Dolores River	Dolores River below Rico, CO; Dolores River at Dolores, CO	No	Dolores River upstream of McPhee Reservoir
Middle Dolores River	Dolores River at Bedrock, CO	Yes	Dolores River downstream of McPhee Reservoir and upstream of the confluence with the San Miguel River
Lower Dolores River	Dolores River at Cisco, UT	Yes	Dolores River downstream of the confluence with the San Miguel River
San Miguel River	San Miguel River near Placerville, CO	No	San Miguel River

Of the five gages used in the analysis, only two are influenced by McPhee Reservoir, as shown by circles on Figure 21. However, climatic differences between the pre- and post-impact time periods can affect the IHA analysis (Richter, et al., 1996). In order to assess whether the Watershed has experienced other influences, such as climatic changes, the other three gages (uninfluenced by the McPhee Reservoir) were also analyzed. These are shown by squares on Figure 21.

The IHA and RVA analyses results for each gage are presented in Appendix A. The following sections describe: the general watershed alterations, observations of uninfluenced stream segments, and observations of influenced stream segments.

As discussed in Section 1.4, the DRD 2005 Core Science Report conducted an IHA analysis and presented results as the percent difference between pre- and post-impact parameters. This approach was not used for this Report. Instead, the RVA method approach was used because it allows for a different perspective on the results.



IHA ANALYSIS
DOLORES RIVER WATERSHED ASSESSMENT
FIGURE 20

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\MAP_DOCS\IHA_GAGE_ANALYSIS.MXD - USER: KRANNEY - DATE: 11/15/2019

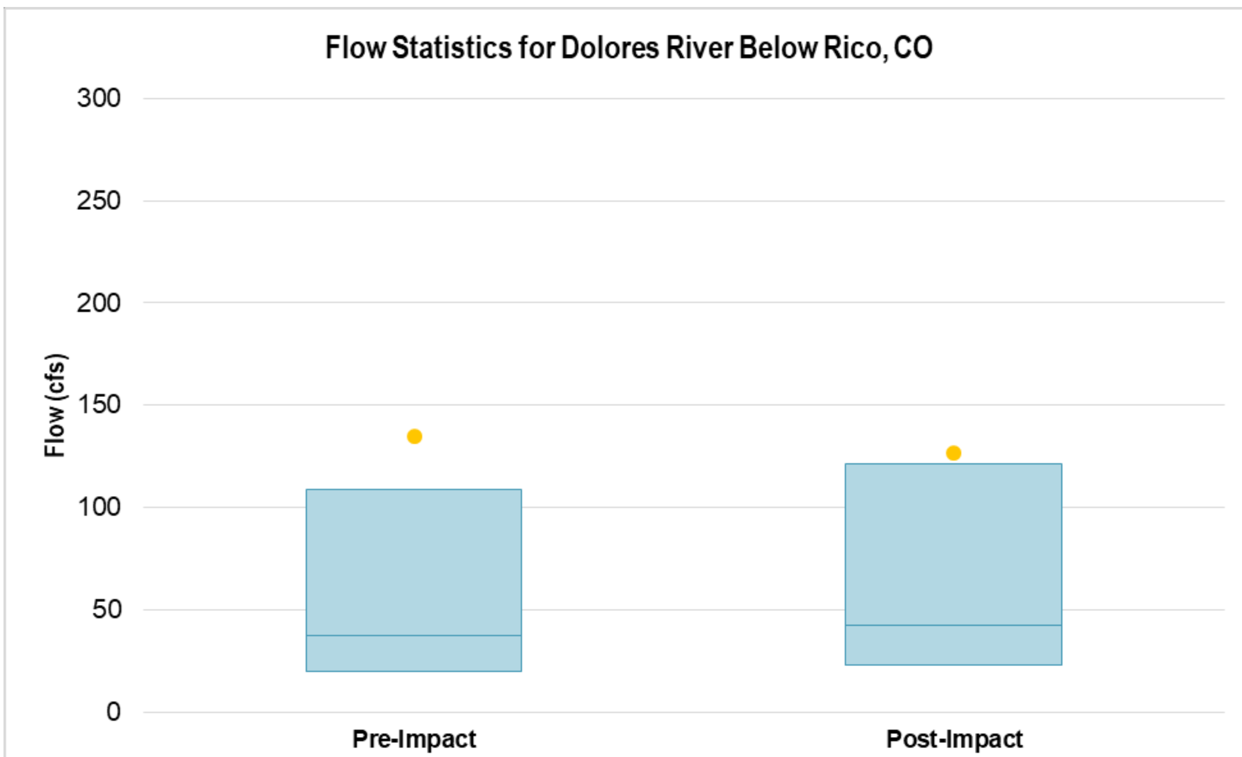
3.3.3.1 GENERAL WATERSHED ALTERATIONS

To gain a general understanding of overall changes in Watershed flows, flow statstics were compared for both the pre-impact and post-impact periods at each gage. These statistics include: average (represented in yellow dots in the following plots) and the first quartile, median, and third quartile (represented as blue boxes in the following plots). Daily average data for all gages can be found in Appendix A.

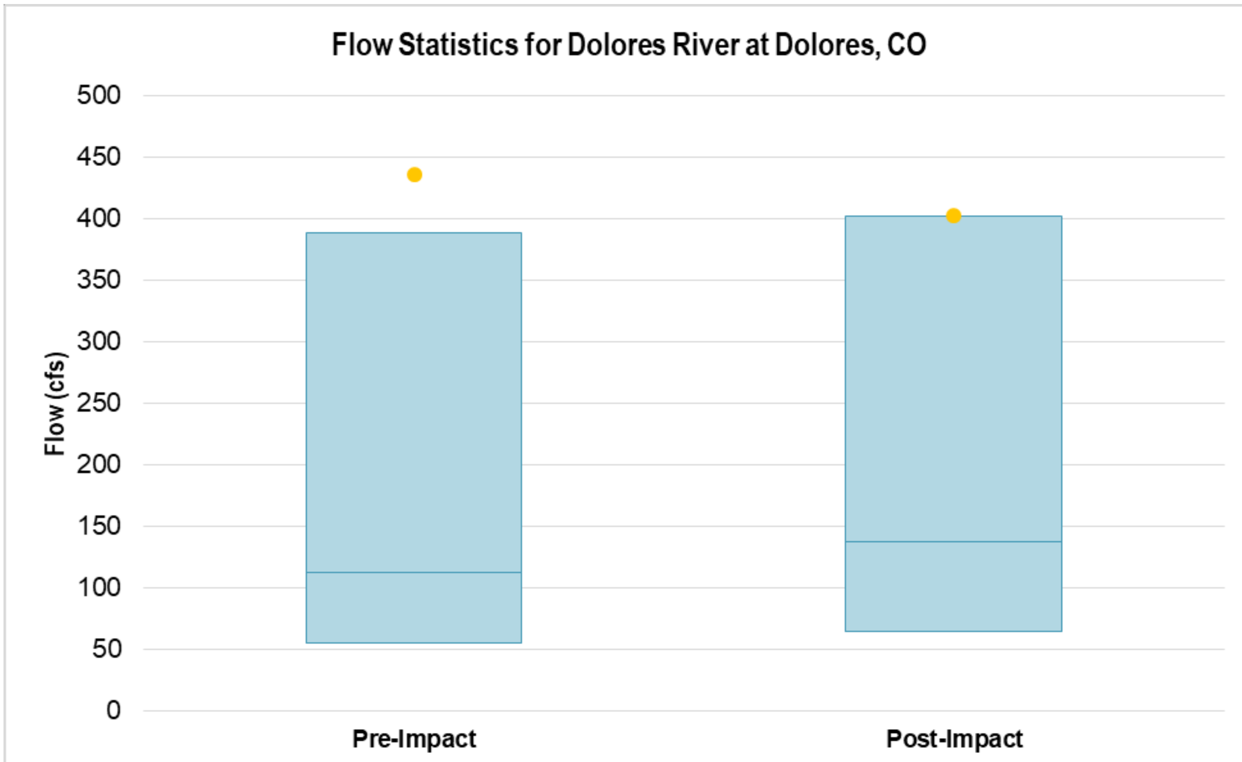
The uninfluenced Upper Dolores River gages are presented in Plot 2 and Plot 3. Both gages experienced an increase in median and interquartile flows despite a general decrease in average flows. However, the changes appear to be small, suggesting miminal general changes in flows.

The influenced gages on both the Middle and Lower Dolores River (Plot 4 and Plot 5) saw similar trends to those on the uninfluenced Upper Dolores River. However, the changes in flow are greater, suggesting these stream segments have experienced greater change.

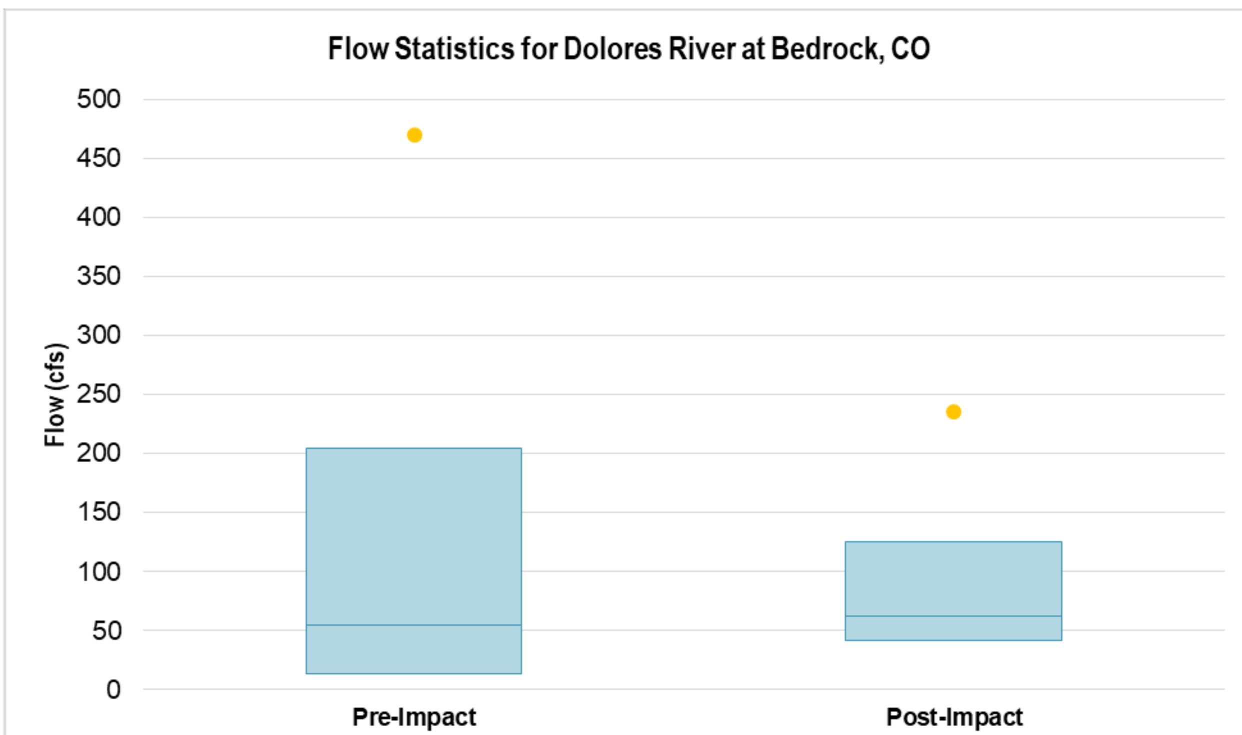
The uninfluenced San Miguel River (Plot 6) experiences a slight increase in both the average and interquartile range, however the increase appears to be minimal suggusting little to no change in general flow trends. This stream segment was the only case where the average flows for both periods were within the interquartile range. This suggests the presence of large outliers in the datasets of the other segments.



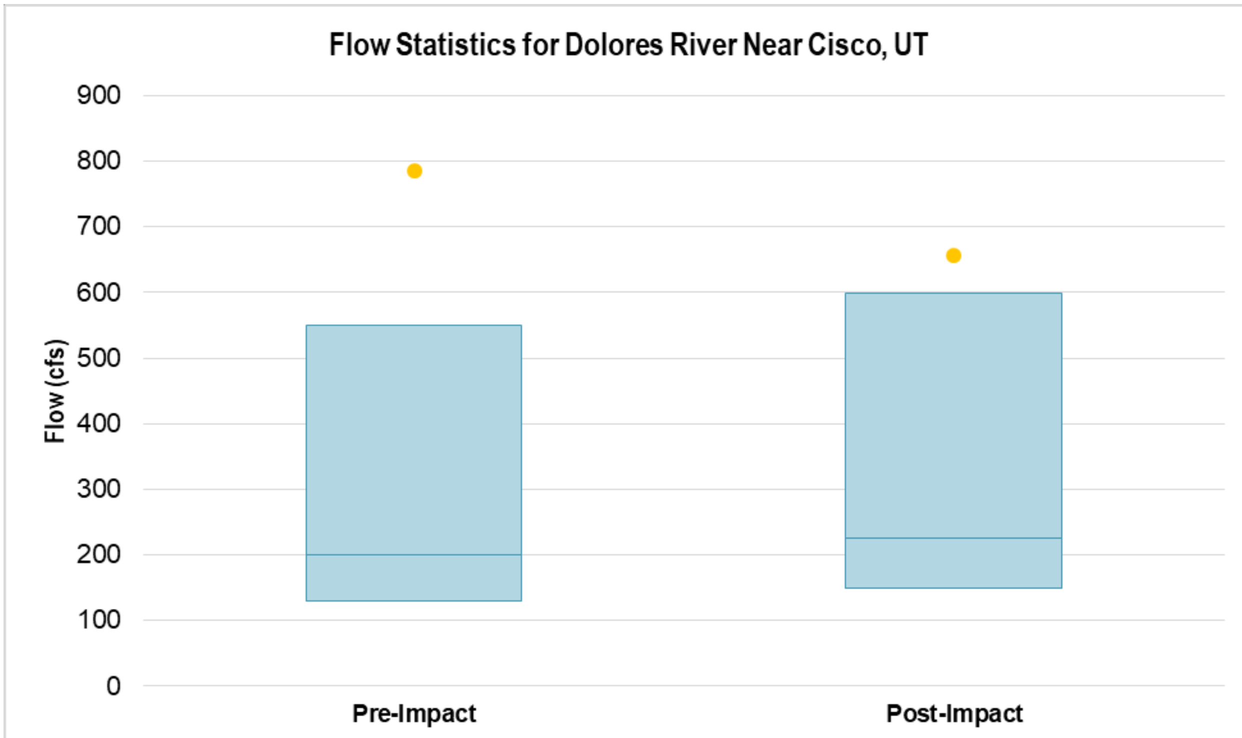
Plot 2. Flow Statistics for Dolores River Below Rico, CO.



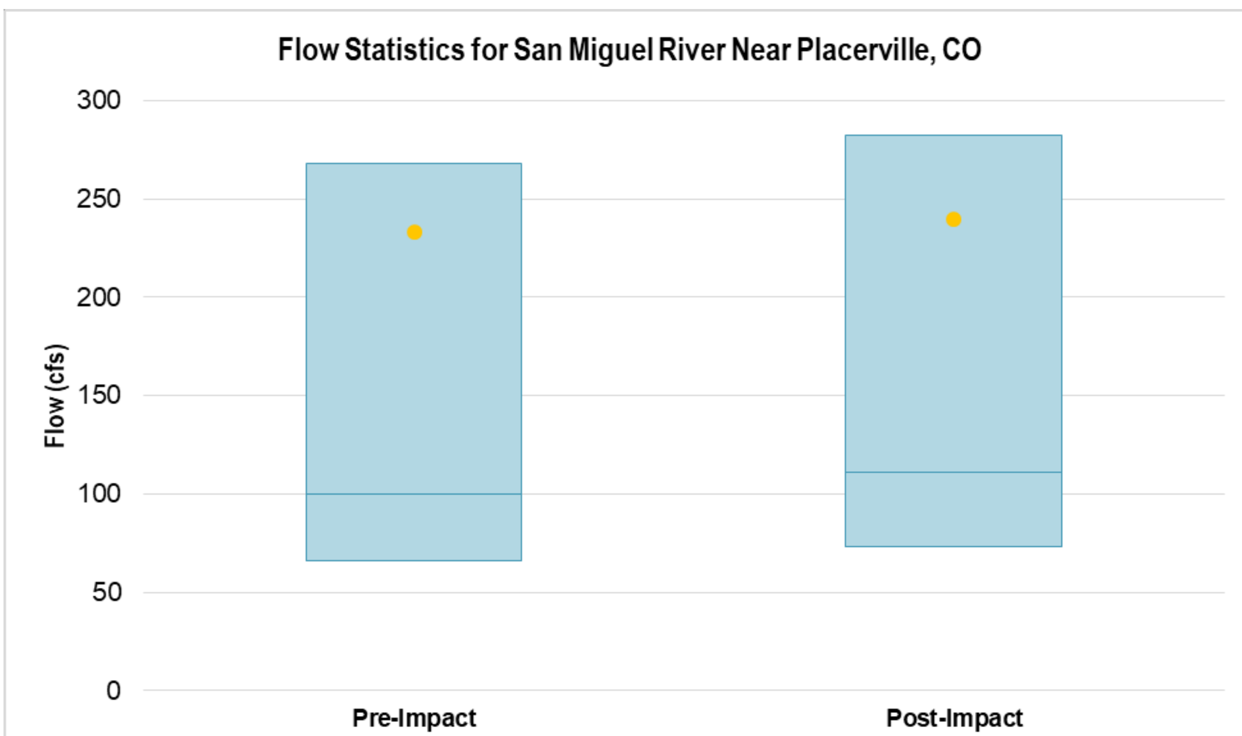
Plot 3. Flow Statistics for Dolores River at Dolores, CO.



Plot 4. Flow Statistics for Dolores River at Bedrock, CO.



Plot 5. Flow Statistics for Dolores River near Cisco, UT.



Plot 6. Flow Statistics for San Miguel River near Placerville, CO.

To further understand the Watershed-wide alterations, the middle category HA's were reviewed. First, the HA for each IHA parameter was classified as low (L), medium (M), or high (H) based on the following criteria (and as described in Section 3.3.1.2):

- **Low (L)**: HA of 0 to 33 percent; represents little or no alteration
- **Medium (M)**: HA of 34 to 67 percent ; represents moderate alteration
- **High (H)**: HA of 68 to 100; represents a high degree of alteration

This classification was completed for each of the 33 IHA parameters calculated. Then the total number of low, medium, and high parameters were determined, along with the percentage based on the total parameters. An example includes: the *San Miguel River near Placerville, CO* gage has 19 parameters that are classified as low alteration. When that value is divided by the total number of parameters (33), the resulting percentage is 57.6.

The results are presented in Table 20. The uninfluenced gages all have a majority of **low** HA's. The Lower Dolores River also has a majority of **low** HA's, and more **low** HA's than the San Miguel River. This again demonstrates the influence the San Miguel River has over the Dolores River. The Middle Dolores River majority is composed of both **medium** and **high** HA's, demonstrating the potential impact of McPhee Reservoir on this stream segment.

Additionally, the average absolute value of all HA's calculated for the 33 IHA parameters for each gage was determined. As expected based on percentages, the uninfluenced stream segments and the Lower Dolores River had **low** HA's, with the Lower Dolores River having the highest average of 0.3 in this grouping. The Middle Dolores River had an average HA of 0.49, which is classified as **medium**. This is expected based on the range of HA's that resulted at the *Dolores River at Bedrock, CO* gage.

Table 20. Summary of Low, Medium, and High HA Percentages and HA Average

Gage	Stream Segment	Percentage of Total HA's			Average HA[1]
		Low	*Medium*	*High*	
Dolores River Below Rico, CO	Uninfluenced Upper Dolores River	**72.7**	27.3	0.0	0.25
Dolores River at Dolores, CO	Uninfluenced Upper Dolores River	**69.7**	27.3	3.0	0.27
Dolores River at Bedrock, CO[2]	Influenced Middle Dolores River	48.5	**18.2**	**33.3**	0.49
Dolores River Near Cisco, UT	Influenced Lower Dolores River	**60.6**	27.3	12.1	0.30
San Miguel River Near Placerville, CO	Uninfluenced San Miguel River	**57.6**	39.4	3.0	0.29

[1] Average of the absolute value of HA
[2] The sum of the medium and high HA's is 51.5%

3.3.3.2 UNINFLUENCED GAGE SUMMARY

As seen in Table 20, the average HA of the uninfluenced gages is low (and therefore not within the target range). Because the HA's for these stream segments are not altered by significant storage and diversion projects, then other factors are responsible. Recent climate studies by the State of Colorado have shown projections for decreases in annual streamflow by 2050 for the San Juan and Rio Grande basins (CWCB, 2014), suggesting climate change could be playing a role in alterations to the Watershed. This is further suspected as all gages saw decreases of medium alterations in their minimum stream flows (1-day minimum stream flow, 30-day minimum streamflow, and 90-day minimum streamflow). Other Watershed impacts may include: changes in upper-Watershed water resources operations, fire suppression activities, forest fires, etc. These potential impacts have not been addressed in this assessment, but should be considered for future studies to better understand overall Watershed changes.

3.3.3.3 INFLUENCED GAGE SUMMARY

The HA was calculated for all 33 IHA parameters. The resulting HA values were ranked in descending order, with the highest degree of alteration being ranked first. The top ten ranked parameters based on the *Dolores River at Bedrock, CO* gage are presented in Table 21. The *Dolores River at Bedrock, CO* gage sees the highest alterations with decreases in minimum flow parameters, including the base flow index. The *Dolores River near Cisco, UT* gage sees this same trend. The *Dolores River at Bedrock, CO* gage also sees high alterations through decreases in low pulse count and duration, along with high alterations in some monthly flows (both increases and decreases). Plots of each of these parameters, including the pre-impact time series, post-impact time series, and RVA limits, are presented in Appendix C. A summary of alterations per parameter group is presented in Table 22.

Table 21. Top Ten Ranked Parameters based on *Dolores River at Bedrock, CO* Gage

IHA Parameter	Dolores River at Bedrock, CO	Dolores River Near Cisco, UT
December (cfs)	1.11 (H)	0.17 (L)[1]
July (cfs)	1.43 (H)	-0.25 (L)[1]
August (cfs)	-1.00 (H)	-0.33 (M)[1]
1-Day Min (cfs)	**-0.86 (H)**	**-0.92 (H)**
3-Day Min (cfs)	**-0.92 (H)**	**-0.92 (H)**
7-Day Min (cfs)	**-0.92 (H)**	**-0.83 (H)**
30-Day Min (cfs)	-0.84 (H)	-0.17 (L)[1]
Base Flow Index[2]	**-1.00 (H)**	**-0.67 (M)**
Low Pulse Count	-0.86 (H)	-0.08 (L)[1]
Low Pulse Duration (days)	-0.86 (H)	-0.28 (L)[1]

[1] Not top ten ranked for *Dolores River near Cisco, UT* gage
[2] Base flow index is the 7-day minimum divided by the annual mean flow
Note: Blue indicates an increase between pre-impact and post-impact. Red indicates a decrease between pre-impact and post-impact.

Table 22. Summary of Alternations by Parameter Group

IHA Parameter Group	Dolores River at Bedrock, CO	Dolores River Near Cisco, UT
Magnitude of Monthly Water Conditions *(Group 1)*	There is a mix of low to high alterations, with both increases and decreases from expected ranges. The following months have high alterations: July (+), August (-), September (-1), and December (+). With the exception of February having medium alternation (+), the remaining months have low alterations.	This parameter group primarily sees low alternations, with the exception of November and August. These lower alterations suggest the San Miguel River has an important influence over the Lower Dolores River.
Magnitude and Duration of Annual Extreme Water Conditions *(Group 2)*	There are high alterations in minimum daily flows, including the base flow index. All high alternations are decreases from the expected range (-). All other parameters have low alternations, and are primarily increases from the expected range (+).	Similar to the Bedrock gage, there are high alterations in minimum flow days, all resulting in decreases (-). All other parameters are primarily low alternation decreases (-).
Timing of Annual Extreme Water Conditions *(Group 3)*	Both gages show a decreased medium alteration.	
Frequency and Duration of High and Low Pulses *(Group 4)*	The low pulse count and duration have high alterations with decreases from expected ranges (-). The remaining parameters have medium alterations with decreases from expected ranges (-).	This parameter group has low and medium alterations with decreases from expected ranges (-).
Rate and Frequency of Water Condition Changes *(Group 5)*	This parameter group has low and medium alterations, with both increases (+) and decreases (-) from the expected range.	This parameter group has medium and high alternations, all being decreases from the expected range (-).

3.4 San Miguel River's Influence over Lower Dolores River

As discussed in Section 1.4, the following statement was made about the influence of the San Miguel River over the Lower Dolores River: "*average annual discharge of the Dolores River declined from 504 cfs (as measured at Bedrock, CO) to about 240 cfs after dam construction in 1984….**The lowermost reaches of the Dolores River receive considerable flow input…from the San Miguel River on a year-round basis…***" (BOR, 2018).

While this is a reasonable conclusion, it is limiting because it is based on the one metric of average annual discharge. In order to gain a greater understanding of how the San Miguel River influences the Lower Dolores River, the percent contribution of San Miguel River flows at the confluence of the San Miguel River and the Middle Dolores River ("Confluence") was evaluated.

3.4.1 Methodology

Three components were evaluated for this analysis:

1. The change in the percent contribution of San Miguel River flows at the Confluence pre-impact and post-impact.
2. The change in the percent contribution of San Miguel River flows at the Confluence pre-impact and post-impact relative to flows on the Middle Dolores River.
3. The change in the percent contribution of San Miguel River flows at the Confluence pre-impact and post-impact relative to flows on the San Miguel River.

Two gages were used in this evaluation to represent different stream segments in the Watershed, as presented in Table 23 and Figure 22. Both gages had average daily discharge data from October 1, 1973 to present. The percent contribution of the San Miguel River at the Confluence was calculated based on a daily time step, as follows:

$$\text{Confluence} = \text{San Miguel River Flows} + \text{Middle Dolores River Flows}$$

$$\text{Percentage of San Miguel River Flows} = \frac{\text{San Miguel River Flows}}{\text{Confluence}} \times 100$$

Table 23. Gages used for Evaluation of the San Miguel River's Influence over Lower Dolores River

Gage	Stream Segment
Dolores River at Bedrock, CO[1]	Influenced Middle Dolores River
San Miguel River at Uravan, CO[1]	Uninfluenced San Miguel River
[1]Did not meet the minimum of 20 years of pre-impact data requirement	

The first component reviewed was a comparison of the percent contribution of San Miguel River flows at the Confluence. This was completed for both time periods as follows:

1. The percent contribution of the San Miguel River at the Confluence was ranked from smallest to lowest.
2. The minimum, 25th percentile, 50th percentile, 75th percentile, and maximum percentages were found and plotted as a box-and-whisker.

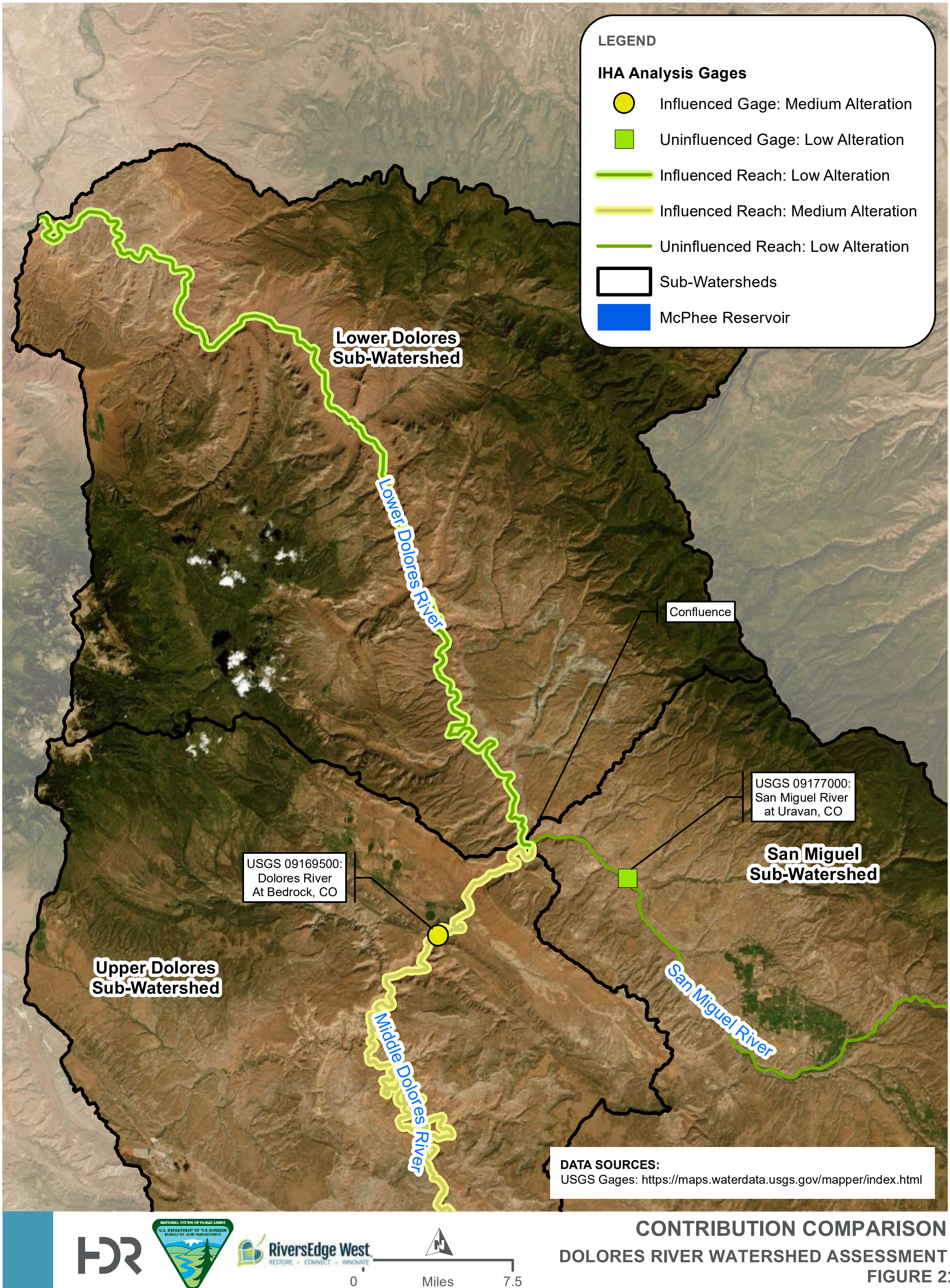
The second component reviewed was a comparison of the percent contribution of San Miguel River flows at the Confluence relative to flows at the Dolores River at Bedrock gage. This was completed for both time periods as follows:

1. The time series of flow at the Dolores River at Bedrock gage was sorted from highest to lowest and given an associated ranked position number.
2. The exceedance probability for each Dolores River at Bedrock gage event was determined using the following equation:

$$\text{Exceedance Probability} = \frac{\text{Ranked Position}}{\text{Total Number of Events in Period of Record} + 1} \times 100$$

3. The Dolores River at Bedrock gage times series was then divided into three categories based on the exceedance probabilities calculated in Step 2:
    a. Top 25 percent (representative of high flows)
    b. Middle 50 percent (representative of medium flows)
    c. Bottom 25 percent (representative of low flows)
4. For each of the categories in Step 3, the percent contribution of San Miguel River flows at the Confluence was determined. The associated minimum, 25^{th} percentile, 50^{th} percentile, 75^{th} percentile, and maximum percentages were then determined and plotted utilizing a box-and-whisker plot.

The third component reviewed was a comparison of the percent contribution of San Miguel River flows at the Confluence as they relate to flows at the San Miguel River at Uravan gage. The process was the same as the second component, with the exception that the times series of flow for the San Miguel River at Uravan gage was sorted from highest to lowest (Step 1).



CONTRIBUTION COMPARISON

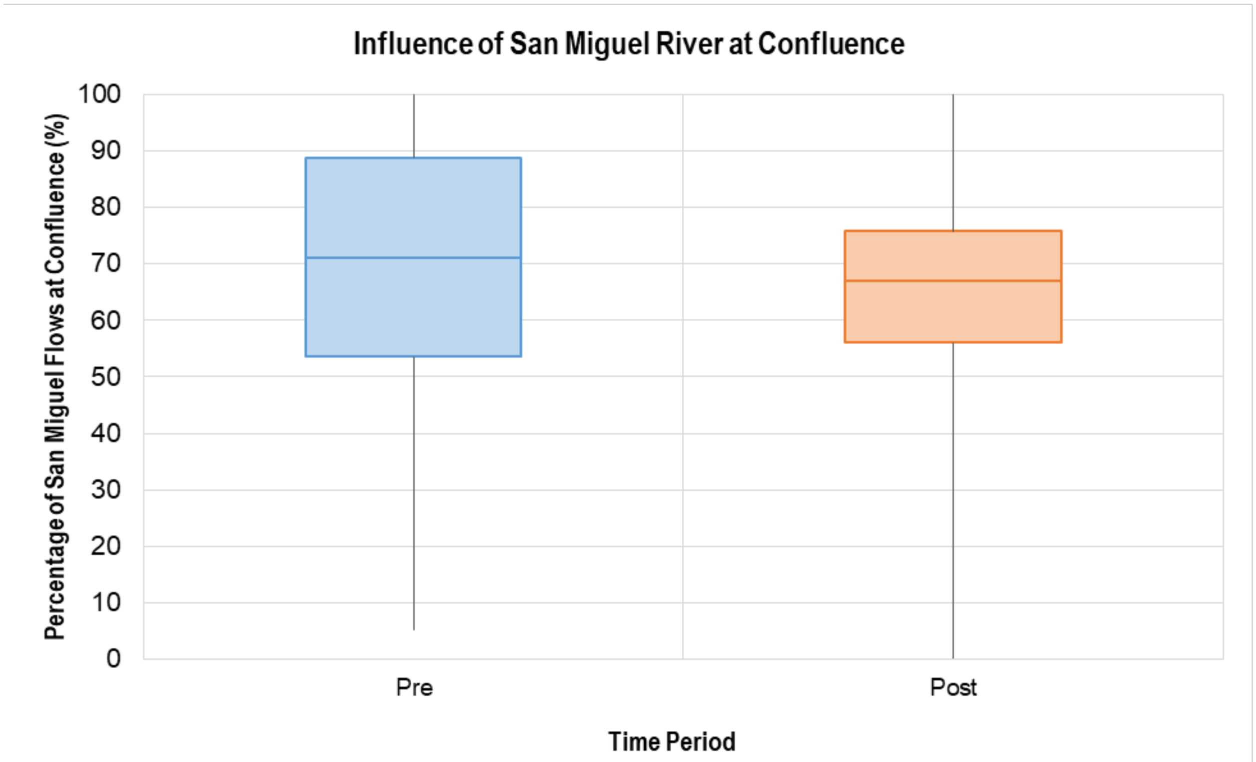
DOLORES RIVER WATERSHED ASSESSMENT

FIGURE 21

PATH: \\DEN-GISSRV1\GISDATA\PROJECTS\10180605_RIVERSEDGE_DOLORESRIVER\MAP_DOCS\SANMIGUEL_DOLORES_COMPARISON.MXD - USER: KRANNEY - DATE: 12/12/2019

3.4.2 Results and Discussion

The results of the first component are presented in Plot 7. It can be seen that the interquartile range (difference between the third and first quartile) for pre-impact is 54 to 89 percent (a range of 35 percent), while the post-impact is 56 to 75 percent (a range of 20 percent). The median for pre-impact (71 percent) is greater than the median for post-impact (67 percent). These results suggest that influence of the San Miguel River at the confluence has generally **decreased** since the construction of McPhee Dam. This is somewhat counterintuitive to what was expected, when compared to the time series averages at the Dolores River at Bedrock gage: 470 cfs pre-impact vs 235.9 cfs post-impact, a 50 percent decrease[1]. Therefore, the influence of the San Miguel River during different flow conditions was also evaluated.



Plot 7. Influence of the San Miguel River at the Confluence, Pre-Impact vs Post-Impact

The results of the second component are presented in Plot 8. The following trends are observed:

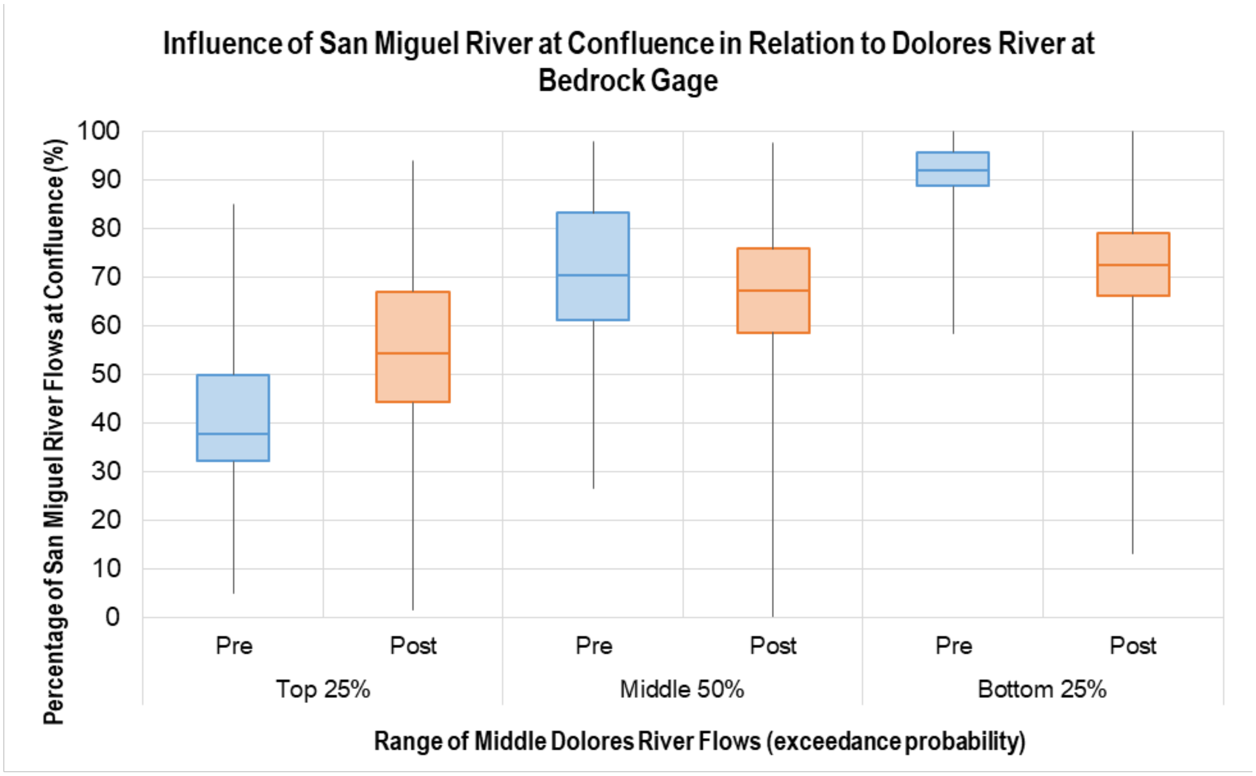
1. During Middle Dolores River high flows, the San Miguel River has a greater influence during the post-impact time period.
2. During Middle Dolores River medium flows, the influence of the San Miguel River is similar between both time periods. However, the pre-impact period has a slightly greater influence than post-impact.

[1] The time series average values are different than those reported by BOR (2018).

3. During Middle Dolores River low flows, the San Miguel River has a greater influence during the pre-impact time period.

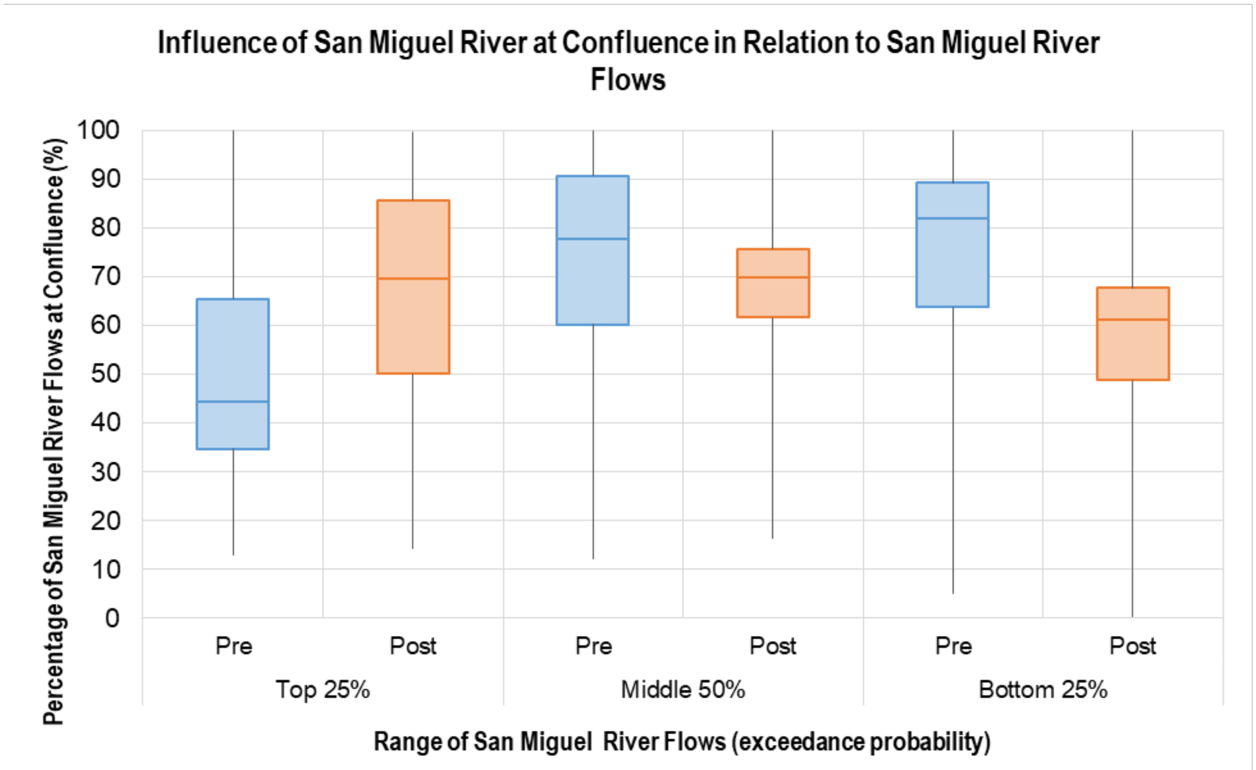
Observation 1 may suggest that McPhee Dam is controlling the release of higher flow events on the Middle Dolores River.

Observations 2 and 3 may suggest that the Middle Dolores River is being controlled by releases from McPhee Dam, whereas flows may have been lower or zero during similar conditions pre-impact.



Plot 8. Influence of the San Miguel River at the Confluence in relation to the Dolores River at Bedrock gage, Pre-Impact vs Post-Impact

The results of the third component are presented in Plot 9, and have similar observations to those in the second component. Overall, it appears McPhee Reservoir is potentially (1) controlling the release of historically large flow events, and (2) providing a more constant and higher release of lower flows than historically experienced. This is consistent with the conclusion of the 2005 DRD report which states: "*…McPhee Dam increased the depletion of the annual flows from 30% to 69% of natural flow…Construction of the McPhee Dam in 1984 affected the flow regime of the Dolores River by altering the spring peak flows and the magnitude and variability of the base flow. Between 1986 and 2004, the spring peak was essentially eliminated downstream from the dam for six of the 19 years of record.* ***In an average runoff year, both the magnitude and duration of the spring peak flows are decreased. Correlation of the peak flows above and below the dam show a distinct decrease in the peak flows below the dam****.*"



Plot 9. Influence of the San Miguel River at the Confluence in relation to the San Miguel River at Uravan gage, Pre-Impact vs Post-Impact

3.5 Dolores River Form and Function

3.5.1 Channel Forming Discharge

The channel forming discharge for the Lower and Middle Dolores River segments for the pre- and post-impact time periods was evaluated by comparing annual exceedance probabilities (AEP) developed using USACE Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) Version 2.1. The Expected Moments Algorithm (EMA) (Bulletin 17c) method was applied using a station skew. The channel forming discharge is assumed to be a two-year (50 percent AEP) for this level of analysis.

The channel forming discharge at both gages decreased from the pre-impact period to the post-impact period. Results show the Middle Dolores River (49 percent decrease) having a greater decrease than the Lower Dolores River (28 percent decrease). This is again likely attributed to the impact of the San Miguel River on the Lower Dolores River flow regime. A summary of the data used and results for this analysis is presented in Table 24, and the full results are available in Appendix D.

Table 24. Data and Results for Channeling Forming Discharge Comparison

Gage	Stream Segment	Pre-Impact Data	Post-Impact Data	Pre-Impact 2-Year Flow (cfs)	Post-Impact 2-Year Flow (cfs)	Percent Difference[2]
Dolores River at Bedrock, CO	Influenced Middle Dolores River	1918-1921[1] 1971-1983	1984-2018	4387 *(3262, 5822)*	2249 *(1822, 2771)*	49% (decrease)
Dolores River Near Cisco, UT	Influenced Lower Dolores River	1951-1983	1984-2018	5530 *(4511, 6793)*	1000 *(3241, 4933)*	28% (decrease)
[1] The 1918-1921 data was input into HEC-SSP as 1967-1970 to allow for a continuous dataset [2] [Post – Pre] / [Pre] x 100						

3.5.2 Baseflow Probabilities

Speas (2018) recommended the optimum annual baseflow for fisheries improvements was 150 to 300 cfs. However, it was recognized that these flows were not likely achievable, and Speas (2018) recommended the following seasonal ranges:

- Spring: 50 cfs
- Summer: 60 to 120 cfs
- Fall: 40 to 60 cfs
- Winter: 25 to 35 cfs

The IHA software provides flow duration curves (see Appendix E) both on an annual and monthly basis. Exceedance probabilities associated with both the annual and monthly flow duration curves for the *Dolores River at Bedrock, CO* and *Dolores River Near Cisco, UT* gages were found and are presented in Table 25 and Table 26, respectively.

Overall, the baseflow recommendations for the Lower Dolores River will likely be easier to obtain than the Middle Dolores River due the exceedance probabilities being higher for the same flows.

Table 25. Recommended Baseflows (Speas, 2018) and Associated Post-Impact Exceedance Probabilities based on Annual Flow Duration Curve for *Dolores River at Bedrock, CO* Gage

Season *(Months)*	Recommended Baseflow (cfs)	Exceedance Probability (%) based on Annual Flow Duration Curve	Exceedance Probability (%) based on Monthly Flow Duration Curves
Spring ***(March, April, and May)***	50	64	77-85
Summer ***(June, July, August)***	60-120	24-50	20-68
Fall ***(September, October, November)***	40-60	50-77	25-74
Winter ***(December, January, February)***	25-35	85-94	72-98
Optimal	150-300	14-20	N/A

Table 26. Recommended Baseflows (Speas, 2018) and Associated Post-Impact Exceedance Probabilities based on Annual Flow Duration Curve for *Dolores River Near Cisco, UT* Gage

Season *(Months)*	Recommended Baseflow (cfs)	Exceedance Probability (%) based on Annual Flow Duration Curve	Exceedance Probability (%) based on Monthly Flow Duration Curves
Spring ***(March, April, and May)***	50	98	Does not extend full range of data
Summer ***(June, July, August)***	60-120	86-98	77-98
Fall ***(September, October, November)***	40-60	98-99	96-100
Winter ***(December, January, February)***	25-35	99	Does not extend full range of data
Optimal	150-300	39-75	N/A

3.5.3 Pre-Impact Hydrologic Parameter Goals

As discussed in previous sections, the RVA uses the pre-impact natural variation of IHA parameter values as a reference for defining the extent to which natural flow regimes have been altered. The pre-impact variation can also be used by ecosystem managers as a basis for defining initial environmental flow goals. The pre-impact RVA variations are presented in Table 27.

Table 27. Pre-Impact RVA Variations

Parameter	Dolores River at Bedrock, CO		Dolores River Near Cisco, UT	
	Low	*High*	*Low*	*High*
Magnitude of Monthly Water Conditions *(Group 1)*				
October	8.3	38.0	102.0	173.6
November	10.9	38.4	118.9	156.1
December	26.9	57.3	112.2	159.3
January	37.1	70.0	126.9	174.7
February	41.1	81.0	162.6	192.9
March	62.0	158.8	180.0	270.6
April	268.4	1,169.0	680.8	1,460.0
May	973.1	3,140.0	1,558.0	3,534.0
June	444.5	2,321.0	926.0	2,159.0
July	19.1	167.2	199.5	486.2
August	8.9	23.7	111.2	228.1
September	7.3	21.5	64.3	142.0
Magnitude and Duration of Annual Extreme Water Conditions *(Group 2)*				
1-day minimum	0.5	5.6	30.2	44.6
3-day minimum	0.9	5.6	31.6	48.3
7-day minimum	1.4	5.7	33.8	52.9

Parameter	Dolores River at Bedrock, CO		Dolores River Near Cisco, UT	
	Low	*High*	*Low*	*High*
30-day minimum	4.6	17.6	62.7	93.5
90-day minimum	15.3	42.3	107.8	133.1
1-day maximum	1,571.0	5,026.0	2,863.0	5,980.0
3-day maximum	1,556.0	4,741.0	2,777.0	5,861.0
7-day maximum	1,416.0	3,993.0	2,484.0	5,273.0
30-day maximum	1,100.0	3,338.0	1,922.0	4,015.0
90-day maximum	745.6	2,343.0	1,227.0	2,654.0
Number of zero days	-	-	-	-
Base flow index	0.0	0.0	0.1	0.1
Timing of Annual Extreme Water Conditions *(Group 3)*				
Date of minimum	226.5	271.0	248.7	275.0
Date of maximum	118.1	137.4	118.0	139.8
Frequency and Duration of High and Low Pulses *(Group 4)*				
Low pulse count	2.3	5.0	4.0	8.8
Low pulse duration	4.9	10.2	4.0	10.1
High pulse count	3.3	5.0	3.0	4.0
High pulse duration	2.6	5.7	4.2	11.0
Rate and Frequency of Water Condition Changes *(Group 5)*				
Rise rate	9.6	27.4	20.2	32.5
Fall rate	-24.4	-6.0	-24.5	-16.6
Number of reversals	74.0	111.8	93.0	104.8

4 River Geomorphic Assessment *– later phase*

5 Ecologic Analysis *– later phase*

6 Next Steps

7 References

2014, Lower Dolores River Implementation, Monitoring and Evaluation Plan for Native Fish.

Ake, Jon; Mahrer, Kenneth; O'Connell, Daniel; Block, Lisa, 2010, "What's Shaking in Bedrock? The Paradox Valley Deep-Well Injection Program" Rocky Mountain Association of Geologists.

Bestgen, K.R., Miller, W.J., and P. Budy, 2011, Status and Trends of Flannelmouth Sucker Catostomus latipinnis, Bluehead Sucker Catostomus discobolus, and Roundtail Chub Gila robusta, in the Dolores River, Colroado, and Opportunities for Population Improvement: Phase II Report.

Bureau of Land Management, Dolores River, Colorado: The River of Sorrows, Recommendation for Inclusion Under Section 5(d) of the Wild and Scenic Rivers Act.

Bureau of Reclamation, Department of the Interior, 1977, Dolores Project Colorado: Final Environmental Statement.

Coble, A.P. and Kolb, T.E., 2013, Native Riparian Tree Establishment Along the Regulated Dolores River, Colorado: Western North American Naturalist, 73, pp. 41-53.

Coble, A.P., Kolb, T.E., 2012, Riparian Tree Growth Response to Drought and Altered Streamflow along the Dolores River, Colorado: The Society of American Foresters, pp. 205-211.

Colorado Department of Natural Resources, 1976, Dolores River Wild and Scenic Study Repott

Colorado Parks and Wildlife, The Nature Conservancy, and Colorado Mesa Univeristy, 2018, Lower Dolores River 2017 McPhee Reservoir Manages Release Ecological Monitoring and Evaluation, Volumes 1 and 2.

Colorado Water Conservation Board, 2014, Climate Change in Colorado: A Synthesis to Support Water Resouces Management and Adapation. <https://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf>.

Department of the Interior: Fish and Wildlife Service, 1980, Memorandum: Biological Opinion for Dolores Project, Colorado.

Dolores Watershed Plan Appendix 2: History of Dolores River Water Use, the Dolores Project, the Rise of Environmental Consciousness Nationally and Locally, and Stakeholder Collaboration to Promote Conservation of Lower Dolores River Natural Resources.

Dott, C.E., Gianniny, G.L., Clutter, M.J., and Aanes C., 2016, Temporal and Spatial Variation in Riparian Vegetation and Floodplain Aquifers on the Regulated Dolores River, Southwest Colorado, USA: River Research and Applications, 32, p. 2056-2070.

Dolores River Dialogue, 2005, Hydrology Report.

Dolores River Dialogue, 2006, DRAFT Correlation Report: Summary of Hydrologic and Scientific Findings And Resulting Matrix Templates.

Dolores River Dialogue, Core Science Report, 2005.

Dunmire, C., Oliver, A., Wanner, C., Preston, M., Siscoe, J., Graf, D., Anderson, C., Carver, R., and Porter-Norton, M., 2010, The Dolores River Dialogue as an Example of Long-term Collaborative Decision-making.

Fey, N., Stafford, E., and Wynne, K., 2014, Defining Recreational Streamflow Needs in the Lower Dolores River: Integrating Specific and Overall Evaluations of Flow and Recreation Quality, American Whitewater.

Kendrick, D.G., Smith, A.D., Dishman, L., and Gerhold, M., 1981, River of Sorrows: The History of the Lower Dolores River Valley.

National Park Service, 2018, Defining the Southwest: The Colorado Plateau. <https://www.nps.gov/articles/the-colorado-plateau.htm>.

Porter, J., 2001, Transbasin Water Transfer Dolores River Southwestern Colorado.

Richter, B.D., Baumgartner, J.V., Braun, D.P., and Powell, J., 1998, A Spatial Assessment of Hydrologic Alteration within a River Network

Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.P., 1996, A Method for Assessing Hydrologic Alteration within Ecosystems

Richter, B.D., Baumgartner, J.V., Wigington, R., and Braun, D.P., 1997, How much water does a river need?

Rig to Flip, 2015, The River of Sorrow (film).

Shope, C.L., and Gerner, S.J., 2014, Assessment of dissolved-solids loading to the Colorado River in the Paradox Basin between the Dolores River and Gypsum Canyon, Utah: U.S. Geological Survey Scientific Investigations Report 2014-5031.

Speas, D., 2018, Flow Management and Endangered Fish in the Dolores River during 2012-2017: U.S. Bureau of Reclamation.

The Nature Conservancy, 2009, Indicators of Hydrologic Alteration, Version 7.1, User's Manual.

<https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Documents/IHAV7.pdf>.

Trout Unlimited and Mountain Studies Institute, 2017, Climate Change and the Upper Dolores Watershed: A Coldwater-fisheries Adaptive Management Framework.

United States Bureau of Reclamation, 2000, Operating Agreement, McPhee Dam and Resevoir

United States Department of Agriculture, Natural Resource Conservation Service, 2007, Part 630 Hydrology National Engineering Handbook: Chapter 7 Hydrologic Soil Groups.

United States Geological Survey, 2011, Dolores River. Geographic Names Information System.

Vandas, S., 1990, Dolore River Instream Flow Assessment, Project Report.

Voggesser, G., 2001, The Dolores Project.

White, M.S., Tavernia, B.G., Shafroth, P.B., Chapman, T.B., and Sanderson, J.S., 2018, Vegetative and geomorphic complexity at tributary junctions on the Colorado and Dolores Rivers: a blueprint for riparian restoration: Landscape Ecol.

Appendix A

IHA and RVA Results

Non-Parametric IHA Scorecard

DoloresRiverAtBedrock_GapsMaintained

	Pre-impact period: 1918-1983 (18 years)	Post-impact period: 1984-2020 (37 years)
NormalizationFactor	1	1
Mean annual flow	470	235.9
Non-Normalized Mean Flow	470	235.9
Annual C. V.	2.21	2.27
Flow predictability	0.4	0.43
Constancy/predictability	0.38	0.69
% of floods in 60d period	0.39	0.39
Flood-free season	62	22

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	11.5	48.1	6.626	0.6081	3.183	0.9082	0.00	0.05305
November	21.5	42.3	3.315	0.484	0.9674	0.854	0.00	0.09009
December	40	41	1.088	0.4732	0.025	0.5649	0.7247	0.1702
January	51.5	43.5	0.7039	0.6713	0.1553	0.04634	0.4444	0.8689
February	63	48.65	0.8552	0.6418	0.2278	0.2495	0.1872	0.5626
March	100	70	1.388	1.629	0.3	0.1743	0.5786	0.6667
April	925.8	181	1.128	5.398	0.8045	3.786	0.3644	0.03203
May	2050	307	1.322	3.895	0.8502	1.947	0.1932	0.07107
June	1478	133	1.662	5.525	0.91	2.324	0.2322	0.05706
July	87.5	63	3.486	0.904	0.28	0.7407	0.3353	0.1051
August	13.5	67.2	2.38	0.4702	3.978	0.8024	0.00	0.05906
September	10.1	53.9	1.677	0.5227	4.337	0.6883	0.00	0.08509
Parameter Group #2								
1-day minimum	3.9	25	1.554	0.564	5.41	0.637	0.00	0.1411
3-day minimum	4	26.67	1.513	0.49	5.667	0.6762	0.00	0.1231
7-day minimum	4.35	28.49	1.788	0.51	5.548	0.7147	0.00	0.08609
30-day minimum	6.687	35.09	2.944	0.4621	4.247	0.843	0.00	0.0991
90-day minimum	21.78	41.38	2.639	0.412	0.8994	0.8438	0.00	0.06106
1-day maximum	3420	1380	1.452	1.839	0.5965	0.2664	0.1532	0.5415
3-day maximum	3337	1250	1.329	2.162	0.6254	0.6274	0.1401	0.2052
7-day maximum	2986	1131	1.434	2.225	0.6211	0.5518	0.1622	0.3063
30-day maximum	2201	795	1.572	2.307	0.6388	0.4674	0.1351	0.3393
90-day maximum	1766	401.8	1.326	2.876	0.7725	1.168	0.2212	0.1542
Number of zero days	0	0	0	0				
Base flow index	0.01039	0.1733	1.321	1.181	15.69	0.1064	0.00	0.8008
Parameter Group #3								
Date of minimum	246	269	0.1462	0.3593	0.1257	1.458	0.08609	0.06807
Date of maximum	125	147	0.06421	0.2773	0.1202	3.319	0.008008	0.03604
Parameter Group #4								
Low pulse count	4	0	1.125	0	1	1	0.00	0.00
Low pulse duration	7	6	1.464	1.333	0.1429	0.08943	0.8669	0.8959
High pulse count	4	4	0.625	1	0	0.6	0.3113	0.0951
High pulse duration	4	2	1.156	4.75	0.5	3.108	0.07608	0.01101
Low Pulse Threshold	14							
High Pulse Threshold	245.5							
Parameter Group #5								
Rise rate	16.25	3.85	2.106	2.078	0.7631	0.0134	0.09009	0.971
Fall rate	-11.75	-4.05	-2.191	-1.407	0.6553	0.3578	0.01301	0.4254
Number of reversals	103	110	0.4515	0.2045	0.06796	0.5469	0.2863	0.2052
EFC Low flows								
October Low Flow	12	47.95	6.463	0.61	2.996	0.9056	0.00	0.05205
November Low Flow	22.5	42.3	3.184	0.484	0.88	0.848	0.00	0.09109
December Low Flow	42	41	1.048	0.4732	0.02381	0.5483	0.7638	0.1682
January Low Flow	55	43.5	0.6636	0.6713	0.2091	0.01149	0.1982	0.974
February Low Flow	65	48.65	0.8423	0.6418	0.2515	0.238	0.1441	0.6196
March Low Flow	100	64.25	1.125	1.001	0.3575	0.1104	0.2362	0.7668
April Low Flow	149.5	104.3	0.6647	1.005	0.3027	0.5114	0.3163	0.2743
May Low Flow	27	78.1	3.163	1.008	1.893	0.6814	0.01001	0.1401
June Low Flow	80	73	1.827	0.8252	0.0875	0.5482	0.7708	0.1592
July Low Flow	42	63	2.095	0.6845	0.5	0.6733	0.006006	0.08509
August Low Flow	16	67.15	3.319	0.3872	3.197	0.8833	0.00	0.07307
September Low Flow	14	53.5	1.168	0.4986	2.821	0.5731	0.00	0.1181
EFC Parameters								
Extreme low peak	2.2	1.33	1.489	2.249	0.3955	0.5108	0.5906	0.4494
Extreme low duration	8	11	1.813	3.182	0.375	0.7555	0.6206	0.2693
Extreme low timing	215	211	0.1195	0.1325	0.02186	0.1086	0.8498	0.8018
Extreme low freq.	0.5	0	6	0	1	1	0.00	0.00
High flow peak	392	417	0.8954	0.5204	0.06378	0.4188	0.6887	0.7277
High flow duration	2.5	2	0.9	2.25	0.2	1.5	0.4144	0.01702
High flow timing	205.5	190	0.3531	0.3538	0.0847	0.001934	0.3393	0.993
High flow frequency	4	4	0.75	1	0	0.3333	0.5305	0.3834
High flow rise rate	144	158.5	1.158	0.7232	0.1009	0.3756	0.7337	0.3544
High flow fall rate	-131	-120	-0.673	-0.8118	0.08397	0.2062	0.6547	0.5526
Small Flood peak	5670	3860	0.6989	0.2345	0.3192	0.6645	0.06507	0.2913
Small Flood duration	98.5	93	0.1929	0.2849	0.05584	0.4772	0.3053	0.3714
Small Flood timing	117	128	0.04235	0.05328	0.06011	0.2581	0.1351	0.5435
Small Flood freq.	0	0	0	0				
Small Flood riserate	177.8	77.36	2.474	0.452	0.565	0.8173	0.1722	0.3574
Small Flood fallrate	-73.5	-85.69	-0.424	-0.5136	0.1659	0.2112	0.2122	0.7678
Large flood peak	8150							
Large flood duration	121							
Large flood timing	121							
Large flood freq.	0	0	0	0				
Large flood riserate	184.2							
Large flood fallrate	-100.7							

EFC low flow threshold:	
EFC high flow threshold:	245.5
EFC extreme low flow threshold:	4.1
EFC small flood minimum peak flow:	3420
EFC large flood minimum peak flow:	8015

IHA Non-Parametric RVA Scorecard

DoloresRiverAtBedrock_GapsMaintained

	Pre-impact period: 1918-1983				Post-impact period: 1984-2020				RVA Boundaries		Hydrologic Alteratic
	Medians	Coeff. of Dispersion	Minimum	Maximum	Medians	Coeff. of Dispersion	Minimum	Maximum	Low	High	(Middle Category)
Parameter Group #1											
October	11.5	6.626	4	212	48.1	0.6081	12.1	244	8.297	37.95	-0.2703
November	21.5	3.315	4	175	42.3	0.484	21.65	407	10.91	38.4	0.1351
December	40	1.088	4	134	41	0.4732	21	205	26.89	57.3	1.108
January	51.5	0.7039	4	120	43.5	0.6713	21.1	130	37.08	70	0.1554
February	63	0.8552	4	150	48.65	0.6418	27.5	186	41.14	80.95	0.6216
March	100	1.388	4	392	70	1.629	37	1080	62	158.8	-0.166
April	925.8	1.128	4	3125	181	5.398	27	2465	268.4	1169	-0.1892
May	2050	1.322	2.8	4940	307	3.895	19.4	3740	973.1	3140	-0.1081
June	1478	1.662	0.09	3025	133	5.525	0.045	1670	444.5	2321	0.2162
July	87.5	3.486	0.1	730	63	0.904	2.16	414	19.08	167.2	1.432
August	13.5	2.38	0.4	338	67.2	0.4702	2.14	252	8.905	23.65	-1
September	10.1	1.677	3.9	264	53.9	0.5227	11.3	190.5	7.327	21.46	-0.7568
Parameter Group #2											
1-day minimum	3.9	1.554	0	16	25	0.564	0	55	0.52	5.649	-0.861
3-day minimum	4	1.513	0	16.67	26.67	0.49	0	60	0.9011	5.649	-0.9189
7-day minimum	4.35	1.788	0.01143	17.43	28.49	0.51	0	61.14	1.439	5.711	-0.9189
30-day minimum	6.687	2.944	0.384	49.97	35.09	0.4621	0.05267	125	4.588	17.59	-0.8378
90-day minimum	21.78	2.639	3.492	120.3	41.38	0.412	2.384	176.1	15.27	42.26	0.2973
1-day maximum	3420	1.452	763	8150	1380	1.839	51	5060	1571	5026	0.2973
3-day maximum	3337	1.329	623	7643	1250	2.162	51	4883	1556	4741	0.2162
7-day maximum	2986	1.434	440.4	6547	1131	2.225	51	4463	1416	3993	0.1351
30-day maximum	2201	1.572	157.8	5504	795	2.307	45.75	3548	1100	3338	0.05405
90-day maximum	1766	1.326	55.46	3475	401.8	2.876	42.13	2529	745.6	2343	-0.02703
Number of zero days	0	0	0	4	0	0	0	24	0	0	0.06419
Base flow index	0.01039	1.321	0.00009276	0.06608	0.1733	1.181	0	0.7067	0.005936	0.01251	-1
Parameter Group #3											
Date of minimum	246	0.1462	181	278	269	0.3593	1	365	226.5	271	-0.3745
Date of maximum	125	0.06421	105	241	147	0.2773	88	295	118.1	137.4	-0.5135
Parameter Group #4											
Low pulse count	4	1.125	0	15	0	0	0	11	2.27	5	-0.861
Low pulse duration	7	1.464	1	44	6	1.333	2	11	4.94	10.18	-0.861
High pulse count	4	0.625	1	9	4	1	0	11	3.27	5	-0.4527
High pulse duration	4	1.156	1	93	2	4.75	1	51	2.635	5.73	-0.5135
The low pulse threshold is			14								
The high pulse threshold is			245.5								
Parameter Group #5											
Rise rate	16.25	2.106	1	101.5	3.85	2.078	0.36	24.5	9.568	27.37	-0.1892
Fall rate	-11.75	-2.191	-55	-1	-4.05	-1.407	-17	-0.5	-24.38	-6	-0.166
Number of reversals	103	0.4515	11	136	110	0.2045	6	148	73.97	111.8	0.6216

Assessment of Hydrologic Alteration

	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	12.33	9	-0.2703	12.33	28	1.27	12.33	0	-1
November	12.33	14	0.1351	12.33	23	0.8649	12.33	0	-1
December	12.33	26	1.108	12.33	8	-0.3514	12.33	3	-0.7568
January	16.44	19	0.1554	8.222	7	-0.1486	12.33	11	-0.1081
February	12.33	20	0.6216	12.33	7	-0.4324	12.33	10	-0.1892
March	14.39	12	-0.166	12.33	10	-0.1892	10.28	15	0.4595
April	12.33	10	-0.1892	12.33	7	-0.4324	12.33	20	0.6216
May	12.33	11	-0.1081	12.33	2	-0.8378	12.33	24	0.9459
June	12.33	15	0.2162	12.33	0	-1	12.33	22	0.7838
July	12.33	30	1.432	12.33	3	-0.7568	12.33	4	-0.6757
August	12.33	0	-1	12.33	35	1.838	12.33	2	-0.8378
September	12.33	3	-0.7568	12.33	34	1.757	12.33	0	-1
Parameter Group #2									
1-day minimum	14.39	2	-0.861	12.33	33	1.676	10.28	2	-0.8054
3-day minimum	12.33	1	-0.9189	12.33	34	1.757	12.33	2	-0.8378
7-day minimum	12.33	1	-0.9189	12.33	34	1.757	12.33	2	-0.8378
30-day minimum	12.33	2	-0.8378	12.33	32	1.595	12.33	3	-0.7568
90-day minimum	12.33	16	0.2973	12.33	18	0.4595	12.33	3	-0.7568
1-day maximum	12.33	16	0.2973	12.33	1	-0.9189	12.33	20	0.6216
3-day maximum	12.33	15	0.2162	12.33	1	-0.9189	12.33	21	0.7027
7-day maximum	12.33	14	0.1351	12.33	2	-0.8378	12.33	21	0.7027
30-day maximum	12.33	13	0.05405	12.33	2	-0.8378	12.33	22	0.7838
90-day maximum	12.33	12	-0.02703	12.33	1	-0.9189	12.33	24	0.9459
Number of zero days	32.89	35	0.06419	4.111	2	-0.5135	0	0	
Base flow index	12.33	0	-1	12.33	35	1.838	12.33	2	-0.8378
Parameter Group #3									
Date of minimum	14.39	9	-0.3745	10.28	18	0.7514	12.33	10	-0.1892
Date of maximum	12.33	6	-0.5135	12.33	26	1.108	12.33	5	-0.5946
Parameter Group #4									
Low pulse count	14.39	2	-0.861	10.28	3	-0.7081	12.33	32	1.595
Low pulse duration	14.39	2	-0.861	10.28	1	-0.9027	10.28	2	-0.8054
High pulse count	16.44	9	-0.4527	8.222	12	0.4595	12.33	16	0.2973
High pulse duration	12.33	6	-0.5135	12.33	10	-0.1892	12.33	19	0.5405
Parameter Group #5									
Rise rate	12.33	10	-0.1892	12.33	0	-1	12.33	27	1.189
Fall rate	14.39	12	-0.166	10.28	25	1.432	12.33	0	-1
Number of reversals	12.33	20	0.6216	12.33	16	0.2973	12.33	1	-0.9189

IHA Percentile Data

DoloresRiverAtBedrock_GapsMaintained

	Pre-impact period: 1918-1983 (18 years)		Pre-Impact				Post-impact period: 1984-2020 (37 years)		Post-Impact			
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	5.53	6.8	11.5	83	122	6.626	24.16	37.75	48.1	67	87.2	0.6081
November	7.06	9.488	21.5	80.75	121	3.315	31.47	36.03	42.3	56.5	83.6	0.484
December	7.6	20.25	40	63.75	108.8	1.088	26.8	33.1	41	52.5	82	0.4732
January	15.7	35	51.5	71.25	111	0.7039	26.9	34.8	43.5	64	90	0.6713
February	22.9	38.25	63	92.13	105.9	0.8552	31.86	40.58	48.65	71.8	106.4	0.6418
March	13.9	50	100	188.8	282.2	1.388	40.84	50.45	70	164.5	324.8	1.629
April	7.69	195.9	925.8	1240	2374	1.128	36.95	85	181	1062	1755	5.398
May	3.88	678.3	2050	3388	4508	1.322	30.38	64.3	307	1260	2370	3.895
June	3.609	200.5	1478	2656	3003	1.662	11.13	52.18	133	787	1433	5.525
July	2.71	10.25	87.5	315.3	560.8	3.486	15.11	53.05	63	110	163.6	0.904
August	1.21	6.875	13.5	39	209.3	2.38	26.96	54.65	67.2	86.25	140.4	0.4702
September	3.99	5.563	10.1	22.5	68.7	1.677	32.12	42.33	53.9	70.5	106	0.5227
Parameter Group #2												
1-day minimum	0	0.315	3.9	6.375	11.5	1.554	3.472	19.45	25	33.55	45.2	0.564
3-day minimum	0.006	0.405	4	6.458	14.57	1.513	5.467	21.33	26.67	34.4	47.13	0.49
7-day minimum	0.03971	0.8296	4.35	8.607	16.01	1.788	7.228	23.47	28.49	38	49.2	0.51
30-day minimum	0.423	2.499	6.687	22.18	42.83	2.944	11.19	28.54	35.09	44.76	58.41	0.4621
90-day minimum	3.639	14.14	21.78	71.61	90.67	2.639	19.69	32.27	41.38	49.32	79.19	0.412
1-day maximum	967.3	1355	3420	6323	8015	1.452	351.2	776.5	1380	3315	4134	1.839
3-day maximum	690.8	1223	3337	5656	7643	1.329	244.4	499	1250	3202	4079	2.162
7-day maximum	520.4	1084	2986	5365	6474	1.434	141.4	318.9	1131	2836	3654	2.225
30-day maximum	177.3	729.8	2201	4190	4667	1.572	78.35	150.3	795	1984	2622	2.307
90-day maximum	79.37	389.2	1766	2732	3406	1.326	64.54	101.7	401.8	1257	1985	2.876
Number of zero days	0	0	0	0	1.3	0	0	0	0	0	0	0
Base flow index	0.0001861	0.003938	0.01039	0.01766	0.03634	1.321	0.04297	0.0767	0.1733	0.2814	0.4324	1.181
Parameter Group #3												
Date of minimum	197.2	221.8	246	275.3	277.1	0.1462	20.6	180.5	269	312	360	0.3593
Date of maximum	109.5	116.8	125	140.3	230.2	0.06421	109	128	147	229.5	259.4	0.2773
Parameter Group #4												
Low pulse count	0.9	1.75	4	6.25	12.3	1.125	0	0	0	0	3.6	0
Low pulse duration	1	3.75	7	14	38.4	1.464	2	2.5	6	10.5	11	1.333
High pulse count	1.9	2.75	4	5.25	7.2	0.625	1	2	4	6	9	1
High pulse duration	1.45	2.375	4	7	54.3	1.156	1	1.5	2	11	36.4	4.75
Parameter Group #5												
Rise rate	5.5	7.9	16.25	42.13	81.25	2.106	1.24	2	3.85	10	20	2.078
Fall rate	-49.6	-30.75	-11.75	-5	-1.05	-2.191	-14.2	-8.25	-4.05	-2.55	-1.73	-1.407
Number of reversals	40.7	69.5	103	116	121.6	0.4515	80.6	96	110	118.5	126.2	0.2045
EFC Monthly Low Flows												
October Low Flow	6.1	7.7	12	85.25	106.3	6.463	23.36	37.75	47.95	67	84.02	0.61
November Low Flow	8.28	9.85	22.5	81.5	125.6	3.184	31.47	36.03	42.3	56.5	83.6	0.484
December Low Flow	9.6	23.5	42	67.5	111.6	1.048	26.8	33.1	41	52.5	81.7	0.4732
January Low Flow	23.4	36	55	72.5	112	0.6636	26.9	34.8	43.5	64	85.6	0.6713
February Low Flow	25.8	40	65	94.75	110.8	0.8423	31.86	40.58	48.65	71.8	106.4	0.6418
March Low Flow	21.4	55.5	100	168	231	1.125	40.84	50.45	64.25	114.8	162.1	1.001
April Low Flow	13.79	83	149.5	182.4	210.5	0.6647	33.28	53.01	104.3	157.8	217.1	1.005
May Low Flow	4.6	4.6	27	90	90	3.163	26.35	52.18	78.1	130.9	174	1.008
June Low Flow	18	29.63	80	175.8	208	1.827	10.33	50.89	73	111.1	152.2	0.8252
July Low Flow	12.73	21.5	42	109.5	228	2.095	18.98	53.03	63	96.15	136.4	0.6845
August Low Flow	7.18	9.4	16	62.5	151.4	3.319	33.17	55.73	67.15	81.73	134.4	0.3872
September Low Flow	4.67	6.15	14	22.5	34.9	1.168	31.35	42.33	53.5	69	99.2	0.4986
EFC Flow Parameters												
Extreme low peak	0.1	0.475	2.2	3.75	4	1.489	0.185	0.4063	1.33	3.398	4	2.249
Extreme low duration	1	4	8	18.5	26	1.813	1	1.375	11	36.38	42	3.182
Extreme low timing	191	201.5	215	245.3	276	0.1195	173	180.4	211	228.9	232	0.1325
Extreme low freq.	0	0	0.5	3	7	6	0	0	0	0	1.2	0
High flow peak	281.7	327.5	392	678.5	861	0.8954	305.5	332.5	417	549.5	1156	0.5204
High flow duration	1	1.5	2.5	3.75	6.1	0.9	1	1	2	5.5	29.1	2.25
High flow timing	59.3	111	205.5	240.3	297	0.3531	81.3	104.5	190	234	260.8	0.3538
High flow frequency	0.9	2	4	5	7.2	0.75	1	2	4	6	8.2	1
High flow rise rate	36.59	87.48	144	254.3	385.3	1.158	90.68	105.4	158.5	220	324.5	0.7232
High flow fall rate	-303.3	-155.7	-131	-67.5	-31.22	-0.673	-254	-182	-120	-84.59	-49.56	-0.8118
Small Flood peak	3590	3808	5670	7770	8000	0.6989	3520	3555	3860	4460	5060	0.2345
Small Flood duration	93	95.25	98.5	114.3	140	0.1929	74	83.5	93	110	110	0.2849
Small Flood timing	105	111	117	126.5	144	0.04235	109	127	128	146.5	149	0.05328
Small Flood freq.	0	0	0	1	1	0	0	0	0	0.5	1	0
Small Flood riserate	60.56	108.9	177.8	548.8	589.2	2.474	47.01	64.19	77.36	99.15	207.5	0.452
Small Flood fallrate	-94.53	-88.46	-73.5	-57.29	-42.41	-0.424	-144.3	-116.2	-85.69	-72.17	-42.59	-0.5136
Large flood peak			8150									
Large flood duration			121									
Large flood timing			121									
Large flood freq.	0	0	0	0	0.1	0	0	0	0	0	0	0
Large flood riserate			184.2									
Large flood fallrate			-100.7									

11 Messages:

The longest period of missing data is 345 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
304 daily values have been interpolated in year 1971
345 daily values have been interpolated in year 2020
An EFC extreme low flow event has been truncated at the end by missing year 1923 This event is used to compute annual statistics but its length has been truncated.
An EFC extreme low flow event has been truncated at the beginning by missing year 1970 This event is not used to compute annual statistics.
A low pulse has been truncated by missing year 1923
WARNING: Some of the Colwell parameters are based on fewer than twenty years of data.
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Non-Parametric IHA Scorecard

DoloresRiverNearCiscoUT_NP_v2

	Pre-impact period: 1951-1983 (33 years)	Post-impact period: 1984-2019 (36 years)
NormalizationFactor	1	1
Mean annual flow	785.3	655.7
Non-Normalized Mean Flow	785.3	655.7
Annual C. V.	1.95	1.82
Flow predictability	0.44	0.46
Constancy/predictability	0.54	0.61
% of floods in 60d period	0.41	0.4
Flood-free season	30	36

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	126	204.5	0.8889	0.5391	0.623	0.3935	0.001001	0.09409
November	133	173	0.5338	0.3649	0.3008	0.3165	0.001001	0.3844
December	141	156	0.6064	0.4151	0.1064	0.3155	0.1502	0.5185
January	145	156	0.5345	0.4519	0.07586	0.1545	0.3824	0.5606
February	175	177.3	0.4557	0.4062	0.01286	0.1086	0.9069	0.8258
March	206	242	1.143	1.279	0.1748	0.1187	0.2783	0.8128
April	1050	875.5	1.571	1.82	0.1662	0.1584	0.6406	0.6436
May	2230	1360	1.447	1.792	0.3901	0.238	0.1522	0.4685
June	1310	1065	1.654	1.751	0.1872	0.05832	0.6607	0.8368
July	296	325	1.718	1.62	0.09797	0.05699	0.7688	0.8569
August	174	230.5	0.9569	0.859	0.3247	0.1023	0.05005	0.7367
September	115	153.8	1.152	0.9829	0.337	0.1469	0.01802	0.7878
Parameter Group #2								
1-day minimum	38	81.15	0.5132	0.6232	1.136	0.2145	0.00	0.4915
3-day minimum	38	84.42	0.6447	0.66	1.221	0.0237	0.00	0.9299
7-day minimum	41.43	88.81	0.8845	0.6859	1.144	0.2245	0.00	0.3473
30-day minimum	69.67	120	0.634	0.6167	0.7221	0.02718	0.00	0.8839
90-day minimum	120.4	148.2	0.4067	0.3088	0.2306	0.2406	0.007007	0.3083
1-day maximum	3890	3345	1.778	1.316	0.1401	0.2596	0.5295	0.4374
3-day maximum	3697	3030	1.72	1.422	0.1803	0.1736	0.3884	0.6066
7-day maximum	3374	2674	1.78	1.554	0.2077	0.1268	0.4264	0.6977
30-day maximum	2494	1984	1.613	1.435	0.2048	0.1104	0.3023	0.7177
90-day maximum	1933	1286	1.521	1.508	0.3346	0.008442	0.2072	0.98
Number of zero days	0	0	0	0				
Base flow index	0.07605	0.1499	1.198	0.7442	0.9707	0.3788	0.00	0.2372
Parameter Group #3								
Date of minimum	264	249	0.1052	0.2097	0.08197	0.9935	0.1612	0.07608
Date of maximum	128	141.5	0.09563	0.1175	0.07377	0.2286	0.03904	0.4645
Parameter Group #4								
Low pulse count	6	4	1	1.688	0.3333	0.6875	0.2022	0.06707
Low pulse duration	6.25	4	1.32	1.719	0.36	0.3021	0.4204	0.4044
High pulse count	4	4	0.5	0.6875	0	0.375	0.1181	0.2543
High pulse duration	5.5	4	2.591	1.375	0.2727	0.4693	0.1642	0.6046
Low Pulse Threshold	125							
High Pulse Threshold	582							
Parameter Group #5								
Rise rate	26	19	0.7404	0.7553	0.2692	0.0201	0.08408	0.9369
Fall rate	-20	-15.75	-0.75	-0.7698	0.2125	0.02646	0.3003	0.9119
Number of reversals	97	119	0.1959	0.145	0.2268	0.26	0.00	0.1732
EFC Low flows								
October Low Flow	134.5	204.5	0.816	0.4963	0.5204	0.3917	0.001001	0.05005
November Low Flow	136	173	0.5221	0.3649	0.2721	0.3011	0.001001	0.4254
December Low Flow	144	156	0.599	0.4151	0.08333	0.307	0.2633	0.5866
January Low Flow	147.5	156	0.5085	0.4351	0.05763	0.1443	0.4965	0.5776
February Low Flow	175	177.3	0.4557	0.3427	0.01286	0.2479	0.9069	0.6336
March Low Flow	206	210	0.6529	0.5738	0.01942	0.1212	0.8659	0.6757
April Low Flow	331	385	0.5517	0.6221	0.1631	0.1275	0.2663	0.6096
May Low Flow	389	416.8	0.5723	0.3761	0.07134	0.3428	0.4745	0.5636
June Low Flow	425.8	427	0.3206	0.4587	0.002936	0.4308	0.968	0.2633
July Low Flow	255	291	0.6961	0.9278	0.1412	0.3329	0.2142	0.2633
August Low Flow	187	227.8	0.6029	0.5225	0.2179	0.1334	0.1291	0.6697
September Low Flow	144.5	157.5	0.7751	0.7683	0.08997	0.008815	0.3163	0.983
EFC Parameters								
Extreme low peak	62.75	71.38	0.4143	0.1975	0.1375	0.5232	0.05205	0.1662
Extreme low duration	9.25	4	1.257	1.094	0.5676	0.1297	0.1742	0.7648
Extreme low timing	259	253	0.1393	0.138	0.03279	0.009804	0.7467	0.971
Extreme low freq.	3	1	1	4	0.6667	3	0.1802	0.00
High flow peak	1070	843	0.654	0.5907	0.2121	0.09668	0.1131	0.7838
High flow duration	3.5	3	0.6429	1.667	0.1429	1.593	0.5385	0.009009
High flow timing	170	163.5	0.3043	0.2842	0.03552	0.06622	0.7317	0.7728
High flow frequency	3	3.5	0.8333	0.8571	0.1667	0.02857	0.1692	0.7487
High flow rise rate	204.8	155	1.095	0.7449	0.243	0.3197	0.07508	0.4915
High flow fall rate	-174.7	-119.1	-0.6108	-0.9222	0.3185	0.5098	0.1171	0.1161
Small Flood peak	6353	6200	0.8113	0.429	0.02401	0.4712	0.9129	0.3784
Small Flood duration	100.5	108	0.1095	0.3287	0.07463	2.003	0.1101	0.06106
Small Flood timing	117	144	0.07855	0.05601	0.1475	0.287	0.02102	0.2643
Small Flood freq.	0	0	0	0				
Small Flood riserate	283.1	154.2	1.98	1.364	0.4551	0.311	0.4214	0.7678
Small Flood fallrate	-108.6	-86.49	-0.6503	-0.8095	0.2037	0.2448	0.4535	0.6777
Large flood peak	14000	13100	0.2214	0.03053	0.06429	0.8621	0.4935	0.3864
Large flood duration	126	135	0.5238	0.1926	0.07143	0.6323	0.7267	0.2352
Large flood timing	133	137.5	0.06011	0.008197	0.02459	0.8636	0.3704	0.4434
Large flood freq.	0	0	0	0				
Large flood riserate	236.2	267.7	1.206	0.4545	0.1335	0.6231	0.8649	0.4735
Large flood fallrate	-169	-156.1	-0.5205	-0.516	0.07668	0.008693	0.6587	0.6476

EFC low flow threshold:	
EFC high flow threshold:	582
EFC extreme low flow threshold:	85
EFC small flood minimum peak flow:	3890
EFC large flood minimum peak flow:	12680

IHA Non-Parametric RVA Scorecard

DoloresRiverNearCiscoUT_NP_v2

	Pre-impact period: 1951-1983				Post-impact period: 1984-2019				RVA Boundaries		Hydrologic Alteratic
	Medians	Coeff. of Dispersion	Minimum	Maximum	Medians	Coeff. of Dispersion	Minimum	Maximum	Low	High	(Middle Category)
Parameter Group #1											
October	126	0.8889	21	452	204.5	0.5391	107	611	102	173.6	0.1667
November	133	0.5338	93.5	389	173	0.3649	96.8	839.5	118.9	156.1	-0.3333
December	141	0.6064	70	336	156	0.4151	81	576	112.2	159.3	0.1667
January	145	0.5345	80	320	156	0.4519	73.8	340	126.9	174.7	0.08333
February	175	0.4557	105	434	177.3	0.4062	74	532.5	162.6	192.9	-0.25
March	206	1.143	96	897	242	1.279	126	1600	180	270.6	-0.1597
April	1050	1.571	103	5645	875.5	1.82	119	5585	680.8	1460	-0.1667
May	2230	1.447	85	8660	1360	1.792	107	9370	1558	3534	-0.1667
June	1310	1.654	181	6320	1065	1.751	74.2	3685	926	2159	-0.1667
July	296	1.718	70	2420	325	1.62	5.2	1970	199.5	486.2	-0.25
August	174	0.9569	33	971	230.5	0.859	6.8	870	111.2	228.1	-0.3333
September	115	1.152	14	825	153.8	0.9829	19.95	831	64.26	142	0.1667
Parameter Group #2											
1-day minimum	38	0.5132	4.2	224	81.15	0.6232	1	183	30.22	44.56	-0.9167
3-day minimum	38	0.6447	5.533	240	84.42	0.66	1.567	193.7	31.55	48.3	-0.9167
7-day minimum	41.43	0.8845	9.157	246.6	88.81	0.6859	1.729	200.1	33.75	52.87	-0.8333
30-day minimum	69.67	0.634	13.84	256.8	120	0.6167	4.757	319.8	62.68	93.46	-0.1667
90-day minimum	120.4	0.4067	73.74	300	148.2	0.3088	14.26	477.3	107.8	133.1	-0.4167
1-day maximum	3890	1.778	1460	16100	3345	1.316	350	13300	2863	5980	-0.1667
3-day maximum	3697	1.72	1267	15570	3030	1.422	278.3	13030	2777	5861	-0.08333
7-day maximum	3374	1.78	1051	13910	2674	1.554	267.4	12590	2484	5273	-0.25
30-day maximum	2494	1.613	448.6	9543	1984	1.435	199.4	9397	1922	4015	-0.08333
90-day maximum	1933	1.521	242.7	6563	1286	1.508	158.9	6053	1227	2654	-0.08333
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.07605	1.198	0.01219	0.2824	0.1499	0.7442	0.01608	0.3698	0.05135	0.1058	-0.6667
Parameter Group #3											
Date of minimum	264	0.1052	7	282	249	0.2097	10	363	248.7	275	-0.3529
Date of maximum	128	0.09563	88	298	141.5	0.1175	86	281	118	139.8	-0.3889
Parameter Group #4											
Low pulse count	6	1	0	18	4	1.688	0	16	4	8.78	-0.08333
Low pulse duration	6.25	1.32	1	89	4	1.719	1	54	4	10.06	-0.2798
High pulse count	4	0.5	1	6	4	0.6875	0	14	3	4	-0.338
High pulse duration	5.5	2.591	1	112	4	1.375	1	73	4.22	10.95	-0.08333
The low pulse threshold is			125								
The high pulse threshold is			582								
Parameter Group #5											
Rise rate	26	0.7404	10	79.5	19	0.7553	5	50	20.22	32.5	-0.3654
Fall rate	-20	-0.75	-87.5	-9	-15.75	-0.7698	-40	-3.4	-24.5	-16.55	-0.3889
Number of reversals	97	0.1959	67	122	119	0.145	96	136	93	104.8	-0.6944

Assessment of Hydrologic Alteration

	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	12	14	0.1667	12	22	0.8333	12	0	-1
November	12	8	-0.3333	12	25	1.083	12	3	-0.75
December	12	14	0.1667	12	17	0.4167	12	5	-0.5833
January	12	13	0.08333	12	13	0.08333	12	10	-0.1667
February	12	9	-0.25	12	15	0.25	12	12	0
March	13.09	11	-0.1597	12	15	0.25	10.91	10	-0.08333
April	12	10	-0.1667	12	16	0.3333	12	10	-0.1667
May	12	10	-0.1667	12	7	-0.4167	12	19	0.5833
June	12	10	-0.1667	12	9	-0.25	12	17	0.4167
July	12	9	-0.25	12	15	0.25	12	12	0
August	12	8	-0.3333	12	19	0.5833	12	9	-0.25
September	12	14	0.1667	12	21	0.75	12	1	-0.9167
Parameter Group #2									
1-day minimum	12	1	-0.9167	12	30	1.5	12	5	-0.5833
3-day minimum	12	1	-0.9167	12	30	1.5	12	5	-0.5833
7-day minimum	12	2	-0.8333	12	31	1.583	12	3	-0.75
30-day minimum	12	10	-0.1667	12	23	0.9167	12	3	-0.75
90-day minimum	12	7	-0.4167	12	23	0.9167	12	6	-0.5
1-day maximum	12	10	-0.1667	12	9	-0.25	12	17	0.4167
3-day maximum	12	11	-0.08333	12	8	-0.3333	12	17	0.4167
7-day maximum	12	9	-0.25	12	9	-0.25	12	18	0.5
30-day maximum	12	11	-0.08333	12	8	-0.3333	12	17	0.4167
90-day maximum	12	11	-0.08333	12	9	-0.25	12	16	0.3333
Number of zero days	36	36	0	0	0		0	0	
Base flow index	12	4	-0.6667	12	30	1.5	12	2	-0.8333
Parameter Group #3									
Date of minimum	18.55	12	-0.3529	5.455	6	0.1	12	18	0.5
Date of maximum	13.09	8	-0.3889	12	19	0.5833	10.91	9	-0.175
Parameter Group #4									
Low pulse count	15.27	14	-0.08333	12	9	-0.25	8.727	13	0.4896
Low pulse duration	15.27	11	-0.2798	10.91	6	-0.45	8.727	13	0.4896
High pulse count	19.64	13	-0.338	9.818	15	0.5278	6.545	8	0.2222
High pulse duration	12	11	-0.08333	12	6	-0.5	12	18	0.5
Parameter Group #5									
Rise rate	14.18	9	-0.3654	9.818	5	-0.4907	12	22	0.8333
Fall rate	13.09	8	-0.3889	12	21	0.75	10.91	7	-0.3583
Number of reversals	13.09	4	-0.6944	12	32	1.667	10.91	0	-1

IHA Percentile Data

DoloresRiverNearCiscoUT_NP_v2

	Pre-impact period: 1951-1983 (33 years)						Post-impact period: 1984-2019 (36 years)					
	Pre-Impact						Post-Impact					
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	55	82.5	126	194.5	366.2	0.8889	117.8	149	204.5	259.3	415.1	0.5391
November	100	111.5	133	182.5	305.2	0.5338	116.2	152.3	173	215.4	313.5	0.3649
December	89.4	107	141	192.5	296	0.6064	97.98	128.3	156	193	264.3	0.4151
January	90	117.5	145	195	255.4	0.5345	90.2	115.3	156	185.8	224.4	0.4519
February	127.8	150	175	229.8	300.3	0.4557	115.4	154.3	177.3	226.3	269.2	0.4062
March	130.2	158.5	206	394	524.6	1.143	141.2	176.3	242	485.8	855.6	1.279
April	320.8	480.8	1050	2130	3896	1.571	236.2	582	875.5	2175	3499	1.82
May	470.8	958	2230	4185	6446	1.447	369.9	646	1360	3083	4939	1.792
June	372	697.8	1310	2865	5221	1.654	241.2	459.5	1065	2324	3100	1.751
July	104.8	167	296	675.5	1808	1.718	60.62	186.3	325	712.8	1097	1.62
August	59.8	89	174	255.5	696	0.9569	68.1	105.5	230.5	303.5	556.7	0.859
September	36.8	59.75	115	192.3	352	1.152	81.64	111.8	153.8	262.9	393	0.9829
Parameter Group #2												
1-day minimum	13.4	28.5	38	48	92.8	0.5132	12.17	58.18	81.15	108.8	155.4	0.6232
3-day minimum	15.67	29	38	53.5	94.67	0.6447	21.98	60.28	84.42	116	167.3	0.66
7-day minimum	17.6	31.36	41.43	68	102.8	0.8845	30.14	65.01	88.81	125.9	182.9	0.6859
30-day minimum	28.59	56.67	69.67	100.8	129.3	0.634	64.52	81.55	120	155.5	207.3	0.6167
90-day minimum	81.72	103.1	120.4	152.1	228.5	0.4067	85.68	126.5	148.2	172.3	243.1	0.3088
1-day maximum	1736	2435	3890	9350	12680	1.778	1111	1703	3345	6105	9321	1.316
3-day maximum	1474	2350	3697	8710	12250	1.72	1075	1382	3030	5690	9151	1.422
7-day maximum	1199	2158	3374	8164	11270	1.78	854.8	1198	2674	5354	8618	1.554
30-day maximum	839.1	1454	2494	5476	8240	1.613	539.2	929.4	1984	3775	6156	1.435
90-day maximum	584.7	953.5	1933	3893	5326	1.521	384	765	1286	2704	4293	1.508
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.023	0.03551	0.07605	0.1266	0.1906	1.198	0.0617	0.1164	0.1499	0.2279	0.2796	0.7442
Parameter Group #3												
Date of minimum	38.4	236.5	264	275	278.6	0.1052	19.4	196.3	249	273	300.2	0.2097
Date of maximum	98	114.5	128	149.5	190.6	0.09563	102.7	119	141.5	162	255.6	0.1175
Parameter Group #4												
Low pulse count	1.4	3.5	6	9.5	13.2	1	0	2	4	8.75	13	1.688
Low pulse duration	2	3.625	6.25	11.88	24.45	1.32	1	2	4	8.875	12.9	1.719
High pulse count	2	3	4	5	6	0.5	1.7	3	4	5.75	7	0.6875
High pulse duration	3	3.75	5.5	18	81	2.591	1	2.5	4	8	38.2	1.375
Parameter Group #5												
Rise rate	10.7	14.25	26	33.5	57.8	0.7404	8.61	11.15	19	25.5	39.55	0.7553
Fall rate	-42.4	-29.5	-20	-14.5	-11.2	-0.75	-28.65	-22.38	-15.75	-10.25	-7.955	-0.7698
Number of reversals	81	88.5	97	107.5	114.2	0.1959	99.1	108.5	119	125.8	131	0.145
EFC Monthly Low Flows												
October Low Flow	100.8	109.3	134.5	219	271.4	0.816	119.1	150.8	204.5	252.3	383.6	0.4963
November Low Flow	103	111.5	136	182.5	297.7	0.5221	118.7	152.3	173	215.4	302.3	0.3649
December Low Flow	100	111.3	144	197.5	297	0.599	102.5	128.3	156	193	264.3	0.4151
January Low Flow	100	120	147.5	195	255.4	0.5085	101.6	117.9	156	185.8	224.4	0.4351
February Low Flow	127.8	150	175	229.8	300.3	0.4557	124.2	154.3	177.3	215	268.6	0.3427
March Low Flow	130.2	158.5	206	293	425.4	0.6529	146.5	169.3	210	289.8	408.3	0.5738
April Low Flow	157.4	249.8	331	432.4	541	0.5517	181.8	254.5	385	494	521.4	0.6221
May Low Flow	129.8	274.1	389	496.8	510	0.5723	130.4	346.3	416.8	503	551.1	0.3761
June Low Flow	258.7	342.3	425.8	478.8	519	0.3206	136.8	317	427	512.9	570.9	0.4587
July Low Flow	146	173	255	350.5	473.4	0.6961	152.8	194	291	464	557.5	0.9278
August Low Flow	114.8	142.9	187	255.6	417.1	0.6029	107.8	176.3	227.8	295.3	367	0.5225
September Low Flow	97.3	116.8	144.5	228.8	296.9	0.7751	103	131	157.5	252	366.5	0.7683
EFC Flow Parameters												
Extreme low peak	40.5	49	62.75	75	81.95	0.4143	61.69	65.3	71.38	79.4	82.93	0.1975
Extreme low duration	1	4.375	9.25	16	26.35	1.257	1	2	4	6.375	14.95	1.094
Extreme low timing	203.6	233	259	284	321.8	0.1393	215	229.3	253	279.8	347.8	0.138
Extreme low freq.	0.4	1	3	4	5	1	0	0	1	4	7	4
High flow peak	653.9	751.5	1070	1451	1685	0.654	646.6	702	843	1200	1930	0.5907
High flow duration	1	3	3.5	5.25	22	0.6429	1	2	3	7	35.3	1.667
High flow timing	86.55	109	170	220.4	301.3	0.3043	95.1	137	163.5	241	258.6	0.2842
High flow frequency	0.4	2	3	4.5	6	0.8333	1	2	3.5	5	6.3	0.8571
High flow rise rate	110.2	156.3	204.8	380.5	696.2	1.095	60.43	105.8	155	221.2	376.2	0.7449
High flow fall rate	-369.7	-229.5	-174.7	-122.8	-69.13	-0.6108	-234.1	-181	-119.1	-71.21	-57.87	-0.9222
Small Flood peak	4170	5171	6353	10330	11300	0.8113	4230	4715	6200	7375	9612	0.429
Small Flood duration	62.25	93.5	100.5	104.5	114	0.1095	29.2	86.5	108	122	135	0.3287
Small Flood timing	99	113.5	117	142.3	195.5	0.07855	108	126	144	146.5	228.6	0.05601
Small Flood freq.	0	0	0	1	1	0	0	0	0	1	1	0
Small Flood riserate	108.9	162.1	283.1	722.5	1302	1.98	73.29	91.52	154.2	301.9	1729	1.364
Small Flood fallrate	-212.7	-136.1	-108.6	-65.46	-50.36	-0.6503	-439.7	-145.2	-86.49	-75.23	-66.45	-0.8095
Large flood peak	13000	13000	14000	16100	16100	0.2214	12900	12900	13100	13300	13300	0.03053
Large flood duration	103	103	126	169	169	0.5238	122	122	135	148	148	0.1926
Large flood timing	112	112	133	134	134	0.06011	136	136	137.5	139	139	0.008197
Large flood freq.	0	0	0	0	0.6	0	0	0	0	0	0	0
Large flood riserate	217.8	217.8	236.2	502.7	502.7	1.206	206.9	206.9	267.7	328.6	328.6	0.4545
Large flood fallrate	-212.8	-212.8	-169	-124.8	-124.8	-0.5205	-196.3	-196.3	-156.1	-115.8	-115.8	-0.516

8 Messages:

The longest period of missing data is 61 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
61 daily values have been interpolated in year 1951
42 daily values have been interpolated in year 2019
Dates of extreme flows are widely scattered. Use statistics with caution.
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Non-Parametric IHA Scorecard

DoloresRiverBelowRicoCO_v2

	Pre-impact period: 1952-1983 (32 years)	Post-impact period: 1984-2019 (34 years)
NormalizationFactor	1	1
Mean annual flow	134.5	126.6
Non-Normalized Mean Flow	134.5	126.6
Annual C. V.	1.77	1.63
Flow predictability	0.54	0.49
Constancy/predictability	0.47	0.49
% of floods in 60d period	0.49	0.47
Flood-free season	151	80

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	28.5	34	1.088	0.7103	0.193	0.347	0.1181	0.4645
November	22	24.4	0.8125	0.7884	0.1091	0.02963	0.2603	0.9109
December	18.5	19.2	0.5676	0.7669	0.03784	0.3513	0.4474	0.5175
January	16.5	18.55	0.5455	0.7278	0.1242	0.3342	0.3393	0.3323
February	15.25	17.95	0.5328	0.5578	0.177	0.04695	0.1131	0.8689
March	20	31.6	0.5375	0.6092	0.58	0.1334	0.001001	0.6667
April	76	122.3	1.184	0.5691	0.6086	0.5194	0.002002	0.1051
May	392.5	461	0.6032	0.493	0.1745	0.1828	0.0971	0.4324
June	435	345.8	1.482	1.48	0.2052	0.001252	0.4875	0.997
July	89.5	85.85	1.223	1.097	0.04078	0.1034	0.9019	0.7337
August	57	56.1	0.6404	0.6087	0.01579	0.04937	0.8939	0.8679
September	38	42.4	0.8914	0.8228	0.1158	0.07699	0.5085	0.7487
Parameter Group #2								
1-day minimum	12	12	0.4167	0.7473	0	0.7935	0.2172	0.06306
3-day minimum	12.83	12.67	0.4156	0.6889	0.01299	0.6578	0.9209	0.1161
7-day minimum	13.79	13.37	0.4378	0.6502	0.03005	0.4851	0.7187	0.1662
30-day minimum	15.12	15.54	0.3897	0.4783	0.02767	0.2271	0.3844	0.4755
90-day minimum	16.17	18.19	0.4263	0.6679	0.1253	0.5669	0.06807	0.1742
1-day maximum	1020	910	0.6588	0.5393	0.1078	0.1814	0.4695	0.4585
3-day maximum	951.2	854.3	0.6558	0.5726	0.1018	0.1269	0.5726	0.6827
7-day maximum	856.3	812.3	0.6846	0.5016	0.05138	0.2673	0.6106	0.3784
30-day maximum	650.5	617.1	0.8148	0.5176	0.05137	0.3647	0.6617	0.1812
90-day maximum	360.7	366.3	1.028	0.5946	0.01528	0.4218	0.9269	0.1101
Number of zero days	0	0	0	0				
Base flow index	0.1269	0.123	0.5548	0.6191	0.03093	0.1158	0.7838	0.6326
Parameter Group #3								
Date of minimum	32	30.5	0.1605	0.1646	0.008197	0.02553	0.8539	0.9469
Date of maximum	157	149.5	0.0403	0.05601	0.04098	0.3898	0.1421	0.0991
Parameter Group #4								
Low pulse count	5	3	0.95	1.417	0.4	0.4912	0.1191	0.2002
Low pulse duration	5	5.75	1.6	3.413	0.15	1.133	0.5746	0.1061
High pulse count	3	4	1	1	0.3333	0	0.03804	0.7457
High pulse duration	8	8	5.656	4.203	0	0.2569	0.9499	0.5255
Low Pulse Threshold	20							
High Pulse Threshold	114							
Parameter Group #5								
Rise rate	5	4.025	0.675	0.8727	0.195	0.2928	0.3013	0.3063
Fall rate	-4	-3.975	-0.75	-0.4654	0.00625	0.3795	0.07508	0.3704
Number of reversals	98	100	0.2321	0.2275	0.02041	0.02	0.6577	0.9399
EFC Low flows								
October Low Flow	28.5	34	0.9781	0.7103	0.193	0.2738	0.1181	0.5005
November Low Flow	22	25.5	0.7955	0.6902	0.1591	0.1323	0.2112	0.5776
December Low Flow	19	20.8	0.6579	0.5889	0.09474	0.1048	0.2633	0.7798
January Low Flow	18	20.8	0.5556	0.5048	0.1556	0.09135	0.1111	0.6396
February Low Flow	17	20.4	0.4706	0.4099	0.2	0.1289	0.04004	0.5526
March Low Flow	21	31.1	0.6667	0.4188	0.481	0.3718	0.002002	0.1041
April Low Flow	53.5	70.6	0.6916	0.3909	0.3196	0.4347	0.01502	0.1311
May Low Flow	93	107	0.2903	0.1907	0.1505	0.3433	0.1912	0.4384
June Low Flow	92	86.75	0.2473	0.5444	0.05707	1.201	0.4154	0.1231
July Low Flow	72	69	0.4583	0.5116	0.04167	0.1162	0.8659	0.7538
August Low Flow	54	55.5	0.6296	0.5342	0.02778	0.1515	0.6627	0.5245
September Low Flow	36	41	0.7778	0.6256	0.1389	0.1956	0.3964	0.4044
EFC Parameters								
Extreme low peak	14.5	13.3	0.1379	0.3308	0.08276	1.398	0.2292	0.02302
Extreme low duration	2.5	4	0.6	2.625	0.6	3.375	0.08609	0.01201
Extreme low timing	24	30	0.127	0.2117	0.03279	0.6667	0.6717	0.1331
Extreme low freq.	5.5	1	1.591	5	0.8182	2.143	0.1842	0.07207
High flow peak	163.3	172.5	1.156	0.4116	0.05666	0.644	0.4735	0.6326
High flow duration	4.25	4.75	5.647	1.921	0.1176	0.6598	0.5135	0.4955
High flow timing	181.8	200.3	0.2865	0.2456	0.1011	0.143	0.6336	0.3914
High flow frequency	3	4	0.9167	0.75	0.3333	0.1818	0.05305	0.6527
High flow rise rate	28.47	28.21	0.8238	0.7293	0.009116	0.1148	0.9489	0.7578
High flow fall rate	-24.71	-23.17	-0.3638	-0.661	0.06258	0.8171	0.5516	0.09009
Small Flood peak	1190	1230	0.2668	0.2846	0.03361	0.06651	0.8198	0.8398
Small Flood duration	89.5	86	0.6453	0.3372	0.03911	0.4774	0.7187	0.3183
Small Flood timing	160.5	159	0.06148	0.04918	0.008197	0.2	0.7778	0.7147
Small Flood freq.	0	0	0	0				
Small Flood riserate	32.65	30	1.738	0.5189	0.08114	0.7015	0.5185	0.4875
Small Flood fallrate	-26.28	-27.55	-0.4536	-0.2636	0.04834	0.419	0.6336	0.3764
Large flood peak	1790		0.01117					
Large flood duration	103		0.2524					
Large flood timing	157		0.03825					
Large flood freq.	0	0	0	0				
Large flood riserate	40.86		3.021					
Large flood fallrate	-36.13		-0.6577					

EFC low flow threshold:	
EFC high flow threshold:	114
EFC extreme low flow threshold:	15
EFC small flood minimum peak flow:	1020
EFC large flood minimum peak flow:	1739

IHA Non-Parametric RVA Scorecard

DoloresRiverBelowRicoCO_v2

	Pre-impact period: 1952-1983				Post-impact period: 1984-2019				RVA Boundaries		Hydrologic Alteration
	Medians	Coeff. of Dispersion	Minimum	Maximum	Medians	Coeff. of Dispersion	Minimum	Maximum	Low	High	(Middle Category)
Parameter Group #1											
October	28.5	1.088	14	104	34	0.7103	12	178	25	36.55	-0.05882
November	22	0.8125	13	56	24.4	0.7884	11	65	20	27.78	-0.2036
December	18.5	0.5676	12	42	19.2	0.7669	5.67	55.6	16	22	-0.2803
January	16.5	0.5455	10	38	18.55	0.7278	7.5	114	15	19.11	-0.2036
February	15.25	0.5328	8	32	17.95	0.5578	7.6	115	14.5	18.22	-0.395
March	20	0.5375	11	79	31.6	0.6092	11.1	167	18	25.11	-0.5656
April	76	1.184	26	240	122.3	0.5691	39.85	422.5	56.95	134	0.5686
May	392.5	0.6032	88	894	461	0.493	116	913	327.1	477.3	-0.2157
June	435	1.482	56.5	1315	345.8	1.48	30.35	1065	302.5	671.4	-0.2941
July	89.5	1.223	32	650	85.85	1.097	16.8	517	67	144.3	-0.1312
August	57	0.6404	29	210	56.1	0.6087	12	262	44	73.44	-0.05882
September	38	0.8914	16	212	42.4	0.8228	13.55	193	33.34	51.33	-0.1373
Parameter Group #2											
1-day minimum	12	0.4167	7	26	12	0.7473	4.65	26	11	13.11	-0.6533
3-day minimum	12.83	0.4156	7.167	28.67	12.67	0.6889	4.867	27.33	12.3	14.48	-0.5294
7-day minimum	13.79	0.4378	7.571	29.43	13.37	0.6502	5.044	29.14	13.11	14.98	-0.6078
30-day minimum	15.12	0.3897	8.05	30.8	15.54	0.4783	5.883	31.87	14.28	15.58	-0.6078
90-day minimum	16.17	0.4263	9.861	34.71	18.19	0.6679	7.781	33.99	15.52	18	-0.451
1-day maximum	1020	0.6588	167	1810	910	0.5393	152	1730	804.9	1211	0.09804
3-day maximum	951.2	0.6558	159.3	1757	854.3	0.5726	148	1693	791.4	1115	0.01961
7-day maximum	856.3	0.6846	143.7	1661	812.3	0.5016	135.4	1580	720.9	1076	0.01961
30-day maximum	650.5	0.8148	102.3	1321	617.1	0.5176	119.4	1078	561.2	867.4	0.09804
90-day maximum	360.7	1.028	78.56	737.5	366.3	0.5946	86.23	617.4	305.3	465.6	-0.1373
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.1269	0.5548	0.04166	0.3276	0.123	0.6191	0.03467	0.2581	0.107	0.1494	-0.2157
Parameter Group #3											
Date of minimum	32	0.1605	2	363	30.5	0.1646	8	363	41.89	321	-0.1933
Date of maximum	157	0.0403	129	250	149.5	0.05601	97	281	148.9	160	-0.3484
Parameter Group #4											
Low pulse count	5	0.95	0	13	3	1.417	0	16	3	7	-0.2249
Low pulse duration	5	1.6	1	64.5	5.75	3.413	1	166	3	6.76	-0.1529
High pulse count	3	1	1	8	4	1	1	8	2	4.11	-0.05882
High pulse duration	8	5.656	1	104	8	4.203	1	71	4	37.94	0.3032
The low pulse threshold is			20								
The high pulse threshold is			114								
Parameter Group #5											
Rise rate	5	0.675	2	15	4.025	0.8727	1	11	4	6.555	-0.1933
Fall rate	-4	-0.75	-11.5	-2	-3.975	-0.4654	-10	-1.2	-5	-4	-0.2605
Number of reversals	98	0.2321	64	123	100	0.2275	57	137	90.89	108.1	-0.05882

Assessment of Hydrologic Alteration

	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	13.81	13	-0.05882	10.63	16	0.5059	9.563	5	-0.4771
November	13.81	11	-0.2036	10.63	15	0.4118	9.563	8	-0.1634
December	18.06	13	-0.2803	8.5	11	0.2941	7.438	10	0.3445
January	13.81	11	-0.2036	10.63	15	0.4118	9.563	8	-0.1634
February	14.88	9	-0.395	10.63	16	0.5059	8.5	9	0.05882
March	13.81	6	-0.5656	10.63	25	1.353	9.563	3	-0.6863
April	12.75	20	0.5686	10.63	11	0.03529	10.63	3	-0.7176
May	12.75	10	-0.2157	10.63	15	0.4118	10.63	9	-0.1529
June	12.75	9	-0.2941	10.63	10	-0.05882	10.63	15	0.4118
July	13.81	12	-0.1312	10.63	9	-0.1529	9.563	13	0.3595
August	15.94	15	-0.05882	10.63	8	-0.2471	7.438	11	0.479
September	12.75	11	-0.1373	10.63	14	0.3176	10.63	9	-0.1529
Parameter Group #2									
1-day minimum	20.19	7	-0.6533	10.63	13	0.2235	3.188	14	3.392
3-day minimum	12.75	6	-0.5294	10.63	13	0.2235	10.63	15	0.4118
7-day minimum	12.75	5	-0.6078	10.63	13	0.2235	10.63	16	0.5059
30-day minimum	12.75	5	-0.6078	10.63	17	0.6	10.63	12	0.1294
90-day minimum	12.75	7	-0.451	10.63	17	0.6	10.63	10	-0.05882
1-day maximum	12.75	14	0.09804	10.63	8	-0.2471	10.63	12	0.1294
3-day maximum	12.75	13	0.01961	10.63	9	-0.1529	10.63	12	0.1294
7-day maximum	12.75	13	0.01961	10.63	7	-0.3412	10.63	14	0.3176
30-day maximum	12.75	14	0.09804	10.63	7	-0.3412	10.63	13	0.2235
90-day maximum	12.75	11	-0.1373	10.63	11	0.03529	10.63	12	0.1294
Number of zero days	34	34	0	0	0		0	0	
Base flow index	12.75	10	-0.2157	10.63	10	-0.05882	10.63	14	0.3176
Parameter Group #3									
Date of minimum	14.88	12	-0.1933	8.5	11	0.2941	10.63	11	0.03529
Date of maximum	13.81	9	-0.3484	9.563	9	-0.05882	10.63	16	0.5059
Parameter Group #4									
Low pulse count	18.06	14	-0.2249	8.5	5	-0.4118	7.438	15	1.017
Low pulse duration	10.63	9	-0.1529	9.563	12	0.2549	8.5	7	-0.1765
High pulse count	20.19	19	-0.05882	10.63	14	0.3176	3.188	1	-0.6863
High pulse duration	13.81	18	0.3032	10.63	8	-0.2471	9.563	8	-0.1634
Parameter Group #5									
Rise rate	14.88	12	-0.1933	10.63	10	-0.05882	8.5	12	0.4118
Fall rate	14.88	11	-0.2605	9.563	17	0.7778	9.563	6	-0.3725
Number of reversals	12.75	12	-0.05882	10.63	11	0.03529	10.63	11	0.03529

IHA Percentile Data

DoloresRiverBelowRicoCO_v2

	Pre-impact period: 1952-1983 (32 years)						Post-impact period: 1984-2019 (34 years)					
			Pre-Impact						Post-Impact			
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	19	24	28.5	55	76.4	1.088	24.1	27.23	34	51.38	87.55	0.7103
November	16.6	18.75	22	36.63	48.7	0.8125	13.23	19.79	24.4	39.03	51.83	0.7884
December	13	16	18.5	26.5	34	0.5676	9.94	14.25	19.2	28.98	36.05	0.7669
January	12.3	14	16.5	23	28	0.5455	7.99	13.88	18.55	27.38	31	0.7278
February	11.6	14.13	15.25	22.25	30.1	0.5328	9.66	14	17.95	24.01	30.88	0.5578
March	14.3	17	20	27.75	38.8	0.5375	17.05	24.2	31.6	43.45	83.2	0.6092
April	41.9	50.88	76	140.9	169.6	1.184	62.3	96.05	122.3	165.6	210.3	0.5691
May	162.5	294	392.5	530.8	680.4	0.6032	246.5	310.5	461	537.8	652.5	0.493
June	164.2	219	435	863.5	1140	1.482	75.73	197.1	345.8	708.8	869	1.48
July	45.3	61.5	89.5	171	397.2	1.223	32.1	58.08	85.85	152.3	226	1.097
August	32.6	44	57	80.5	153.8	0.6404	27.3	38.9	56.1	73.05	109	0.6087
September	24.65	30.13	38	64	112	0.8914	24.53	29.13	42.4	64.01	96.18	0.8228
Parameter Group #2												
1-day minimum	10.3	11	12	16	21.4	0.4167	5.965	8.233	12	17.2	23.05	0.7473
3-day minimum	11	11.67	12.83	17	22	0.4156	6.565	8.648	12.67	17.38	24.33	0.6889
7-day minimum	11	12.25	13.79	18.29	23.74	0.4378	6.945	9.341	13.37	18.04	25.01	0.6502
30-day minimum	11.2	13.78	15.12	19.67	25.48	0.3897	7.509	11.94	15.54	19.37	26.78	0.4783
90-day minimum	12.28	14.6	16.17	21.49	28.47	0.4263	9.83	13.85	18.19	26	29.91	0.6679
1-day maximum	603	685.5	1020	1358	1739	0.6588	476	686.8	910	1178	1480	0.5393
3-day maximum	545	666.3	951.2	1290	1634	0.6558	434.3	643.3	854.3	1133	1415	0.5726
7-day maximum	494.4	604.8	856.3	1191	1508	0.6846	382.7	599.7	812.3	1007	1314	0.5016
30-day maximum	374.4	474.6	650.5	1005	1218	0.8148	315.1	479.6	617.1	799	994.6	0.5176
90-day maximum	231	262.4	360.7	633.4	685.5	1.028	190.5	279.5	366.3	497.3	594.4	0.5946
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.06491	0.08434	0.1269	0.1548	0.1908	0.5548	0.07213	0.07861	0.123	0.1548	0.1909	0.6191
Parameter Group #3												
Date of minimum	321.6	351.8	32	44.5	64.4	0.1605	330.5	357.3	30.5	51.5	64	0.1646
Date of maximum	130.3	147.3	157	162	174.8	0.0403	131.5	140.5	149.5	161	169	0.05601
Parameter Group #4												
Low pulse count	0	3	5	7.75	9.7	0.95	0	1	3	5.25	11.5	1.417
Low pulse duration	1	2	5	10	26.2	1.6	1.95	2.625	5.75	22.25	74.1	3.413
High pulse count	1.3	2	3	5	5	1	2	2	4	6	8	1
High pulse duration	2	2.125	8	47.38	63.85	5.656	2	3.875	8	37.5	52.25	4.203
Parameter Group #5												
Rise rate	3	3.625	5	7	7.85	0.675	2.25	3.375	4.025	6.888	8	0.8727
Fall rate	-7	-6	-4	-3	-3	-0.75	-6.75	-5	-3.975	-3.15	-2.225	-0.4654
Number of reversals	83.3	88	98	110.8	118	0.2321	79	88.25	100	111	125.5	0.2275
EFC Monthly Low Flows												
October Low Flow	19	24	28.5	51.88	66.7	0.9781	24.1	27.23	34	51.38	81.9	0.7103
November Low Flow	18	20	22	37.5	49.3	0.7955	17.29	21.45	25.5	39.05	52.76	0.6902
December Low Flow	16	16	19	28.5	34	0.6579	16.4	18.1	20.8	30.35	36.1	0.5889
January Low Flow	16	16	18	26	28.6	0.5556	16	17.35	20.8	27.85	32	0.5048
February Low Flow	16	16	17	24	31	0.4706	16	17.25	20.4	25.61	32.2	0.4099
March Low Flow	17	18	21	32	35.6	0.6667	19.6	26.4	31.1	39.43	48.6	0.4188
April Low Flow	28	38	53.5	75	86.9	0.6916	47.2	55.9	70.6	83.5	100.8	0.3909
May Low Flow	63	78.5	93	105.5	108	0.2903	70.12	88.6	107	109	109.4	0.1907
June Low Flow	59	87.75	92	110.5	113.6	0.2473	31.85	56.15	86.75	103.4	113.5	0.5444
July Low Flow	43.2	58	72	91	108.4	0.4583	31	53.18	69	88.48	106	0.5116
August Low Flow	32.4	41	54	75	82.8	0.6296	27.24	37.8	55.5	67.45	76.96	0.5342
September Low Flow	24.6	30	36	58	75.8	0.7778	24.63	31.41	41	57.06	65.1	0.6256
EFC Flow Parameters												
Extreme low peak	12.2	13	14.5	15	15	0.1379	8.804	10.3	13.3	14.7	15	0.3308
Extreme low duration	1	2	2.5	3.5	13.2	0.6	1	1.5	4	12	82.2	2.625
Extreme low timing	324.4	0.5	24	47	64.8	0.127	318.6	345.5	30	57	157.2	0.2117
Extreme low freq.	0	0	5.5	8.75	12.4	1.591	0	0	1	5	6.5	5
High flow peak	130.8	144.3	163.3	333	484.7	1.156	130.5	147.1	172.5	218.1	477.8	0.4116
High flow duration	1.55	2	4.25	26	46.05	5.647	1.75	3.375	4.75	12.5	38	1.921
High flow timing	118.8	130.1	181.8	235	257	0.2865	105	126.4	200.3	216.3	235.5	0.2456
High flow frequency	1	1.25	3	4	5	0.9167	1	2	4	5	7.5	0.75
High flow rise rate	15.72	19.55	28.47	43	67.95	0.8238	12.71	21.34	28.21	41.91	55.75	0.7293
High flow fall rate	-42.9	-28.58	-24.71	-19.59	-16.42	-0.3638	-39.28	-27.31	-23.17	-12	-9.5	-0.661
Small Flood peak	1020	1100	1190	1418	1585	0.2668	1038	1100	1230	1450	1670	0.2846
Small Flood duration	41.25	46.25	89.5	104	128	0.6453	49	73	86	102	110.4	0.3372
Small Flood timing	139	150.5	160.5	173	216	0.06148	138.4	145	159	163	213.8	0.04918
Small Flood freq.	0	0	0	1	1	0	0	0	0	1	1	0
Small Flood riserate	18.91	24.96	32.65	81.72	242	1.738	19.2	21.46	30	37.02	167.3	0.5189
Small Flood fallrate	-40.8	-30.39	-26.28	-18.47	-13.86	-0.4536	-41.32	-29.21	-27.55	-21.95	-17.59	-0.2636
Large flood peak	1790	1790	1790	1810	1810	0.01117						
Large flood duration	82	82	103	108	108	0.2524						
Large flood timing	148	148	157	162	162	0.03825						
Large flood freq.	0	0	0	0	0.7	0	0	0	0	0	0	0
Large flood riserate	29.82	29.82	40.86	153.3	153.3	3.021						
Large flood fallrate	-40.9	-40.9	-36.13	-17.14	-17.14	-0.6577						

6 Messages:

The longest period of missing data is 49 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
91 daily values have been interpolated in year 2019
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Non-Parametric IHA Scorecard

DoloresRiverAtDoloresCO_v2

Pre-impact period: 1922-1983 (62 years)		Post-impact period: 1984-2019 (36 years)
NormalizationFactor	1	1
Mean annual flow	436.2	402
Non-Normalized Mean Flow	436.2	402
Annual C. V.	1.66	1.6
Flow predictability	0.52	0.5
Constancy/predictability	0.45	0.44
% of floods in 60d period	0.49	0.46
Flood-free season	102	109

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	81	90.3	1.117	0.8007	0.1148	0.2834	0.3574	0.6056
November	60.75	69.28	0.677	0.817	0.1403	0.2069	0.1902	0.6547
December	48	51.95	0.5052	0.5255	0.08229	0.04018	0.2382	0.8879
January	45	48	0.3389	0.5969	0.06667	0.7613	0.2633	0.04404
February	50	55.85	0.5	0.4528	0.117	0.09445	0.1451	0.6857
March	80	129.5	0.5688	1.014	0.6188	0.782	0.00	0.04004
April	534	652.3	1.153	0.5772	0.2214	0.4995	0.1081	0.05806
May	1630	1550	0.7147	0.6274	0.04908	0.1222	0.7968	0.5666
June	1168	833.8	1.096	1.441	0.2859	0.3148	0.1642	0.2152
July	296	238.5	0.7348	0.9224	0.1943	0.2554	0.1491	0.2823
August	221	195	0.6335	0.4667	0.1176	0.2633	0.2312	0.2823
September	121	137.5	0.8058	0.55	0.1364	0.3174	0.3133	0.2723
Parameter Group #2								
1-day minimum	34	35	0.5147	0.7457	0.02941	0.4488	0.4945	0.07908
3-day minimum	35.67	37.5	0.5093	0.6998	0.0514	0.3739	0.5165	0.1742
7-day minimum	37.43	39.5	0.4981	0.7055	0.05534	0.4164	0.3463	0.1081
30-day minimum	42.38	45.35	0.3995	0.6594	0.07	0.6504	0.2112	0.01902
90-day minimum	46.63	51.07	0.4518	0.5517	0.09506	0.2213	0.1251	0.3203
1-day maximum	2935	2645	0.7871	0.6153	0.09881	0.2182	0.3353	0.3624
3-day maximum	2787	2450	0.7395	0.6469	0.1208	0.1252	0.2422	0.6336
7-day maximum	2458	2258	0.7419	0.5815	0.08137	0.2163	0.4895	0.4605
30-day maximum	1965	1845	0.722	0.5343	0.06085	0.26	0.5235	0.3544
90-day maximum	1313	1117	0.8212	0.7414	0.149	0.09718	0.2713	0.6807
Number of zero days	0	0	0	0				
Base flow index	0.09792	0.1091	0.6648	0.5774	0.1145	0.1316	0.3433	0.5906
Parameter Group #3								
Date of minimum	346.5	362.5	0.14	0.1728	0.08743	0.2341	0.2713	0.4675
Date of maximum	139.5	142	0.05191	0.0485	0.01366	0.06579	0.6777	0.6476
Parameter Group #4								
Low pulse count	4.5	3	1.333	2	0.3333	0.5	0.2122	0.1131
Low pulse duration	4.25	4	1.588	1.406	0.05882	0.1146	0.8769	0.7147
High pulse count	3	2.5	0.6667	0.8	0.1667	0.2	0.09409	0.3724
High pulse duration	9	9	4.361	4.403	0	0.009554	0.9059	0.979
Low Pulse Threshold	55							
High Pulse Threshold	388							
Parameter Group #5								
Rise rate	14.5	11.75	1.078	1.087	0.1897	0.008953	0.1802	0.992
Fall rate	-13	-10.45	-0.7788	-0.6459	0.1962	0.1707	0.1301	0.5375
Number of reversals	113	110	0.2434	0.2023	0.02655	0.1688	0.5365	0.4825
EFC Low flows								
October Low Flow	80	90.3	0.8188	0.8007	0.1288	0.02209	0.2633	0.974
November Low Flow	63.5	70	0.6063	0.7429	0.1024	0.2252	0.2903	0.6927
December Low Flow	51	60	0.3799	0.3833	0.1765	0.009032	0.05005	0.987
January Low Flow	50	53.5	0.34	0.4065	0.07	0.1957	0.4234	0.4915
February Low Flow	55	58	0.3636	0.5362	0.05455	0.4746	0.3594	0.1381
March Low Flow	84	114	0.4821	0.5197	0.3571	0.07797	0.00	0.7477
April Low Flow	209	244.5	0.6298	0.4964	0.1699	0.2118	0.07307	0.3524
May Low Flow	323	286	0.3096	0.2972	0.1146	0.04003	0.3073	0.9419
June Low Flow	292	258.3	0.2911	0.4516	0.1156	0.5514	0.2002	0.1802
July Low Flow	269	236.3	0.461	0.628	0.1217	0.3624	0.1391	0.08609
August Low Flow	214	191	0.5864	0.4817	0.1075	0.1787	0.2603	0.4294
September Low Flow	121	133.3	0.6591	0.4587	0.1012	0.304	0.3003	0.2222
EFC Parameters								
Extreme low peak	38	35.5	0.1579	0.2613	0.06579	0.6547	0.05706	0.1001
Extreme low duration	3	4	1.167	1.188	0.3333	0.01786	0.1732	0.971
Extreme low timing	349	364	0.1086	0.1503	0.08197	0.3836	0.2022	0.1752
Extreme low freq.	3.5	2	1.714	2.375	0.4286	0.3854	0.2913	0.3313
High flow peak	501	665	1.013	1.328	0.3273	0.3111	0.08008	0.4695
High flow duration	3	5	2.792	6.4	0.6667	1.293	0.1121	0.06507
High flow timing	189	183	0.2445	0.2391	0.03279	0.02235	0.7678	0.9089
High flow frequency	3	2	1	0.875	0.3333	0.125	0.3654	0.7648
High flow rise rate	81.49	72.36	0.9591	0.7459	0.1121	0.2223	0.6306	0.4795
High flow fall rate	-65.5	-58.5	-0.6864	-0.4934	0.1069	0.2812	0.2312	0.3383
Small Flood peak	3880	3835	0.2925	0.2829	0.0116	0.03284	0.9419	0.8969
Small Flood duration	96	104	0.2266	0.2163	0.08333	0.04509	0.2102	0.8699
Small Flood timing	142	143	0.05533	0.04986	0.005464	0.09877	0.8208	0.8418
Small Flood freq.	0	0	0	0				
Small Flood riserate	94.57	67.64	0.9776	0.4622	0.2847	0.5272	0.009009	0.5756
Small Flood fallrate	-65.24	-61.38	-0.4503	-0.592	0.05917	0.3148	0.4855	0.4525
Large flood peak	5775	5540	0.2394		0.04069		0.7107	
Large flood duration	101.5	99	0.3768		0.02463		0.8288	
Large flood timing	155	145	0.1113		0.05464		0.4795	
Large flood freq.	0	0	0	0				
Large flood riserate	105.3	110.1	2.478		0.04634		0.8368	
Large flood fallrate	-87.72	-97.74	-1.642		0.1142		0.8048	

EFC low flow threshold:	
EFC high flow threshold:	388
EFC extreme low flow threshold:	41
EFC small flood minimum peak flow:	2935
EFC large flood minimum peak flow:	5158

IHA Non-Parametric RVA Scorecard

DoloresRiverAtDoloresCO_v2

	Pre-impact period: 1922-1983				Post-impact period: 1984-2019				RVA Boundaries		Hydrologic Alteration
	Medians	Coeff. of Dispersion	Minimum	Maximum	Medians	Coeff. of Dispersion	Minimum	Maximum	Low	High	(Middle Category)
Parameter Group #1											
October	81	1.117	24	1260	90.3	0.8007	35.5	471	67.58	109.3	0.1742
November	60.75	0.677	30	441	69.28	0.817	29.05	334	51.5	80	0.2199
December	48	0.5052	22	147	51.95	0.5255	18	180	44	60	-0.3111
January	45	0.3389	26	110	48	0.5969	19	150	41.79	51.21	-0.452
February	50	0.5	30	100	55.85	0.4528	20.5	140	44.79	56.05	-0.452
March	80	0.5688	30	308	129.5	1.014	39.4	558	69.58	99.21	-0.3737
April	534	1.153	146	1850	652.3	0.5772	154.5	1530	391.2	794.1	0.4091
May	1630	0.7147	238	3440	1550	0.6274	286	4020	1212	1935	0.09596
June	1168	1.096	85	3275	833.8	1.441	52.8	2985	911.6	1599	-0.3737
July	296	0.7348	48	1320	238.5	0.9224	82.5	999	233.8	380.8	-0.2172
August	221	0.6335	50	540	195	0.4667	24.9	651	159.5	252.8	0.09596
September	121	0.8058	29.5	766.5	137.5	0.55	30.65	407	96.48	165.2	0.1742
Parameter Group #2											
1-day minimum	34	0.5147	11	75	35	0.7457	10.3	89	29	36.63	-0.713
3-day minimum	35.67	0.5093	13	80	37.5	0.6998	12.9	89	30.26	40	-0.5507
7-day minimum	37.43	0.4981	17.43	82.86	39.5	0.7055	15.59	95	33.79	43.6	-0.2955
30-day minimum	42.38	0.3995	21.5	84.67	45.35	0.6594	17.67	125.6	38.03	45.84	-0.6086
90-day minimum	46.63	0.4518	27.52	101.7	51.07	0.5517	19.7	155.3	43.41	52.46	-0.6086
1-day maximum	2935	0.7871	385	6950	2645	0.6153	444	5540	2247	3605	0.09596
3-day maximum	2787	0.7395	340.3	6240	2450	0.6469	401	5480	2146	3442	0.1742
7-day maximum	2458	0.7419	312.1	5613	2258	0.5815	360	5151	1994	3121	0.2525
30-day maximum	1965	0.722	257.6	3890	1845	0.5343	332.2	3872	1566	2461	0.2525
90-day maximum	1313	0.8212	183.1	2464	1117	0.7414	216.8	2138	975.1	1693	0.2525
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.09792	0.6648	0.03118	0.2414	0.1091	0.5774	0.0473	0.2264	0.07226	0.1167	0.2525
Parameter Group #3											
Date of minimum	346.5	0.14	1	366	362.5	0.1728	6	364	63.79	328.1	-0.452
Date of maximum	139.5	0.05191	110	263	142	0.0485	106	167	133.6	148.2	0.09596
Parameter Group #4											
Low pulse count	4.5	1.333	0	19	3	2	0	10	2	7	-0.09105
Low pulse duration	4.25	1.588	1	90	4	1.406	1	125	3	8	0.2729
High pulse count	3	0.6667	0	8	2.5	0.8	1	9	2	4	0.03333
High pulse duration	9	4.361	1	100	9	4.403	1.5	100	3.5	36.58	0.2525
The low pulse threshold is			55								
The high pulse threshold is			388								
Parameter Group #5											
Rise rate	14.5	1.078	4	200	11.75	1.087	2	40	11	19.21	-0.2824
Fall rate	-13	-0.7788	-108.5	-5	-10.45	-0.6459	-29	-3.65	-18.21	-10.4	0.01768
Number of reversals	113	0.2434	50	138	110	0.2023	87	139	101	119	0.04831

Assessment of Hydrologic Alteration

	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	12.77	15	0.1742	11.61	14	0.2056	11.61	7	-0.3972
November	13.94	17	0.2199	11.03	13	0.1784	11.03	6	-0.4561
December	14.52	10	-0.3111	10.45	14	0.3395	11.03	12	0.08772
January	12.77	7	-0.452	11.61	16	0.3778	11.61	13	0.1194
February	12.77	7	-0.452	11.61	17	0.4639	11.61	12	0.03333
March	12.77	8	-0.3737	11.61	22	0.8944	11.61	6	-0.4833
April	12.77	18	0.4091	11.61	11	-0.05278	11.61	7	-0.3972
May	12.77	14	0.09596	11.61	11	-0.05278	11.61	11	-0.05278
June	12.77	8	-0.3737	11.61	9	-0.225	11.61	19	0.6361
July	12.77	10	-0.2172	11.61	9	-0.225	11.61	17	0.4639
August	12.77	14	0.09596	11.61	7	-0.3972	11.61	15	0.2917
September	12.77	15	0.1742	11.61	17	0.4639	11.61	4	-0.6556
Parameter Group #2									
1-day minimum	13.94	4	-0.713	11.61	17	0.4639	10.45	15	0.4352
3-day minimum	13.35	6	-0.5507	11.03	15	0.3596	11.61	15	0.2917
7-day minimum	12.77	9	-0.2955	11.61	13	0.1194	11.61	14	0.2056
30-day minimum	12.77	5	-0.6086	11.61	18	0.55	11.61	13	0.1194
90-day minimum	12.77	5	-0.6086	11.61	17	0.4639	11.61	14	0.2056
1-day maximum	12.77	14	0.09596	11.61	9	-0.225	11.61	13	0.1194
3-day maximum	12.77	15	0.1742	11.61	9	-0.225	11.61	12	0.03333
7-day maximum	12.77	16	0.2525	11.61	9	-0.225	11.61	11	-0.05278
30-day maximum	12.77	16	0.2525	11.61	7	-0.3972	11.61	13	0.1194
90-day maximum	12.77	16	0.2525	11.61	9	-0.225	11.61	11	-0.05278
Number of zero days	36	36	0	0	0		0	0	
Base flow index	12.77	16	0.2525	11.61	13	0.1194	11.61	7	-0.3972
Parameter Group #3									
Date of minimum	12.77	7	-0.452	11.61	14	0.2056	11.61	15	0.2917
Date of maximum	12.77	14	0.09596	11.61	12	0.03333	11.61	10	-0.1389
Parameter Group #4									
Low pulse count	20.9	19	-0.09105	9.29	6	-0.3542	5.806	11	0.8944
Low pulse duration	13.35	17	0.2729	9.871	5	-0.4935	9.29	8	-0.1389
High pulse count	23.23	24	0.03333	7.548	7	-0.07265	5.226	5	-0.04321
High pulse duration	12.77	16	0.2525	11.61	10	-0.1389	11.03	10	-0.09357
Parameter Group #5									
Rise rate	13.94	10	-0.2824	11.61	9	-0.225	10.45	17	0.6265
Fall rate	12.77	13	0.01768	11.61	18	0.55	11.61	5	-0.5694
Number of reversals	13.35	14	0.04831	11.03	9	-0.1842	11.61	13	0.1194

IHA Percentile Data

DoloresRiverAtDoloresCO_v2

	Pre-impact period: 1922-1983 (62 years)						Post-impact period: 1984-2019 (36 years)					
	Pre-Impact						Post-Impact					
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	44.2	62.5	81	153	241.2	1.117	57.9	69.2	90.3	141.5	209.9	0.8007
November	43.1	49	60.75	90.13	140.6	0.677	38.49	54.4	69.28	111	130.9	0.817
December	34	40	48	64.25	88.7	0.5052	25.54	41.7	51.95	69	91.41	0.5255
January	33	40	45	55.25	75	0.3389	28.1	36	48	64.65	79.3	0.5969
February	34.75	40	50	65	83.5	0.5	31.9	40.24	55.85	65.52	97.7	0.4528
March	54.3	60.75	80	106.3	152.8	0.5688	59.41	81.5	129.5	212.8	371.6	1.014
April	204.1	276.3	534	892.1	1188	1.153	284.7	462	652.3	838.5	1190	0.5772
May	688.6	1038	1630	2203	2839	0.7147	745.4	1113	1550	2085	2552	0.6274
June	425.5	751.5	1168	2031	2635	1.096	181.9	420.9	833.8	1623	2082	1.441
July	151	204.8	296	422.3	823.5	0.7348	131	168.5	238.5	388.5	517.1	0.9224
August	84.3	132	221	272	394	0.6335	102.4	139.5	195	230.5	346	0.4667
September	57.9	80.5	121	178	295.9	0.8058	76.07	119.6	137.5	195.3	272.9	0.55
Parameter Group #2												
1-day minimum	19	27.5	34	45	50	0.5147	11.57	21.4	35	47.5	64.3	0.7457
3-day minimum	22.03	29.33	35.67	47.5	54.73	0.5093	17.11	22.73	37.5	48.97	66.47	0.6998
7-day minimum	25.46	30.57	37.43	49.21	57.06	0.4981	20.61	25.32	39.5	53.19	72.16	0.7055
30-day minimum	29.58	35.33	42.38	52.27	66.52	0.3995	23.49	29.89	45.35	59.79	79.46	0.6594
90-day minimum	31.94	40.6	46.63	61.67	79.44	0.4518	30.36	37.89	51.07	66.07	81.76	0.5517
1-day maximum	1463	1865	2935	4175	5158	0.7871	1300	1980	2645	3608	4375	0.6153
3-day maximum	1301	1833	2787	3894	4799	0.7395	1242	1925	2450	3510	4265	0.6469
7-day maximum	1180	1666	2458	3489	4145	0.7419	1089	1848	2258	3161	4103	0.5815
30-day maximum	897.6	1308	1965	2727	3320	0.722	871.6	1350	1845	2336	3122	0.5343
90-day maximum	596	836.1	1313	1914	2229	0.8212	541.4	889.1	1117	1717	1976	0.7414
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.06108	0.06781	0.09792	0.1329	0.1762	0.6648	0.05761	0.07885	0.1091	0.1419	0.1589	0.5774
Parameter Group #3												
Date of minimum	262.3	323.3	346.5	8.5	52.4	0.14	271.9	333.3	362.5	30.5	51.2	0.1728
Date of maximum	125	131	139.5	150	160.7	0.05191	125.7	132	142	149.8	158.9	0.0485
Parameter Group #4												
Low pulse count	0.3	2	4.5	8	11	1.333	0	1	3	7	8	2
Low pulse duration	1	2.125	4.25	8.875	37.35	1.588	1.1	2.375	4	8	9.9	1.406
High pulse count	1	2	3	4	6	0.6667	1	2	2.5	4	7.3	0.8
High pulse duration	2	3	9	42.25	66.5	4.361	2	3	9	42.63	70.6	4.403
Parameter Group #5												
Rise rate	8	10	14.5	25.63	49.5	1.078	4.41	6.975	11.75	19.75	29.3	1.087
Fall rate	-38.2	-20	-13	-9.875	-8	-0.7788	-22.4	-14.75	-10.45	-8	-6	-0.6459
Number of reversals	63.3	93.5	113	121	128.7	0.2434	88	97.25	110	119.5	125.3	0.2023
EFC Monthly Low Flows												
October Low Flow	49	62	80	127.5	204.2	0.8188	58.14	69.2	90.3	141.5	209.9	0.8007
November Low Flow	48.2	51.75	63.5	90.25	141.7	0.6063	51.36	59	70	111	131.2	0.7429
December Low Flow	44	46.38	51	65.75	92	0.3799	46.02	50	60	73	93.76	0.3833
January Low Flow	42	45	50	62	80	0.34	42.53	44.53	53.5	66.28	79.9	0.4065
February Low Flow	44.4	48	55	68	85.3	0.3636	43.34	48.9	58	80	107.6	0.5362
March Low Flow	55.2	67	84	107.5	148	0.4821	63.63	81.5	114	140.8	209.2	0.5197
April Low Flow	134.6	162	209	293.6	326.1	0.6298	148.7	183.6	244.5	305	346.1	0.4964
May Low Flow	222.7	270.3	323	370.3	382.7	0.3096	227	227	286	312	312	0.2972
June Low Flow	168.8	240.8	292	325.8	352	0.2911	84.49	189.4	258.3	306	370.5	0.4516
July Low Flow	148	204	269	328	361.5	0.461	136.8	170	236.3	318.4	355.6	0.628
August Low Flow	87.2	132	214	257.5	303.2	0.5864	101.2	137	191	229	298	0.4817
September Low Flow	65.3	89	121	168.8	243.7	0.6591	95.94	119.6	133.3	180.8	239.1	0.4587
EFC Flow Parameters												
Extreme low peak	29.6	33.75	38	39.75	40	0.1579	23.27	28.93	35.5	38.2	40	0.2613
Extreme low duration	1	2	3	5.5	24.6	1.167	1	1.25	4	6	50.7	1.188
Extreme low timing	260.6	330.3	349	4	31.7	0.1086	310.9	340	364	29	37.4	0.1503
Extreme low freq.	0	0	3.5	6	11	1.714	0	0	2	4.75	7	2.375
High flow peak	411.1	441.6	501	949	1704	1.013	423	460	665	1343	1638	1.328
High flow duration	1	2	3	10.38	52.15	2.792	1.5	2	5	34	68.2	6.4
High flow timing	103.4	132.8	189	222.3	242.8	0.2445	99.4	125.5	183	213	250.5	0.2391
High flow frequency	1	1	3	4	5.7	1	1	2	2	3.75	7	0.875
High flow rise rate	30.1	51.97	81.49	130.1	191.3	0.9591	31.68	48.03	72.36	102	216.4	0.7459
High flow fall rate	-114.9	-89.13	-65.5	-44.17	-34.63	-0.6864	-107	-75.25	-58.5	-46.39	-31.37	-0.4934
Small Flood peak	3013	3180	3880	4315	4834	0.2925	2990	3088	3835	4173	4825	0.2829
Small Flood duration	32.85	82.5	96	104.3	111	0.2266	84	88.5	104	111	122	0.2163
Small Flood timing	124.4	131.8	142	152	213.3	0.05533	127	133.5	143	151.8	164	0.04986
Small Flood freq.	0	0	0	1	1	0	0	0	0	1	1	0
Small Flood riserate	61.96	78.94	94.57	171.4	606.7	0.9776	44.99	59.06	67.64	90.32	96.82	0.4622
Small Flood fallrate	-180.4	-79.76	-65.24	-50.39	-40.32	-0.4503	-94.7	-89.05	-61.38	-52.72	-43.81	-0.592
Large flood peak	5200	5268	5775	6650	6950	0.2394			5540			
Large flood duration	84	93	101.5	131.3	135	0.3768			99			
Large flood timing	126	132.8	155	173.5	181	0.1113			145			
Large flood freq.	0	0	0	0	0.7	0	0	0	0	0	0	0
Large flood riserate	55.94	75.53	105.3	336.3	411.6	2.478			110.1			
Large flood fallrate	-284.7	-209.8	-87.72	-65.8	-52.8	-1.642			-97.74			

6 Messages:

The longest period of missing data is 42 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
42 daily values have been interpolated in year 2019
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Non-Parametric IHA Scorecard

SanMiguelRiverNearPlacervilleCO_v2

	Pre-impact period: 1942-1983 (42 years)	Post-impact period: 1984-2019 (36 years)
NormalizationFactor	1	1
Mean annual flow	233.1	239.6
Non-Normalized Mean Flow	233.1	239.6
Annual C. V.	1.25	1.19
Flow predictability	0.62	0.61
Constancy/predictability	0.59	0.58
% of floods in 60d period	0.47	0.47
Flood-free season	158	154

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	93.5	105.5	0.4305	0.6246	0.1283	0.451	0.1241	0.2563
November	78.5	86.2	0.3503	0.3238	0.09809	0.07567	0.3413	0.7878
December	65	63	0.3308	0.407	0.03077	0.2305	0.6146	0.1802
January	61.5	59	0.1748	0.4174	0.04065	1.388	0.5616	0.002002
February	60	62.68	0.1979	0.3779	0.04458	0.9096	0.3644	0.01201
March	61.5	85.5	0.2439	0.4956	0.3902	1.032	0.00	0.008008
April	145.3	222	0.7676	0.6098	0.5284	0.2056	0.001001	0.4645
May	487	499.5	0.6473	0.525	0.02567	0.1889	0.9029	0.5596
June	752	766.5	0.7264	0.7397	0.01928	0.01835	0.9019	0.9289
July	354	345	0.8453	1.053	0.02542	0.2455	0.8989	0.3233
August	180	185.5	0.7361	0.5647	0.03056	0.2329	0.8258	0.4655
September	111	123.8	0.482	0.5788	0.1149	0.2008	0.1962	0.7618
Parameter Group #2								
1-day minimum	44	44.05	0.233	0.4268	0.001136	0.8321	0.959	0.01301
3-day minimum	47.5	46.78	0.2404	0.4111	0.01509	0.7105	0.9079	0.009009
7-day minimum	50.21	49.43	0.2589	0.4403	0.01565	0.7008	0.7177	0.004004
30-day minimum	55.37	53.42	0.1934	0.3771	0.03522	0.9497	0.5495	0.002002
90-day minimum	60.49	61.09	0.2205	0.3497	0.009836	0.5855	0.9039	0.01902
1-day maximum	1155	1235	0.5673	0.4951	0.06926	0.1272	0.5676	0.4805
3-day maximum	1112	1192	0.5609	0.4886	0.07196	0.129	0.4555	0.4625
7-day maximum	1009	1131	0.5865	0.4456	0.1209	0.2402	0.4374	0.2803
30-day maximum	798.3	873.7	0.6569	0.4905	0.09448	0.2533	0.4985	0.2653
90-day maximum	603.2	607.2	0.6289	0.5244	0.006715	0.1662	0.8579	0.5936
Number of zero days	0	0	0	0				
Base flow index	0.2474	0.208	0.5247	0.4104	0.1593	0.2179	0.1752	0.3483
Parameter Group #3								
Date of minimum	24.5	20	0.1154	0.1974	0.02459	0.7101	0.6206	0.01101
Date of maximum	161	154.5	0.05806	0.04508	0.03552	0.2235	0.1001	0.3814
Parameter Group #4								
Low pulse count	7.5	4	0.9667	1.25	0.4667	0.2931	0.03303	0.3564
Low pulse duration	4	3.5	1.281	1.5	0.125	0.1707	0.5445	0.6677
High pulse count	3	3	0.75	1	0	0.3333	0.1852	0.3343
High pulse duration	7.5	5	6.15	7	0.3333	0.1382	0.3323	0.7217
Low Pulse Threshold	65							
High Pulse Threshold	271							
Parameter Group #5								
Rise rate	7.5	7	0.5333	0.6714	0.06667	0.2589	0.5455	0.2422
Fall rate	-8	-6.75	-0.5	-0.737	0.1563	0.4741	0.2182	0.03003
Number of reversals	125.5	124	0.1355	0.1633	0.01195	0.2056	0.7237	0.4755
EFC Low flows								
October Low Flow	93.5	105.5	0.4305	0.6246	0.1283	0.451	0.1241	0.2593
November Low Flow	78.5	86.2	0.3376	0.3173	0.09809	0.06012	0.3283	0.8128
December Low Flow	65	70.2	0.2577	0.2949	0.08	0.1443	0.1692	0.5235
January Low Flow	65	67.1	0.1538	0.2712	0.03231	0.763	0.07407	0.02202
February Low Flow	63.25	67.5	0.1581	0.2444	0.06719	0.5461	0.1341	0.08609
March Low Flow	65	85.5	0.2231	0.4637	0.3154	1.079	0.00	0.006006
April Low Flow	121	158	0.5465	0.6503	0.3058	0.19	0.009009	0.4975
May Low Flow	215	230.5	0.2302	0.1746	0.07209	0.2415	0.4014	0.4324
June Low Flow	252	206.5	0.251	0.434	0.1806	0.7292	0.3734	0.2172
July Low Flow	201.5	193.8	0.2531	0.451	0.03846	0.7818	0.6426	0.04104
August Low Flow	176.5	167.3	0.4873	0.5284	0.05241	0.08445	0.7838	0.8308
September Low Flow	111	122.3	0.473	0.2853	0.1014	0.3968	0.1902	0.3794
EFC Parameters								
Extreme low peak	50.75	47.15	0.07882	0.2185	0.07094	1.772	0.00	0.002002
Extreme low duration	3	5.5	0.6667	5.432	0.8333	7.148	0.005005	0.002002
Extreme low timing	23	13.75	0.111	0.1482	0.05055	0.3354	0.1461	0.3423
Extreme low freq.	5	2	1.45	1.75	0.6	0.2069	0.2613	0.6076
High flow peak	365.5	349.8	0.6005	0.4149	0.04309	0.3091	0.5516	0.6066
High flow duration	5	3.75	4.2	1.3	0.25	0.6905	0.3744	0.2302
High flow timing	182	175.8	0.1995	0.2182	0.03415	0.09418	0.6827	0.5986
High flow frequency	2	3	1.5	0.9167	0.5	0.3889	0.005005	0.4535
High flow rise rate	42.11	49.65	1.086	0.7624	0.1792	0.2982	0.2462	0.2893
High flow fall rate	-30	-38.93	-0.8542	-0.574	0.2976	0.328	0.05906	0.1071
Small Flood peak	1430	1430	0.2552	0.1329	0	0.4795	0.957	0.3053
Small Flood duration	89	101	0.5478	0.3465	0.1348	0.3674	0.2673	0.3834
Small Flood timing	163	159	0.06421	0.02732	0.02186	0.5745	0.3433	0.08609
Small Flood freq.	0	1	0	1				
Small Flood riserate	31.29	29.36	1.026	0.432	0.06159	0.5789	0.7117	0.5145
Small Flood fallrate	-27.64	-20.87	-0.7129	-0.5496	0.245	0.2291	0.2162	0.5195
Large flood peak	2090	2400	0.25		0.1483		0.2222	
Large flood duration	109.5	138	0.1279		0.2603		0.00	
Large flood timing	176	136	0.02254		0.2186		0.00	
Large flood freq.	0	0	0	0				
Large flood riserate	31.04	66.56	0.3432		1.144		0.00	
Large flood fallrate	-37.44	-20	-0.0962		0.4658		0.02703	

EFC low flow threshold:	
EFC high flow threshold:	271
EFC extreme low flow threshold:	55
EFC small flood minimum peak flow:	1155
EFC large flood minimum peak flow:	2035

IHA Non-Parametric RVA Scorecard

SanMiguelRiverNearPlacervilleCO_v2

	Pre-impact period: 1942-1983				Post-impact period: 1984-2019				RVA Boundaries		Hydrologic Alteratic
	Medians	Coeff. of Dispersion	Minimum	Maximum	Medians	Coeff. of Dispersion	Minimum	Maximum	Low	High	(Middle Category)
Parameter Group #1											
October	93.5	0.4305	50	174	105.5	0.6246	60	217	80	104.8	-0.1444
November	78.5	0.3503	55.5	124	86.2	0.3238	49.2	140	68.38	87.5	-0.1444
December	65	0.3308	38	123	63	0.407	40.7	107	60	72.81	-0.4896
January	61.5	0.1748	38	123	59	0.4174	38.3	100	57.57	65	-0.6759
February	60	0.1979	44	123	62.68	0.3779	37	95	55	64.22	-0.287
March	61.5	0.2439	47	123	85.5	0.4956	51.9	207	58.19	69.43	-0.3333
April	145.3	0.7676	73.5	610	222	0.6098	90.3	512	127.7	188.3	-0.4167
May	487	0.6473	124	1530	499.5	0.525	175	1700	402.4	531.8	-0.4167
June	752	0.7264	253.5	1420	766.5	0.7397	134	1430	576.2	967.7	-0.08333
July	354	0.8453	99	1080	345	1.053	63.4	1120	263.8	456.3	-0.25
August	180	0.7361	80	476	185.5	0.5647	53.4	496	154.6	224.4	0.25
September	111	0.482	60.5	298	123.8	0.5788	52.9	358	98.57	123.8	-0.08333
Parameter Group #2											
1-day minimum	44	0.233	26	113	44.05	0.4268	26.2	70	40	50	-0.5435
3-day minimum	47.5	0.2404	30	117	46.78	0.4111	29.7	73.67	43.46	52.54	-0.25
7-day minimum	50.21	0.2589	31.14	123	49.43	0.4403	32.2	76.43	47.86	53.4	-0.6111
30-day minimum	55.37	0.1934	34.93	123	53.42	0.3771	36.67	86	51.45	60.26	-0.5833
90-day minimum	60.49	0.2205	40.54	123	61.09	0.3497	41.36	93.24	55.47	63.36	-0.6667
1-day maximum	1155	0.5673	376	2740	1235	0.4951	354	2400	912.7	1360	-0.1444
3-day maximum	1112	0.5609	349	2617	1192	0.4886	303	2273	870	1317	0
7-day maximum	1009	0.5865	325.7	2386	1131	0.4456	241.7	2017	808.4	1208	0.08333
30-day maximum	798.3	0.6569	231.7	1677	873.7	0.4905	210.7	1679	637.8	1046	0.5
90-day maximum	603.2	0.6289	158.1	1219	607.2	0.5244	158.6	1155	442.5	685.4	0.3333
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.2474	0.5247	0.1037	0.4027	0.208	0.4104	0.1193	0.487	0.1991	0.2806	0.1667
Parameter Group #3											
Date of minimum	24.5	0.1154	1	364	20	0.1974	12	361	30.38	63.62	-0.08333
Date of maximum	161	0.05806	135	250	154.5	0.04508	120	255	154.6	165.8	-0.08333
Parameter Group #4											
Low pulse count	7.5	0.9667	0	19	4	1.25	0	13	5.19	11	-0.02778
Low pulse duration	4	1.281	1	29.5	3.5	1.5	1	120	3	6	-0.1574
High pulse count	3	0.75	1	8	3	1	1	9	2	4	0.1181
High pulse duration	7.5	6.15	1	124	5	7	1	119	5.595	33.22	-0.4167
The low pulse threshold is			65								
The high pulse threshold is			271								
Parameter Group #5											
Rise rate	7.5	0.5333	5	30	7	0.6714	0.45	20	7	9.405	-0.4556
Fall rate	-8	-0.5	-26	-4	-6.75	-0.737	-18	-2.6	-9	-7	-0.5882
Number of reversals	125.5	0.1355	65	149	124	0.1633	81	159	122	134.9	-0.06667

Assessment of Hydrologic Alteration

	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	12.86	11	-0.1444	12	19	0.5833	11.14	6	-0.4615
November	12.86	11	-0.1444	11.14	17	0.5256	12	8	-0.3333
December	13.71	7	-0.4896	12	13	0.08333	10.29	16	0.5556
January	15.43	5	-0.6759	8.571	14	0.6333	12	17	0.4167
February	15.43	11	-0.287	12	16	0.3333	8.571	9	0.05
March	12	8	-0.3333	12	26	1.167	12	2	-0.8333
April	12	7	-0.4167	12	23	0.9167	12	6	-0.5
May	12	7	-0.4167	12	17	0.4167	12	12	0
June	12	11	-0.08333	12	13	0.08333	12	12	0
July	12	9	-0.25	12	12	0	12	15	0.25
August	12	15	0.25	12	7	-0.4167	12	14	0.1667
September	12	11	-0.08333	12	18	0.5	12	7	-0.4167
Parameter Group #2									
1-day minimum	19.71	9	-0.5435	8.571	12	0.4	7.714	15	0.9444
3-day minimum	12	9	-0.25	12	12	0	12	15	0.25
7-day minimum	12.86	5	-0.6111	12	14	0.1667	11.14	17	0.5256
30-day minimum	12	5	-0.5833	12	15	0.25	12	16	0.3333
90-day minimum	12	4	-0.6667	12	17	0.4167	12	15	0.25
1-day maximum	12.86	11	-0.1444	11.14	15	0.3462	12	10	-0.1667
3-day maximum	12	12	0	12	14	0.1667	12	10	-0.1667
7-day maximum	12	13	0.08333	12	16	0.3333	12	7	-0.4167
30-day maximum	12	18	0.5	12	12	0	12	6	-0.5
90-day maximum	12	16	0.3333	12	12	0	12	8	-0.3333
Number of zero days	36	36	0	0	0		0	0	
Base flow index	12	14	0.1667	12	7	-0.4167	12	15	0.25
Parameter Group #3									
Date of minimum	12	11	-0.08333	12	18	0.5	12	7	-0.4167
Date of maximum	12	11	-0.08333	12	7	-0.4167	12	18	0.5
Parameter Group #4									
Low pulse count	15.43	15	-0.02778	8.571	1	-0.8833	12	20	0.6667
Low pulse duration	15.43	13	-0.1574	10.29	10	-0.02778	8.571	11	0.2833
High pulse count	20.57	23	0.1181	8.571	10	0.1667	6.857	3	-0.5625
High pulse duration	12	7	-0.4167	12	10	-0.1667	12	19	0.5833
Parameter Group #5									
Rise rate	12.86	7	-0.4556	12	12	0	11.14	17	0.5256
Fall rate	14.57	6	-0.5882	11.14	18	0.6154	10.29	12	0.1667
Number of reversals	12.86	12	-0.06667	12	8	-0.3333	11.14	16	0.4359

IHA Percentile Data

SanMiguelRiverNearPlacervilleCO_v2

	Pre-impact period: 1942-1983 (42 years)		Pre-Impact				Post-impact period: 1984-2019 (36 years)		Post-Impact			
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	65	69.75	93.5	110	156.2	0.4305	70.99	86.85	105.5	152.8	179.3	0.6246
November	57.8	64	78.5	91.5	115.8	0.3503	53.98	69.21	86.2	97.13	112.8	0.3238
December	52.9	55.75	65	77.25	94.4	0.3308	49.33	51.66	63	77.3	89.3	0.407
January	47.2	55	61.5	65.75	74.4	0.1748	43.23	47.7	59	72.33	82.9	0.4174
February	48.6	54.75	60	66.63	77.1	0.1979	45.12	52.56	62.68	76.25	82.3	0.3779
March	51.6	56	61.5	71	81.4	0.2439	62.33	66.63	85.5	109	126.7	0.4956
April	87.15	104	145.3	215.5	376.6	0.7676	109.3	156.8	222	292.1	344.5	0.6098
May	235.1	327.8	487	643	939.5	0.6473	289.4	370.8	499.5	633	834	0.525
June	411.2	518.8	752	1065	1187	0.7264	306.9	510.5	766.5	1078	1230	0.7397
July	162	208.3	354	507.5	848.5	0.8453	108.6	188.8	345	552	699.2	1.053
August	97	129.8	180	262.3	328.3	0.7361	96	117.5	185.5	222.3	319.9	0.5647
September	77.9	90	111	143.5	217.8	0.482	88.09	102.6	123.8	174.3	230.4	0.5788
Parameter Group #2												
1-day minimum	35	40	44	50.25	60	0.233	28.61	36.2	44.05	55	62	0.4268
3-day minimum	38.2	42	47.5	53.42	64.03	0.2404	31.98	39.1	46.78	58.33	66.3	0.4111
7-day minimum	40.91	44.64	50.21	57.64	65.14	0.2589	34.59	40.4	49.43	62.16	73.4	0.4403
30-day minimum	45.56	50.1	55.37	60.81	68.47	0.1934	41.15	46.44	53.42	66.58	76.27	0.3771
90-day minimum	49.88	54.18	60.49	67.52	74.68	0.2205	48.09	51.14	61.09	72.5	80.47	0.3497
1-day maximum	677	869.8	1155	1525	2035	0.5673	621.6	893.5	1235	1505	1698	0.4951
3-day maximum	647.4	833.9	1112	1458	1944	0.5609	582.9	858.6	1192	1441	1681	0.4886
7-day maximum	615.1	771.3	1009	1363	1765	0.5865	534.4	835.8	1131	1340	1612	0.4456
30-day maximum	500.3	595.7	798.3	1120	1341	0.6569	452.4	678.7	873.7	1107	1318	0.4905
90-day maximum	329.8	422.6	603.2	802	979.6	0.6289	299.9	457.5	607.2	775.9	929.9	0.5244
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.1426	0.1764	0.2474	0.3062	0.3485	0.5247	0.1529	0.1769	0.208	0.2623	0.3469	0.4104
Parameter Group #3												
Date of minimum	345.9	2.5	24.5	44.75	64.7	0.1154	330.7	345.3	20	51.5	66.9	0.1974
Date of maximum	143.9	149	161	170.3	181.4	0.05806	138.1	146.5	154.5	163	170.3	0.04508
Parameter Group #4												
Low pulse count	2	4	7.5	11.25	13.4	0.9667	1	2	4	7	10	1.25
Low pulse duration	2	2.625	4	7.75	15.3	1.281	1	2	3.5	7.25	56	1.5
High pulse count	1	2	3	4.25	6	0.75	1.7	2	3	5	8	1
High pulse duration	1.65	3.75	7.5	49.88	88.7	6.15	1.5	2.125	5	37.13	81.65	7
Parameter Group #5												
Rise rate	5	6	7.5	10	12	0.5333	3	5.3	7	10	13.2	0.6714
Fall rate	-12	-10	-8	-6	-5	-0.5	-12.15	-10	-6.75	-5.025	-4.32	-0.737
Number of reversals	110.1	121	125.5	138	145.7	0.1355	110	113.8	124	134	148.6	0.1633
EFC Monthly Low Flows												
October Low Flow	65.6	69.75	93.5	110	156.2	0.4305	70.99	86.85	105.5	152.8	173.4	0.6246
November Low Flow	60.3	65	78.5	91.5	115.8	0.3376	62.34	69.77	86.2	97.13	112.8	0.3173
December Low Flow	60	61	65	77.75	94.8	0.2577	57.2	60.3	70.2	81	89.9	0.2949
January Low Flow	58.8	60	65	70	76	0.1538	56.82	59.8	67.1	78	86	0.2712
February Low Flow	57	60	63.25	70	78.4	0.1581	59	61.6	67.5	78.1	82.8	0.2444
March Low Flow	59.2	60.5	65	75	88	0.2231	64.68	68.6	85.5	108.3	127	0.4637
April Low Flow	75.3	94.88	121	161	200	0.5465	98.07	115.8	158	218.5	232.3	0.6503
May Low Flow	127.2	196.8	215	246.3	260	0.2302	183.3	206.8	230.5	247	256.7	0.1746
June Low Flow	145	194.8	252	258	258	0.251	134	164.6	206.5	254.3	271	0.434
July Low Flow	148.2	185	201.5	236	251.8	0.2531	88.65	149.5	193.8	236.9	264.5	0.451
August Low Flow	97	129.8	176.5	215.8	247.2	0.4873	94	113.8	167.3	202.1	215.5	0.5284
September Low Flow	77.9	90	111	142.5	208	0.473	88.09	102.6	122.3	137.5	198.9	0.2853
EFC Flow Parameters												
Extreme low peak	45.7	50	50.75	54	55	0.07882	29.86	42.16	47.15	52.46	55	0.2185
Extreme low duration	1	2	3	4	6	0.6667	1	2.25	5.5	32.13	66.1	5.432
Extreme low timing	359	9.25	23	49.88	70.5	0.111	325.9	345	13.75	33.25	69.6	0.1482
Extreme low freq.	0	1.75	5	9	17.7	1.45	0	1	2	4.5	8.3	1.75
High flow peak	292	319.5	365.5	539	808	0.6005	308.3	320	349.8	465.1	680.8	0.4149
High flow duration	1	2.5	5	23.5	57	4.2	1.25	2	3.75	6.875	18	1.3
High flow timing	125	149	182	222	251.5	0.1995	111.5	137	175.8	216.9	231.3	0.2182
High flow frequency	1	1	2	4	5.7	1.5	1	1.25	3	4	8	0.9167
High flow rise rate	16.23	24.26	42.11	70	109	1.086	25.99	34.58	49.65	72.44	157.1	0.7624
High flow fall rate	-55.5	-48	-30	-22.38	-13.44	-0.8542	-78.13	-50.75	-38.93	-28.41	-20.38	-0.574
Small Flood peak	1192	1255	1430	1620	1936	0.2552	1200	1360	1430	1550	1740	0.1329
Small Flood duration	40.4	62.75	89	111.5	123.2	0.5478	60	84	101	119	128	0.3465
Small Flood timing	139	148	163	171.5	218.4	0.06421	139	153	159	163	171	0.02732
Small Flood freq.	0	0	0	1	1	0	0	0	1	1	1	1
Small Flood riserate	22.74	24.51	31.29	56.61	254.5	1.026	19.36	24.66	29.36	37.34	68.63	0.432
Small Flood fallrate	-71.96	-38.87	-27.64	-19.17	-15.04	-0.7129	-36	-30.64	-20.87	-19.17	-11.31	-0.5496
Large flood peak	2050	2058	2090	2580	2740	0.25			2400			
Large flood duration	107	107	109.5	121	124	0.1279			138			
Large flood timing	171	171.5	176	179.8	180	0.02254			136			
Large flood freq.	0	0	0	0	0.7	0	0	0	0	0	0	0
Large flood riserate	29.36	29.62	31.04	40.28	43.14	0.3432			66.56			
Large flood fallrate	-37.96	-37.93	-37.44	-34.32	-33.42	-0.0962			-20			

7 Messages:

The longest period of missing data is 182 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
182 daily values have been interpolated in year 1942
141 daily values have been interpolated in year 2019
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Non-Parametric IHA Scorecard

SanMiguelRiverAtUravanCO_Non-Parametric

	Pre-impact period: 1974-1983 (10 years)	Post-impact period: 1984-2019 (35 years)
NormalizationFactor	1	1
Mean annual flow	363.5	329.3
Non-Normalized Mean Flow	363.5	329.3
Annual C. V.	1.54	1.43
Flow predictability	0.55	0.47
Constancy/predictability	0.5	0.55
% of floods in 60d period	0.4	0.4
Flood-free season	125	79

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	102.5	129	0.5415	0.7039	0.2585	0.3	0.0981	0.5866
November	87.5	105.5	0.4114	0.5166	0.2057	0.2556	0.06206	0.5746
December	82.5	81.2	0.5455	0.5936	0.01576	0.08826	0.9299	0.7718
January	75	85.5	0.5433	0.5415	0.14	0.003337	0.3914	0.994
February	81.75	99.5	0.6284	0.5196	0.2171	0.1732	0.1131	0.6016
March	102.5	142	0.6659	0.8345	0.3854	0.2533	0.05105	0.5676
April	293.5	617	2.591	0.8071	1.102	0.6885	0.01401	0.1932
May	1110	846	1.061	0.8085	0.2378	0.2377	0.1902	0.6146
June	1080	756.5	0.9102	1.007	0.2995	0.1067	0.3824	0.7578
July	451	233	1.068	1.644	0.4834	0.5389	0.3654	0.2583
August	121.5	135	1.71	0.9926	0.1111	0.4195	0.7668	0.3083
September	78.25	83.15	1.387	0.9314	0.06262	0.3282	0.7598	0.5015
Parameter Group #2								
1-day minimum	27.5	30	0.7545	1.033	0.09091	0.3695	0.7718	0.3483
3-day minimum	30.83	33.1	0.7811	1.027	0.07351	0.3151	0.8999	0.4545
7-day minimum	34.57	38.13	0.7335	0.9963	0.1029	0.3583	0.8218	0.3634
30-day minimum	56.97	53.32	0.493	0.9847	0.06396	0.9975	0.9159	0.02703
90-day minimum	75.64	85.16	0.2342	0.4517	0.1258	0.9283	0.4394	0.05105
1-day maximum	2170	1790	0.8502	0.6704	0.1751	0.2115	0.3624	0.5796
3-day maximum	1948	1580	0.8749	0.6555	0.1891	0.2508	0.3183	0.5465
7-day maximum	1595	1346	1.031	0.7178	0.1563	0.3036	0.4545	0.5566
30-day maximum	1252	1013	0.9285	0.8039	0.191	0.1341	0.2793	0.7648
90-day maximum	1092	803.3	0.9448	0.783	0.2643	0.1712	0.1522	0.6997
Number of zero days	0	0	0	0				
Base flow index	0.1165	0.1402	0.755	0.5548	0.2032	0.2651	0.2392	0.5526
Parameter Group #3								
Date of minimum	282	251	0.2876	0.1366	0.1694	0.5249	0.03704	0.3574
Date of maximum	128.5	133	0.08607	0.1448	0.02459	0.6825	0.8058	0.1451
Parameter Group #4								
Low pulse count	14	6	0.75	1.333	0.5714	0.7778	0.1321	0.1702
Low pulse duration	2	5	0.75	0.7	1.5	0.06667	0.00	0.8779
High pulse count	4.5	3	1	1	0.3333	0	0.2192	0.7467
High pulse duration	3.75	4	17.13	5.25	0.06667	0.6936	0.9029	0.5886
Low Pulse Threshold	75							
High Pulse Threshold	356							
Parameter Group #5								
Rise rate	15	12.6	0.5667	0.873	0.16	0.5406	0.3844	0.1962
Fall rate	-12.75	-11	-0.3529	-0.6636	0.1373	0.8803	0.4444	0.1171
Number of reversals	129.5	124	0.1873	0.1935	0.04247	0.03359	0.5355	0.9429
EFC Low flows								
October Low Flow	106	129.5	0.4764	0.689	0.2217	0.4462	0.1041	0.4384
November Low Flow	88.75	107.5	0.3859	0.507	0.2113	0.3137	0.05906	0.5005
December Low Flow	85	88.7	0.5132	0.5048	0.04353	0.01645	0.8839	0.9469
January Low Flow	75	87.15	0.5433	0.455	0.162	0.1626	0.3223	0.6557
February Low Flow	81.75	101.3	0.5749	0.4319	0.2385	0.2489	0.06907	0.4334
March Low Flow	102.5	127	0.622	0.4724	0.239	0.2404	0.07808	0.5045
April Low Flow	185	244	0.7378	0.4129	0.3189	0.4404	0.01101	0.3273
May Low Flow	120.5	265.8	0.4896	0.3791	1.205	0.2257	0.03704	0.6176
June Low Flow	283	240	0.4841	0.6104	0.1519	0.2609	0.6607	0.6106
July Low Flow	205	194.8	0.6049	0.7176	0.05	0.1863	0.8148	0.6136
August Low Flow	123.8	138	1.153	0.6377	0.1152	0.4467	0.5205	0.2322
September Low Flow	89.75	109.5	0.8329	0.5621	0.2201	0.3251	0.3814	0.4314
EFC Parameters								
Extreme low peak	37	39.15	0.4257	0.2024	0.05811	0.5245	0.5005	0.1421
Extreme low duration	2.5	4.75	1	0.9737	0.9	0.02632	0.03704	0.976
Extreme low timing	337	246.8	0.3033	0.1475	0.4932	0.5135	0.07908	0.6476
Extreme low freq.	4	2	1.5	2.5	0.5	0.6667	0.0991	0.2182
High flow peak	489	548	0.4034	0.5255	0.1207	0.3029	0.4454	0.7277
High flow duration	1.5	3.75	3.167	2.267	1.5	0.2842	0.00	0.7908
High flow timing	154.5	159.8	0.3637	0.2541	0.02869	0.3014	0.9249	0.3293
High flow frequency	4	3	1.188	1	0.25	0.1579	0.2903	0.6737
High flow rise rate	123.8	105.6	1.725	1.127	0.1465	0.3469	0.4755	0.3724
High flow fall rate	-121.3	-57.93	-1.167	-0.981	0.5222	0.1591	0.007007	0.7818
Small Flood peak	2520	2885	0.4415	0.2288	0.1448	0.4818	0.1942	0.4915
Small Flood duration	99	121	0.4242	0.2562	0.2222	0.3961	0.3804	0.8198
Small Flood timing	115.5	118.5	0.04918	0.0929	0.01639	0.8889	0.6046	0.3403
Small Flood freq.	0	0	0	0				
Small Flood riserate	289.7	73.4	1.353	0.6418	0.7466	0.5255	0.04605	0.4945
Small Flood fallrate	-29.21	-30.63	-0.7846	-0.7276	0.04852	0.07266	0.971	0.7077
Large flood peak	4980	5440			0.09237		0.00	
Large flood duration	127	119			0.06299		0.1772	
Large flood timing	131	137			0.03279		0.00	
Large flood freq.	0	0	0	0				
Large flood riserate	205.7	125.7			0.3891		0.1772	
Large flood fallrate	-44.11	-64.41			0.46		0.00	

EFC low flow threshold:	
EFC high flow threshold:	356
EFC extreme low flow threshold:	50.3
EFC small flood minimum peak flow:	2170
EFC large flood minimum peak flow:	4861

IHA Non-Parametric RVA Scorecard

SanMiguelRiverAtUravanCO_Non-Parametric

	Pre-impact period: 1974-1983 Medians	Coeff. of Dispersion	Minimum	Maximum	Post-impact period: 1984-2019 Medians	Coeff. of Dispersion	Minimum	Maximum	RVA Boundaries Low	High	Hydrologic Alteratio (Middle Category)
Parameter Group #1											
October	102.5	0.5415	35	234	129	0.7039	40	332	79	115.4	-0.3143
November	87.5	0.4114	64	161	105.5	0.5166	40	335.5	80.34	101.2	-0.2857
December	82.5	0.5455	49	133	81.2	0.5936	38.2	170	66.3	93.7	-0.4286
January	75	0.5433	50	130	85.5	0.5415	40	140	68.78	90.92	-0.2857
February	81.75	0.6284	55	152	99.5	0.5196	40	170	68.52	103.3	0
March	102.5	0.6659	61	201	142	0.8345	40	696	89.41	130.1	-0.3571
April	293.5	2.591	75.5	1171	617	0.8071	40	2055	248.4	670.7	-0.07143
May	1110	1.061	77	2190	846	0.8085	40	3280	782.6	1466	0.07143
June	1080	0.9102	208	2345	756.5	1.007	40	1630	552	1297	0.2143
July	451	1.068	59	1210	233	1.644	8.07	881	235.2	552.4	-0.2143
August	121.5	1.71	28	590	135	0.9926	6.32	607	63.41	223.5	0.5714
September	78.25	1.387	23	383.5	83.15	0.9314	12.5	308	46.08	108.4	0.07143
Parameter Group #2											
1-day minimum	27.5	0.7545	9.4	90	30	1.033	2.61	104	24.63	37.11	-0.4286
3-day minimum	30.83	0.7811	10.8	94	33.1	1.027	3.08	106	25.59	37.78	-0.5
7-day minimum	34.57	0.7335	14.06	99.57	38.13	0.9963	3.947	114.3	26.73	41.68	-0.4286
30-day minimum	56.97	0.493	21.57	118.5	53.32	0.9847	8.515	129.8	49.25	65.05	-0.7857
90-day minimum	75.64	0.2342	50.77	135.1	85.16	0.4517	15.14	163.6	68.7	79.94	-0.5
1-day maximum	2170	0.8502	805	4980	1790	0.6704	197	5440	1587	2491	-0.2143
3-day maximum	1948	0.8749	758.3	4613	1580	0.6555	155.3	5170	1355	2290	-0.07143
7-day maximum	1595	1.031	420.4	3583	1346	0.7178	127	4819	1190	2052	-0.1429
30-day maximum	1252	0.9285	184.3	2694	1013	0.8039	73.7	3558	1001	1693	-0.1429
90-day maximum	1092	0.9448	139.8	2239	803.3	0.783	51.21	2327	653	1354	0.2143
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.1165	0.755	0.05315	0.2525	0.1402	0.5548	0.05341	0.7584	0.08165	0.1508	0.1429
Parameter Group #3											
Date of minimum	282	0.2876	1	365	251	0.1366	22	366	254.4	304.1	-0.07143
Date of maximum	128.5	0.08607	110	229	133	0.1448	92	280	117.6	136.7	-0.7143
Parameter Group #4											
Low pulse count	14	0.75	0	20	6	1.333	0	19	9.63	17.74	-0.2143
Low pulse duration	2	0.75	1	6	5	0.7	1	17	2	2	-0.8286
High pulse count	4.5	1	1	10	3	1	0	11	3.26	6	-0.2571
High pulse duration	3.75	17.13	1	105	4	5.25	1	119	1.945	24.5	0.6429
The low pulse threshold is			75								
The high pulse threshold is			356								
Parameter Group #5											
Rise rate	15	0.5667	6	24	12.6	0.873	2.205	38	12.32	17.48	-0.6429
Fall rate	-12.75	-0.3529	-21	-7	-11	-0.6636	-30	-2.8	-14	-11	-0.7143
Number of reversals	129.5	0.1873	106	147	124	0.1935	8	144	119.7	135.1	0.1429

Assessment of Hydrologic Alteration

	Middle RVA Category Expected	Observed	Alter.	High RVA Category Expected	Observed	Alter.	Low RVA Category Expected	Observed	Alter.
Parameter Group #1									
October	17.5	12	-0.3143	10.5	19	0.8095	7	4	-0.4286
November	14	10	-0.2857	10.5	20	0.9048	10.5	5	-0.5238
December	14	8	-0.4286	10.5	16	0.5238	10.5	11	0.04762
January	14	10	-0.2857	10.5	15	0.4286	10.5	10	-0.04762
February	14	14	0	10.5	16	0.5238	10.5	5	-0.5238
March	14	9	-0.3571	10.5	20	0.9048	10.5	6	-0.4286
April	14	13	-0.07143	10.5	16	0.5238	10.5	6	-0.4286
May	14	15	0.07143	10.5	5	-0.5238	10.5	15	0.4286
June	14	17	0.2143	10.5	5	-0.5238	10.5	13	0.2381
July	14	11	-0.2143	10.5	6	-0.4286	10.5	18	0.7143
August	14	22	0.5714	10.5	4	-0.619	10.5	9	-0.1429
September	14	15	0.07143	10.5	13	0.2381	10.5	7	-0.3333
Parameter Group #2									
1-day minimum	14	8	-0.4286	10.5	14	0.3333	10.5	13	0.2381
3-day minimum	14	7	-0.5	10.5	16	0.5238	10.5	12	0.1429
7-day minimum	14	8	-0.4286	10.5	17	0.619	10.5	10	-0.04762
30-day minimum	14	3	-0.7857	10.5	16	0.5238	10.5	16	0.5238
90-day minimum	14	7	-0.5	10.5	18	0.7143	10.5	10	-0.04762
1-day maximum	14	11	-0.2143	10.5	8	-0.2381	10.5	16	0.5238
3-day maximum	14	13	-0.07143	10.5	8	-0.2381	10.5	14	0.3333
7-day maximum	14	12	-0.1429	10.5	8	-0.2381	10.5	15	0.4286
30-day maximum	14	12	-0.1429	10.5	7	-0.3333	10.5	16	0.5238
90-day maximum	14	17	0.2143	10.5	6	-0.4286	10.5	12	0.1429
Number of zero days	35	35	0	0	0		0	0	
Base flow index	14	16	0.1429	10.5	14	0.3333	10.5	5	-0.5238
Parameter Group #3									
Date of minimum	14	13	-0.07143	10.5	3	-0.7143	10.5	19	0.8095
Date of maximum	14	4	-0.7143	10.5	17	0.619	10.5	14	0.3333
Parameter Group #4									
Low pulse count	14	11	-0.2143	10.5	1	-0.9048	10.5	23	1.19
Low pulse duration	17.5	3	-0.8286	7	24	2.429	7	2	-0.7143
High pulse count	17.5	13	-0.2571	7	3	-0.5714	10.5	19	0.8095
High pulse duration	14	23	0.6429	10.5	8	-0.2381	10.5	2	-0.8095
Parameter Group #5									
Rise rate	14	5	-0.6429	10.5	13	0.2381	10.5	17	0.619
Fall rate	24.5	7	-0.7143	3.5	16	3.571	7	12	0.7143
Number of reversals	14	16	0.1429	10.5	6	-0.4286	10.5	13	0.2381

IHA Percentile Data

SanMiguelRiverAtUravanCO_Non-Parametric

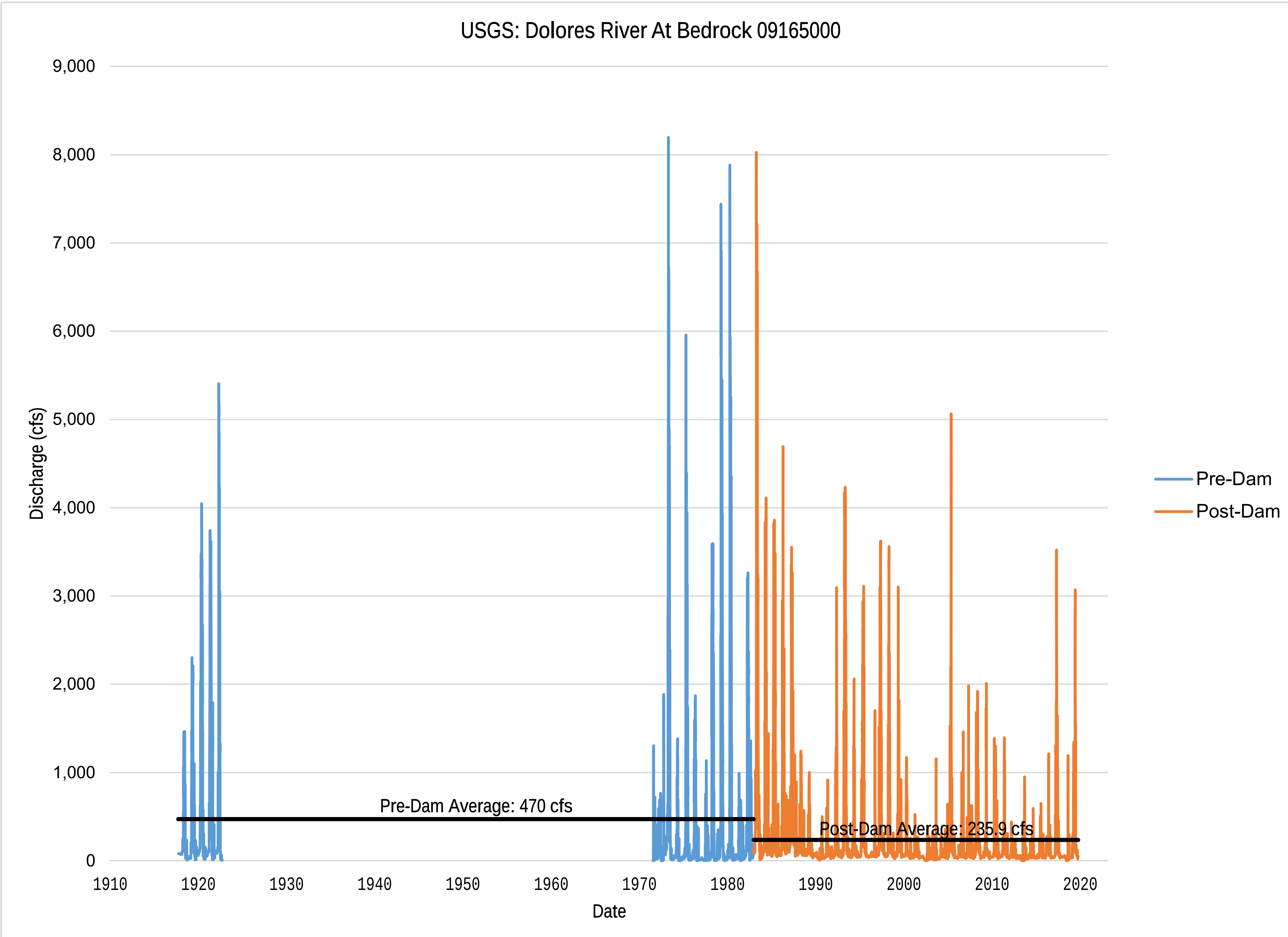
	Pre-impact period: 1974-1983 (10 years)						Post-impact period: 1984-2019 (35 years)					
	Pre-Impact						Post-Impact					
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	37.8	75	102.5	130.5	224.4	0.5415	73.18	91.2	129	182	247.4	0.7039
November	64.95	76.5	87.5	112.5	156.9	0.4114	71.61	87.5	105.5	142	171.6	0.5166
December	49.7	59	82.5	104	131.3	0.5455	52.32	61.8	81.2	110	145.4	0.5936
January	51.5	65	75	105.8	129	0.5433	48.28	62.7	85.5	109	125.2	0.5415
February	55.55	64.63	81.75	116	149	0.6284	61.17	73.3	99.5	125	133	0.5196
March	62.8	83.5	102.5	151.8	198.4	0.6659	74.56	97.5	142	216	374.8	0.8345
April	81.15	184.1	293.5	944.5	1151	2.591	156.9	445	617	943	1195	0.8071
May	85.6	480.3	1110	1658	2145	1.061	238.4	516	846	1200	1994	0.8085
June	227.3	463.3	1080	1446	2256	0.9102	130.2	433	756.5	1195	1477	1.007
July	66.9	195.8	451	677.5	1189	1.068	37.84	117	233	500	678.8	1.644
August	30.6	57.75	121.5	265.5	565.8	1.71	31.14	63	135	197	301.4	0.9926
September	23.5	40.38	78.25	148.9	361.5	1.387	36.79	59.55	83.15	137	267.6	0.9314
Parameter Group #2												
1-day minimum	9.66	21	27.5	41.75	86	0.7545	12.14	21	30	52	91.6	1.033
3-day minimum	11.02	21.5	30.83	45.58	90.93	0.7811	14.61	22.33	33.1	56.33	98.33	1.027
7-day minimum	14.12	22.64	34.57	48	96.26	0.7335	16.43	25.16	38.13	63.14	106.7	0.9963
30-day minimum	22.3	40.95	56.97	69.03	113.6	0.493	30.8	39.16	53.32	91.67	118.4	0.9847
90-day minimum	51.91	65.53	75.64	83.24	130.5	0.2342	46.72	65.66	85.16	104.1	133.6	0.4517
1-day maximum	812.5	1075	2170	2920	4861	0.8502	615	1070	1790	2270	3340	0.6704
3-day maximum	762.2	837.9	1948	2543	4480	0.8749	561.9	967.7	1580	2003	3097	0.6555
7-day maximum	452.8	790.9	1595	2435	3533	1.031	473.5	902.6	1346	1869	2878	0.7178
30-day maximum	213.4	660	1252	1823	2621	0.9285	355.4	703.5	1013	1518	2281	0.8039
90-day maximum	159.7	475.9	1092	1507	2181	0.9448	251.1	528	803.3	1157	1691	0.783
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index	0.05334	0.06755	0.1165	0.1555	0.243	0.755	0.06564	0.09455	0.1402	0.1723	0.2559	0.5548
Parameter Group #3												
Date of minimum	225.7	255.3	282	360.5	0.8	0.2876	30	224	251	274	298.6	0.1366
Date of maximum	110.4	116.3	128.5	147.8	222.3	0.08607	99.6	106	133	159	259	0.1448
Parameter Group #4												
Low pulse count	0.7	8.5	14	19	19.9	0.75	0	3	6	11	14.2	1.333
Low pulse duration	1	1.5	2	3	6	0.75	2	3	5	6.5	9	0.7
High pulse count	1	1.75	4.5	6.25	9.7	1	1	2	3	5	6.4	1
High pulse duration	1	1	3.75	65.25	103.8	17.13	2	2.5	4	23.5	53	5.25
Parameter Group #5												
Rise rate	6.4	11.5	15	20	23.6	0.5667	7.02	10	12.6	21	30.4	0.873
Fall rate	-20.9	-15.5	-12.75	-11	-7.4	-0.3529	-23.4	-16.3	-11	-9	-5.56	-0.6636
Number of reversals	106.7	113.8	129.5	138	146.4	0.1873	96	109	124	133	140.4	0.1935
EFC Monthly Low Flows												
October Low Flow	64.6	79.75	106	130.3	224.3	0.4764	85.88	94.52	129.5	183.8	248.8	0.689
November Low Flow	67	78.25	88.75	112.5	156.9	0.3859	79.78	87.5	107.5	142	171.8	0.507
December Low Flow	60	60.38	85	104	131.3	0.5132	60.25	65.23	88.7	110	146	0.5048
January Low Flow	56	65	75	105.8	129	0.5433	55.25	69.6	87.15	109.3	126	0.455
February Low Flow	60.6	69	81.75	116	149	0.5749	68.8	81.4	101.3	125.1	133.3	0.4319
March Low Flow	66.85	85.75	102.5	149.5	197.5	0.622	81	101	127	161	223.5	0.4724
April Low Flow	83	109	185	245.5	305.5	0.7378	124.2	199.5	244	300.3	330.1	0.4129
May Low Flow	91	91	120.5	150	150	0.4896	107.3	221.8	265.8	322.5	334.4	0.3791
June Low Flow	208	208	283	345	345	0.4841	120	159	240	305.5	347.8	0.6104
July Low Flow	101	132	205	256	334.5	0.6049	100.9	118.3	194.8	258	315.3	0.7176
August Low Flow	68.05	89.88	123.8	232.5	291.6	1.153	72.56	93	138	181	220	0.6377
September Low Flow	60	83.88	89.75	158.6	331	0.8329	66.4	77.45	109.5	139	211.4	0.5621
EFC Flow Parameters												
Extreme low peak	29.5	31.75	37	47.5	50	0.4257	27.63	35.5	39.15	43.43	48.3	0.2024
Extreme low duration	1	1	2.5	3.5	27	1	1	2	4.75	6.625	13.1	0.9737
Extreme low timing	239.5	270.5	337	15.5	71	0.3033	18.25	213.5	246.8	267.5	311.2	0.1475
Extreme low freq.	0.1	1.75	4	7.75	18.4	1.5	0	0	2	5	10.6	2.5
High flow peak	411.5	428.3	489	625.5	1293	0.4034	408.5	423.5	548	711.5	1109	0.5255
High flow duration	1	1	1.5	5.75	56	3.167	1.65	2	3.75	10.5	44.4	2.267
High flow timing	16.5	101	154.5	234.1	275	0.3637	105.2	122.5	159.8	215.5	261.7	0.2541
High flow frequency	0	1.5	4	6.25	9.7	1.188	0.6	2	3	5	6.4	1
High flow rise rate	40.92	88.5	123.8	302	349.2	1.725	35.62	51.58	105.6	170.6	271.8	1.127
High flow fall rate	-301.3	-204.1	-121.3	-62.63	-53.46	-1.167	-126.9	-95.54	-57.93	-38.71	-28.9	-0.981
Small Flood peak	2380	2388	2520	3500	3790	0.4415	2270	2698	2885	3358	3940	0.2288
Small Flood duration	54	63.75	99	105.8	106	0.4242	74	107	121	138	152	0.2562
Small Flood timing	110	111	115.5	129	133	0.04918	106	109.3	118.5	143.3	164	0.0929
Small Flood freq.	0	0	0	1	1	0	0	0	0	0	1	0
Small Flood riserate	100.6	132.3	289.7	524.1	581.5	1.353	49.94	52.35	73.4	99.46	226.1	0.6418
Small Flood fallrate	-50.78	-46.59	-29.21	-23.67	-23.43	-0.7846	-51.92	-47	-30.63	-24.71	-21.66	-0.7276
Large flood peak			4980						5440			
Large flood duration			127						119			
Large flood timing			131						137			
Large flood freq.	0	0	0	0	0.9	0	0	0	0	0	0	0
Large flood riserate			205.7						125.7			
Large flood fallrate			-44.11						-64.41			

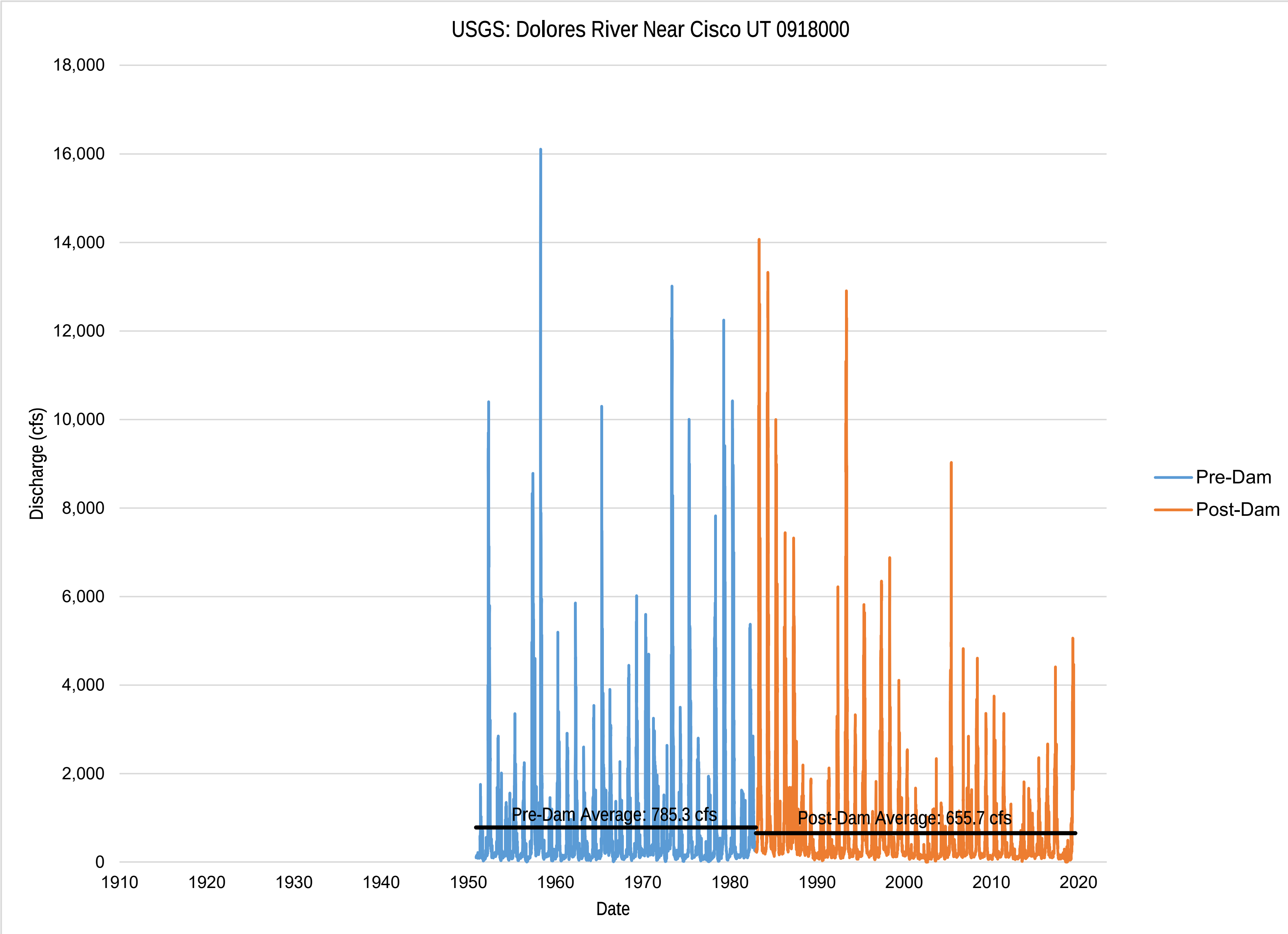
9 Messages:

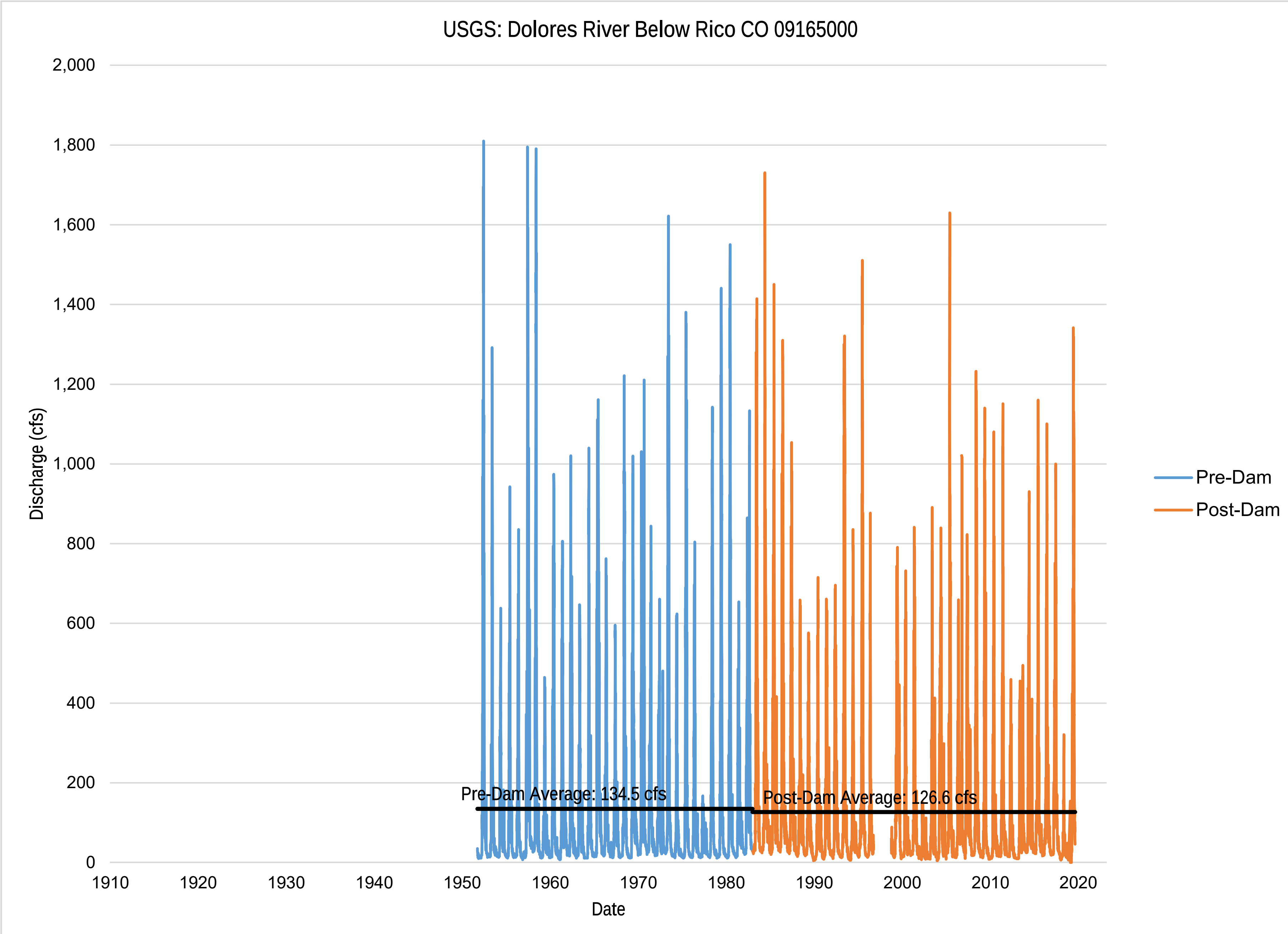
The longest period of missing data is 334 days.
Interpolating across this gap may cause anomalies in the statistics. Please use them with caution.
334 daily values have been interpolated in year 1996
44 daily values have been interpolated in year 2019
An EFC extreme low flow event has been truncated at the beginning by missing year 1995 This event is not used to compute annual statistics.
WARNING: Some of the Colwell parameters are based on fewer than twenty years of data.
Warning: For two-period analyses, IHA re-assigns each daily flow value into a new EFC category.
Therefore, post-impact EFC magnitude values (e.g. monthly low flows) are not directly comparable to the pre-impact values.
To compare pre- to post-impact flow magnitudes, use IHA parameter groups #1 and #2 instead of EFCs.

Appendix B

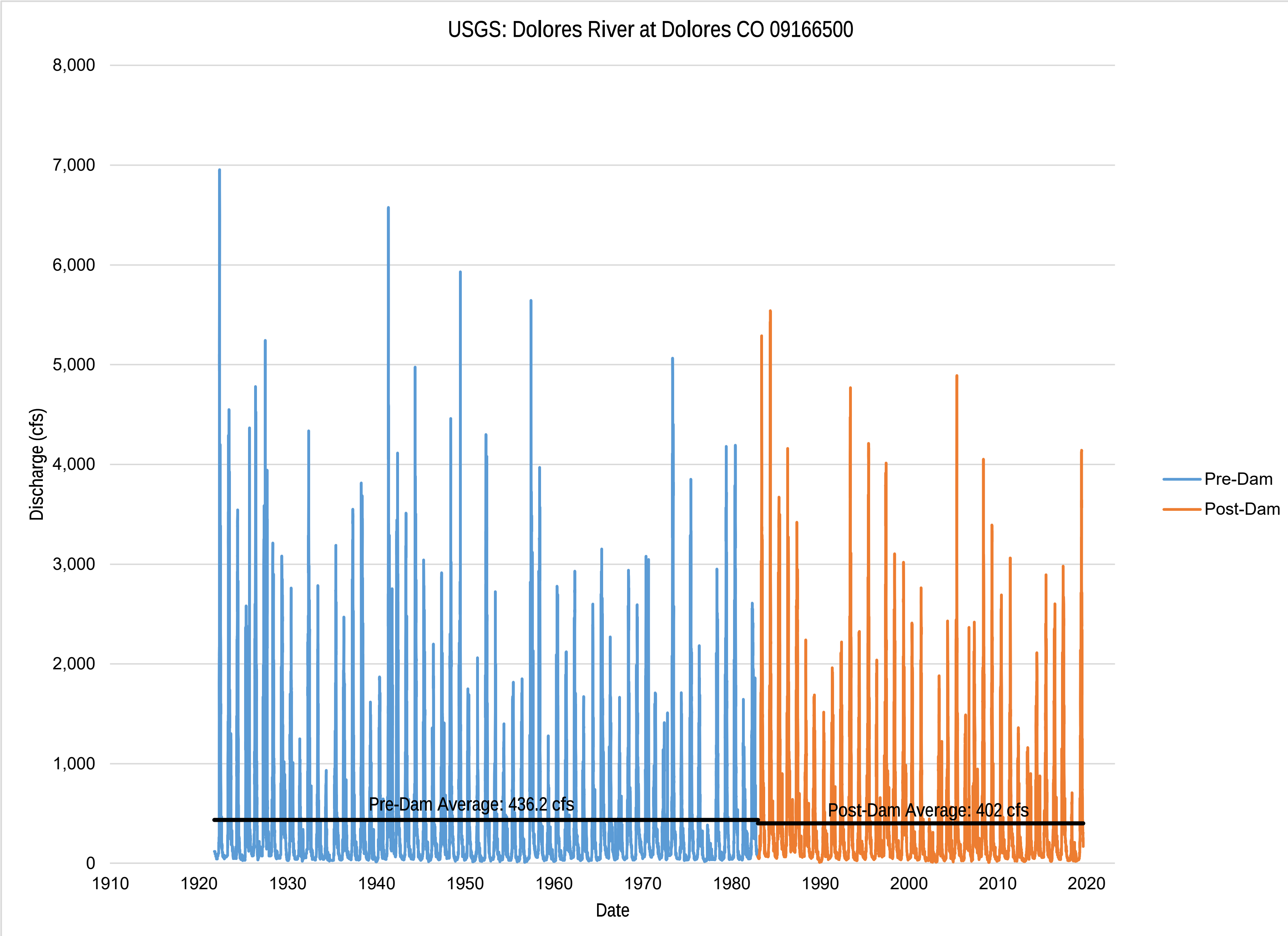
Daily Average Data and Time-Series Average

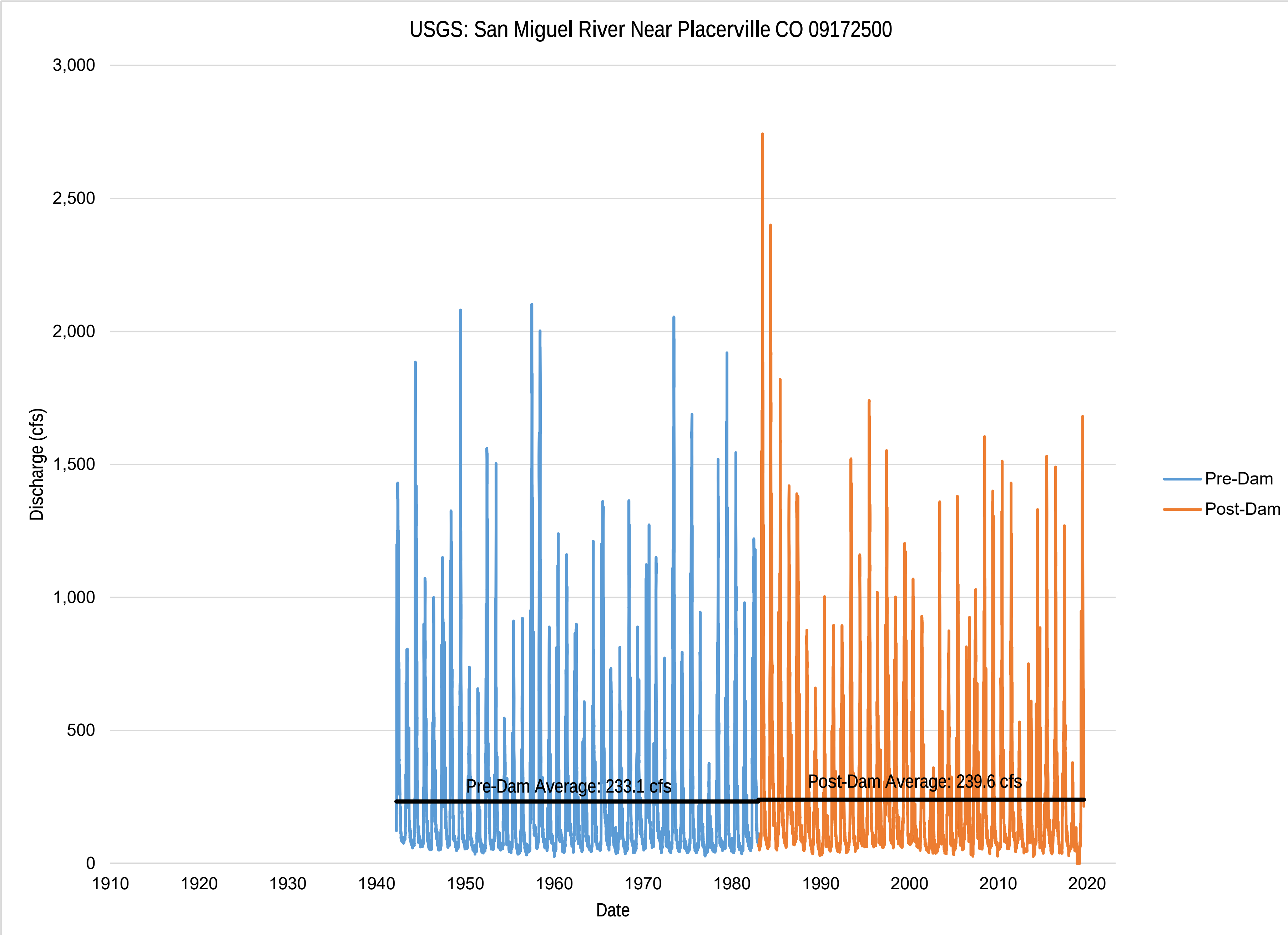

USGS: Dolores River At Bedrock 09165000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Discharge (cfs)
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam Average: 470 cfs
Post-Dam Average: 235.9 cfs
Pre-Dam
Post-Dam

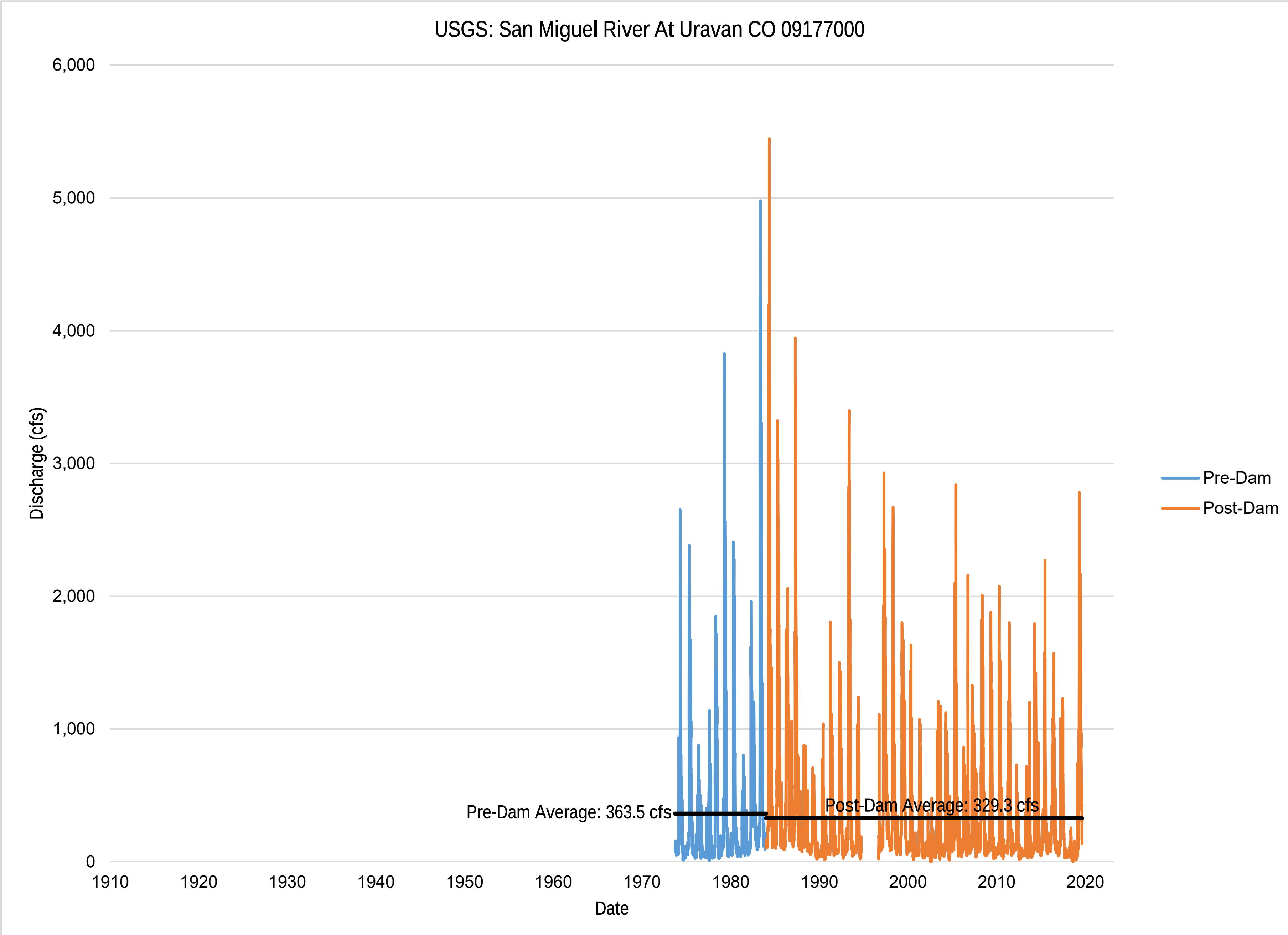

USGS: Dolores River Near Cisco UT 0918000
Discharge (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam Average: 785.3 cfs
Post-Dam Average: 655.7 cfs
Pre-Dam
Post-Dam



USGS: Dolores River Below Rico CO 09165000
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Discharge (cfs)
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam Average: 134.5 cfs
Post-Dam Average: 126.6 cfs
Pre-Dam
Post-Dam


USGS: Dolores River at Dolores CO 09166500
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Discharge (cfs)
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam Average: 436.2 cfs
Post-Dam Average: 402 cfs
Pre-Dam
Post-Dam

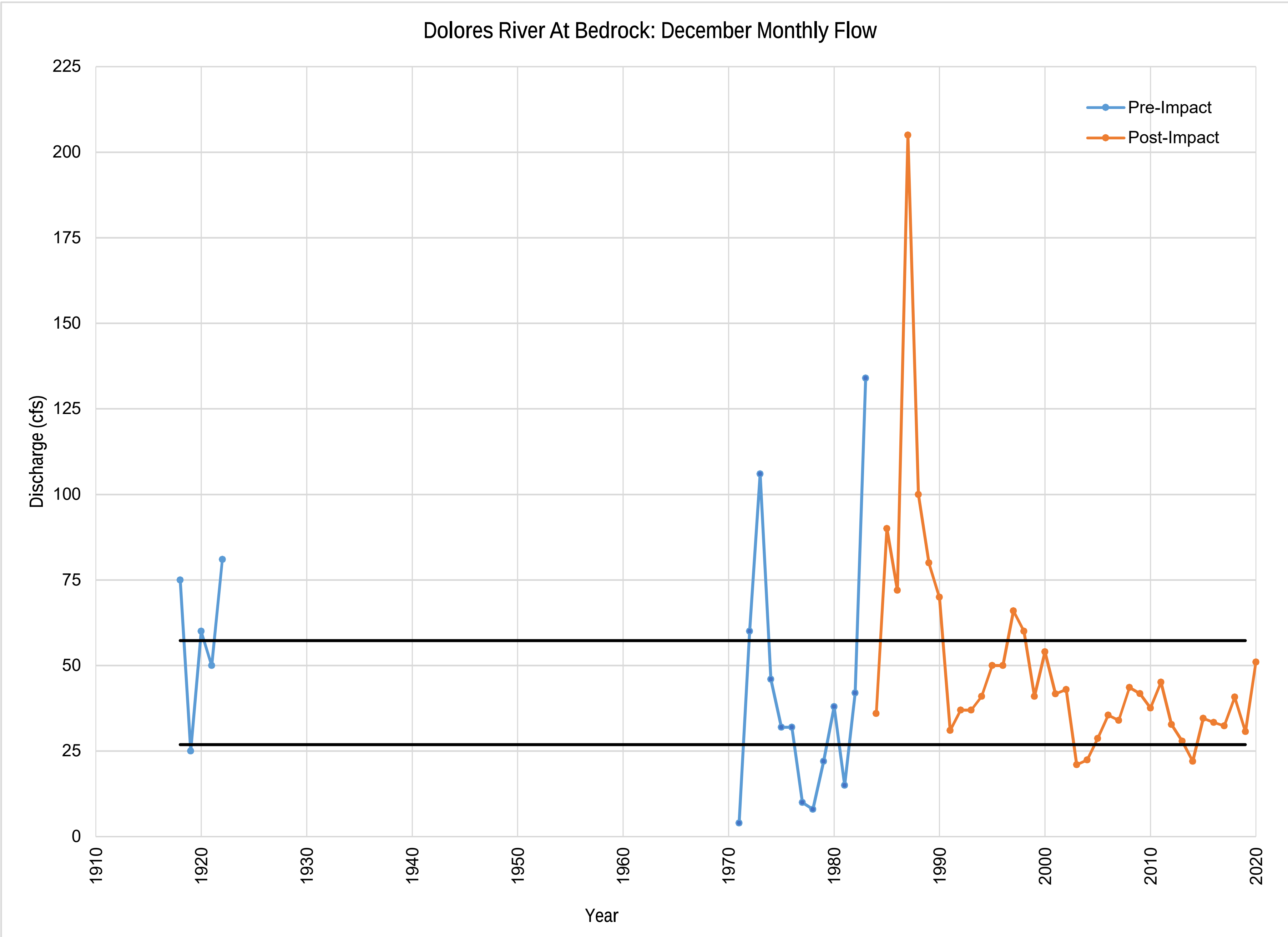

USGS: San Miguel River Near Placerville CO 09172500
3,000
2,500
2,000
1,500
1,000
500
0
Discharge (cfs)
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam Average: 233.1 cfs
Post-Dam Average: 239.6 cfs
Pre-Dam
Post-Dam

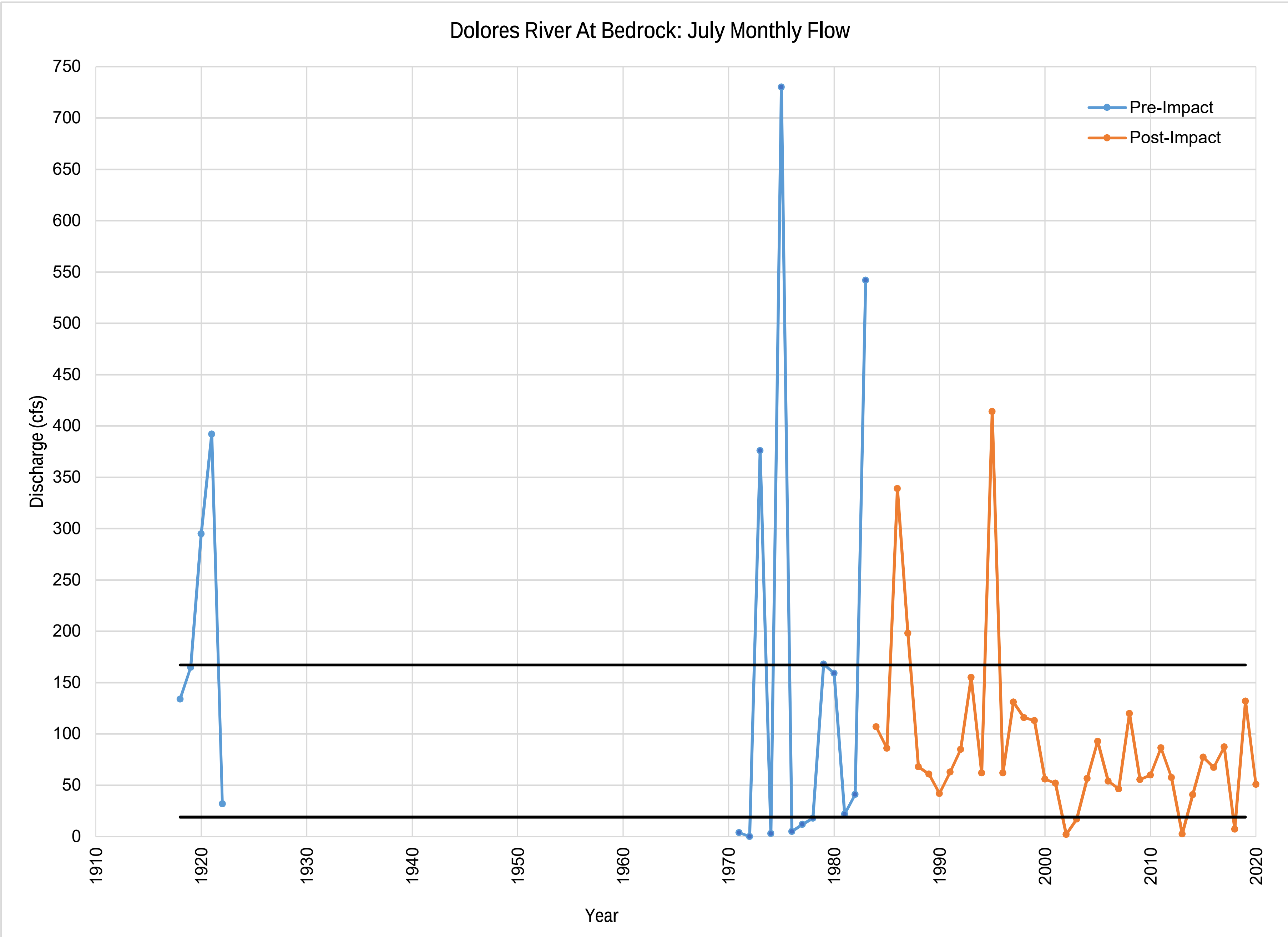


USGS: San Miguel River At Uravan CO 09177000
Discharge (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Date
Pre-Dam
Post-Dam
Pre-Dam Average: 363.5 cfs
Post-Dam Average: 329.3 cfs

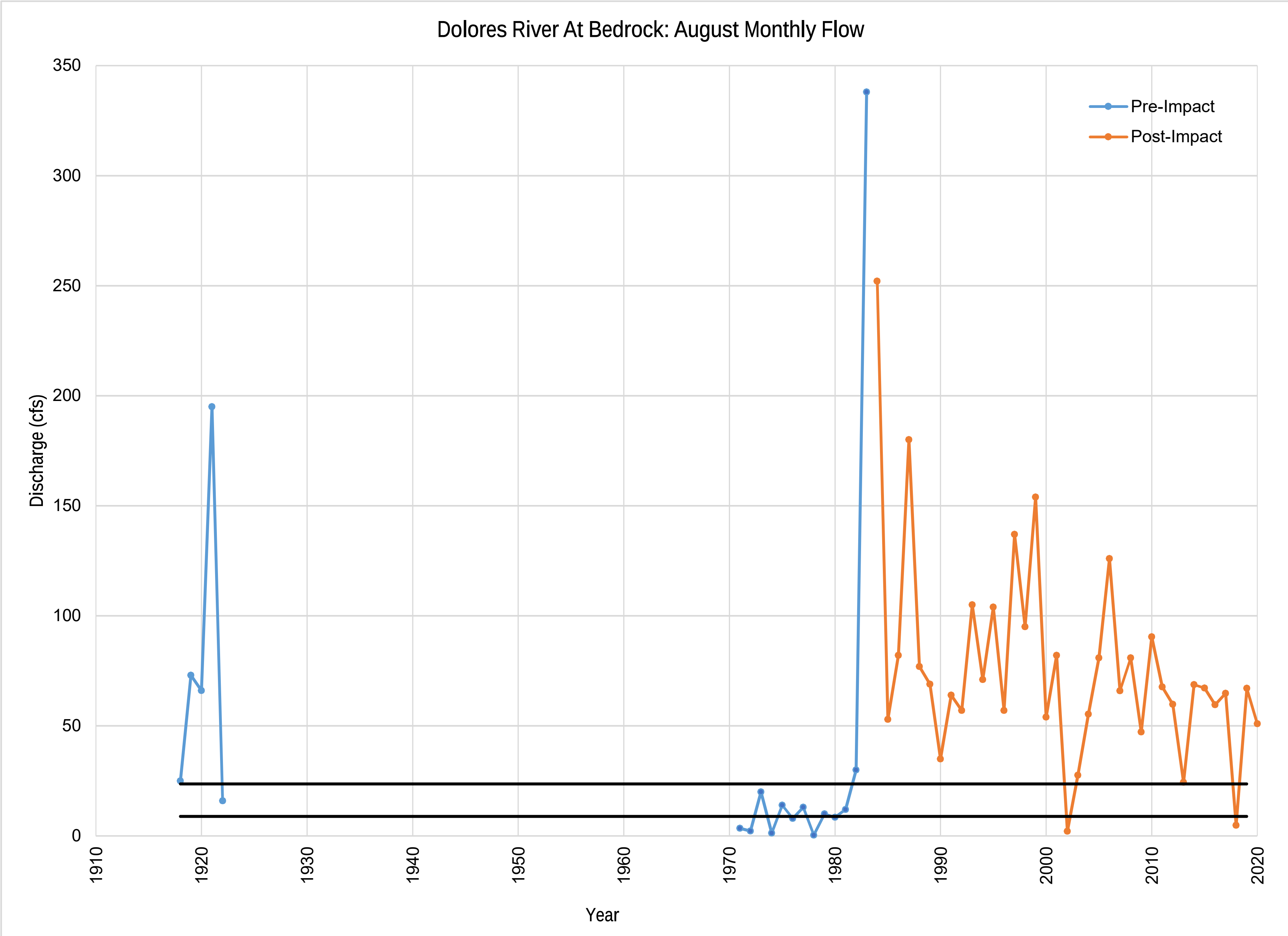
Appendix C

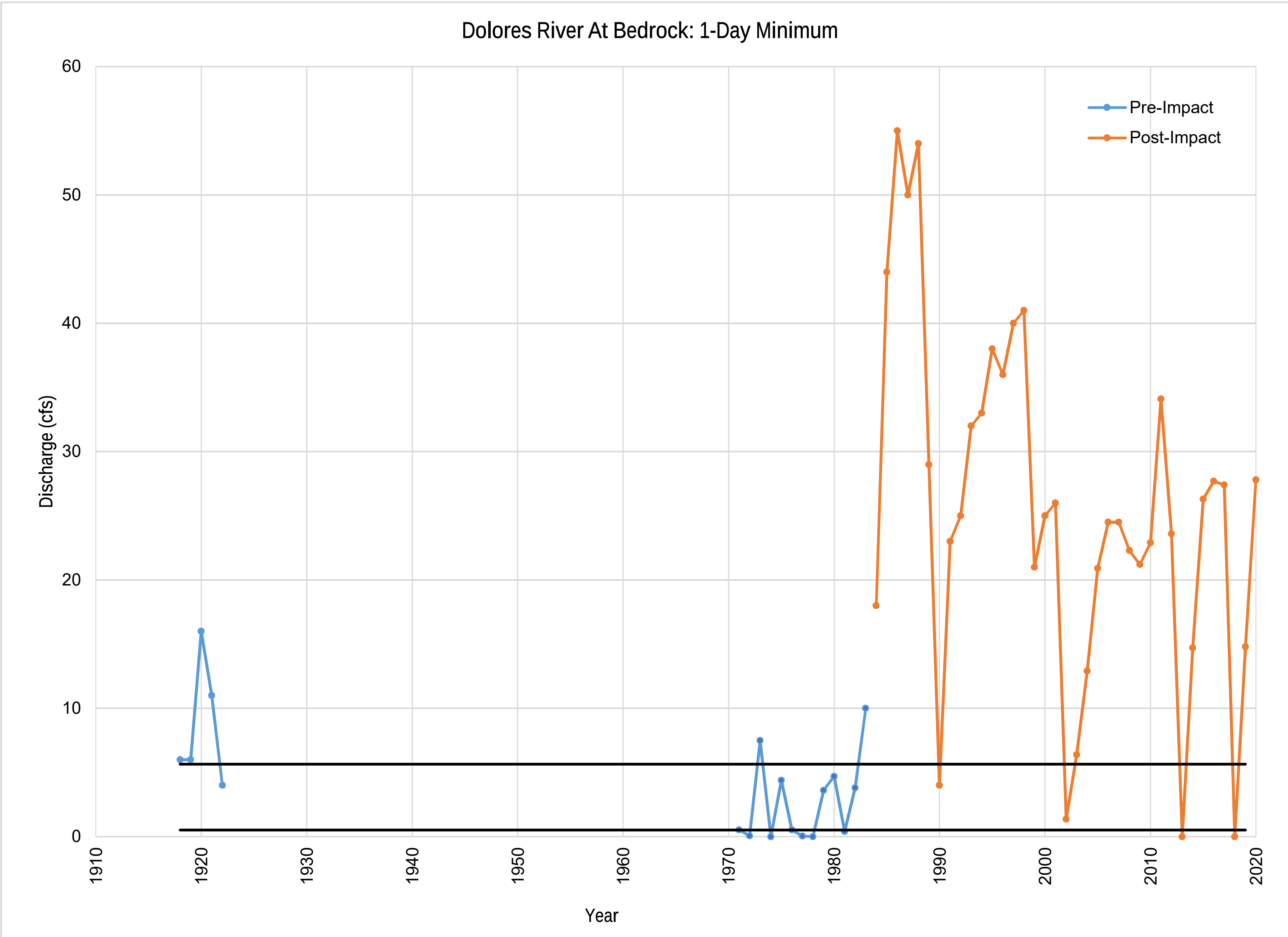
Plots of Top Ten Ranked Parameters based on Dolores River at Bedrock, CO Gage

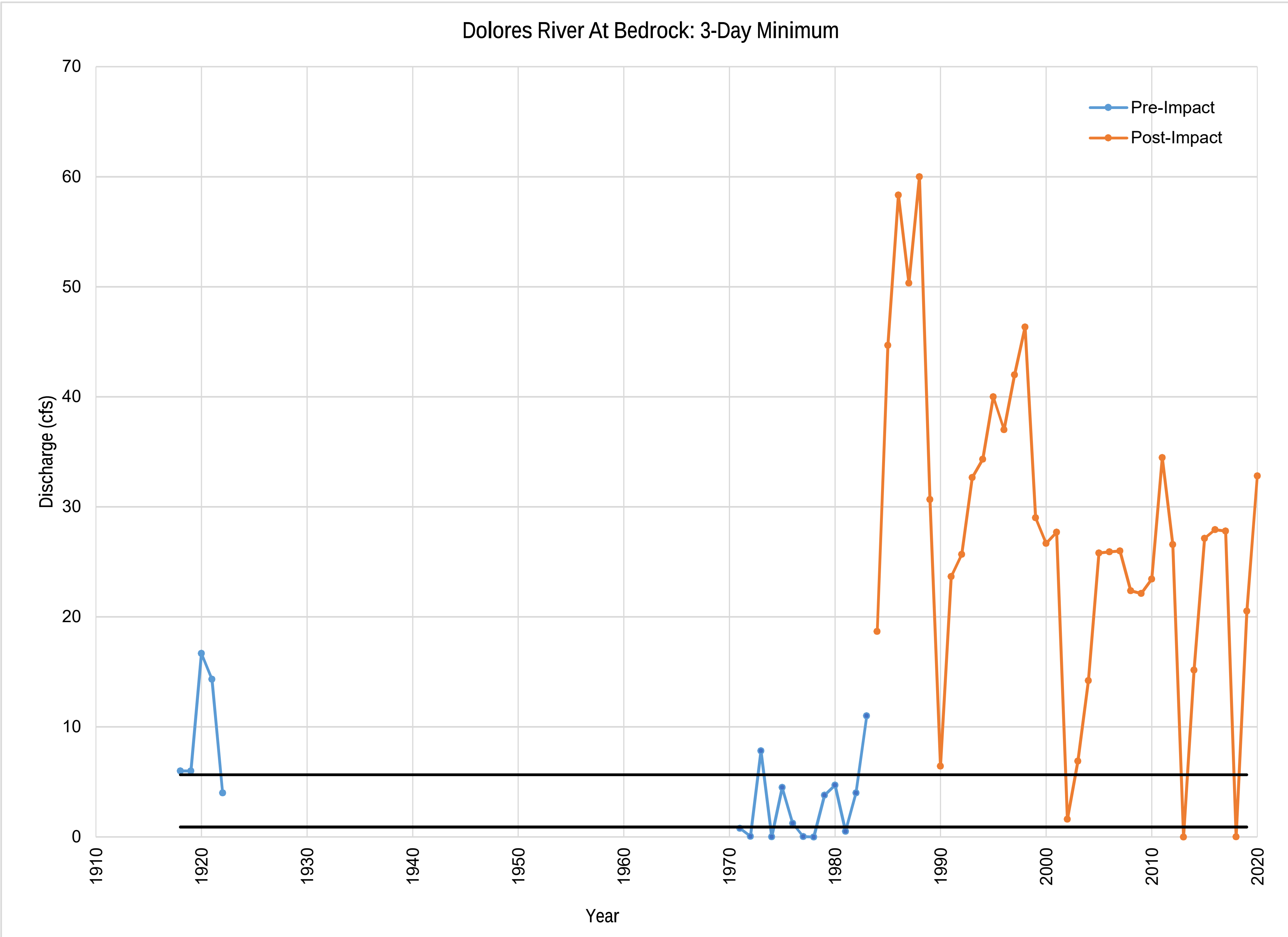

Dolores River At Bedrock: December Monthly Flow
Discharge (cfs)
Year
Pre-Impact
Post-Impact
225
200
175
150
125
100
75
50
25
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020



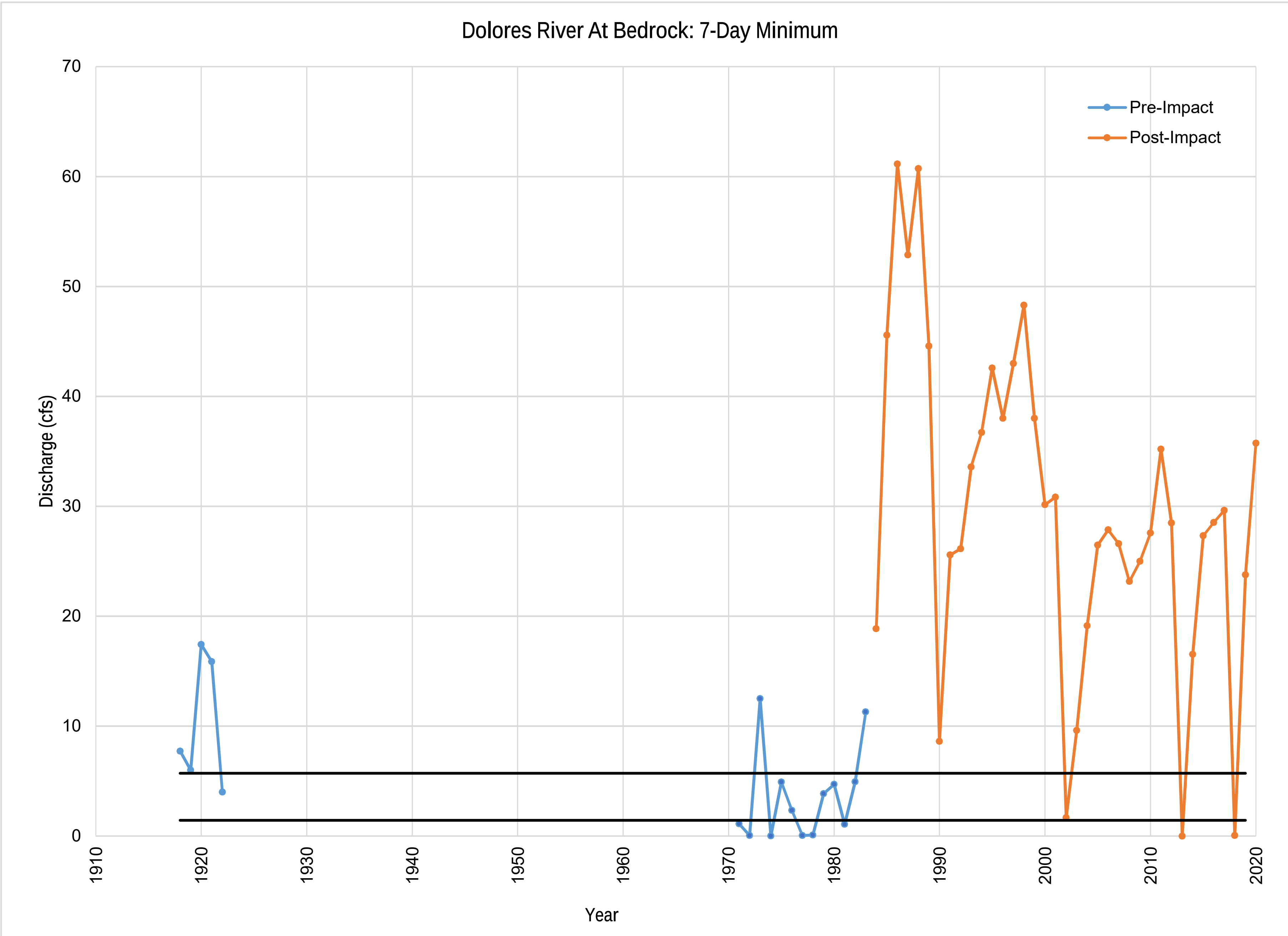
Dolores River At Bedrock: July Monthly Flow
Discharge (cfs)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

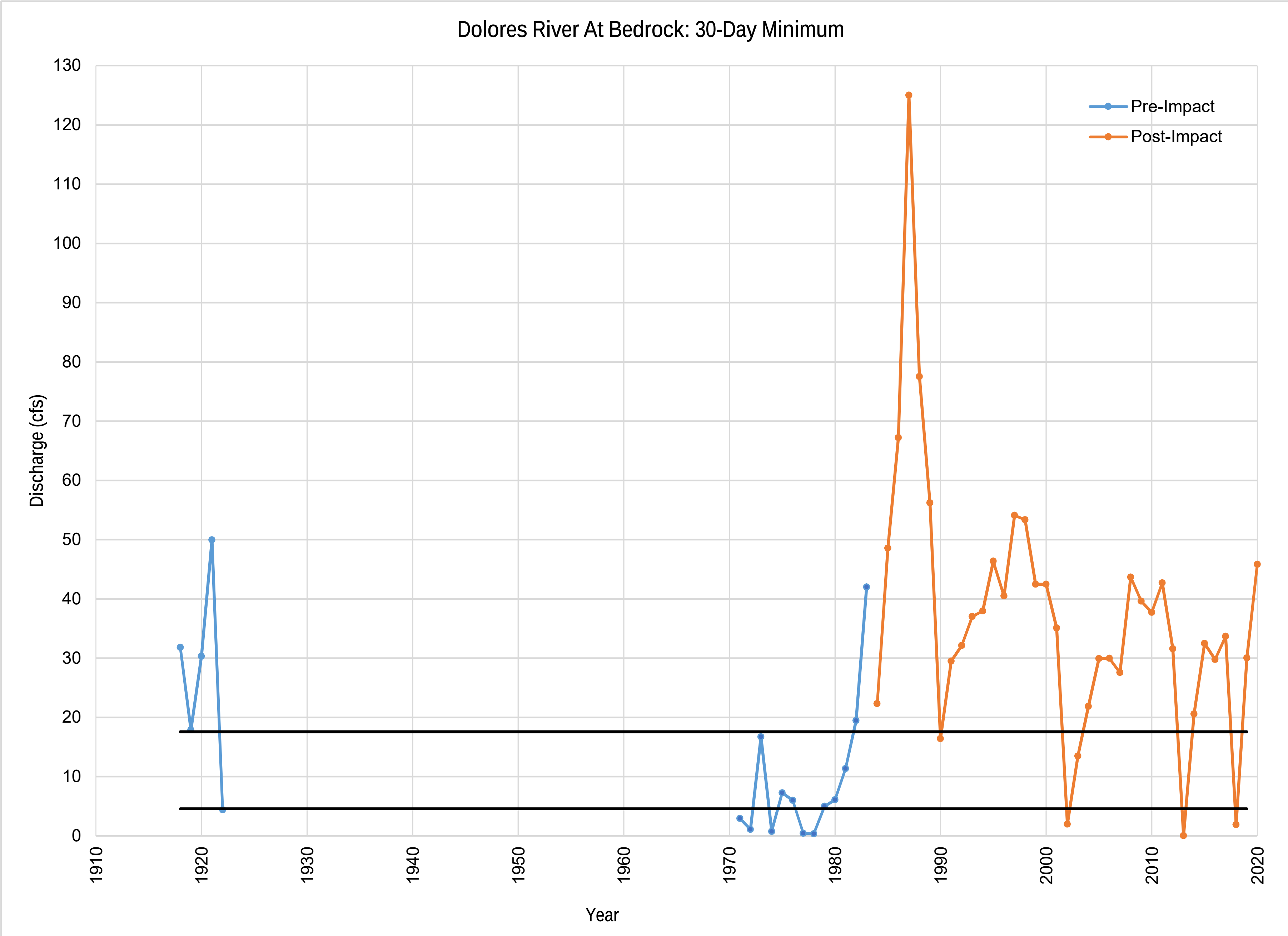

Dolores River At Bedrock: August Monthly Flow
Pre-Impact
Post-Impact
Discharge (cfs)
350
300
250
200
150
100
50
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

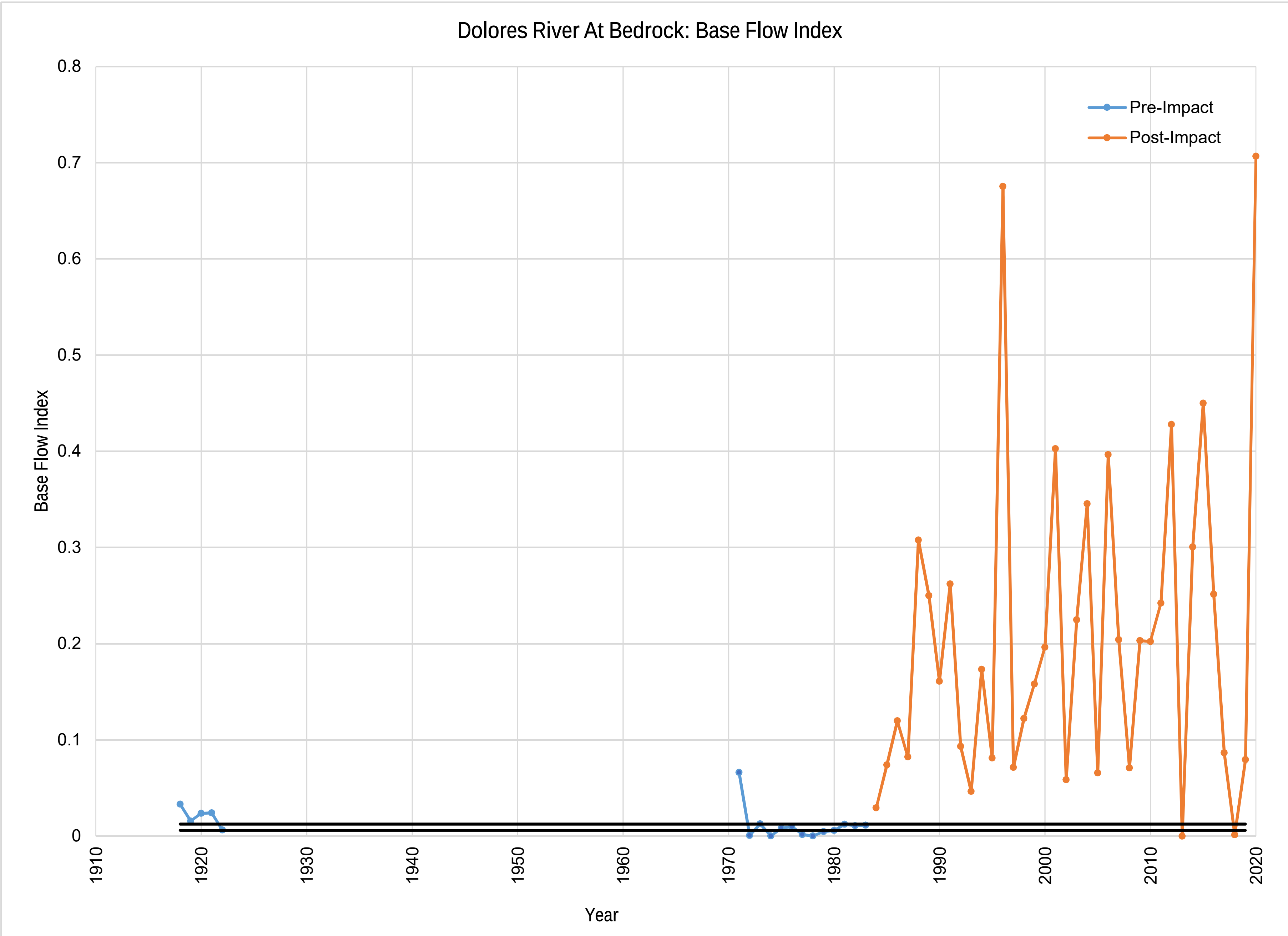

Dolores River At Bedrock: 1-Day Minimum
Discharge (cfs)
60
50
40
30
20
10
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

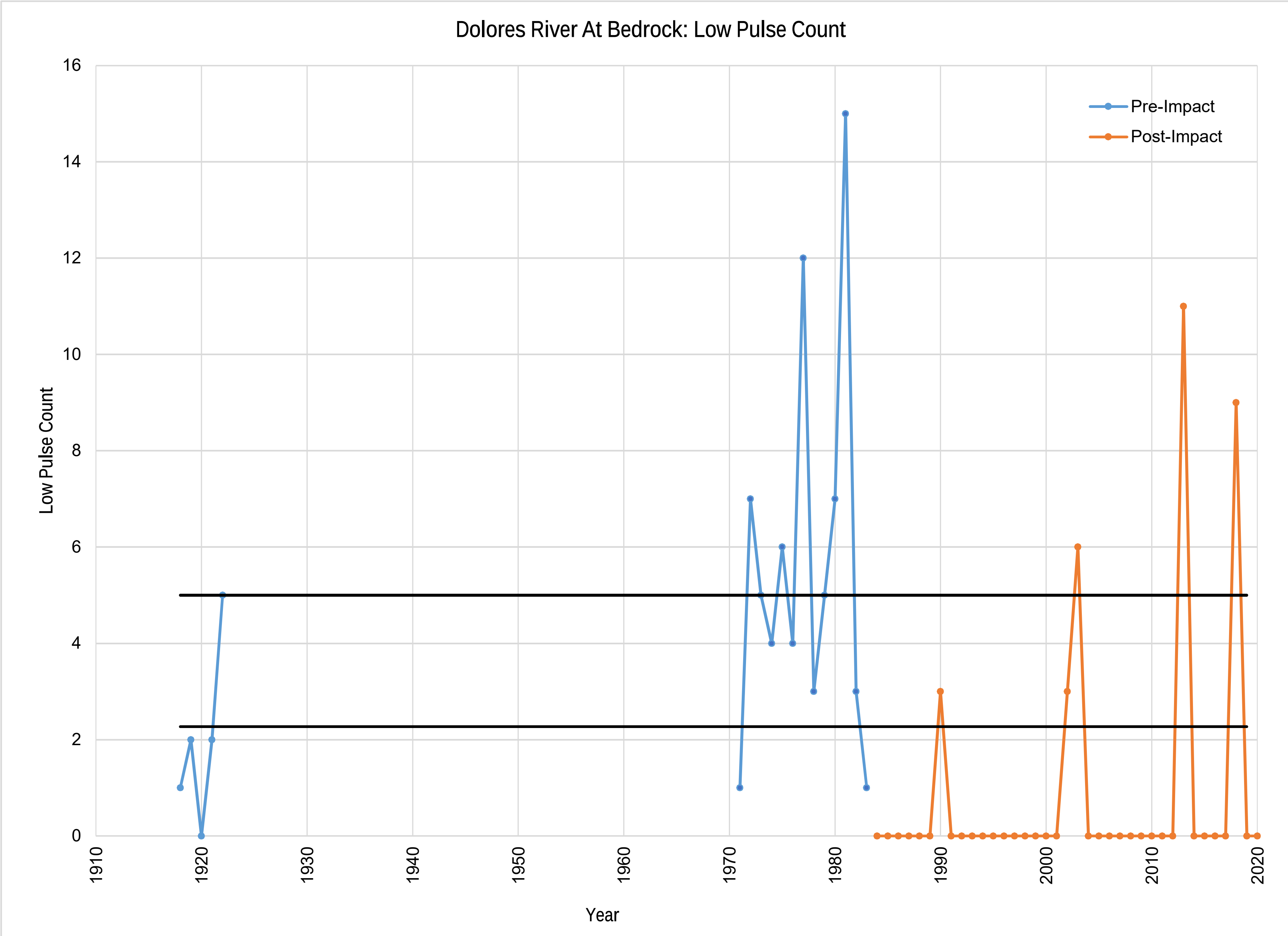


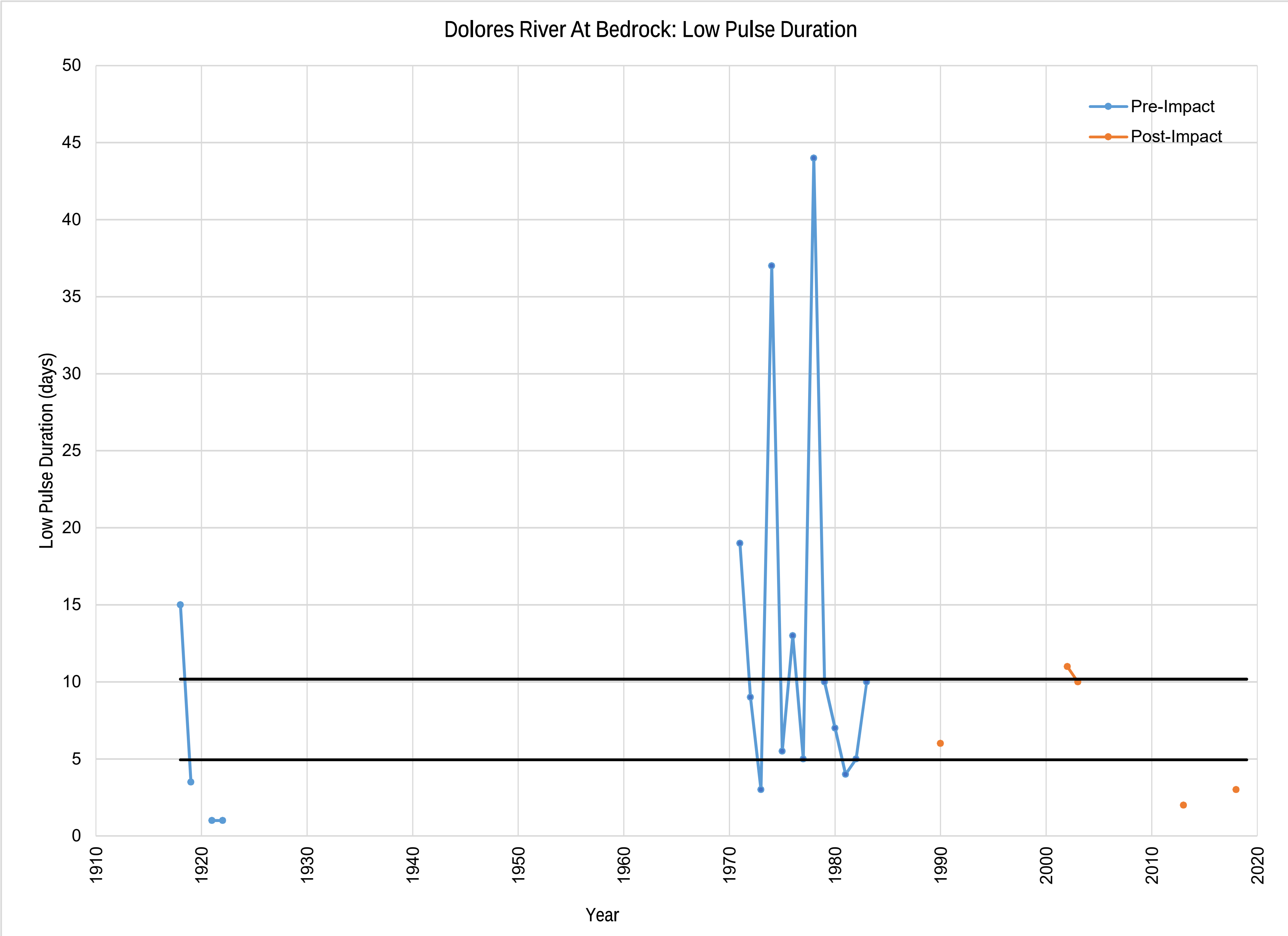
Dolores River At Bedrock: 3-Day Minimum
Pre-Impact
Post-Impact
Discharge (cfs)
0
10
20
30
40
50
60
70
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

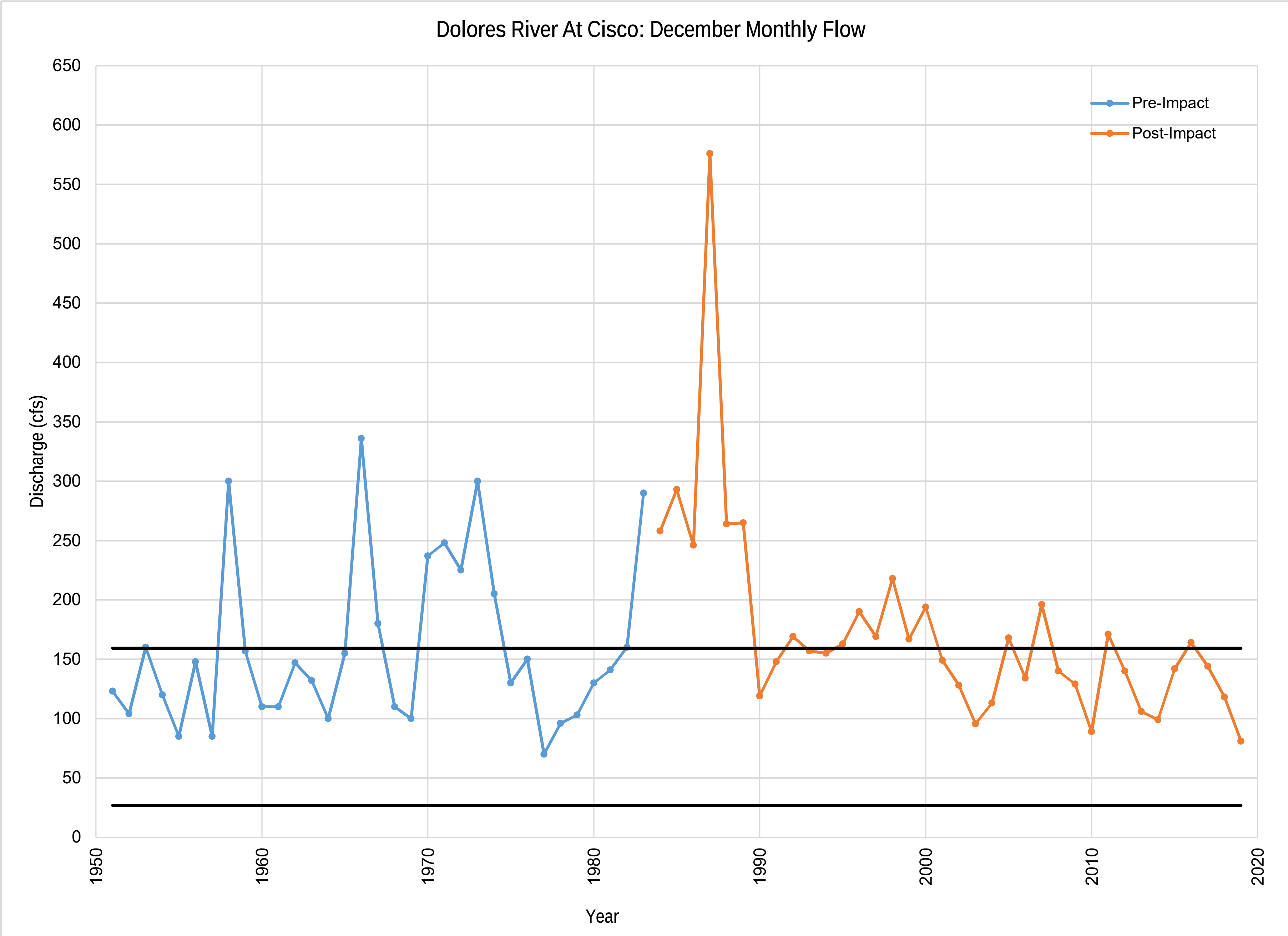

Dolores River At Bedrock: 7-Day Minimum
Pre-Impact
Post-Impact
Discharge (cfs)
Year
70
60
50
40
30
20
10
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

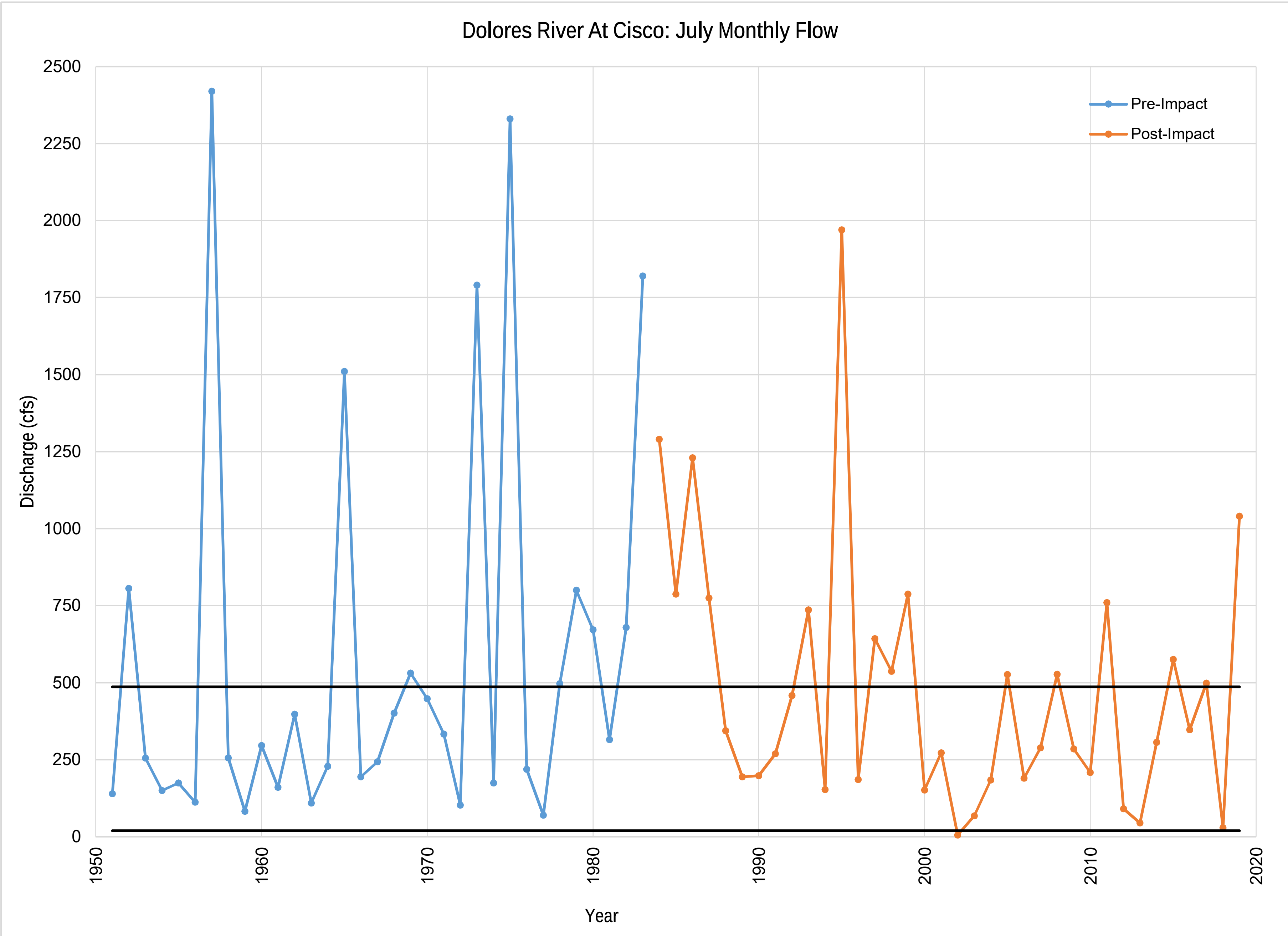

Dolores River At Bedrock: 30-Day Minimum
Discharge (cfs)
Year
Pre-Impact
Post-Impact
0
10
20
30
40
50
60
70
80
90
100
110
120
130
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

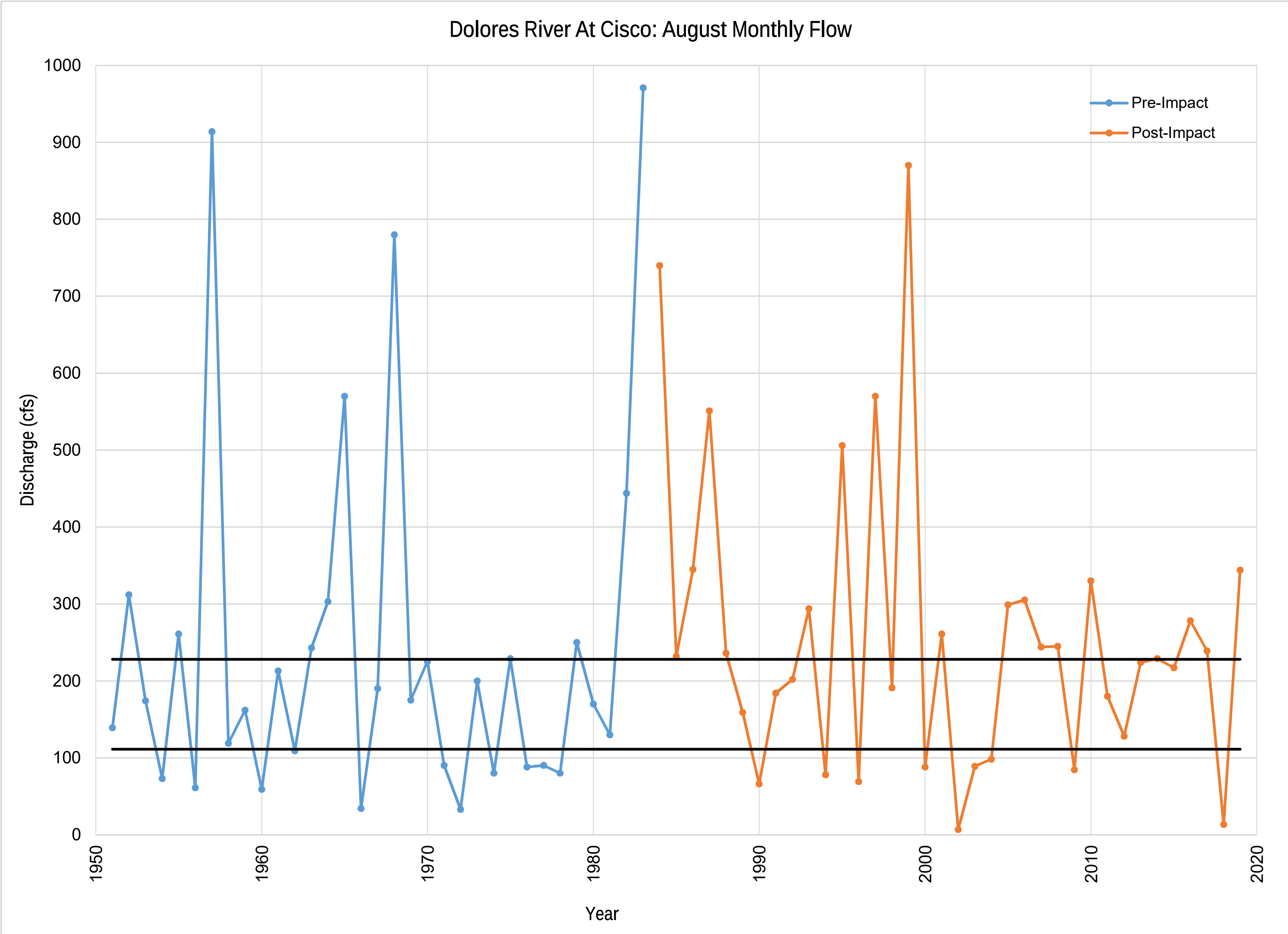

Dolores River At Bedrock: Base Flow Index
Base Flow Index
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

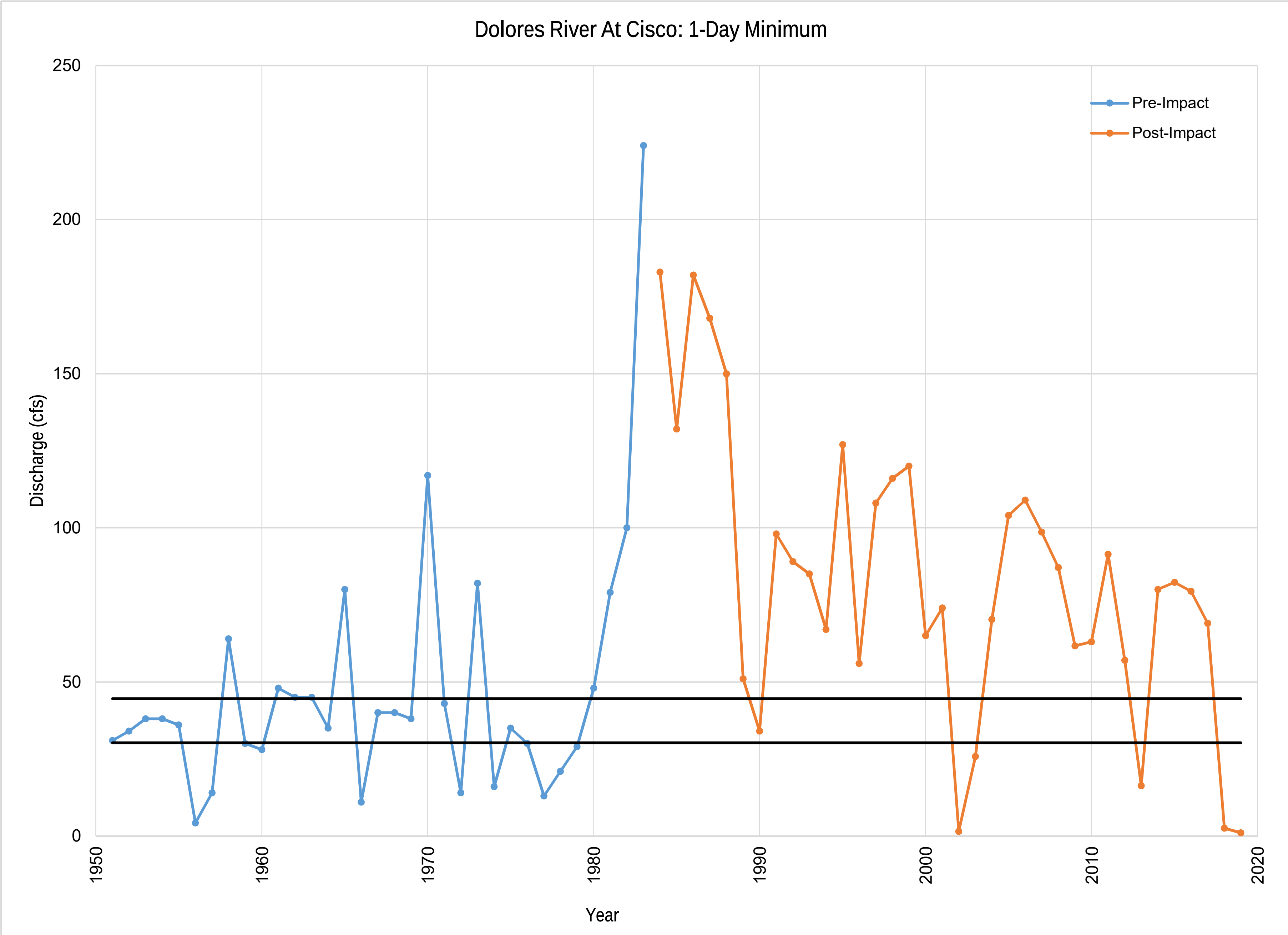

Dolores River At Bedrock: Low Pulse Count
16
14
12
10
8
6
4
2
0
Low Pulse Count
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

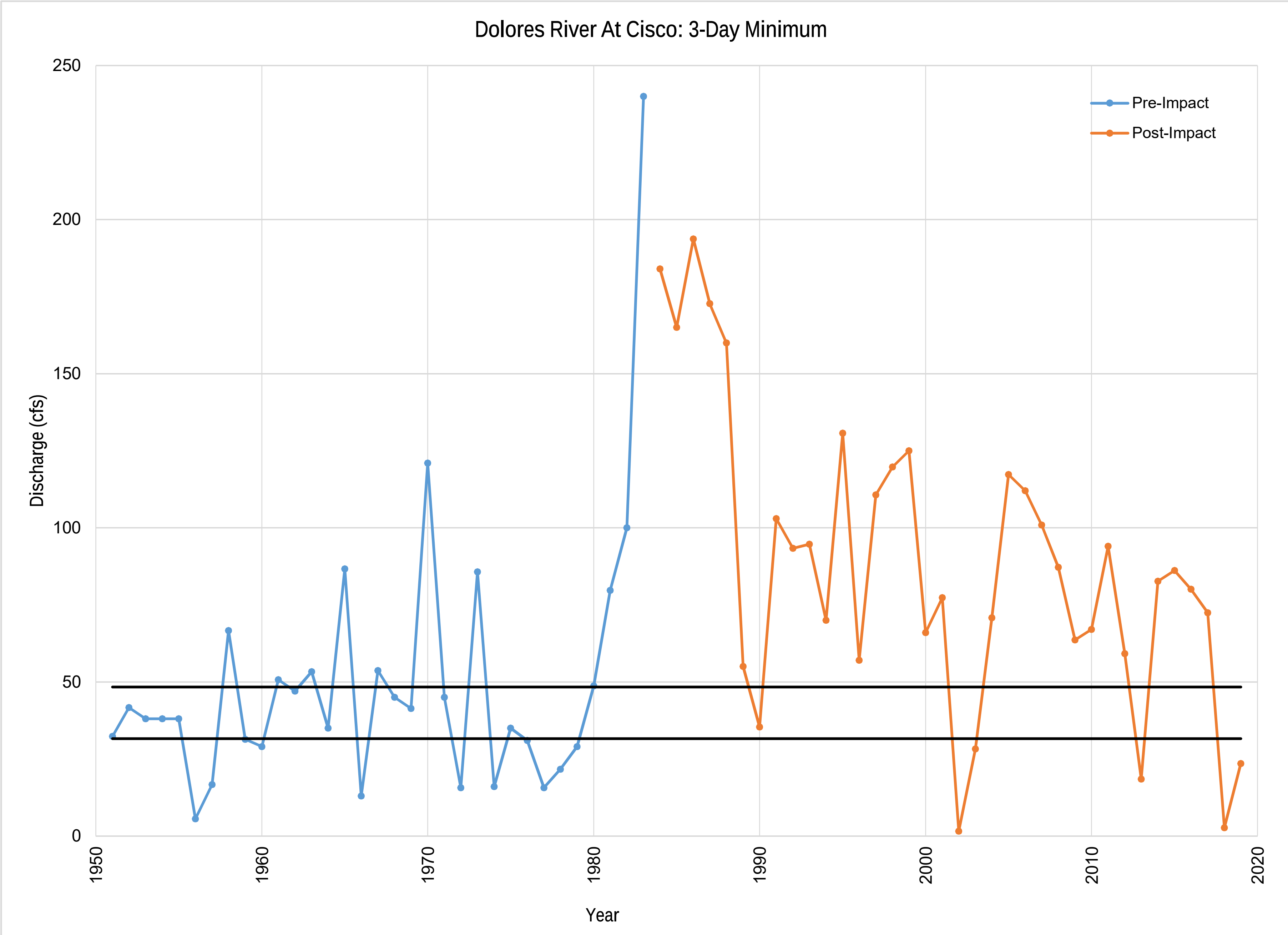

Dolores River At Bedrock: Low Pulse Duration
Low Pulse Duration (days)
50
45
40
35
30
25
20
15
10
5
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

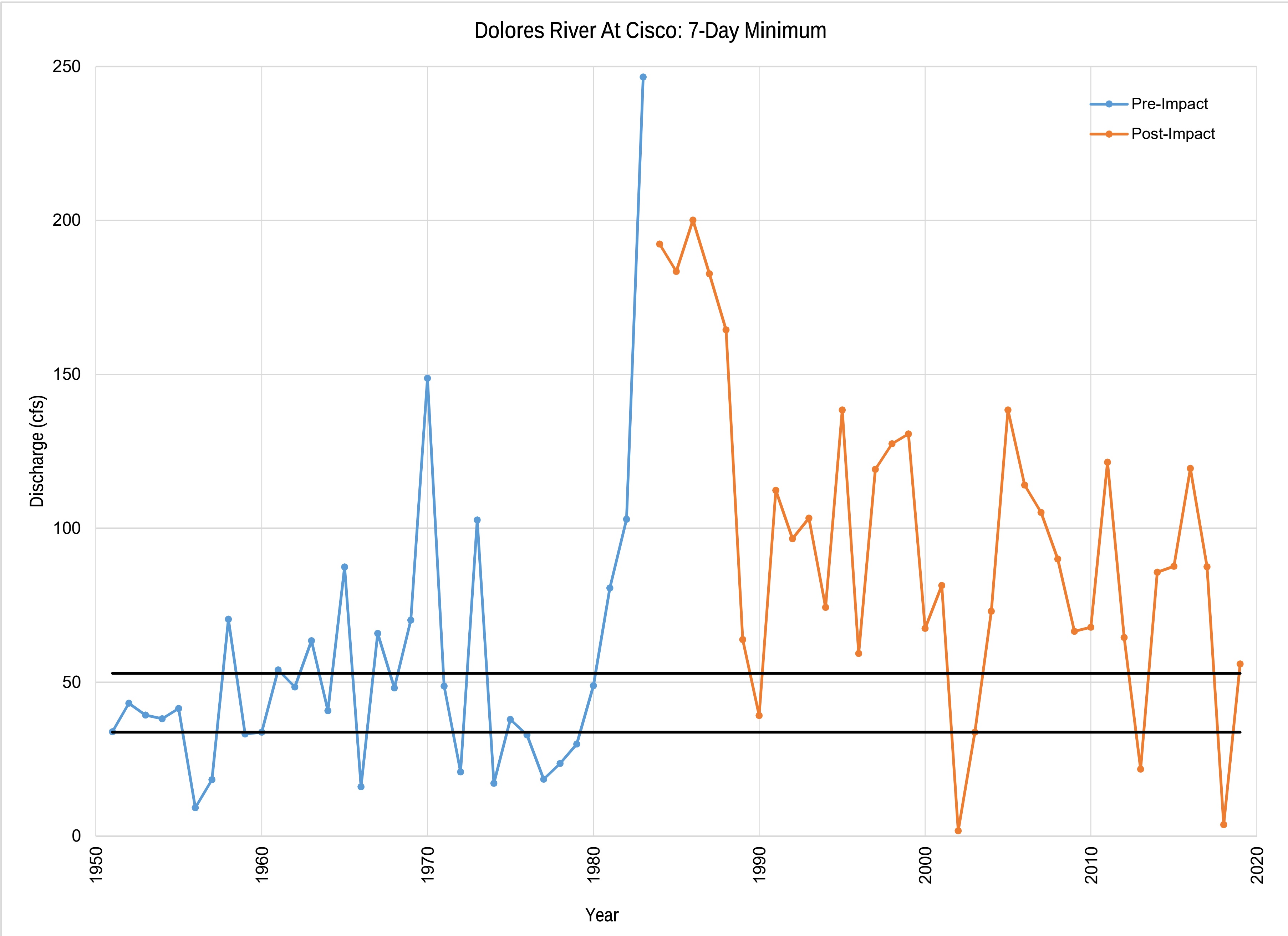

Dolores River At Cisco: December Monthly Flow
Pre-Impact
Post-Impact
Discharge (cfs)
Year
0
50
100
150
200
250
300
350
400
450
500
550
600
650
1950
1960
1970
1980
1990
2000
2010
2020

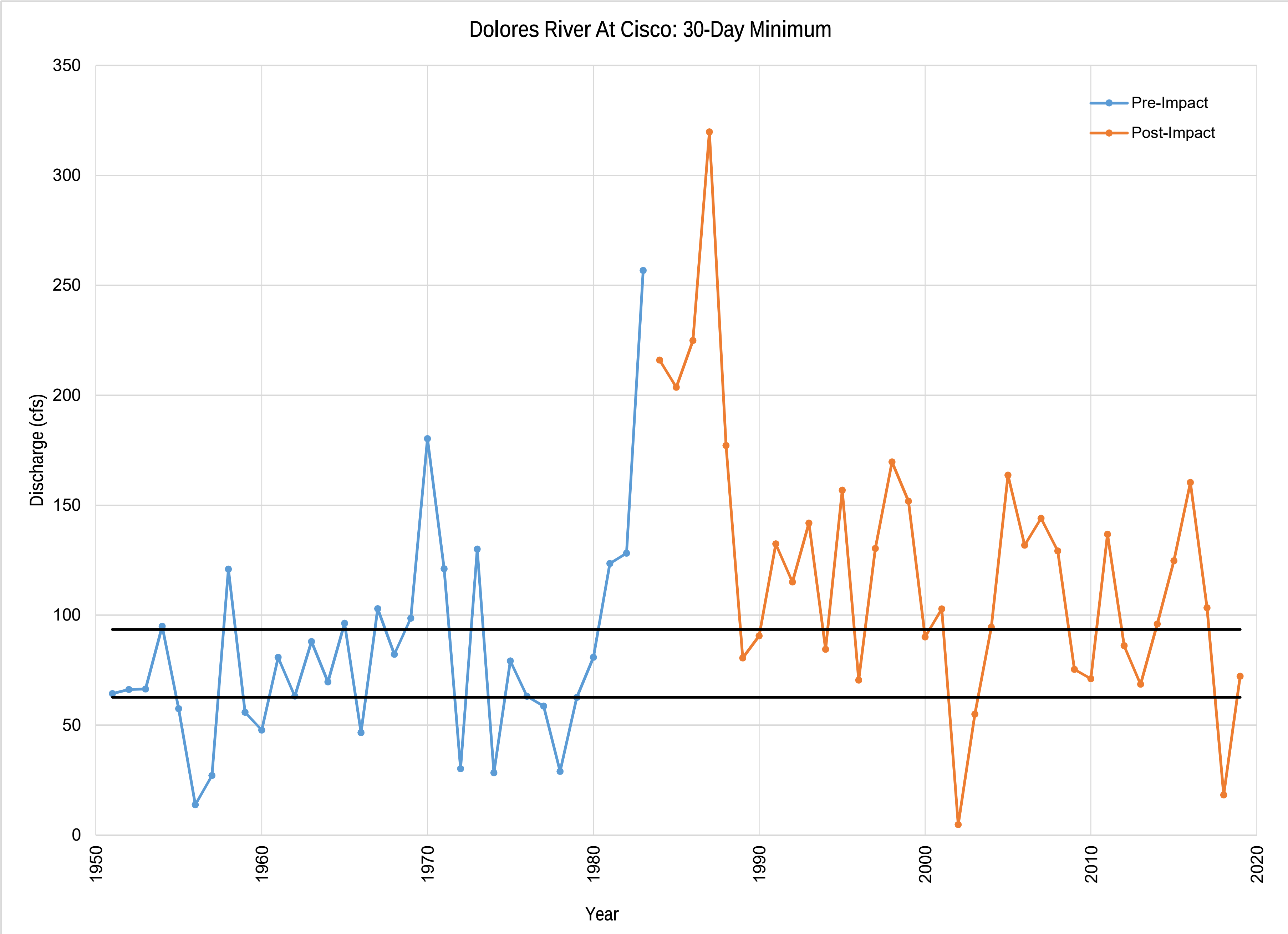

Dolores River At Cisco: July Monthly Flow
Pre-Impact
Post-Impact
Discharge (cfs)
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
1950
1960
1970
1980
1990
2000
2010
2020
Year

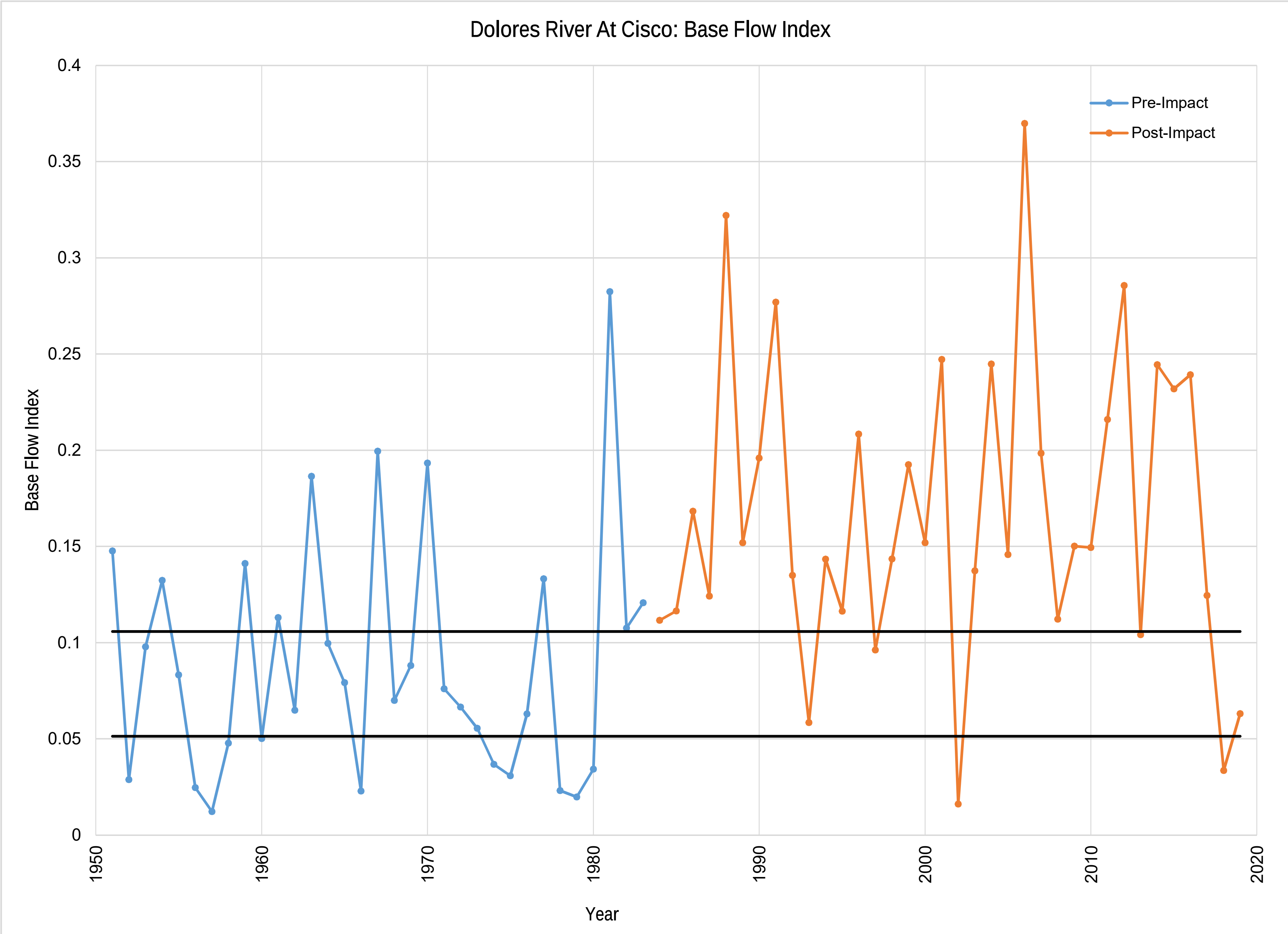

Dolores River At Cisco: August Monthly Flow
Discharge (cfs)
Year
Pre-Impact
Post-Impact
0
100
200
300
400
500
600
700
800
900
1000
1950
1960
1970
1980
1990
2000
2010
2020

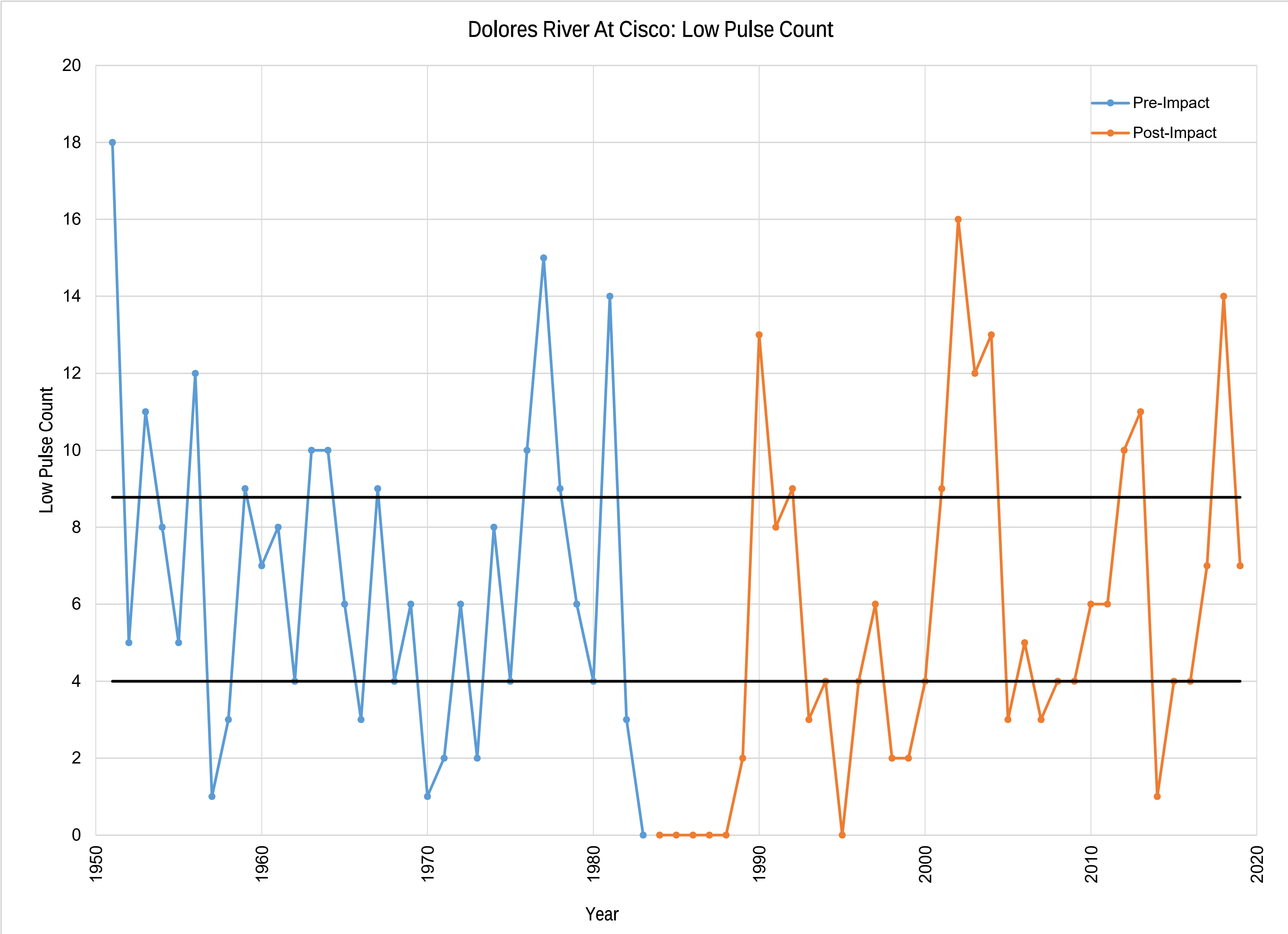

Dolores River At Cisco: 1-Day Minimum
250
200
150
100
50
0
Discharge (cfs)
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact

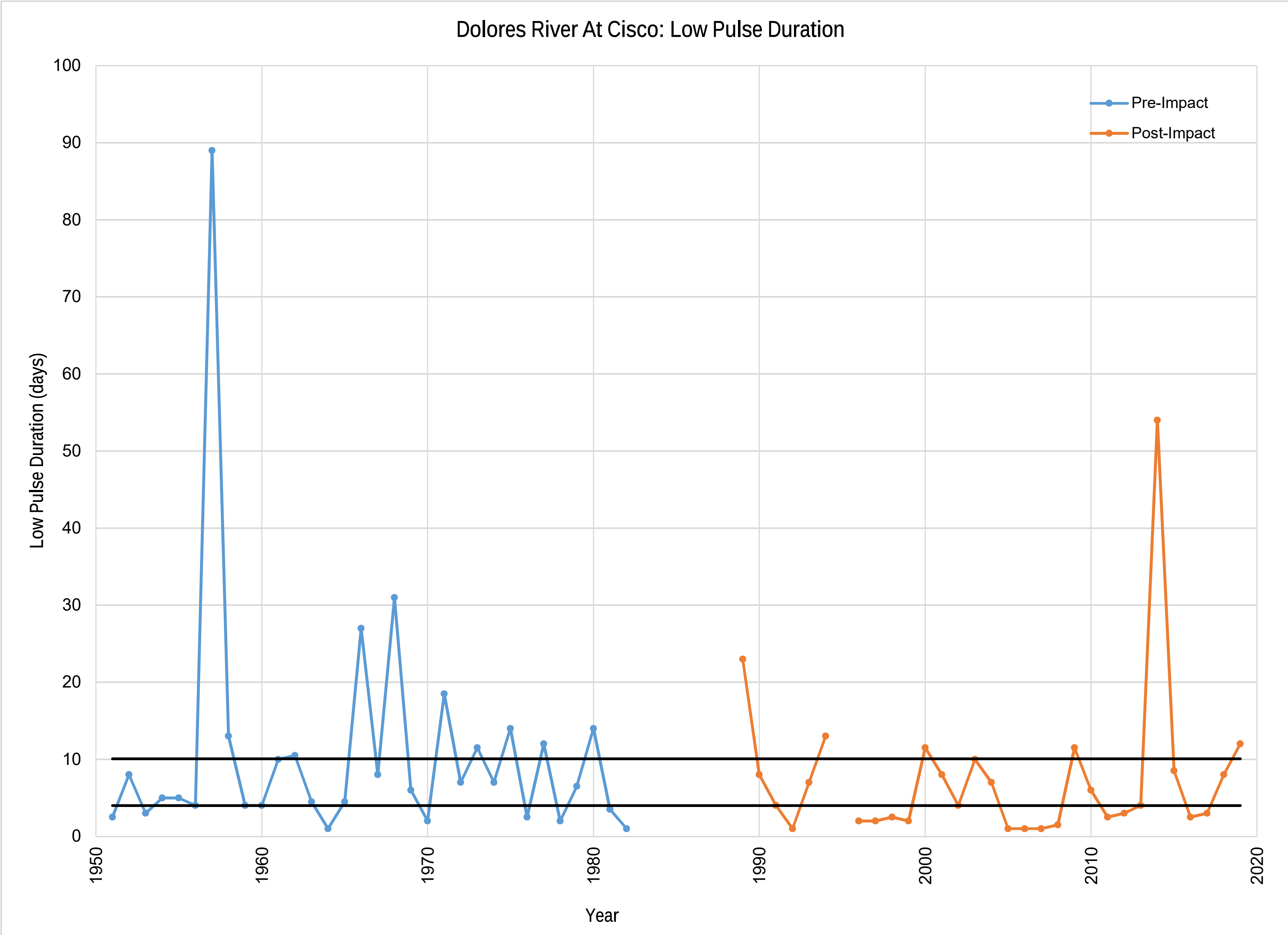

Dolores River At Cisco: 3-Day Minimum
250
200
150
100
50
0
Discharge (cfs)
1950
1960
1970
1980
1990
2000
2010
2020
Year
Pre-Impact
Post-Impact


Dolores River At Cisco: 7-Day Minimum
Discharge (cfs)
Year
Pre-Impact
Post-Impact
0
50
100
150
200
250
1950
1960
1970
1980
1990
2000
2010
2020


Dolores River At Cisco: 30-Day Minimum
Pre-Impact
Post-Impact
Discharge (cfs)
350
300
250
200
150
100
50
0
1950
1960
1970
1980
1990
2000
2010
2020
Year


Dolores River At Cisco: Base Flow Index
Pre-Impact
Post-Impact
Base Flow Index
Year
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1950
1960
1970
1980
1990
2000
2010
2020

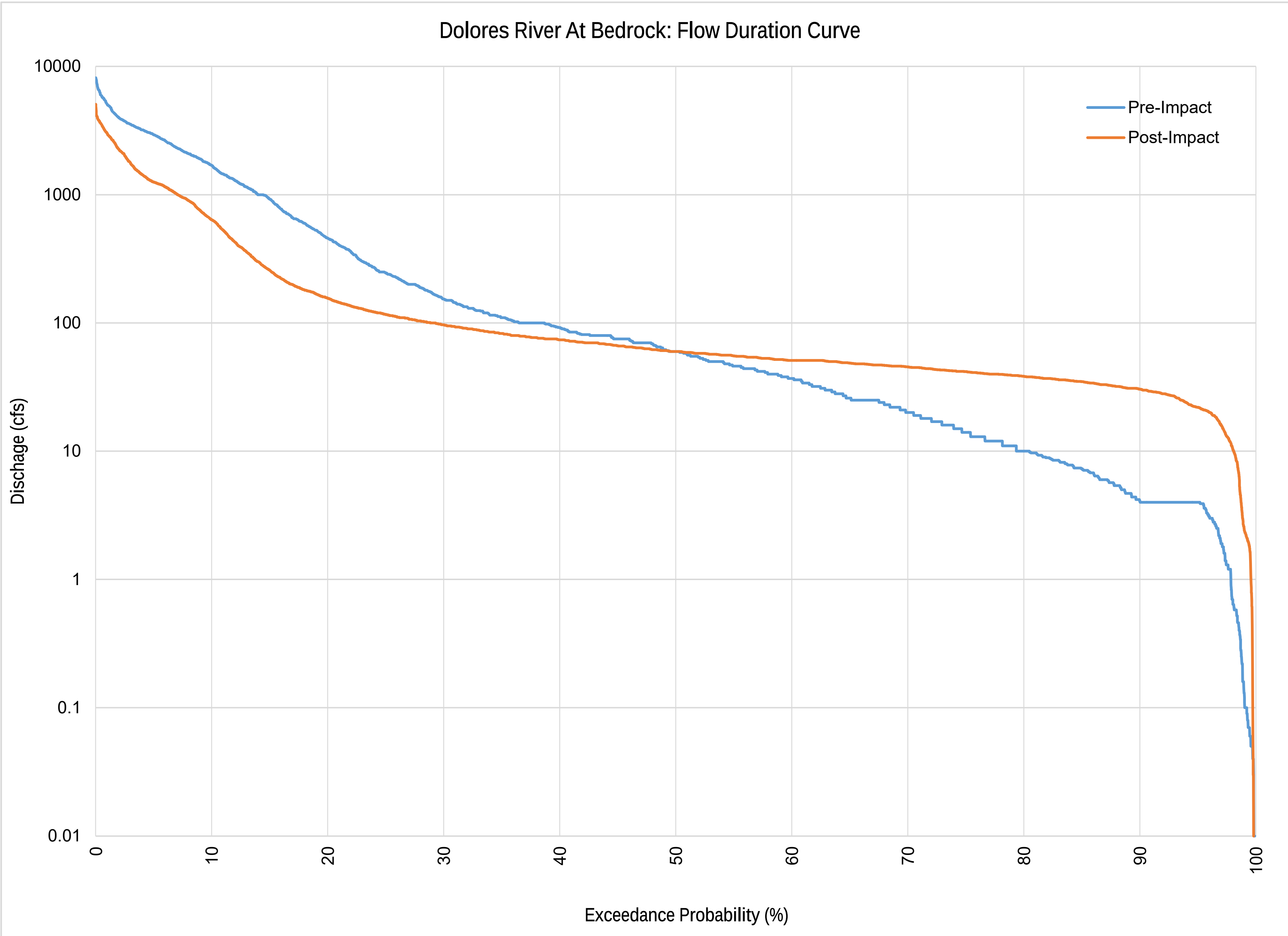

Dolores River At Cisco: Low Pulse Count
Low Pulse Count
Year
Pre-Impact
Post-Impact
0
2
4
6
8
10
12
14
16
18
20
1950
1960
1970
1980
1990
2000
2010
2020

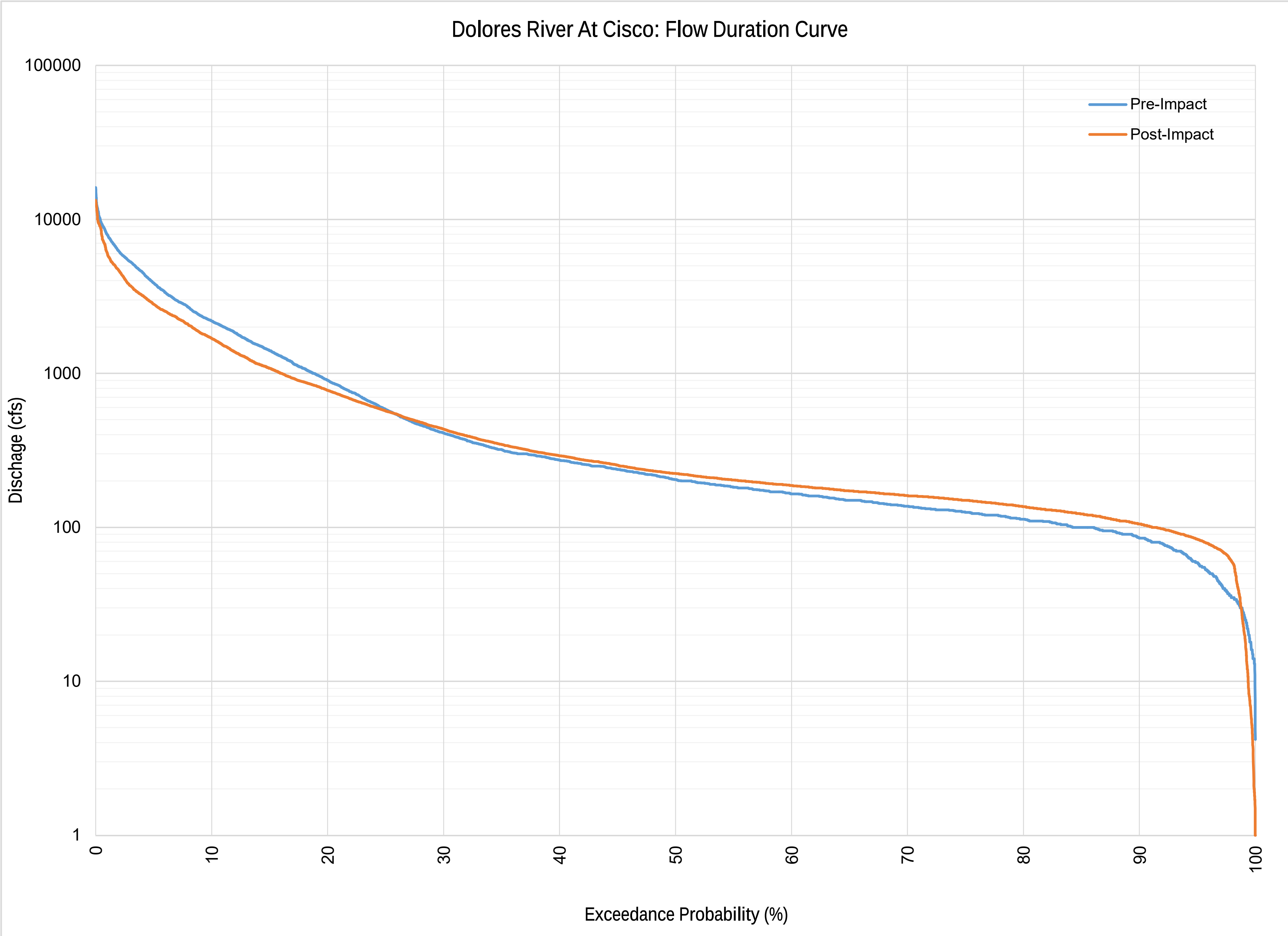


Dolores River At Cisco: Low Pulse Duration
Low Pulse Duration (days)
Year
Pre-Impact
Post-Impact
0
10
20
30
40
50
60
70
80
90
100
1950
1960
1970
1980
1990
2000
2010
2020

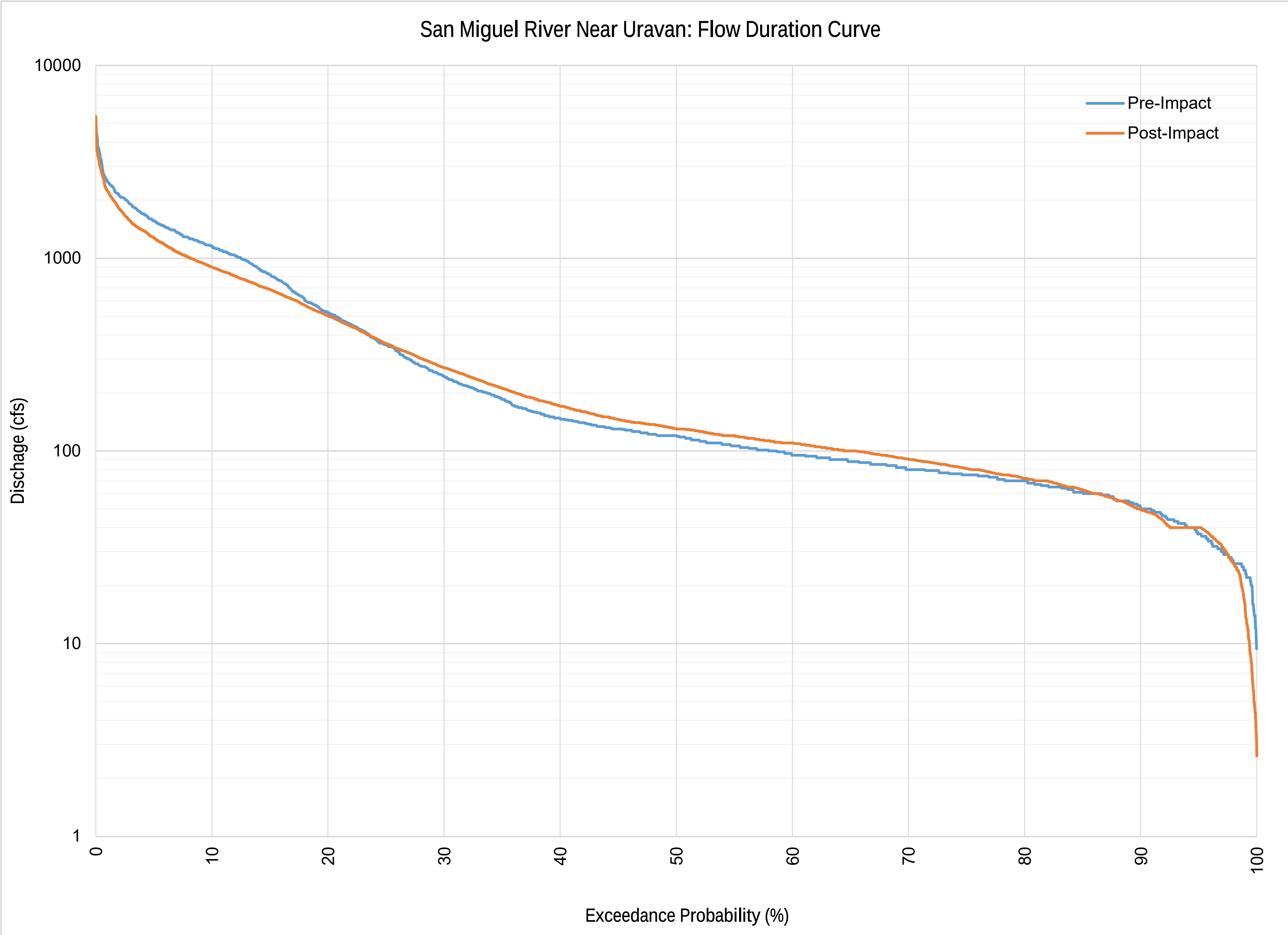
Appendix D

Annual Exceedance Probabilities


Dolores River At Bedrock: Flow Duration Curve
10000
1000
100
10
1
0.1
0.01
Dischage (cfs)
Pre-Impact
Post-Impact
0
10
20
30
40
50
60
70
80
90
100
Exceedance Probability (%)



Dolores River At Cisco: Flow Duration Curve
100000
10000
1000
100
10
1
Dischage (cfs)
0
10
20
30
40
50
60
70
80
90
100
Exceedance Probability (%)
Pre-Impact
Post-Impact


San Miguel River Near Uravan: Flow Duration Curve
10000
1000
100
10
1
Dischage (cfs)
Pre-Impact
Post-Impact
0
10
20
30
40
50
60
70
80
90
100
Exceedance Probability (%)

Appendix E

Flow Duration Curves

```
------------------------------
Bulletin 17B Frequency Analysis
    25 Nov 2019   01:04 PM
------------------------------


--- Input Data ---

Analysis Name: Middle Dolores River - Pre-Dam
Description:

Data Set Name: DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK
DSS File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\ChannelFormingDischarge.dss
DSS Pathname: /DOLORES RIVER/BEDROCK, CO/FLOW-ANNUAL
PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Middle_Dolores_River_-_Pre-Dam\Middle_Dolores
_River_-_Pre-Dam.rpt
XML File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Middle_Dolores_River_-_Pre-Dam\Middle_Dolores
_River_-_Pre-Dam.xml

Start Date:
End Date:

Skew Option: Use Station Skew
Regional Skew: -Infinity
Regional Skew MSE: -Infinity

Plotting Position Type: Hirsch-Stedinger

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---



<< EMA Representation of Data >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK
---------------------------------------------------------------------------------
```

1967 through 1970 represent
1918 to 1921 data

E-1_Dolores River At Bedrock_Pre.txt

Year	Peak	Value Low	Value High	Threshold Low	Threshold High	Type
1967	1,690.0	1,690.0	1,690.0	1.0E-99	1.0E99	Syst
1968	2,340.0	2,340.0	2,340.0	1.0E-99	1.0E99	Syst
1969	4,040.0	4,040.0	4,040.0	1.0E-99	1.0E99	Syst
1970	4,090.0	4,090.0	4,090.0	1.0E-99	1.0E99	Syst
1971	5,690.0	5,690.0	5,690.0	1.0E-99	1.0E99	Syst
1972	1,920.0	1,920.0	1,920.0	1.0E-99	1.0E99	Syst
1973	9,280.0	9,280.0	9,280.0	1.0E-99	1.0E99	Syst
1974	3,430.0	3,430.0	3,430.0	1.0E-99	1.0E99	Syst
1975	8,020.0	8,020.0	8,020.0	1.0E-99	1.0E99	Syst
1976	2,310.0	2,310.0	2,310.0	1.0E-99	1.0E99	Syst
1977	6,720.0	6,720.0	6,720.0	1.0E-99	1.0E99	Syst
1978	4,450.0	4,450.0	4,450.0	1.0E-99	1.0E99	Syst
1979	8,520.0	8,520.0	8,520.0	1.0E-99	1.0E99	Syst
1980	8,700.0	8,700.0	8,700.0	1.0E-99	1.0E99	Syst
1981	1,290.0	1,290.0	1,290.0	1.0E-99	1.0E99	Syst
1982	4,110.0	4,110.0	4,110.0	1.0E-99	1.0E99	Syst
1983	8,360.0	8,360.0	8,360.0	1.0E-99	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	3.624504	0.075985	0.275655	-0.384992
EMA w/ regional info and B17b MSE(G)	3.624504	0.075985	0.275655	-0.384992
EMA w/ regional info and specified MSE(G)	3.624504	0.075985	0.275655	-0.384992

EMA Estimate of MSE[G at-site]	0.321547
MSE[G at-site systematic]	0.321547
Effective Record Length [G at-site]	17.000000
Grubbs-Beck Critical Value	0.000000

--- Final Results ---

<< Plotting Positions >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Events Analyzed Day Mon Year	FLOW CFS	Ordered Events Rank	Water Year	FLOW CFS	H-S Plot Pos
01 Jan 1967	1,690.0	1	1973	9,280.0	5.56
01 Jan 1968	2,340.0	2	1980	8,700.0	11.11
01 Jan 1969	4,040.0	3	1979	8,520.0	16.67
01 Jan 1970	4,090.0	4	1983	8,360.0	22.22
28 Aug 1971	5,690.0	5	1975	8,020.0	27.78
17 Oct 1971	1,920.0	6	1977	6,720.0	33.33
30 Apr 1973	9,280.0	7	1971	5,690.0	38.89
16 Jul 1974	3,430.0	8	1978	4,450.0	44.44
26 Apr 1975	8,020.0	9	1982	4,110.0	50.00
19 May 1976	2,310.0	10	1970	4,090.0	55.56
19 Jul 1977	6,720.0	11	1969	4,040.0	61.11
20 May 1978	4,450.0	12	1974	3,430.0	66.67
19 Apr 1979	8,520.0	13	1968	2,340.0	72.22
22 Apr 1980	8,700.0	14	1976	2,310.0	77.78
04 May 1981	1,290.0	15	1972	1,920.0	83.33
13 Apr 1982	4,110.0	16	1967	1,690.0	88.89
26 Apr 1983	8,360.0	17	1981	1,290.0	94.44

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
19,533.1	0.03284	0.200	54,687.9	11,463.7
17,181.1	0.02314	0.500	40,924.6	10,979.2
15,381.1	0.01712	1.000	32,731.3	10,465.3
13,560.4	0.01226	2.000	25,983.8	9,766.3
11,112.5	0.00769	5.000	18,582.0	8,435.5
9,214.4	0.00563	10.000	13,722.1	7,055.1
7,246.6	0.00473	20.000	9,755.6	5,509.9
4,386.8	0.00516	50.000	5,822.3	3,262.0
2,507.0	0.00732	80.000	3,397.2	1,638.6
1,827.4	0.01055	90.000	2,541.9	1,011.7
1,389.9	0.01571	95.000	2,013.7	606.4
806.3	0.03656	99.000	1,324.9	175.0

|-------------------------|-------------|-------------------------|

<< Systematic Statistics >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Log Transform: FLOW, CFS		Number of Events	
Mean	3.625	Historic Events	0
Standard Dev	0.276	High Outliers	0
Station Skew	-0.385	Low Outliers	0
Regional Skew	---	Zero Events	0
Weighted Skew	---	Missing Events	0
Adopted Skew	-0.385	Systematic Events	17

--- End of Analytical Frequency Curve ---

Bulletin 17B Frequency Analysis
25 Nov 2019   12:59 PM

--- Input Data ---

Analysis Name: Middle Dolores River - Pos-Dam
Description:

Data Set Name: DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK
DSS File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\ChannelFormingDischarge\ChannelFormingDischarge.dss
DSS Pathname: /DOLORES RIVER/BEDROCK, CO/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\ChannelFormingDischarge\Bulletin17Results\Middle_Dolores_River_-_Pos-Dam\Middle_Dolores_River_-_Pos-Dam.rpt
XML File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\ChannelFormingDischarge\Bulletin17Results\Middle_Dolores_River_-_Pos-Dam\Middle_Dolores_River_-_Pos-Dam.xml

Start Date:
End Date:

Skew Option: Use Station Skew
Regional Skew: -Infinity
Regional Skew MSE: -Infinity

Plotting Position Type: Hirsch-Stedinger

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---

<< EMA Representation of Data >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Year	Peak	Value Low	Value High	Threshold Low	Threshold High	Type
1984	4,480.0	4,480.0	4,480.0	1.0E-99	1.0E99	Syst
1985	4,510.0	4,510.0	4,510.0	1.0E-99	1.0E99	Syst
1986	5,230.0	5,230.0	5,230.0	1.0E-99	1.0E99	Syst
1987	4,390.0	4,390.0	4,390.0	1.0E-99	1.0E99	Syst
1988	2,340.0	2,340.0	2,340.0	1.0E-99	1.0E99	Syst
1989	1,010.0	1,010.0	1,010.0	1.0E-99	1.0E99	Syst
1990	956.0	956.0	956.0	1.0E-99	1.0E99	Syst
1991	927.0	927.0	927.0	1.0E-99	1.0E99	Syst
1992	3,340.0	3,340.0	3,340.0	1.0E-99	1.0E99	Syst
1993	4,550.0	4,550.0	4,550.0	1.0E-99	1.0E99	Syst
1994	2,080.0	2,080.0	2,080.0	1.0E-99	1.0E99	Syst
1995	3,140.0	3,140.0	3,140.0	1.0E-99	1.0E99	Syst
1996	636.0	636.0	636.0	1.0E-99	1.0E99	Syst
1997	3,780.0	3,780.0	3,780.0	1.0E-99	1.0E99	Syst
1998	3,740.0	3,740.0	3,740.0	1.0E-99	1.0E99	Syst
1999	3,130.0	3,130.0	3,130.0	1.0E-99	1.0E99	Syst
2000	1,260.0	1,260.0	1,260.0	1.0E-99	1.0E99	Syst
2001	720.0	720.0	720.0	1.0E-99	1.0E99	Syst
2002	1,640.0	1,640.0	1,640.0	1.0E-99	1.0E99	Syst
2003	3,290.0	3,290.0	3,290.0	1.0E-99	1.0E99	Syst
2004	573.0	573.0	573.0	1.0E-99	1.0E99	Syst
2005	5,180.0	5,180.0	5,180.0	1.0E-99	1.0E99	Syst
2006	3,310.0	3,310.0	3,310.0	1.0E-99	1.0E99	Syst
2007	3,120.0	3,120.0	3,120.0	1.0E-99	1.0E99	Syst
2008	1,970.0	1,970.0	1,970.0	1.0E-99	1.0E99	Syst
2009	2,150.0	2,150.0	2,150.0	1.0E-99	1.0E99	Syst
2010	2,080.0	2,080.0	2,080.0	1.0E-99	1.0E99	Syst
2011	1,420.0	1,420.0	1,420.0	1.0E-99	1.0E99	Syst
2012	592.0	592.0	592.0	1.0E-99	1.0E99	Syst
2013	3,650.0	3,650.0	3,650.0	1.0E-99	1.0E99	Syst
2014	1,360.0	1,360.0	1,360.0	1.0E-99	1.0E99	Syst
2015	1,930.0	1,930.0	1,930.0	1.0E-99	1.0E99	Syst
2016	1,240.0	1,240.0	1,240.0	1.0E-99	1.0E99	Syst
2017	3,540.0	3,540.0	3,540.0	1.0E-99	1.0E99	Syst
2018	2,080.0	2,080.0	2,080.0	1.0E-99	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	3.326322	0.082961	0.288030	

```
  -0.536354
  EMA w/ regional info and B17b MSE(G)          3.326322    0.082961    0.288030
  -0.536354
  EMA w/ regional info and specified MSE(G)     3.326322    0.082961    0.288030
  -0.536354
-----------------------------------------------------------------------------------
--------------


  EMA Estimate of MSE[G at-site]                0.189389
  MSE[G at-site systematic]                     0.189389
  Effective Record Length [G at-site]          35.000000
  Grubbs-Beck Critical Value                    0.000000



--- Final Results ---

<< Plotting Positions >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK
--------------------------------------------------------------------
|     Events Analyzed          |           Ordered Events            |
|                      FLOW    |         Water        FLOW     H-S   |
| Day Mon Year          CFS    |  Rank    Year         CFS  Plot Pos |
|------------------------------|-------------------------------------|
|  18 Apr 1984     4,480.0     |    1      1986     5,230.0     2.78 |
|  09 Apr 1985     4,510.0     |    2      2005     5,180.0     5.56 |
|  05 May 1986     5,230.0     |    3      1993     4,550.0     8.33 |
|  21 May 1987     4,390.0     |    4      1985     4,510.0    11.11 |
|  05 Nov 1987     2,340.0     |    5      1984     4,480.0    13.89 |
|  22 Apr 1989     1,010.0     |    6      1987     4,390.0    16.67 |
|  06 Sep 1990       956.0     |    7      1997     3,780.0    19.44 |
|  22 May 1991       927.0     |    8      1998     3,740.0    22.22 |
|  26 May 1992     3,340.0     |    9      2013     3,650.0    25.00 |
|  27 Apr 1993     4,550.0     |   10      2017     3,540.0    27.78 |
|  21 May 1994     2,080.0     |   11      1992     3,340.0    30.56 |
|  22 Jun 1995     3,140.0     |   12      2006     3,310.0    33.33 |
|  14 Sep 1996       636.0     |   13      2003     3,290.0    36.11 |
|  22 May 1997     3,780.0     |   14      1995     3,140.0    38.89 |
|  07 May 1998     3,740.0     |   15      1999     3,130.0    41.67 |
|  25 May 1999     3,130.0     |   16      2007     3,120.0    44.44 |
|  01 May 2000     1,260.0     |   17      1988     2,340.0    47.22 |
|  17 Apr 2001       720.0     |   18      2009     2,150.0    50.00 |
|  12 Sep 2002     1,640.0     |   19      2018     2,080.0    52.78 |
|  10 Sep 2003     3,290.0     |   20      2010     2,080.0    55.56 |
|  21 Sep 2004       573.0     |   21      1994     2,080.0    58.33 |
|  26 May 2005     5,180.0     |   22      2008     1,970.0    61.11 |
|  06 Aug 2006     3,310.0     |   23      2015     1,930.0    63.89 |
```

07 Oct 2006	3,120.0	24	2002	1,640.0	66.67
23 May 2008	1,970.0	25	2011	1,420.0	69.44
25 May 2009	2,150.0	26	2014	1,360.0	72.22
04 Aug 2010	2,080.0	27	2000	1,260.0	75.00
06 Jun 2011	1,420.0	28	2016	1,240.0	77.78
24 Aug 2012	592.0	29	1989	1,010.0	80.56
23 Sep 2013	3,650.0	30	1990	956.0	83.33
05 Aug 2014	1,360.0	31	1991	927.0	86.11
02 Aug 2015	1,930.0	32	2001	720.0	88.89
13 Jun 2016	1,240.0	33	1996	636.0	91.67
07 May 2017	3,540.0	34	2012	592.0	94.44
26 Aug 2018	2,080.0	35	2004	573.0	97.22

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	Confidence Limits 0.95 FLOW, CFS
9,373.2	0.01898	0.200	17,462.0	5,890.1
8,392.9	0.01304	0.500	14,072.1	5,708.2
7,612.7	0.00935	1.000	11,863.4	5,507.9
6,796.1	0.00640	2.000	9,909.5	5,222.3
5,653.4	0.00372	5.000	7,623.4	4,627.0
4,731.3	0.00263	10.000	6,014.4	3,936.8
3,742.2	0.00231	20.000	4,533.2	3,088.8
2,248.8	0.00283	50.000	2,770.5	1,821.8
1,242.8	0.00420	80.000	1,563.8	920.9
880.3	0.00652	90.000	1,142.6	574.8
649.9	0.01051	95.000	883.1	350.0
351.1	0.02761	99.000	545.3	96.6

<< Systematic Statistics >>
DOLORES RIVER-BEDROCK, CO-FLOW-ANNUAL PEAK

Log Transform: FLOW, CFS		Number of Events	
Mean	3.326	Historic Events	0
Standard Dev	0.288	High Outliers	0
Station Skew	-0.536	Low Outliers	0

```
|  Regional Skew          ---  |  Zero Events           0     |
|  Weighted Skew          ---  |  Missing Events        0     |
|  Adopted Skew        -0.536  |  Systematic Events       35  |
|------------------------------|------------------------------|
```

--- End of Analytical Frequency Curve ---

```
-------------------------------
Bulletin 17B Frequency Analysis
    25 Nov 2019   12:40 PM
-------------------------------


--- Input Data ---

Analysis Name: Lower Dolores River - Pre-Dam
Description:

Data Set Name: DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK
DSS File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\ChannelFormingDischarge.dss
DSS Pathname: /DOLORES RIVER/CISCO, UT/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Lower_Dolores_River_-_Pre-Dam\Lower_Dolores_R
iver_-_Pre-Dam.rpt
XML File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Lower_Dolores_River_-_Pre-Dam\Lower_Dolores_R
iver_-_Pre-Dam.xml

Start Date:
End Date:

Skew Option: Use Station Skew
Regional Skew: -Infinity
Regional Skew MSE: -Infinity

Plotting Position Type: Hirsch-Stedinger

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---



<< EMA Representation of Data >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK
---------------------------------------------------------------------------------
|                    |          Value           |         Threshold        |      |
```

Year	Peak	Low	High	Low	High	Type
1951	2,140.0	2,140.0	2,140.0	1.0E-99	1.0E99	Syst
1952	11,100.0	11,100.0	11,100.0	1.0E-99	1.0E99	Syst
1953	3,060.0	3,060.0	3,060.0	1.0E-99	1.0E99	Syst
1954	3,220.0	3,220.0	3,220.0	1.0E-99	1.0E99	Syst
1955	3,690.0	3,690.0	3,690.0	1.0E-99	1.0E99	Syst
1956	2,470.0	2,470.0	2,470.0	1.0E-99	1.0E99	Syst
1957	9,500.0	9,500.0	9,500.0	1.0E-99	1.0E99	Syst
1958	17,400.0	17,400.0	17,400.0	1.0E-99	1.0E99	Syst
1959	3,300.0	3,300.0	3,300.0	1.0E-99	1.0E99	Syst
1960	6,160.0	6,160.0	6,160.0	1.0E-99	1.0E99	Syst
1961	3,510.0	3,510.0	3,510.0	1.0E-99	1.0E99	Syst
1962	6,760.0	6,760.0	6,760.0	1.0E-99	1.0E99	Syst
1963	3,080.0	3,080.0	3,080.0	1.0E-99	1.0E99	Syst
1964	5,310.0	5,310.0	5,310.0	1.0E-99	1.0E99	Syst
1965	11,000.0	11,000.0	11,000.0	1.0E-99	1.0E99	Syst
1966	4,040.0	4,040.0	4,040.0	1.0E-99	1.0E99	Syst
1967	2,650.0	2,650.0	2,650.0	1.0E-99	1.0E99	Syst
1968	4,870.0	4,870.0	4,870.0	1.0E-99	1.0E99	Syst
1969	6,480.0	6,480.0	6,480.0	1.0E-99	1.0E99	Syst
1970	7,000.0	7,000.0	7,000.0	1.0E-99	1.0E99	Syst
1971	4,140.0	4,140.0	4,140.0	1.0E-99	1.0E99	Syst
1972	2,410.0	2,410.0	2,410.0	1.0E-99	1.0E99	Syst
1973	14,600.0	14,600.0	14,600.0	1.0E-99	1.0E99	Syst
1974	4,500.0	4,500.0	4,500.0	1.0E-99	1.0E99	Syst
1975	11,900.0	11,900.0	11,900.0	1.0E-99	1.0E99	Syst
1976	3,030.0	3,030.0	3,030.0	1.0E-99	1.0E99	Syst
1977	12,000.0	12,000.0	12,000.0	1.0E-99	1.0E99	Syst
1978	8,740.0	8,740.0	8,740.0	1.0E-99	1.0E99	Syst
1979	13,600.0	13,600.0	13,600.0	1.0E-99	1.0E99	Syst
1980	12,200.0	12,200.0	12,200.0	1.0E-99	1.0E99	Syst
1981	2,110.0	2,110.0	2,110.0	1.0E-99	1.0E99	Syst
1982	6,220.0	6,220.0	6,220.0	1.0E-99	1.0E99	Syst
1983	15,500.0	15,500.0	15,500.0	1.0E-99	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	3.750973	0.079419	0.281813	0.175441
EMA w/ regional info and B17b MSE(G)	3.750973	0.079419	0.281813	0.175441

```
  EMA w/ regional info and specified MSE(G)        3.750973    0.079419    0.281813
   0.175441
------------------------------------------------------------------------------------
--------------


  EMA Estimate of MSE[G at-site]                   0.166067
  MSE[G at-site systematic]                        0.166067
  Effective Record Length [G at-site]             33.000000
  Grubbs-Beck Critical Value                       0.000000



--- Final Results ---

<< Plotting Positions >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK
--------------------------------------------------------------------
|     Events Analyzed        |            Ordered Events             |
|                      FLOW  |            Water         FLOW    H-S  |
| Day Mon Year          CFS  |   Rank     Year          CFS  Plot Pos |
|----------------------------|--------------------------------------|
|  28 May 1951      2,140.0  |     1       1958    17,400.0    2.94   |
|  06 May 1952     11,100.0  |     2       1983    15,500.0    5.88   |
|  14 Jun 1953      3,060.0  |     3       1973    14,600.0    8.82   |
|  23 Oct 1953      3,220.0  |     4       1979    13,600.0   11.76   |
|  10 May 1955      3,690.0  |     5       1980    12,200.0   14.71   |
|  02 Jun 1956      2,470.0  |     6       1977    12,000.0   17.65   |
|  07 Jun 1957      9,500.0  |     7       1975    11,900.0   20.59   |
|  21 Apr 1958     17,400.0  |     8       1952    11,100.0   23.53   |
|  05 Aug 1959      3,300.0  |     9       1965    11,000.0   26.47   |
|  11 Apr 1960      6,160.0  |    10       1957     9,500.0   29.41   |
|  03 May 1961      3,510.0  |    11       1978     8,740.0   32.35   |
|  21 Apr 1962      6,760.0  |    12       1970     7,000.0   35.29   |
|  31 Mar 1963      3,080.0  |    13       1962     6,760.0   38.24   |
|  13 Aug 1964      5,310.0  |    14       1969     6,480.0   41.18   |
|  24 Apr 1965     11,000.0  |    15       1982     6,220.0   44.12   |
|  03 Apr 1966      4,040.0  |    16       1960     6,160.0   47.06   |
|  27 May 1967      2,650.0  |    17       1964     5,310.0   50.00   |
|  30 May 1968      4,870.0  |    18       1968     4,870.0   52.94   |
|  23 Apr 1969      6,480.0  |    19       1974     4,500.0   55.88   |
|  07 May 1970      7,000.0  |    20       1971     4,140.0   58.82   |
|  28 Mar 1971      4,140.0  |    21       1966     4,040.0   61.76   |
|  18 Oct 1971      2,410.0  |    22       1955     3,690.0   64.71   |
|  30 Apr 1973     14,600.0  |    23       1961     3,510.0   67.65   |
|  26 Apr 1974      4,500.0  |    24       1959     3,300.0   70.59   |
|  27 Apr 1975     11,900.0  |    25       1954     3,220.0   73.53   |
|  19 May 1976      3,030.0  |    26       1963     3,080.0   76.47   |
```

24 Jul 1977	12,000.0	27	1953	3,060.0	79.41
17 May 1978	8,740.0	28	1976	3,030.0	82.35
24 Apr 1979	13,600.0	29	1967	2,650.0	85.29
23 Apr 1980	12,200.0	30	1956	2,470.0	88.24
18 Jul 1981	2,110.0	31	1972	2,410.0	91.18
06 May 1982	6,220.0	32	1951	2,140.0	94.12
10 May 1983	15,500.0	33	1981	2,110.0	97.06

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	Confidence Limits 0.95 FLOW, CFS
41,904.9	0.03484	0.200	159,233.2	25,598.5
33,359.2	0.02428	0.500	97,333.2	21,882.2
27,712.5	0.01781	1.000	66,849.0	19,128.0
22,693.6	0.01260	2.000	45,741.4	16,421.8
16,909.7	0.00757	5.000	27,514.4	12,922.0
13,092.1	0.00507	10.000	18,686.8	10,334.4
9,670.1	0.00356	20.000	12,598.9	7,805.3
5,530.1	0.00275	50.000	6,792.8	4,511.0
3,248.7	0.00294	80.000	3,976.5	2,584.6
2,486.1	0.00376	90.000	3,073.8	1,853.5
2,004.0	0.00531	95.000	2,527.8	1,365.2
1,355.0	0.01201	99.000	1,870.9	736.1

<< Systematic Statistics >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK

Log Transform: FLOW, CFS		Number of Events	
Mean	3.751	Historic Events	0
Standard Dev	0.282	High Outliers	0
Station Skew	0.175	Low Outliers	0
Regional Skew	---	Zero Events	0
Weighted Skew	---	Missing Events	0
Adopted Skew	0.175	Systematic Events	33

--- End of Analytical Frequency Curve ---

```
------------------------------
Bulletin 17B Frequency Analysis
    25 Nov 2019   12:48 PM
------------------------------


--- Input Data ---

Analysis Name: Lower Dolores River - Post-Dam
Description:

Data Set Name: DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK
DSS File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\ChannelFormingDischarge.dss
DSS Pathname: /DOLORES RIVER/CISCO, UT/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Lower_Dolores_River_-_Post-Dam\Lower_Dolores_
River_-_Post-Dam.rpt
XML File Name:
\\den-gissrv1\gisdata\PROJECTS\10180605_RiversEdge_DoloresRiver\models\HEC-SSP\Chan
nelFormingDischarge\Bulletin17Results\Lower_Dolores_River_-_Post-Dam\Lower_Dolores_
River_-_Post-Dam.xml

Start Date:
End Date:

Skew Option: Use Station Skew
Regional Skew: -Infinity
Regional Skew MSE: -Infinity

Plotting Position Type: Hirsch-Stedinger

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---



<< EMA Representation of Data >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK
---------------------------------------------------------------------------------
|                    |          Value            |         Threshold         |      |
```

Year	Peak	Low	High	Low	High	Type
1984	14,700.0	14,700.0	14,700.0	1.0E-99	1.0E99	Syst
1985	11,200.0	11,200.0	11,200.0	1.0E-99	1.0E99	Syst
1986	7,890.0	7,890.0	7,890.0	1.0E-99	1.0E99	Syst
1987	8,440.0	8,440.0	8,440.0	1.0E-99	1.0E99	Syst
1988	2,520.0	2,520.0	2,520.0	1.0E-99	1.0E99	Syst
1989	2,360.0	2,360.0	2,360.0	1.0E-99	1.0E99	Syst
1990	1,340.0	1,340.0	1,340.0	1.0E-99	1.0E99	Syst
1991	2,670.0	2,670.0	2,670.0	1.0E-99	1.0E99	Syst
1992	6,760.0	6,760.0	6,760.0	1.0E-99	1.0E99	Syst
1993	13,600.0	13,600.0	13,600.0	1.0E-99	1.0E99	Syst
1994	3,760.0	3,760.0	3,760.0	1.0E-99	1.0E99	Syst
1995	6,300.0	6,300.0	6,300.0	1.0E-99	1.0E99	Syst
1996	1,260.0	1,260.0	1,260.0	1.0E-99	1.0E99	Syst
1997	6,600.0	6,600.0	6,600.0	1.0E-99	1.0E99	Syst
1998	7,570.0	7,570.0	7,570.0	1.0E-99	1.0E99	Syst
1999	4,490.0	4,490.0	4,490.0	1.0E-99	1.0E99	Syst
2000	2,830.0	2,830.0	2,830.0	1.0E-99	1.0E99	Syst
2001	2,140.0	2,140.0	2,140.0	1.0E-99	1.0E99	Syst
2002	3,380.0	3,380.0	3,380.0	1.0E-99	1.0E99	Syst
2003	3,680.0	3,680.0	3,680.0	1.0E-99	1.0E99	Syst
2004	1,710.0	1,710.0	1,710.0	1.0E-99	1.0E99	Syst
2005	9,420.0	9,420.0	9,420.0	1.0E-99	1.0E99	Syst
2006	1,750.0	1,750.0	1,750.0	1.0E-99	1.0E99	Syst
2007	6,100.0	6,100.0	6,100.0	1.0E-99	1.0E99	Syst
2008	4,750.0	4,750.0	4,750.0	1.0E-99	1.0E99	Syst
2009	3,870.0	3,870.0	3,870.0	1.0E-99	1.0E99	Syst
2010	4,520.0	4,520.0	4,520.0	1.0E-99	1.0E99	Syst
2011	3,710.0	3,710.0	3,710.0	1.0E-99	1.0E99	Syst
2012	1,540.0	1,540.0	1,540.0	1.0E-99	1.0E99	Syst
2013	4,600.0	4,600.0	4,600.0	1.0E-99	1.0E99	Syst
2014	2,430.0	2,430.0	2,430.0	1.0E-99	1.0E99	Syst
2015	7,600.0	7,600.0	7,600.0	1.0E-99	1.0E99	Syst
2016	2,790.0	2,790.0	2,790.0	1.0E-99	1.0E99	Syst
2017	4,540.0	4,540.0	4,540.0	1.0E-99	1.0E99	Syst
2018	1,010.0	1,010.0	1,010.0	1.0E-99	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	3.599489	0.089634	0.299389	-0.050368

EMA w/ regional info and B17b MSE(G) 3.599489 0.089634 0.299389 -0.050368
EMA w/ regional info and specified MSE(G) 3.599489 0.089634 0.299389 -0.050368

EMA Estimate of MSE[G at-site]	0.147819
MSE[G at-site systematic]	0.147819
Effective Record Length [G at-site]	35.000000
Grubbs-Beck Critical Value	0.000000

--- Final Results ---

<< Plotting Positions >>
DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK

Events Analyzed					Ordered Events			
			FLOW		Water	FLOW	H-S
Day	Mon	Year	CFS	Rank	Year	CFS	Plot Pos
15	May	1984	14,700.0	1	1984	14,700.0	2.78
11	Apr	1985	11,200.0	2	1993	13,600.0	5.56
06	May	1986	7,890.0	3	1985	11,200.0	8.33
27	Apr	1987	8,440.0	4	2005	9,420.0	11.11
06	Nov	1987	2,520.0	5	1987	8,440.0	13.89
21	Apr	1989	2,360.0	6	1986	7,890.0	16.67
08	Jul	1990	1,340.0	7	2015	7,600.0	19.44
08	Apr	1991	2,670.0	8	1998	7,570.0	22.22
26	May	1992	6,760.0	9	1992	6,760.0	25.00
17	May	1993	13,600.0	10	1997	6,600.0	27.78
22	May	1994	3,760.0	11	1995	6,300.0	30.56
18	Jun	1995	6,300.0	12	2007	6,100.0	33.33
17	May	1996	1,260.0	13	2008	4,750.0	36.11
23	May	1997	6,600.0	14	2013	4,600.0	38.89
03	May	1998	7,570.0	15	2017	4,540.0	41.67
25	May	1999	4,490.0	16	2010	4,520.0	44.44
10	Apr	2000	2,830.0	17	1999	4,490.0	47.22
10	Jul	2001	2,140.0	18	2009	3,870.0	50.00
12	Sep	2002	3,380.0	19	1994	3,760.0	52.78
11	Sep	2003	3,680.0	20	2011	3,710.0	55.56
26	Mar	2004	1,710.0	21	2003	3,680.0	58.33
26	May	2005	9,420.0	22	2002	3,380.0	61.11
07	Aug	2006	1,750.0	23	2000	2,830.0	63.89
07	Oct	2006	6,100.0	24	2016	2,790.0	66.67

22 May 2008	4,750.0	25	1991	2,670.0	69.44
15 May 2009	3,870.0	26	1988	2,520.0	72.22
18 Apr 2010	4,520.0	27	2014	2,430.0	75.00
08 Jun 2011	3,710.0	28	1989	2,360.0	77.78
29 Mar 2012	1,540.0	29	2001	2,140.0	80.56
23 Sep 2013	4,600.0	30	2006	1,750.0	83.33
11 Apr 2014	2,430.0	31	2004	1,710.0	86.11
11 Jun 2015	7,600.0	32	2012	1,540.0	88.89
13 Jun 2016	2,790.0	33	1990	1,340.0	91.67
08 May 2017	4,540.0	34	1996	1,260.0	94.44
27 Aug 2018	1,010.0	35	2018	1,010.0	97.22

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>

DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	Confidence Limits 0.95 FLOW, CFS
27,726.5	0.03244	0.200	76,471.3	17,280.1
22,724.7	0.02268	0.500	52,535.3	15,219.5
19,269.3	0.01670	1.000	39,160.9	13,580.3
16,078.4	0.01188	2.000	28,842.4	11,866.4
12,235.4	0.00723	5.000	18,759.4	9,487.1
9,583.4	0.00494	10.000	13,224.2	7,626.2
7,114.9	0.00358	20.000	9,114.5	5,752.1
3,999.5	0.00292	50.000	4,933.3	3,240.5
2,229.9	0.00334	80.000	2,768.2	1,722.5
1,637.7	0.00443	90.000	2,073.0	1,165.3
1,267.0	0.00635	95.000	1,651.9	802.2
779.7	0.01445	99.000	1,122.9	354.7

<< Systematic Statistics >>

DOLORES RIVER-CISCO, UT-FLOW-ANNUAL PEAK

Log Transform: FLOW, CFS		Number of Events	
Mean	3.599	Historic Events	0
Standard Dev	0.299	High Outliers	0
Station Skew	-0.050	Low Outliers	0
Regional Skew	---	Zero Events	0

```
|  Weighted Skew          ---  |  Missing Events        0      |
|  Adopted Skew        -0.050  |  Systematic Events       35  |
|------------------------------|-------------------------------|
```

--- End of Analytical Frequency Curve ---