Hydrological Assessment of the San Miguel Watershed

A Product of the San Miguel Pilot Project

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lōtic

Prepared For:

TROUT
UNLIMITED

SAN MIGUEL
WATERSHED
COALITION

DNR

COLORADO
Colorado Water
Conservation Board
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1 Introduction

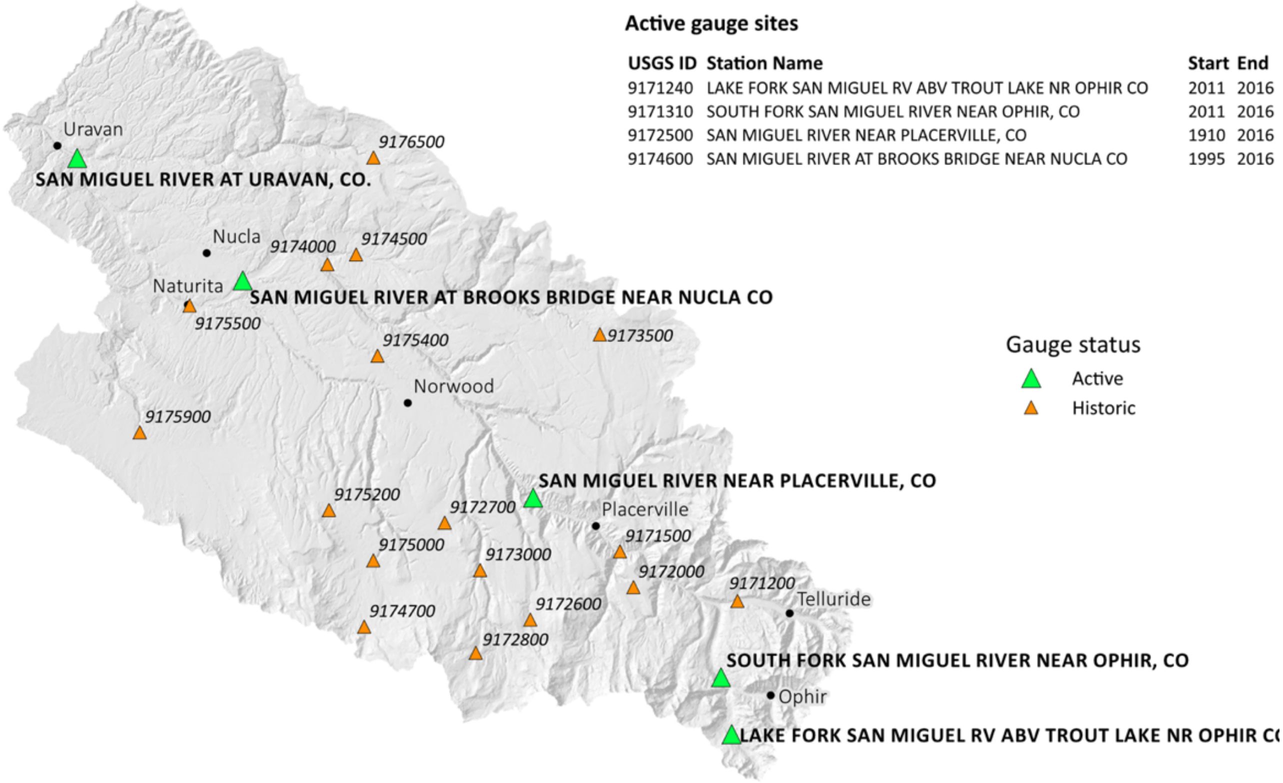
The structural form and functional integrity of a riverine system is described by a suite of hydrological, physiochemical, biological, geomorphological, and hydraulic processes. Complex bi-directional interactions occur between each process, complicating evaluation of any one component of the system in isolation from the others. However, the overall form and function of a river is primarily influenced by its natural hydrology. In turn, fluvial ecologists often treat flow regime as the “master variable” exerting the largest influence on riverine ecosystem form and function. The Natural Flow Paradigm [1] postulates that hydrology represents the key driver of riverine structure and function.

The daily, seasonal, and inter-annual variations in a stream’s flows make up its *hydrologic regime*. Changes in the timing and magnitude of various elements of the hydrological regime can produce cascading effects—or positive feedback loops—between: 1) the availability and quality of aquatic habitat, 2) the condition and extent of riparian zones, and 3) the dynamics and evolutionary trajectory of channel structure. Broad patterns of precipitation and topography largely determine a river’s flow regime. River systems subject to hydrological change due to changing climate or human management are vulnerable to shifts in the composition and resiliency of both structural and biological components of the ecosystem.

Activities that deplete or augment streamflow have the potential to impact important regime characteristics, including: total annual volume, magnitude and duration of peak and low flows, and variability in timing and rate of change. Changes to total annual volume and peak flows may impact channel stability, riparian vegetation, and floodplain functions. Impacts to base flows frequently alter water quality and the quality and availability of aquatic habitat. Alterations to natural patterns of flow variability (e.g. the frequency and timing of floods) impact fish, aquatic insects and other biota with life history strategies tied to predictable rates of occurrence or change [2].

Hydrological characteristics of interest for streams in the San Miguel watershed include the duration, frequency, and magnitude of different flow types on the mainstem San Miguel River and its major tributaries. Surface diversions and reservoir operations strongly alter the longitudinal (upstream-downstream) and temporal (day-to-day or seasonal) patterns of flow in many streams throughout the basin. Additionally, long-term hydrological conditions like drought or wet periods can impart both obvious and subtle changes. Stakeholders in the San Miguel watershed recognize that understanding human and natural controls on hydrological regime behavior is a critical first step for effective resource management. To this end, this effort sought to produce data characterizing the hydrological regime at numerous locations throughout the watershed under a range of climactic conditions.

Characterizing patterns of daily streamflow across a range of hydrological conditions and under different management regimes on the mainstem San Miguel River is possible at several locations where United States Geological Survey (USGS) gauges exist and maintain long data records. Gauges meeting those criteria primarily exist on the mainstem. On tributaries, satisfactory streamflow records are sparse both in geographic and temporal coverage (Figure 1). Historical and current data at these locations are, generally, inadequate to describe typical daily flow conditions at a sufficient spatial resolution to inform water management decisions. Informed evaluations of E&R needs gaps require quantification of streamflow behaviors at streamflow gauges with long records and at additional points intermediate to or above locations where historical data is available. To provide these quantifications/estimates and address the water resource planning questions of stakeholders, this project utilized both stream gauge records and hydrological simulation tools and methods.



Active gauge sites

USGS ID	Station Name	Start	End
9171240	LAKE FORK SAN MIGUEL RV ABV TROUT LAKE NR OPHIR CO	2011	2016
9171310	SOUTH FORK SAN MIGUEL RIVER NEAR OPHIR, CO	2011	2016
9172500	SAN MIGUEL RIVER NEAR PLACERVILLE, CO	1910	2016
9174600	SAN MIGUEL RIVER AT BROOKS BRIDGE NEAR NUCLA CO	1995	2016

Figure 1. Streamflow gauging locations across the San Miguel watershed. Robust data sets exist at several locations, including at the San Miguel River near Placerville (USGS 09172500), the San Miguel River at Naturita (USGS 09175500), and the San Miguel River at Uravan (USGS 09177000). The data records for most tributary locations are extremely limited. Short periods of operation are not ideal for statistical characterization of streamflows or for assessing other attributes.

2 Trends Assessment

Historical hydrological regime behavior on the San MIguel River mainstem was characterized by retrieving daily streamflow time series from historical USGS streamflow gauging stations within the planning area. Data was processed and summarized in the R statistical computing environment using the EGRET, FlowScreen, and fastr libraries. The combined effects of reservoir operation, historical consumptive water use and, perhaps, climate change and long-term drought are observed in the historical streamflow records collected on the San Miguel River near Placerville (USGS 09172500) and on the San Miguel River near Uravan (USGS 09177000). A set of streamflow behavior statistics were used to characterize streamflow behavior at these two locations that effectively characterize typical streamflow regimes in the upper and lower San Miguel Watershed. Results provide a view of typical behaviors and some measure of inter-annual variability at the upstream and downstream ends of the planning area.

Additional steps were taken to identify specific trends or step changes in streamflow behavior over the period of record at these two locations. Trends were assessed using Mann-Kendall trends tests. The magnitude of the trends were assessed using the Theil-Sen approach. Analysis results indicate weak declines in some metrics of annual flow behavior since the 1970s. Similar patterns are observed downstream at the San Miguel River at Uravan. Declines in maximum daily flows may be reducing the channels ability to mobilize and transport sediment downstream. Changes in low-flow metrics like average annual 30-day and 7-day minimum flows likely restrict the availability of aquatic habitat for fish and other species. If the drought conditions observed over the previous 20 years persist into the coming decades, these weak downward trends may become stronger and/or statistically significant.

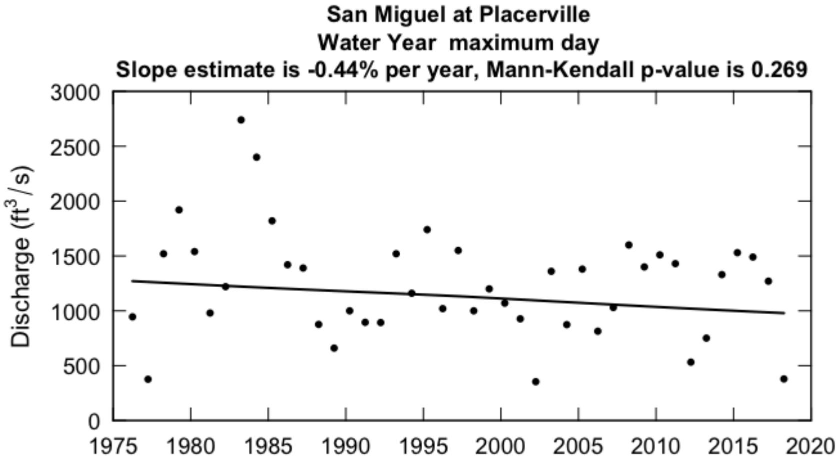


Figure 2. Historical patterns in maximum daily flows recorded on the San Miguel River at Placerville. A Mann-Kendall test indicates a non-statistically significant negative Sen's slope in this metric over recent decades.

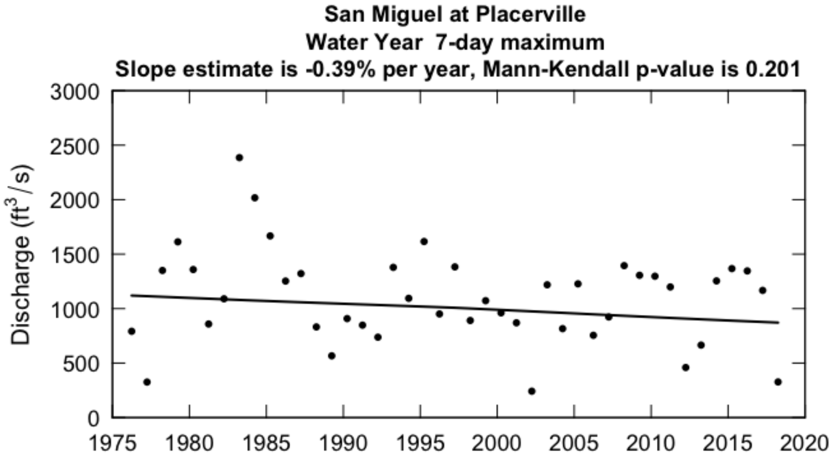


Figure 3. Historical patterns in 7-day maximum daily flows recorded on the San Miguel River at Placerville. A Mann-Kendall test indicates a non-statistically significant negative Sen's slope in this metric over recent decades.

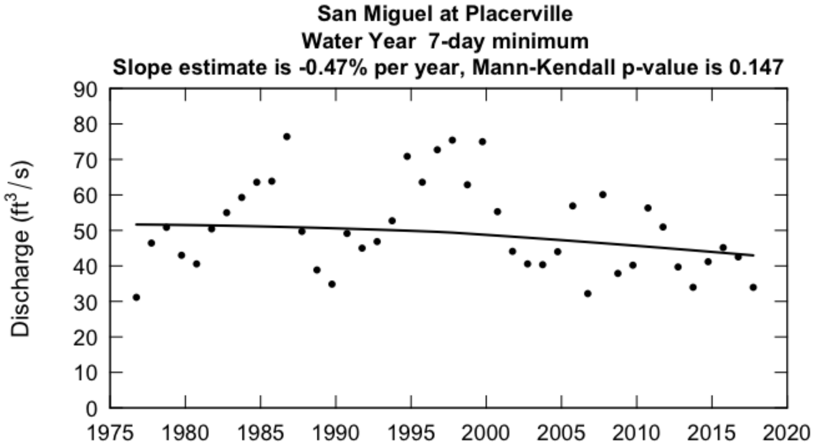


Figure 4. Historical patterns in 7-day minimum daily flows recorded on the San Miguel River at Placerville. A Mann-Kendall test indicates a non-statistically significant negative Sen's slope in this metric over recent decades.

Unfortunately, long-term streamflow records are not available for every tributary in the San Miguel watershed. This assessment, therefore, relied extensively on hydrological simulation modeling to estimate flow behaviors in areas without streamflow gauges. This approach was particularly important for assessing hydrological impacts associated with a range of potential future climate and population growth futures.

3 Scenario Modeling

Different perspectives on natural, existing, and future hydrological behavior and its relationship to consumptive and non-consumptive water uses can be gleaned from trends analysis on historical streamflow records and scenario modeling, as discussed above. Historical data is limited to demonstrating the behaviors that manifested after installation of a stream gauge—an event that is often preceded by water development and use in a watershed. Approximating natural hydrology in many locations, thus, requires application of modeling tools. While trends analysis may be the best tool for understanding near-term future hydrological conditions, extrapolation of historical trends out to 30 or 50-year time horizons may be an insufficient or inappropriate approach. This is especially true where potential future behavior in the joint hydrological/socio-political/administrative system is non-linear with respect to the historical condition, where rapid step changes may affect outcomes, etc.

Scenario modeling is used extensively across Colorado for risk assessment and decision support. That approach is adopted here as well to provide local stakeholders with insights into the ways in which changes in water availability and water use may alter local waterways' ability to deliver goods and services to local communities. Understanding the complex interplay between inflow hydrology and the exercise of surface water diversion rights under Colorado water law requires a water rights allocation and accounting model. Gauge records, diversion histories, and rainfall/runoff simulations provide the inputs necessary to build a functioning simulation model for local streams and rivers. Hydrological simulations for the San Miguel and tributaries were produced by modifying the State of Colorado Stream Simulation Model (StateMOD) developed by the Colorado Water Conservation Board (CWCB) for the Southwest Basin [3].

The CWCB recently provided a Technical Update to the Colorado Water Plan.[1] That update includes a set of revised StateMod scenario planning models for the Southwest Basin. The models simulate the effects of several climate change and development futures. Results generated by the models provide a lens through which potential future conditions in the San Miguel River Watershed can be evaluated. Model results representing natural and existing (i.e. 'baseline') conditions provide a means for assessing the degree of hydrological alteration brought about my human activities. Modeled future scenarios encompass a wide range of future conditions according to the best available science and stakeholder inputs. This scenario planning approach, unlike the more simplistic low to high stress conditions, recognizes that the future holds a degree of uncertainty where the various drivers will impact each other. Each of the planning scenarios presented in the Technical Update reflects a possible future state, which depends on a variety of environmental and social drivers. The differentiating components of the planning scenarios are listed below:

Baseline – Current Conditions

- Current irrigated acreages and irrigation practices
- Historical IWR
- Historical hydrology

Scenario A – Business as Usual

- Includes reduction of irrigated acreage near urbanized areas
- Increased stress to streamflow and water supplies
- Climate is similar to conditions in the 20th century

Scenario B – Weak Economy

- Reduction of irrigated acreage near urbanized areas
- Economy struggles with reduced population growth
- Climate is similar to conditions in the 20th century
- Little change in social values, levels of water conservation, urban land use patterns, and environmental regulations

Scenario C – Cooperative Growth

- Reduction of irrigated acreage
- 20% in Irrigation Water Requirement (IWR) climate factor (i.e. warmer)
- Population growth consistent with current forecasts
- Increased water and energy conservation
- Emergence of water saving technology
- Water development more restrictive requiring high efficiency as well as environmental/recreational benefits
- Moderate warming of the climate increasing water demands in all sectors

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[1] "Technical Update to the Colorado Water Plan," Colorado Water Conservation Board, Volume 1., 2019.

Scenario D – Adaptive Innovation

- Much warmer climate with technological innovation to address the problem
- Population growth higher than current projections
- Reduction of acreage, but lesser than other scenarios due to demand for locally produced food
- 31% IWR climate factor (i.e. warmer)
- 10% IWR reduction (i.e. lower water use by crops)
- 10% system efficiency increase to offsets water use in warmer climate

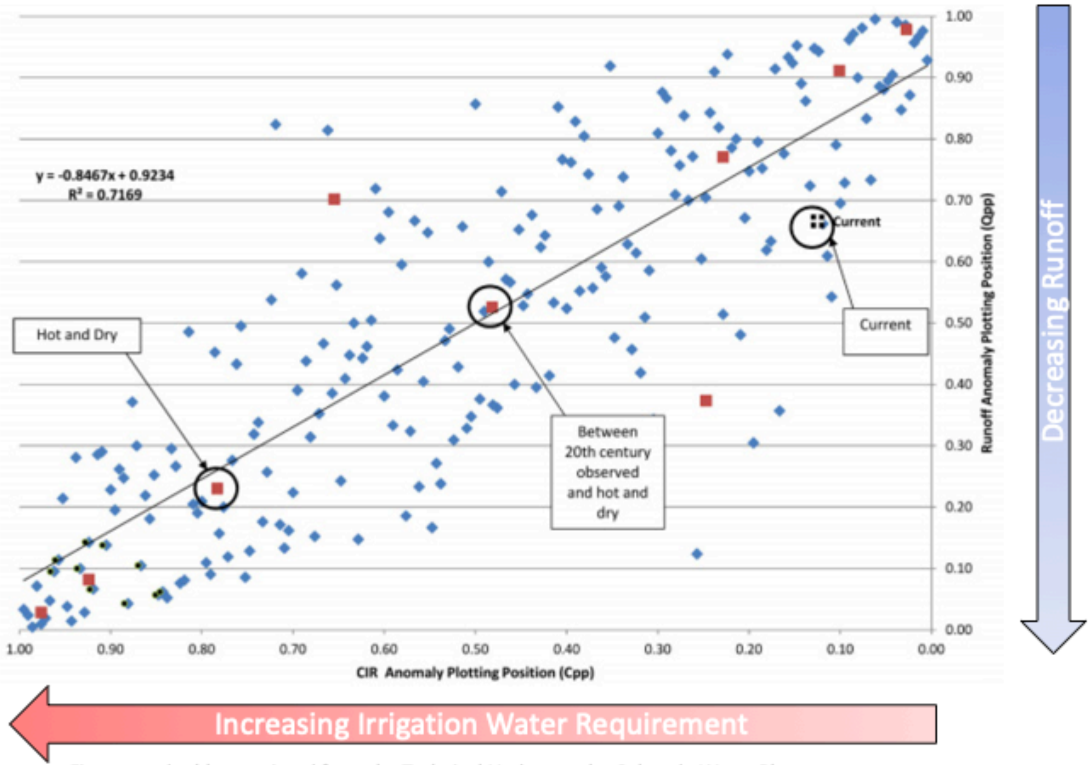
Scenario E – Hot Growth

- Much warmer climate with increased population
- Rapid transition of agricultural lands to urban
- Reduction of acreage
- Decline in streamflow and water supply
- 31% IWR climate factor

Notably, the CWCB did not include Drought Contingency Plan implementation or any other 'Big River' management actions related to Lake Powell in any of the Technical Update models. This is an important data gap that may affect the assessment of risk for hydrological change in the San Miguel River Watershed as a series of recent dry years moves the upper Colorado River Basin closer to enacting measures to protect Lake Powell water elevations.

The climate scenarios included in the Technical Updates models attempt to bracket the range of future conditions predicted by a large number of climate models (Figure 5). Scenarios A and B represent climate using historical patterns of hydrology, temperature and precipitation. Scenarios D and E represent a future climate where runoff anomalies decrease (streamflows decrease) and Crop Irrigation Requirement (CIR) anomalies increase (crop water use increases). Scenario C uses positions for runoff anomalies and CIR anomalies intermediate between the historical condition and the hot-and-dry future characterized by Scenarios D and E.

Streamflows are modified in the simulation models through application of climate adjustment factors that increase irrigation water demand at nodes throughout the simulation network and alter hydrograph shape and total yield at the upstream model boundaries. Increasing crop consumption is driven by increasing evapotranspiration in response to increasing temperatures. These demand increases are included to varying degrees in Scenarios C, D and E. Some of these demand increases are offset by simulation of increased water efficiency in Scenarios C and D (Figure 6). The simulation models also included changes in municipal demand (to simulate population growth) and industrial demand.



Figures and tables reprinted from the Technical Update to the Colorado Water Plan

Figure 5. Three climate scenarios selected for use in the Technical Update models bracket the range of Runoff Anomalies and Crop Irrigation Requirements predicted by a large number of climate models/runs.

Table 1. Predicted changes in streamflow behavior for the San Miguel River at Placerville as a function of several climate and development futures included in the Technical Update to the Colorado Water Plan [5].

Flow Metric	**A** Business as Usual	**B** Weak Economy	**C** Cooperative Growth	**D** Adaptive Innovation	**E** Hot Growth
Cold Water Fish Baseflow Fraction: Aug, Sep	70%	39%	34%	34%	39%
Change in Peak Flow, for Wetland Plants	-7%	-7%	-5%	-14%	-15%
Change in Peak Flow, for Warmwater Fish	-8%	-11%	-21%	-21%	-13%
Change in Average Annual Flow	-8%	-8%	-27%	-37%	-37%
Change in Average Winter Flow	8%	8%	0%	-18%	-18%
Change in Average Late Summer Flow	-10%	-10%	-50%	-57%	-56%
Change in Average January Flow	10%	10%	0%	-19%	-18%
Change in Average February Flow	9%	9%	12%	-6%	-6%
Change in Average March Flow	7%	7%	39%	22%	22%
Change in Average April Flow	-3%	-3%	33%	20%	19%
Change in Average May Flow	-10%	-10%	-2%	-12%	-13%
Change in Average June Flow	-11%	-11%	-42%	-52%	-52%
Change in Average July Flow	-11%	-11%	-62%	-69%	-69%
Change in Average August Flow	-10%	-10%	-55%	-60%	-60%
Change in Average September Flow	-9%	-9%	-42%	-52%	-51%
Change in Average October Flow	-8%	-8%	-35%	-52%	-52%
Change in Average November Flow	4%	4%	-16%	-34%	-33%
Change in Average December Flow	5%	5%	-10%	-29%	-28%

Table 2. Climate change adjustment factors reflected by CWCB planning models.

CWP Planning Scenario Name	CRWAS Climate Projection Name	Climate Stress Impact on 2050 Future Condition			
		CIR*	**Runoff***	**Average Annual Temperature[3]**	**Precipitation Change[3]**
Business as Usual	Current	None	None	None	None
Weak Economy	Current	None	None	None	None
Cooperative Growth	In-Between	Moderate (50th percentile)	Moderate (50th percentile)	+ 3.78 °F (+2.0 °C)	5% increase in annual precipitation
Adaptive Innovation	Hot and Dry	High (75th percentile)	Low (25th percentile)	4.15 °F (+2.3 °C)	1% decrease in annual precipitation
Hot Growth	Hot and Dry	High (75th percentile)	(Low (25th percentile)	+ 4.15 °F (+2.3 °C)	1% decrease in annual precipitation

Table 3. Agricultural demand adjustments included in the CWCB's model for the Southwest Basin. Each of the scenarios includes an approximate 2000 acre reduction in irrigated agriculture in the Norwood and Naturita area.

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction
IWR Climate Factor	-	-	26%	34%	34%
Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-

Table 4. Per capita water use rate changes as affected by municipal growth included in the CWCB planning models.

Demand Category	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Residential Indoor (gpcd)	42.4	42.4	36.4	33.3	42.4
Non-Residential Indoor	0%	-5%	-10%	-10%	+5%
Outdoor	0%	-5%	-15%	-20%	+5%
Non-Revenue Water	0%	+5%	0%	-5%	0%

Table 5. Municipal water conservation measure adoption rates included in the CWCB planning models.

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Adoption Rate	50%	40%	60%	70%	60%

Climate change adjustments to inflow hydrographs at the upstream model boundaries generally resulted in hydrograph behavior characterized by earlier snowmelt runoff, lower late season baseflows, and reductions in annual water yield. The joint effects of population growth, increasing crop demand and altered hydrology were propagated through the simulation network over a period of 38 years.

The scenario models included in the Technical Update run on a monthly timestep. For the purposes of evaluating impacts of climate change, population growth, etc. on ecological characteristics of the San Miguel River, a daily timestep was required. Monthly simulation results were disaggregated to daily results using a method of fragments approach.[2] The method was implemented with custom code in the R statistical computing environment. Observed daily streamflow data was retrieved from existing and historical USGS gauging stations on the San Miguel River at Telluride, Placerville, and Uravan and one location on Fall Creek. The record of daily data was aggregated to monthly acre-feet volume totals. The monthly simulation results were then compared to the aggregated observed data using a three-month moving window. The three-month period from the entire series of observed data that best matched the windowed simulation data was identified using the Kline-Gupta Efficiency measure (Figure 7).

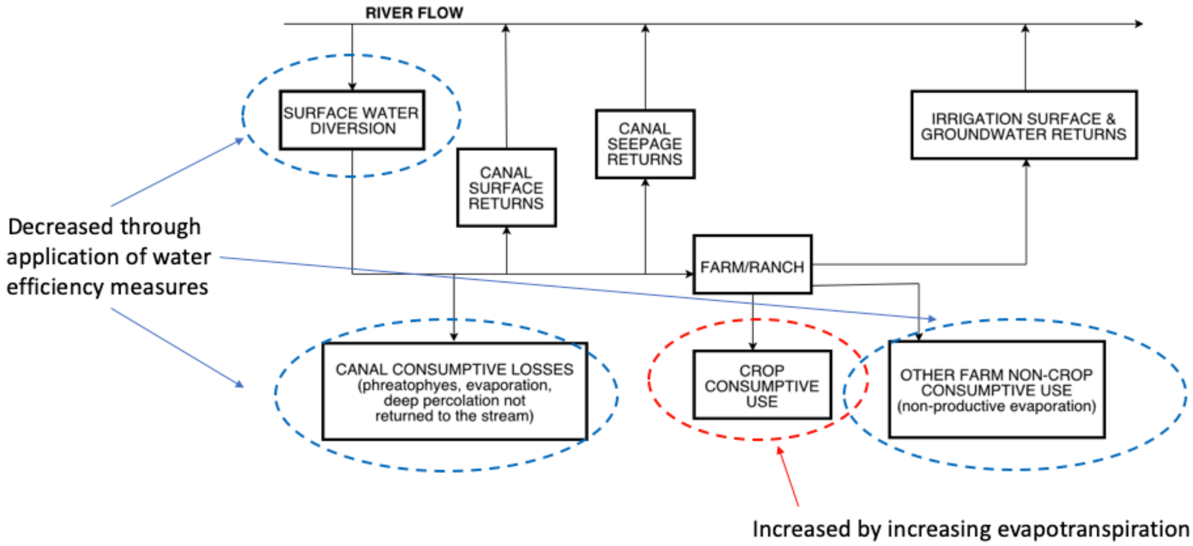


Figure 6. The climate futures represented by Scenarios C, D, and E all include increases in crop consumptive use (red circle) that drives increasing diversion from streams and rivers to satisfy agricultural use demands. Scenarios C and D include water conveyance and application efficiencies that offset this increased demand through simulated introduction of efficiency measures (blue circles).

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[2] Acharya, A., & Ryu, J. H. (2014). Simple method for streamflow disaggregation. Journal of Hydrologic Engineering, 19(3), 509-519.

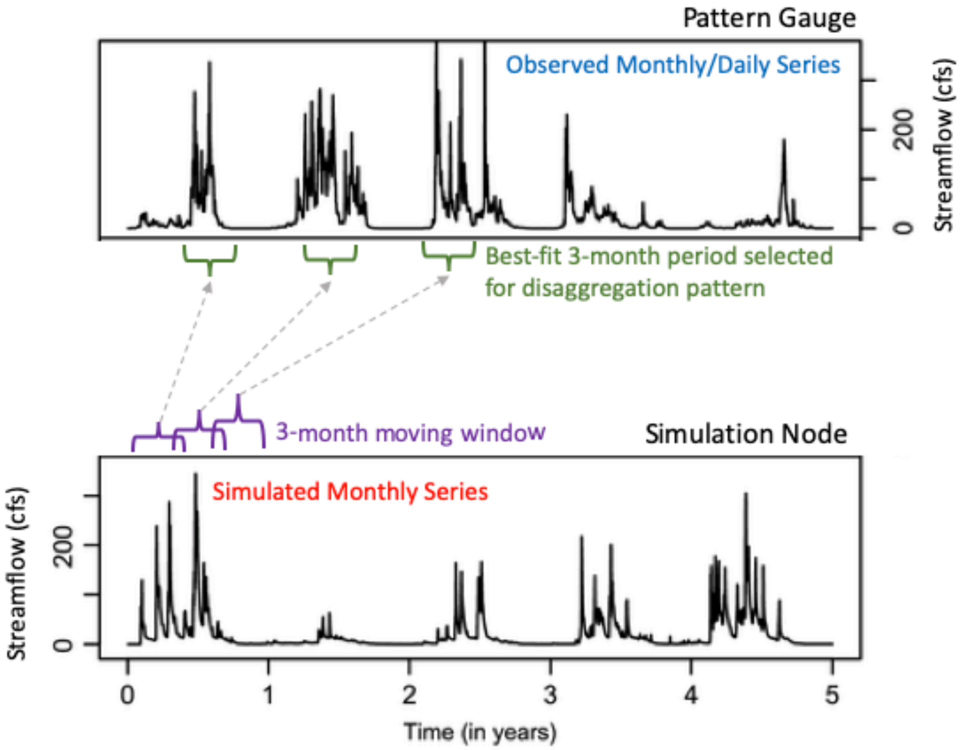

Figure 7. Visual representation of the patterning approach used for monthly-to-daily disaggregation of simulation results using observed streamflow data from nearby USGS gauging stations.

Once a suitable three-month observed period was identified, the daily values from the central month in the window of observed values was retrieved as used to disaggregate the central month in the window of simulation values. Disaggregation was carried out by computing the fraction of the monthly total flow occurred on each day in the observed month and then applying these ratios to each day in the simulation month. This process was carried out for each month in the simulation period. Disaggregating data is this manner is more flexible than methods traditionally applied to StateMod simulation outputs in Colorado. The method-of-fragments approach enables composition of novel simulation time series not directly observed in the historical period of record. This attribute is particularly useful for disaggregation of climate change and population growth scenarios where the assumption that future behavior will closely resemble historical hydrological behavior is not appropriate.

The validity of the disaggregation results was initially assessed by comparing 100 computed metrics of annual streamflow behavior (e.g. 7-day minimum flow, average September flow, 3-day maximum flow, etc.) for Baseline simulation results approximating historical conditions on the San Miguel River at Placerville, Naturita, and Uravan to the same metrics computed on observed streamflow data from those location using a Wilcox Rank Sum test. The goodness of fit of the disaggregated time series was also assessed with various time-series fit measures (e.g. Nash-Sutcliff Efficiency).

Disaggregated daily streamflow simulations were derived for model locations across the San Miguel watershed (Figure 8, Table 6). For the purposes of this study, those results produced along the mainstem San Miguel River and on the lower reaches of tributary streams were selected for further evaluation.

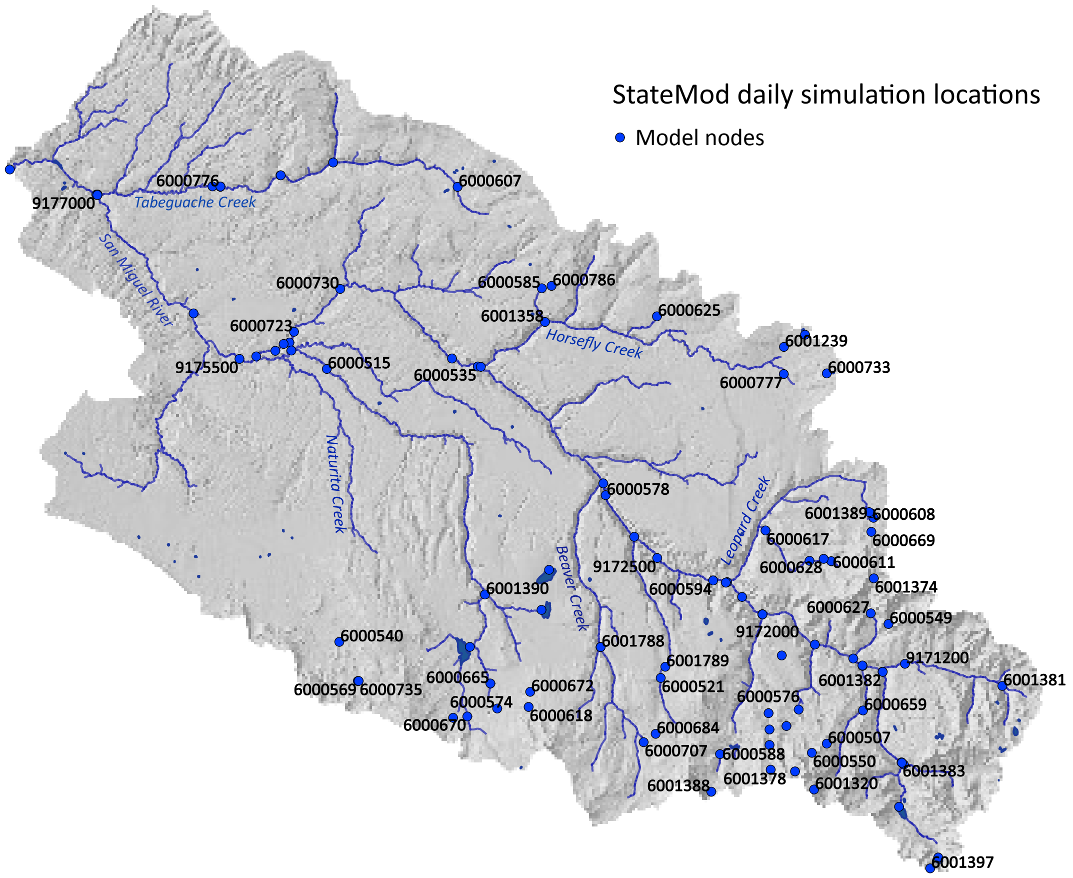

Figure 8. Relative position of reservoir or surface water diversion simulation nodes included in the refined StateMod model for the San Miguel watershed. Tributary junctions and inflow nodes are not displayed. Only simulation locations along the mainstem San Miguel River and along the lower sections of tributaries were selected for further evaluation.

Table 6. Surface water diversions, reservoirs, and instream flow (ISF) rights included in the simulation model. Only simulation locations along the mainstem San Miguel River and along the lower sections of tributaries were selected for further evaluation.

Node ID	Location/Name
600507	ALEXANDER DITCH
600511	AMES ILIUM HYDRO PROJ
600515	AUSTRIAN TWIN DITCH
600520	B C D DITCH
601788	BEAVER CREEK ISF
9173000	BEAVER CREEK NEAR NORWOOD
600521	BEAVER MESA DITCH
601319	BIG BEAR CREEK ISF
601320	BILK CREEK ISF
600535	BRADDOCK DITCH
600540	BURCH MORGAN DITCH
600549	CARR WADDLE DITCH
600550	CARRIERE DITCH
600569	CRAVER DITCH
601374	DEEP CREEK ISF
600574	DENISON DITCH
600576	DILLON DITCH
600578	DOLPHIN DITCH
600583	EAGLE DITCH
600585	EASTON DITCH
600588	ELK CREEK DITCH
601378	ELK CREEK ISF
601388	FALL CREEK ISF
9172000	FALL CREEK NEAR FALL CREEK
600594	FAYETTE PLACER
600607	GLENCOE DITCH
600611	GOLD RUN DITCH
600608	GOLDEN DITCH
600613	GOULDING DITCH
600617	GREEN MT DITCH NO 2
600618	GROVE DITCH
603507	GURLEY RES
600625	HANKS VALLEY DITCH NO 2
600627	HARDSCRABBLE DITCH
600628	HASTINGS DITCH
600633	HIGHLINE CANAL
601358	HORSEFLY CREEK ISF
600650	J M HUGHES DITCH
600652	JARRETT DITCH
600659	KINLEY DITCH
601397	LAKE FORK SAN MIGUEL ISF
603509	LAKE HOPE RES
600665	LAST CHANCE DITCH
9172100	LEOPARD CREEK AT NOEL
600669	LEOPARD CREEK DITCH
601389	LEOPARD CREEK ISF
600670	LILYLANDS CANAL
600672	LONE CONE DITCH
603511	LONE CONE RES
600678	LOWER ELK CREEK DITCH
600831	MAVERICK DRAW DITCH
600684	MCCOLLOCH SCOTT DITCH
600689	MIDDLE ELK CREEK DITCH
603512	MIRAMONTE RES
600707	NATURITA CANAL
601390	NATURITA CREEK ISF
600710	NEILSON DITCH
600723	NUCLA POWER PLANT DITCH
601381	SAN MIGUEL ISF
600730	PARKWAY DITCH
600733	PAXTON DITCH
603519	PAXTON RESERVOIR
600735	PLATEAU BASIN DITCH
600736	PLEASANT VALLEY DITCH
600745	REED CHATFIELD DITCH
601789	SALTADO CREEK ISF
9175500	SAN MIGUEL RIVER AT NATURITA
9177000	SAN MIGUEL RIVER AT URAVAN
601382	SAN MIGUEL RIVER ISF
601950	SAN MIGUEL RIVER ISF
602119	SAN MIGUEL RIVER ISF
9172500	SAN MIGUEL RIVER NEAR PLACERVILLE
9171200	SAN MIGUEL RIVER NEAR TELLURIDE
601383	SOUTH FK SAN MIGUEL ISF
600776	TEMPLETON DITCH
600777	THEO NETHERLY DITCH NO1
601239	THEO NETHERLY DITCH NO3
603527	TROUT LAKE RES
600786	TUMBLE CREEK DITCH

4 Results

Comparison of simulation model results to observed data provided a means for assessing the reliability of simulation results, which were then used to assess potential hydrological futures for the San Miguel River and its tributaries.

4.1 Goodness-of-Fit

Wilcox Rank Sum test results indicate no statistically significant difference in the computed metrics between the simulation results and observation data for all metrics at Placerville. The model was found to under-predict several annual and monthly low-flow metrics at Naturita and Uravan, particularly in the months of August and September. We expect this may be a result of regional groundwater influences or difficulties calibrating stream gauges at very low flow conditions. During late summer periods, the model often predicts period of zero flow while the observed streamflow time series record indicates very low flows buy not zero flow. The CWCB models do not account for regional groundwater inflows and information about gauging accuracy near zero flow at the two locations in question is not immediately available. Another possibility is that the CWCB models do not route irrigation return flows from the Nucla area back to the San Miguel with the correct timing or magnitude. Nonetheless, we found the disaggregation assessment results encouraging and supportive of our intention to use scenario modeling results to characterize changes in annual flow characteristics throughout the planning area (**Error! Reference source not found.**). Some caution is suggested when interpreting simulated flow conditions in the lower watershed when simulation result drop below ~50 cfs.

Table 7. Wilcox Rank Sum results assessing differences between observed daily flow behavior and disaggregated monthly model simulation results for the San Miguel River at Placerville. A p-value less than 0.05 indicates a significant difference between the two sets of results.

Metric	Median Simulation Value	Median Observed Value	Absolute Difference	p-value	Percent Difference
Apr_Maximum	440.50	469.50	-29.00	0.80	0.00
Apr_Mean	227.48	232.95	-5.47	0.77	0.00
Apr_Median	212.25	204.75	7.50	0.85	0.00
Apr_Minimum	84.00	90.00	-6.00	0.74	0.00
Apr_P10	106.30	116.55	-10.25	0.93	0.00
Apr_P90	344.05	357.30	-13.25	0.79	0.00
Aug_Maximum	312.00	330.00	-18.00	0.84	0.00
Aug_Mean	185.92	192.74	-6.82	0.96	0.00
Aug_Median	174.00	183.00	-9.00	0.88	0.00
Aug_Minimum	114.00	111.50	2.50	0.76	0.00
Aug_P10	124.00	127.00	-3.00	0.90	0.00
Aug_P90	251.50	248.50	3.00	0.94	0.00
DoY_25pct_TotalQ	137.00	137.00	0.00	0.98	0.00
DoY_33.3pct_TotalQ	148.00	148.00	0.00	0.92	0.00
DoY_50pct_TotalQ	165.00	165.00	0.00	0.76	0.00
DoY_75pct_TotalQ	203.00	202.50	0.50	0.73	0.00
Jul_Maximum	597.50	621.00	-23.50	0.65	0.00
Jul_Mean	347.34	364.79	-17.45	0.74	0.00
Jul_Median	351.50	352.00	-0.50	0.92	0.00
Jul_Minimum	203.50	225.50	-22.00	0.86	0.00
Jul_P10	218.50	246.50	-28.00	0.91	0.00
Jul_P90	512.00	539.50	-27.50	0.61	0.00
Jun_Maximum	1043.50	1100.00	-56.50	0.50	0.00
Jun_Mean	698.73	742.97	-44.23	0.56	0.00
Jun_Median	689.00	732.00	-43.00	0.56	0.00
Jun_Minimum	444.50	467.50	-23.00	0.86	0.00
Jun_P10	532.25	559.15	-26.90	0.84	0.00
Jun_P90	895.60	949.20	-53.60	0.40	0.00

May_Maximum	843.00	870.50	-27.50	0.53	0.00
May_Mean	519.95	559.02	-39.06	0.40	0.00
May_Median	472.00	517.50	-45.50	0.29	0.00
May_Minimum	292.50	313.50	-21.00	0.41	0.00
May_P10	323.50	348.00	-24.50	0.45	0.00
May_P90	711.00	767.50	-56.50	0.53	0.00
Min_1_Day	67.00	70.00	-3.00	0.32	0.00
Min_1_Day_DoY	280.00	258.00	22.00	0.52	0.00
Min_3_Day	68.67	73.33	-4.67	0.18	0.00
Min_3_Day_DoY	264.00	255.00	9.00	0.63	0.00
Min_30_Day	75.87	76.67	-0.80	0.71	0.00
Min_30_Day_DoY	92.00	92.00	0.00	0.36	0.00
Min_7_Day	68.57	72.86	-4.29	0.23	0.00
Min_7_Day_DoY	272.00	247.00	25.00	0.37	0.00
Oct_Maximum	132.50	134.00	-1.50	0.36	0.00
Oct_Mean	96.92	103.82	-6.90	0.38	0.00
Oct_Median	95.50	102.50	-7.00	0.46	0.00
Oct_Minimum	77.00	82.95	-5.95	0.24	0.00
Oct_P10	82.00	87.75	-5.75	0.28	0.00
Oct_P90	113.50	116.50	-3.00	0.44	0.00
Sep_Maximum	181.00	203.00	-22.00	0.53	0.00
Sep_Mean	125.30	130.69	-5.39	0.65	0.00
Sep_Median	118.00	116.50	1.50	0.74	0.00
Sep_Minimum	85.00	82.10	2.90	0.98	0.00
Sep_P10	92.00	90.36	1.64	0.74	0.00
Sep_P90	159.00	169.00	-10.00	0.44	0.00

Table 8. Wilcox Rank Sum results assessing differences between observed daily flow behavior and disaggregated monthly model simulation results for the San Miguel River at Naturita. A p-value less than 0.05 indicates a significant difference between the two sets of results.

Metric	**Median Simulation Value**	**Median Observed Value**	**Absolute Difference**	**p-value**	**Percent Difference**
Apr_Maximum	1140.50	1053.00	87.50	0.69	0.00
Apr_Mean	499.72	471.48	28.23	0.94	0.00
Apr_Median	215.00	214.00	1.00	0.69	0.00
Apr_Minimum	98.50	89.00	9.50	0.33	0.00
Apr_P10	116.95	97.90	19.05	0.38	0.00
Apr_P90	899.95	811.70	88.25	0.94	0.00
Aug_Maximum	50.00	234.50	-184.50	0.02	0.21
Aug_Mean	18.89	62.24	-43.35	0.01	0.30
Aug_Median	8.50	50.50	-42.00	0.01	0.17
Aug_Minimum	2.50	17.50	-15.00	0.02	0.14
Aug_P10	3.50	26.50	-23.00	0.02	0.13
Aug_P90	43.00	116.50	-73.50	0.02	0.37
DoY_25pct_TotalQ	116.00	118.00	-2.00	0.46	0.00
DoY_33.3pct_TotalQ	124.00	128.00	-4.00	0.40	0.00
DoY_50pct_TotalQ	147.00	152.00	-5.00	0.04	0.97
DoY_75pct_TotalQ	172.00	176.00	-4.00	0.35	0.00
Jul_Maximum	493.00	670.00	-177.00	0.58	0.00
Jul_Mean	232.44	324.40	-91.97	0.47	0.00
Jul_Median	212.50	303.50	-91.00	0.47	0.00
Jul_Minimum	92.00	127.50	-35.50	0.58	0.00
Jul_P10	105.50	150.50	-45.00	0.58	0.00
Jul_P90	395.50	544.50	-149.00	0.58	0.00
Jun_Maximum	1205.50	1190.00	15.50	0.81	0.00

Jun_Mean	721.45	842.72	-121.27	0.58	0.00
Jun_Median	664.75	844.75	-180.00	0.58	0.00
Jun_Minimum	402.50	548.50	-146.00	0.47	0.00
Jun_P10	501.75	667.20	-165.45	0.47	0.00
Jun_P90	1015.65	1110.60	-94.95	0.69	0.00
May_Maximum	946.50	1010.00	-63.50	0.81	0.00
May_Mean	623.45	667.11	-43.66	0.94	0.00
May_Median	629.00	674.00	-45.00	0.94	0.00
May_Minimum	360.50	384.50	-24.00	0.94	0.00
May_P10	396.00	422.50	-26.50	0.94	0.00
May_P90	834.00	887.50	-53.50	0.94	0.00
Min_1_Day	0.00	14.00	-14.00	0.00	0.00
Min_1_Day_DoY	244.00	249.00	-5.00	0.10	0.00
Min_3_Day	0.00	15.00	-15.00	0.00	0.00
Min_3_Day_DoY	246.00	250.00	-4.00	0.11	0.00
Min_30_Day	0.00	26.93	-26.93	0.00	0.00
Min_30_Day_DoY	271.00	276.00	-5.00	0.22	0.00
Min_7_Day	0.00	16.57	-16.57	0.00	0.00
Min_7_Day_DoY	250.00	251.00	-1.00	0.20	0.00
Oct_Maximum	132.00	122.00	10.00	0.94	0.00
Oct_Mean	48.71	64.11	-15.40	0.09	0.00
Oct_Median	14.50	83.00	-68.50	0.05	0.17
Oct_Minimum	8.50	15.00	-6.50	0.07	0.00
Oct_P10	9.00	32.50	-23.50	0.17	0.00
Oct_P90	96.50	99.00	-2.50	0.58	0.00
Sep_Maximum	29.50	123.00	-93.50	0.09	0.00
Sep_Mean	12.28	45.00	-32.72	0.17	0.00
Sep_Median	6.00	35.00	-29.00	0.09	0.00
Sep_Minimum	4.00	16.50	-12.50	0.09	0.00
Sep_P10	4.00	20.30	-16.30	0.07	0.00
Sep_P90	25.10	75.30	-50.20	0.17	0.00

Table 9. Wilcox Rank Sum results assessing differences between observed daily flow behavior and disaggregated monthly model simulation results for the San Miguel River at Uravan. A p-value less than 0.05 indicates a significant difference between the two sets of results.

Metric	Median Simulation Value	Median Observed Value	Absolute Difference	p-value	Percent Difference
Apr_Maximum	1511.00	1405.00	106.00	0.74	0.00
Apr_Mean	730.00	722.72	7.28	0.92	0.00
Apr_Median	617.50	582.75	34.75	0.97	0.00
Apr_Minimum	202.50	198.50	4.00	0.89	0.00
Apr_P10	261.80	266.60	-4.80	0.92	0.00
Apr_P90	1152.45	1209.50	-57.05	0.87	0.00
Aug_Maximum	121.00	289.00	-168.00	0.00	0.42
Aug_Mean	55.84	145.90	-90.06	0.00	0.38
Aug_Median	53.00	129.00	-76.00	0.00	0.41
Aug_Minimum	19.00	54.60	-35.60	0.00	0.35
Aug_P10	22.00	81.30	-59.30	0.00	0.27
Aug_P90	93.00	218.00	-125.00	0.00	0.43
DoY_25pct_TotalQ	112.00	115.00	-3.00	0.15	0.00
DoY_33.3pct_TotalQ	121.00	128.00	-7.00	0.07	0.00
DoY_50pct_TotalQ	141.00	145.00	-4.00	0.05	0.00
DoY_75pct_TotalQ	172.50	178.00	-5.50	0.04	0.97
Jul_Maximum	462.00	603.50	-141.50	0.08	0.00
Jul_Mean	189.47	277.60	-88.13	0.08	0.00

Jul_Median	180.00	252.50	-72.50	0.13	0.00
Jul_Minimum	81.00	120.50	-39.50	0.13	0.00
Jul_P10	99.50	147.00	-47.50	0.11	0.00
Jul_P90	351.50	490.50	-139.00	0.08	0.00
Jun_Maximum	1049.00	1225.00	-176.00	0.37	0.00
Jun_Mean	631.25	744.17	-112.92	0.25	0.00
Jun_Median	586.00	755.50	-169.50	0.20	0.00
Jun_Minimum	366.00	392.50	-26.50	0.38	0.00
Jun_P10	422.10	513.55	-91.45	0.35	0.00
Jun_P90	928.65	1026.00	-97.35	0.29	0.00
May_Maximum	1550.50	1500.00	50.50	0.94	0.00
May_Mean	859.18	874.84	-15.66	0.58	0.00
May_Median	839.00	884.00	-45.00	0.63	0.00
May_Minimum	559.00	611.00	-52.00	0.60	0.00
May_P10	616.00	688.00	-72.00	0.65	0.00
May_P90	1089.00	1185.00	-96.00	0.58	0.00
Min_1_Day	4.00	37.50	-33.50	0.00	0.11
Min_1_Day_DoY	244.00	249.50	-5.50	0.39	0.00
Min_3_Day	4.50	38.23	-33.73	0.00	0.12
Min_3_Day_DoY	244.50	249.50	-5.00	0.45	0.00
Min_30_Day	19.55	68.82	-49.27	0.00	0.28
Min_30_Day_DoY	260.00	267.50	-7.50	0.29	0.00
Min_7_Day	6.21	42.21	-35.99	0.00	0.15
Min_7_Day_DoY	246.50	250.00	-3.50	0.33	0.00
Oct_Maximum	304.00	221.50	82.50	0.08	0.00
Oct_Mean	92.89	118.02	-25.13	0.06	0.00
Oct_Median	79.50	116.50	-37.00	0.01	0.68
Oct_Minimum	20.00	72.60	-52.60	0.00	0.28
Oct_P10	28.00	86.85	-58.85	0.00	0.32
Oct_P90	162.50	148.50	14.00	0.90	0.00
Sep_Maximum	149.00	268.50	-119.50	0.02	0.55
Sep_Mean	47.40	103.26	-55.86	0.00	0.46
Sep_Median	35.75	79.28	-43.53	0.00	0.45
Sep_Minimum	13.00	42.05	-29.05	0.00	0.31
Sep_P10	17.25	47.40	-30.15	0.00	0.36
Sep_P90	62.30	164.85	-102.55	0.00	0.38

Qualitative reviews of data produced at other locations in the simulation network with the local water commissioner and other stakeholders indicated that the model performed best at mainstem San Miguel River locations, with increasing discrepancies between simulated and observed streamflows on tributaries and below reservoirs. Locations with poor model fit also exhibit relatively short observed flow records or where records of streamflow diversion and reservoir operations are scarce, inaccurate, or non-existent. Limited data quality for historical reservoir operations produced particularly acute problems on the Lake Fork of the San Miguel River. Other inaccuracies in model results reflect inherent issues in using mainstem hydrological patterns and physical basin characteristics to predict runoff in small, ungauged drainages. A high degree of uncertainty is expected with predictions of tributary flows during times of severe drought or flood, when correlations between watershed position, geographic characteristics, and hydrological behavior between drainages begin to weaken. This is particularly true in the lower watershed where episodic late-season rainfall events may drive peak streamflow characteristics.

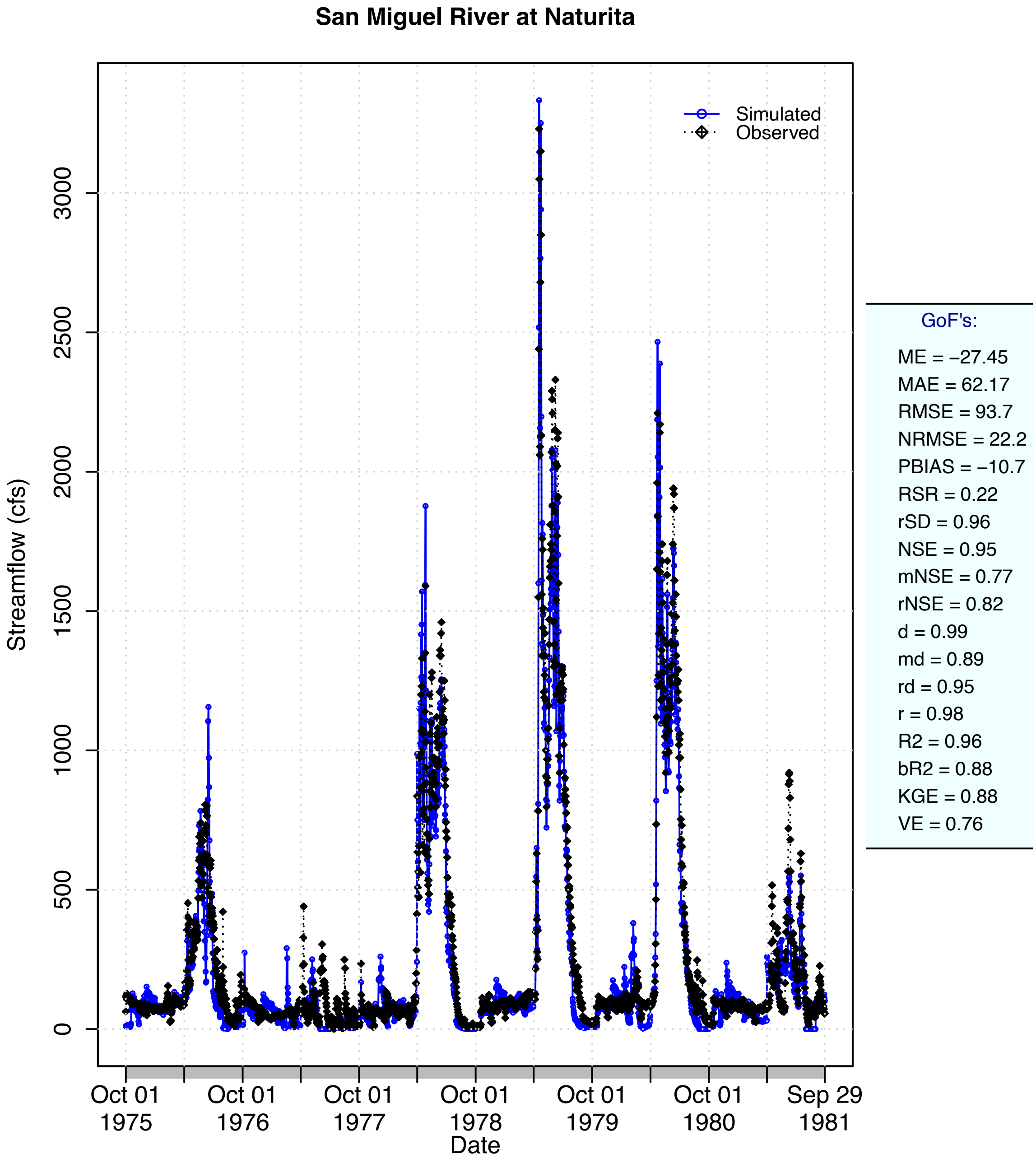

Figure 9. Historical simulation results compared to observed streamflow data for the San Miguel River at Naturita. Various goodness-of-fit (GoF) measures provided. Model outputs generally match observed conditions. However, simulations results tend to be less variable than observed data during low flow conditions. Late-season spikes in streamflow, presumably caused by monsoonal rainfall, were not reflected in the model. This behavior was also observed for the San Miguel near Uravan. The San Miguel at Placerville show much greater fidelity to observed data across all time periods.

The simulation models presented here are not intended to be a perfect representation of streamflow in the San Miguel watershed. As with all simulation models of this type, the primary utility of the tool is in characterizing changes in hydrological behavior between modeled scenarios. The model's ability to approximate changes in streamflow under different water management, climate change, or development futures with a reasonable degree of accuracy determines its usefulness in a planning context. Validation results suggest that the model is suitable for scenario planning in the San Miguel watershed and that modeling performed on the mainstem San Miguel River will enjoy a higher degree of certainty than results produced for tributary streams. Focused investigations during future planning phases may yield more reliable data for model parameterization in tributary systems.

4.2 Scenario Modeling Results

Comparison of the various climate change and population growth scenario simulation results to the baseline simulation result indicate a shift toward earlier peak runoff and lower total annual runoff volumes associated with increasingly warm climate futures (Figure 13). These patterns are typical of predictions elsewhere on Colorado's western slope. Simulation results for the mainstem San Miguel River indicate relative insensitivity to the changes from the baseline condition included in scenarios A and B. It's worth noting that the CWCB developed each of the scenarios discussed above as representative positions along a continuum of equally probable future conditions. No weighting is provided by CWCB or by this effort regarding the "best" scenario to plan for. Instead, the reader is encouraged to consider how results associated with the full range of scenarios might inform a "no-regrets" strategy for managing conditions in the San Miguel Watershed.

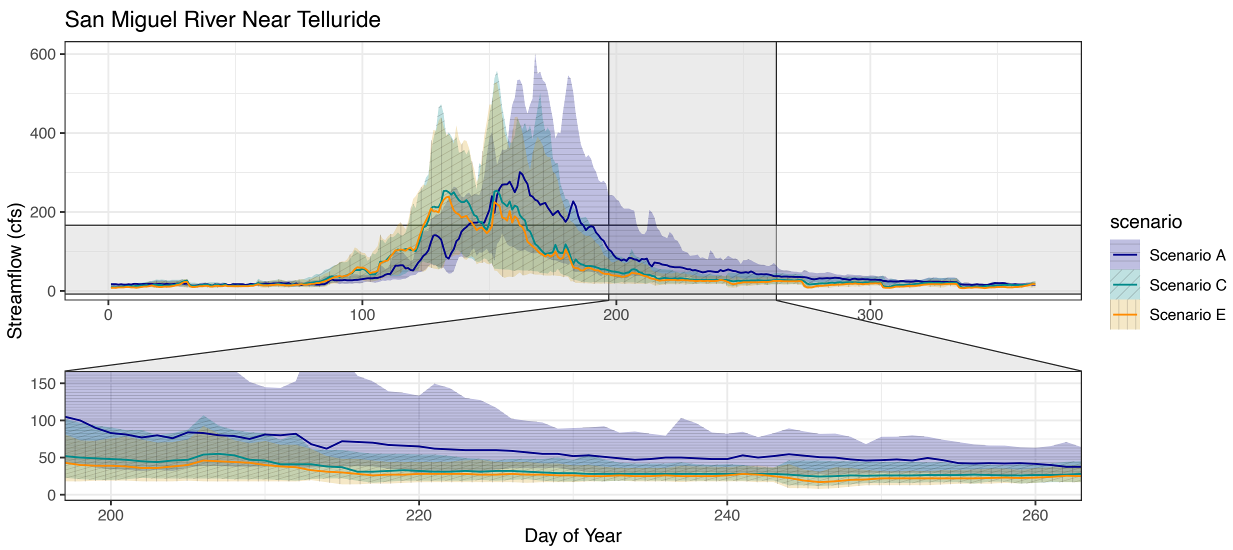

Figure 10. Hydrographs for the San Miguel near Telluride predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

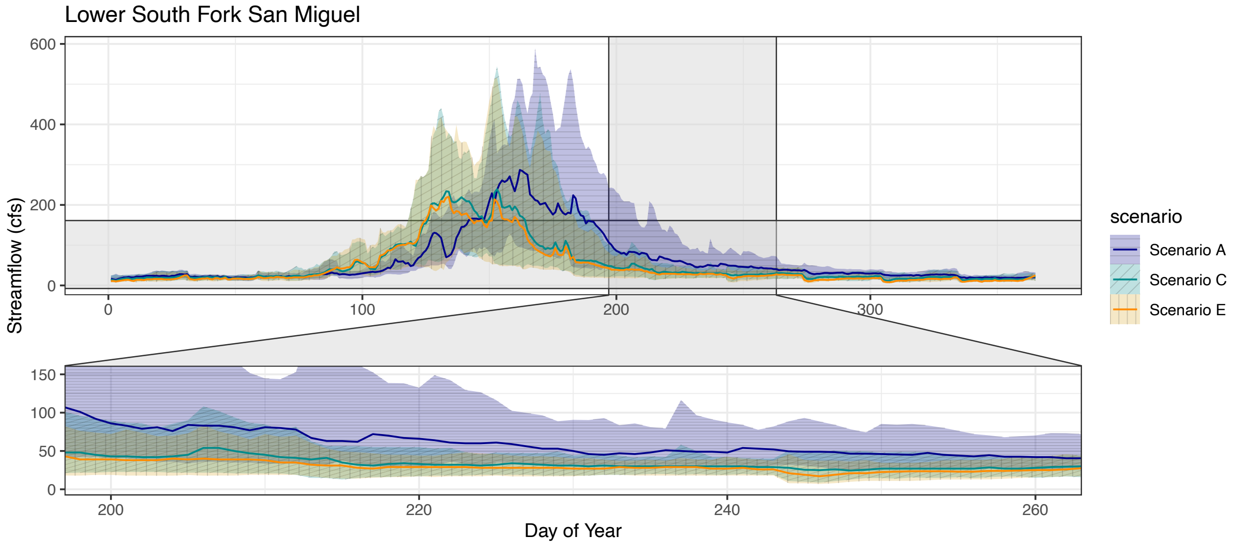

Figure 11. Hydrographs for the lower South Fork San Miguel River as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

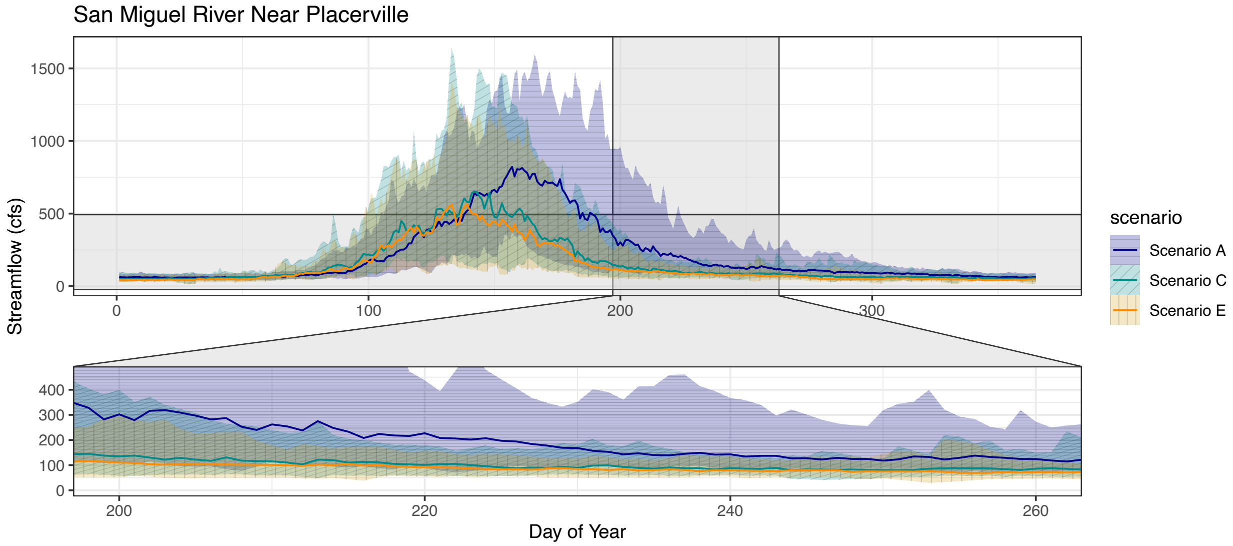

Figure 12. Hydrographs for the San Miguel near Placerville as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

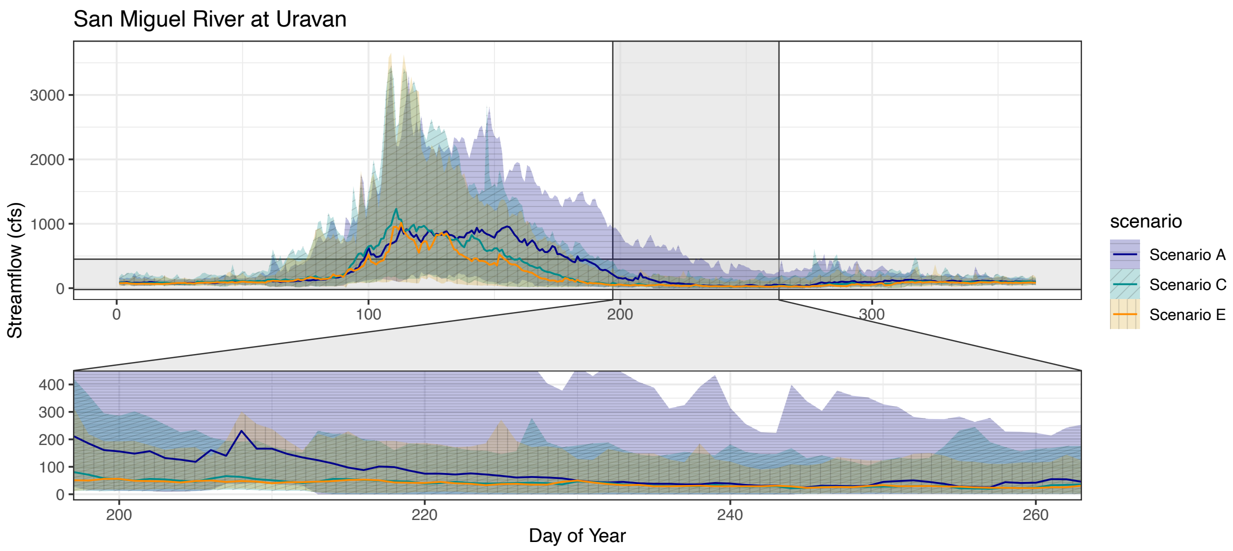

Figure 13. Hydrographs for the San Miguel near Uravan as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

The analysis of hydrological regime behavior at locations throughout the San Miguel watershed considered numerous measures of streamflow behavior. Metrics characterizing flow magnitude, duration, and rate of change were derived through statistical examination of the entire simulation period at each node in the modelling network, which covered a range of wet, average, and dry hydrological conditions. Exceedance probabilities were calculated for flows simulated on each day of each calendar year to provide a pathway for building hydrological time series representative of different drought and flood conditions (Table 10, Table 11). The absolute values of these streamflow behavior metrics and the degree of change in each metric across planning scenarios was used in subsequent evaluations of aquatic habitat, riparian health, sediment transport, and recreational use opportunities for the San Miguel watershed.

Table 10. Predicted annual peak flow magnitude changes under the five different planning scenarios at four different locations along the San Miguel River.

Location	Percentile	Baseline Value	Scenario A % Change	Scenario B % Change	Scenario C % Change	Scenario D % Change	Scenario E % Change
San Miguel River near Telluride	25th	322.5	0	0	-15	-26	-26
	50th	412	0	0	-7	-24	-24
	75th	537.5	0	0	-9	-18	-18
San Miguel River near Placerville	25th	863	0	0	-18	-24	-26
	50th	1113	0	0	-19	-20	-21
	75th	1461	0	0	-8	-20	-21
San Miguel River near Naturita	25th	966.5	15	15	-18	-13	-9
	50th	1472	5	6	9	-27	-25
	75th	2184	2	2	-2	-9	-7
San Miguel River near Uravan	25th	1112	-1	-1	7	-6	-5
	50th	1922	-2	-2	-1	-10	-11
	75th	2454.5	1	1	4	-8	-16

Table 11. Predicted August minimum flow changes under the five different planning scenarios at four different locations along the San Miguel River.

Location	Percentile	Baseline Value	Scenario A % Change	Scenario B % Change	Scenario C % Change	Scenario D % Change	Scenario E % Change
San Miguel River near Telluride	25th	31.5	0	0	-40	-46	-46
	50th	39	0	0	-33	-44	-44
	75th	48.5	0	0	-40	-48	-48
San Miguel River near Placerville	25th	93.5	2	2	-34	-44	-43
	50th	114	1	1	-37	-39	-40
	75th	140	0	0	-37	-44	-44
San Miguel River near Naturita	25th	6	17	17	-17	-33	-17
	50th	12	8	8	-42	-42	-25
	75th	31.5	32	32	-65	-57	-56
San Miguel River near Uravan	25th	10	10	10	43	-20	30
	50th	24	0	0	-8	-33	-12
	75th	62	6	6	-41	-50	-48

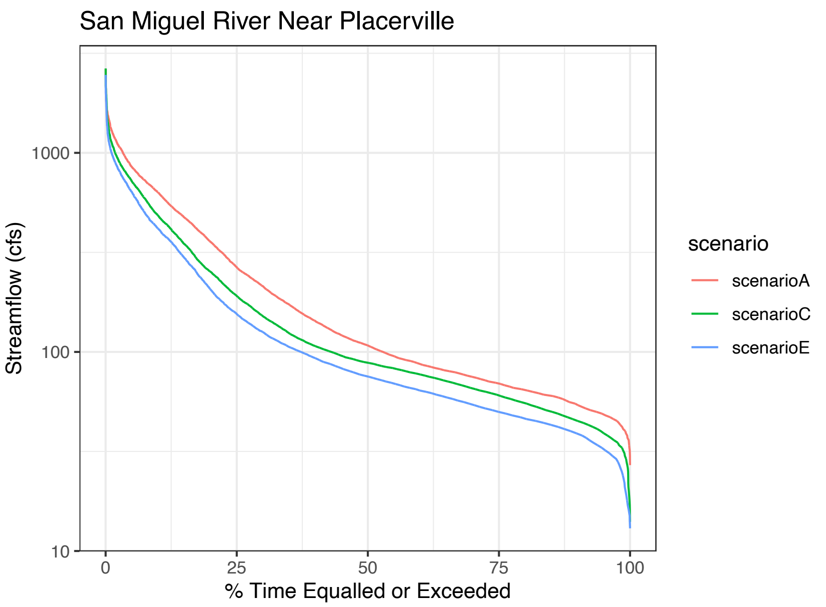

Figure 14. Streamflow exceedance probabilities for the San Miguel River near Placerville under the various planning scenarios. Simulation results indicate increasing flow reductions corresponding to increasingly warm climate futures captured in scenarios C, D, and E.

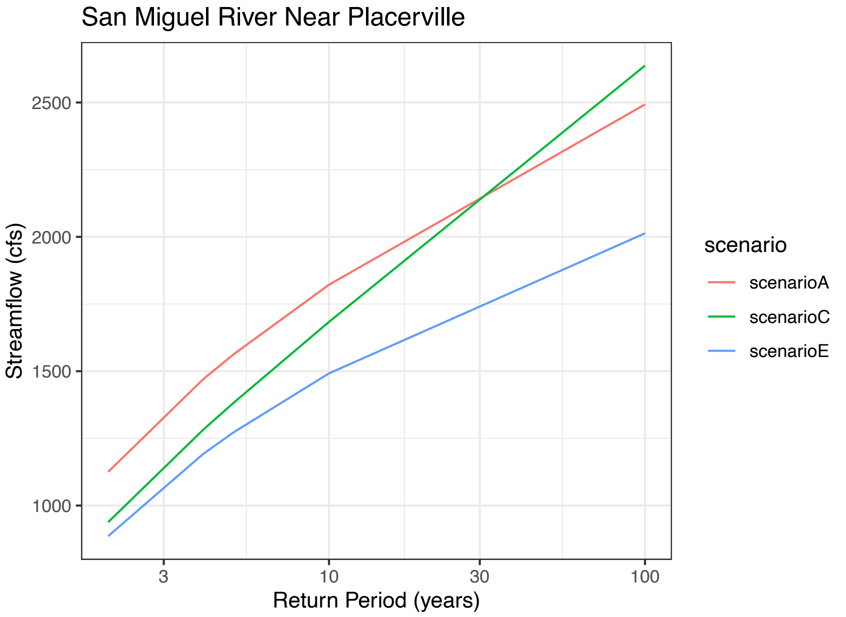

Figure 15. Peak snowmelt runoff event magnitudes and return intervals for the San Miguel River near Placerville under the various planning scenarios. Simulation results indicate peak flow reductions for floods with return periods less than ~30 years corresponding to increasingly warm climate futures captured in scenarios C, D, and E.

Simulation results representing the potential effects of climate change were produced by applying adjustment factors to historical hydrology and, thus, do not effectively demonstrate potential or expected changes in extreme rainfall events produced by a warming climate. The Colorado Dam Safety Office proposed Rule 7.2.4 suggests that a warming atmosphere may increase the magnitude of extreme rainfall events by 7%. This potential increase might affect the magnitude and frequency of potential peak flow events that fall outside the snowmelt runoff season. Characterizing the effects of increasingly severe rainfall events requires some consideration of all the potential locations of such events across the watershed, the relative intensity and duration of any given event, and the effects of flow routing on flood waves propagating along the stream network—not a trivial task. The reader should take note that such changes were not captured by simulation modeling results that form the basis for scenario comparisons in this effort. This caution is particularly relevant to the presentation of peak flow return periods that indicate declining snowmelt runoff peak flows associated with an increasingly warm future at, for example, a 10-year return period (Figure 14). Increasing atmospheric moisture content and an associated increase in extreme rainfall event frequency and/or severity might produce the opposite pattern during the summer monsoon period.

4.2.1 Location-Specific Results

Examination of regime behavior results indicates a hydrological system dominated by snowmelt runoff and minimally impacted by patterns of water use. Peak flows increase with increasing watershed size. The summer and fall are typically characterized by a short recession of peak flows followed by a period of stable low flows between early fall and late spring. Tributary streams in the lower watershed exhibit much flashier discharge regimes, reflecting the strong influence of late-summer monsoonal rainfall in the drier, less vegetated parts of the watershed. In the upper San Miguel watershed, construction of small reservoirs and management of flow for the production of hydropower somewhat impacts peak flow timing and magnitude on downstream river segments. Winter operation of the Ames Hydroelectric Plant produces unnatural diurnal fluctuations in streamflow that are partially blamed for creation of frazil ice and ensuing ice floe events [7]. Late season water depletions in the lower watershed on the mainstem San Miguel create some discontinuities in longitudinal patterns in flow magnitude and low-flow duration. The effects are most prominent on the San Miguel River between Horsefly Creek and Calamity Draw where streamflows in the late summer may be significantly lower when compared to upstream and downstream reaches. Hydrological behavior in headwaters streams in several tributary basins in the lower watershed (e.g. Beaver Creek) is significantly impacted by diversion activity that greatly reduces peak flow magnitudes and, at times, completely dewaters long sections of stream. Identification of locations across the watershed where management activities appear to impact the hydrological regime most significantly provides indication of stream reaches where management actions may propagate other physical or biological changes to the ecosystem.

Despite some limitations in tributary streams, overall model performance was deemed satisfactory and simulations on the mainstem San Miguel River are very good. The daily simulation modeling results were statistically sorted into quantiles representing different hydrological conditions. These probabilistic representations of streamflow during different hydrological year types were produced to aid in assessments of other environmental and recreational attributes. Three threshold exceedance probabilities were selected to generate hydrological time series representing moderate-wet, average, and moderate-drought conditions at each simulation node. An exceedance probability reflects the odds that a given flow will be exceeded in a time period of interest. For example, a streamflow with a 0.25 daily exceedance probability means that flows are equal-to or greater-than that discharge 25% of the time on that date. Flows equal-to or greater-than the 0.25 exceedance probability flow have a 1-in-4 chance of occurring on that date during the period of record. Daily hydrological time series corresponding to 0.25, 0.5, 0.75 exceedance probabilities were generated for use by subsequent assessments. Model outputs for a suite fo representative watershed locations are summarized in the following subsections.

4.2.2 Deep Creek

No stream gauges exist on Deep Creek to validate the accuracy of simulation results. The simulated hydrological regime for Deep Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Deep Creek of approximately 20 cfs. Water use and late season conditions in all years reduce flows below 1 cfs in the lower portions of the creek. Some data quality problems were identified when incorporating surface water diversion records into the model. The reliability of simulation results for Deep Creek is generally expected to be moderate.

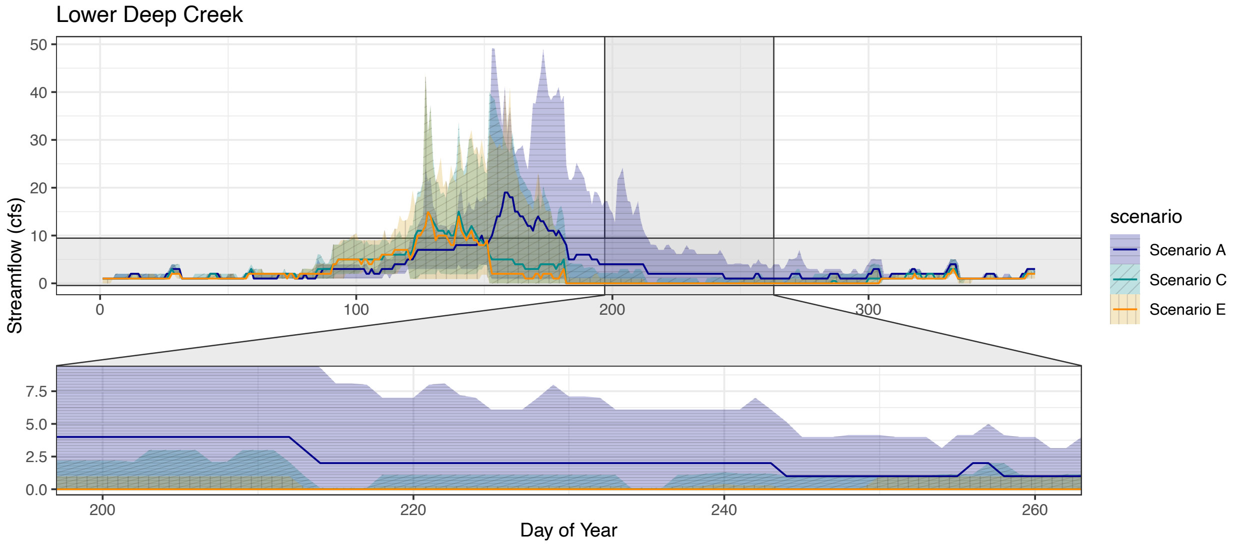

Figure 16. Hydrographs for lower Deep Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 12. A selected set of streamflow metrics for lower Deep Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	257	257	257	218.5	181.5	176
Annual Max	50th	cfs	294	294	294	261	250	244
Annual Max	75th	cfs	334	334	334	370.5	306.5	299.5
75pct Total Yield	25th	doy	164	164	164	153	153	153
75pct Total Yield	50th	doy	173	173	173	159	158	159
75pct Total Yield	75th	doy	180	180	180	173	167	167

April Max	25th	cfs	132.5	132.5	132.5	128.5	113	114.5
April Max	50th	cfs	154	154	154	171	149	147
April Max	75th	cfs	191	191	191	214.5	194	193
May Max	25th	cfs	225.5	225.5	225.5	217	181	172
May Max	50th	cfs	292	292	292	252	239	234
May Max	75th	cfs	332	332	332	370.5	306.5	296
June Max	25th	cfs	118.5	118.5	118.5	59.5	53	53
June Max	50th	cfs	201	201	201	97	80	79
June Max	75th	cfs	257.5	257.5	257.5	188	161.5	166
July Max	25th	cfs	40.5	40.5	40.5	15	11	10.5
July Max	50th	cfs	70	70	70	33	28	27
July Max	75th	cfs	108.5	108.5	108.5	74.5	46.5	51.5
July Min	25th	cfs	2.5	2.5	2.5	1	2	2
July Min	50th	cfs	5	5	5	4	3	3
July Min	75th	cfs	9	9	9	5	6.5	6.5
August Min	25th	cfs	2	2	2	2	3	3
August Min	50th	cfs	6	6	6	5	5	4
August Min	75th	cfs	8	8	8	7	7	7
September Min	25th	cfs	4	4	4	4	4	4
September Min	50th	cfs	6.5	6.5	6	5.5	5	5
September Min	75th	cfs	8.75	8.75	8.75	7.5	6	6
Octobr Min	25th	cfs	4	4	4	3	3	3
October Min	50th	cfs	6	6	6	5.5	4	4
3-day Min	75th	cfs	2	2	2	1.5	2	2
3-day Min	25th	cfs	1	1	1	1	1	1
3-day Min	50th	cfs	1.33	1.33	1.33	1	1	1
7-day Min	25th	cfs	1.14	1.14	1.14	1	1	1
7-day Min	50th	cfs	1.71	1.71	1.71	1	1.14	1.14
7-day Min	75th	cfs	2.5	2.5	2.5	1.93	2	2
30-day Min	25th	cfs	3.02	3.02	3.02	2.95	2.3	2.33
30-day Min	50th	cfs	4	4	4	3.4	3	3
30-day Min	75th	cfs	5.3	5.3	5.3	4.03	3.92	3.9

4.2.3 Fall Creek

No stream gauges exist on Fall Creek to validate the accuracy of simulation results. The simulated hydrological regime for Fall Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Fall Creek of approximately 150 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. Some data quality problems were identified when incorporating surface water diversion records into the model. The reliability of simulation results for Fall Creek is generally expected to be moderate.

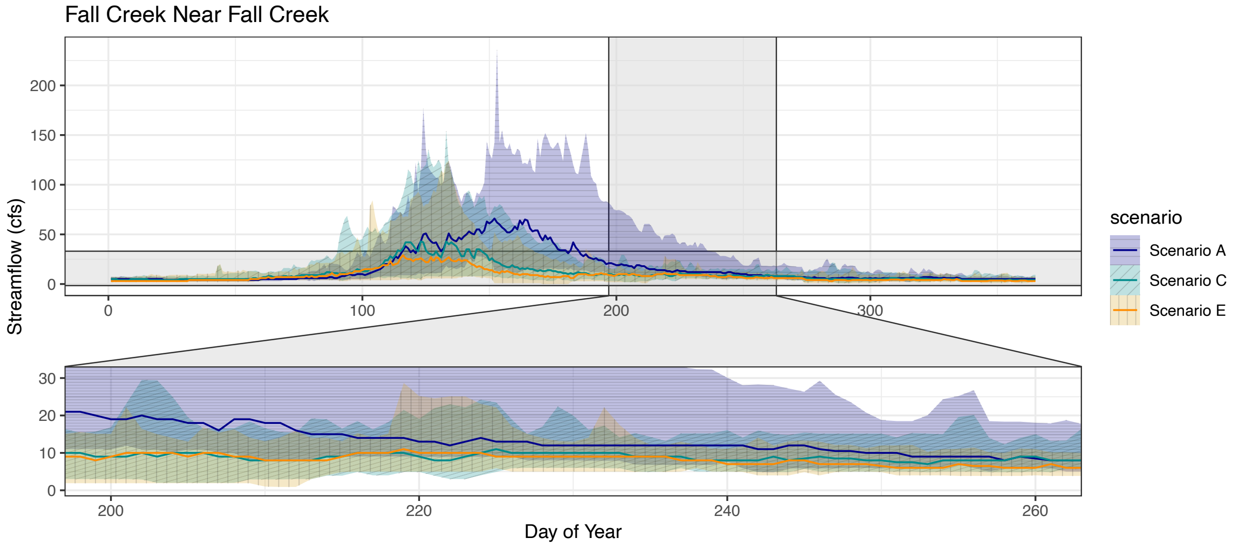

Figure 17. Hydrographs for Fall Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 13. A selected set of streamflow metrics for Fall Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	93	96	93	48.5	35.5	35.5
Annual Max	50th	cfs	129	140	140	76	49	50
Annual Max	75th	cfs	189.5	191.5	191.5	128.5	100	89
75pct Total Yield	25th	doy	192	192	192	178	175	186
75pct Total Yield	50th	doy	200	200	200	211	211	214
75pct Total Yield	75th	doy	207	206	206	234	237	238
April Max	25th	cfs	28.5	28.5	28.5	31.5	19	15
April Max	50th	cfs	42	42	42	49	40	40
April Max	75th	cfs	68.5	68.5	68.5	85.5	61.5	66
May Max	25th	cfs	73	73	73	46	26.5	27
May Max	50th	cfs	92	92	92	63	45	40
May Max	75th	cfs	133.5	133.5	133.5	125.5	89.5	57.5
June Max	25th	cfs	55.5	57.5	55.5	13	6.5	6
June Max	50th	cfs	80	90	80	29	12	13
June Max	75th	cfs	178	189.5	189.5	47.5	27.5	30.5
July Max	25th	cfs	25	25	25	12	8	9.5

July Max	50th	cfs	39	43	43	18	13	14
July Max	75th	cfs	63.5	67	67	30	27	28
July Min	25th	cfs	12	11.5	11.5	3.5	3.5	3
July Min	50th	cfs	16	15	15	6	5	5
July Min	75th	cfs	20.5	19.5	19.5	8	6.5	6.5
August Min	25th	cfs	8	8	8	5	4	4.5
August Min	50th	cfs	9	9	9	6	5	5
August Min	75th	cfs	11.5	12	12	8.5	7	7
September Min	25th	cfs	5	5	5	5	4	4
September Min	50th	cfs	7	6.5	6.5	6	4	5
September Min	75th	cfs	8.75	8	8	8	6	6
Octobr Min	25th	cfs	3	3	3	3	2	2
October Min	50th	cfs	4	4	4	4	3	3
3-day Min	75th	cfs	3.33	3.33	3.33	3	2	2
3-day Min	25th	cfs	2	2	2	2	0.5	1
3-day Min	50th	cfs	3	3	3	2.33	1	1
7-day Min	25th	cfs	2.64	2.64	2.64	2	0.79	1
7-day Min	50th	cfs	3	3	3	2.71	1.14	1.57
7-day Min	75th	cfs	4	4	4	3	2	2
30-day Min	25th	cfs	3.53	3.53	3.53	2.63	1	1.05
30-day Min	50th	cfs	4	4	4	3	1.77	1.83
30-day Min	75th	cfs	4.07	4.07	4.07	3.83	2	2.25

4.2.4 Leopard Creek

No stream gauges exist on Leopard Creek to validate the accuracy of simulation results. The simulated hydrological regime for Leopard Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Leopard Creek of approximately 100 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. Some data quality problems were identified when incorporating reservoir operations into the model. The model’s handling of reservoir operations at the end of each month produces distinct (and likely inaccurate) steps in daily streamflow patterns. The reliability of simulation results for Leopard Creek is generally expected to be moderate to low.

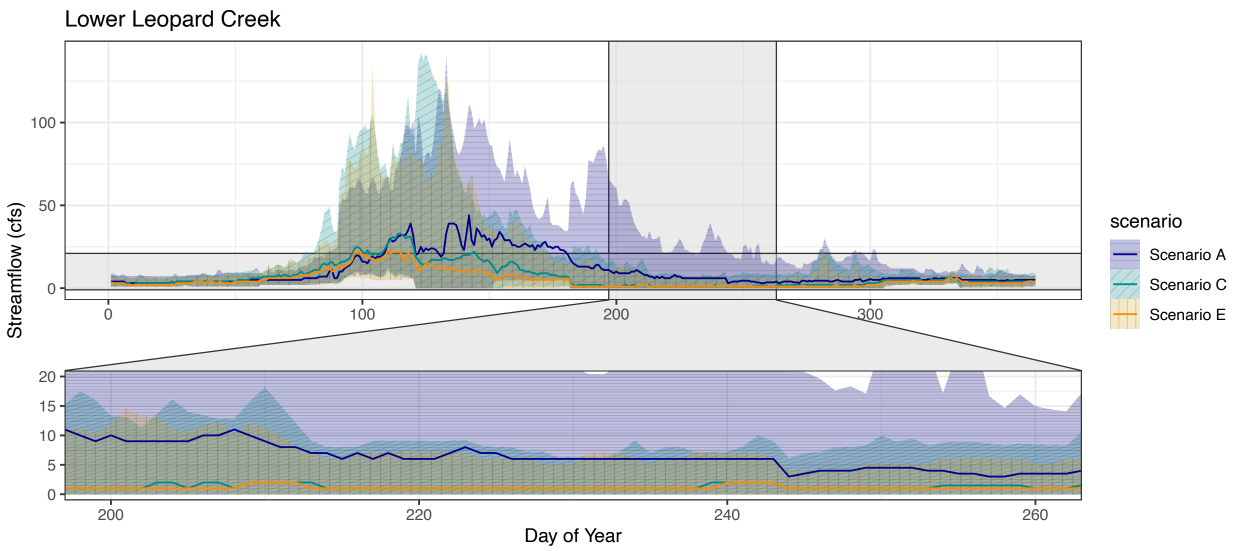

Figure 18. Hydrographs for lower Leopard Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 14. A selected set of streamflow metrics for lower Leopard Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	48.5	48.5	48.5	42.5	39.5	35
Annual Max	50th	cfs	78	78	78	59	49	52
Annual Max	75th	cfs	122	122	122	98.5	94.5	87
75pct Total Yield	25th	doy	176	176	176	152	152	147
75pct Total Yield	50th	doy	188	188	188	162	168	164
75pct Total Yield	75th	doy	232	232	232	207	215	237
April Max	25th	cfs	38	38	38	34.5	27	23
April Max	50th	cfs	49	49	49	59	47	45
April Max	75th	cfs	64	64	64	88.5	76	78
May Max	25th	cfs	19.5	19.5	19.5	2	0	0
May Max	50th	cfs	68	68	68	26	26	21
May Max	75th	cfs	107	107	107	60	54	50
June Max	25th	cfs	33.5	33.5	33.5	8	5.5	4
June Max	50th	cfs	43	43	43	22	17	11
June Max	75th	cfs	70	70	70	42.5	38	27.5
July Max	25th	cfs	3.5	3.5	3.5	1.5	1	1

July Max	50th	cfs	17	17	17	3	2	3
July Max	75th	cfs	41	41	41	7	5	4
July Min	25th	cfs	1	1	1	0.5	0	0
July Min	50th	cfs	8	8	8	1	1	1
July Min	75th	cfs	12.5	12.5	12.5	2	2	2
August Min	25th	cfs	1	1	1	0	0	0
August Min	50th	cfs	3	3	3	1	1	1
August Min	75th	cfs	8	8	8	2	2.5	1.5
September Min	25th	cfs	0	0	0	0	0	0
September Min	50th	cfs	2	2	2	1	1	1
September Min	75th	cfs	4	4	4	3	2.75	2
Octobr Min	25th	cfs	1	1	1	0.25	0	0
October Min	50th	cfs	3	3	3	2	1	1
3-day Min	75th	cfs	2	2	2	1	0	0
3-day Min	25th	cfs	0	0	0	0	0	0
3-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	25th	cfs	0	0	0	0	0	0
7-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	75th	cfs	2	2	2	1	0.36	0.36
30-day Min	25th	cfs	0	0	0	0	0	0
30-day Min	50th	cfs	0.6	0.6	0.6	0	0	0
30-day Min	75th	cfs	2.85	2.85	2.85	1.02	0.83	0.85

4.2.5 San Miguel River at Placerville

A stream gauge on the San Miguel River at Placerville supported calibration of the simulation model and provides a means for characterizing the reliability of simulation results on the mainstem San Miguel River. Simulation results show a high degree of fidelity to observed data at this location. The simulated hydrological regime for the lower San Miguel River generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in the San Miguel River at Placerville of approximately 1250 cfs. Flows may dip to below 40 cfs in a 1-in-5 year drought. The reliability of simulation results for the San Miguel River at Placerville is expected to be high.

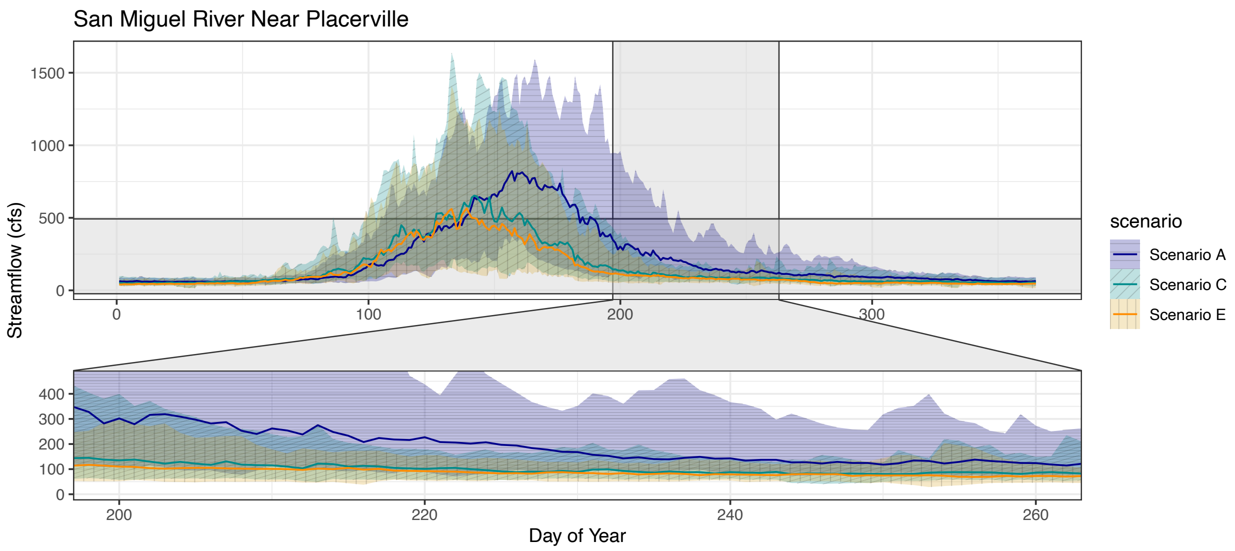

Figure 19. Hydrographs for the San Miguel River near Placerville as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 15. A selected set of streamflow metrics for the San Miguel River near Placerville evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	863	864	864	703.5	654.5	642
Annual Max	50th	cfs	1113	1115	1115	902	885	877
Annual Max	75th	cfs	1461	1463.5	1463.5	1337.5	1175	1160.5
75pct Total Yield	25th	doy	198	198	198	177	175.5	176
75pct Total Yield	50th	doy	203	203	203	185.5	184	185
75pct Total Yield	75th	doy	211	212	212	198	195.5	197.5
April Max	25th	cfs	346	346	346	382.5	364	340.5
April Max	50th	cfs	481	482	482	588	545	520
April Max	75th	cfs	619.5	619.5	619.5	799.5	762.5	690.5
May Max	25th	cfs	655.5	657	657	635.5	592.5	585
May Max	50th	cfs	834	835	835	868	847	837
May Max	75th	cfs	1038	1039.5	1039.5	1110	1050	1085
June Max	25th	cfs	812	813.5	813.5	508.5	412.5	405
June Max	50th	cfs	1092	1094	1094	688	647	634
June Max	75th	cfs	1447.5	1450	1450	1139.5	967.5	957.5
July Max	25th	cfs	364	335.5	335.5	169.5	135.5	135.5
July Max	50th	cfs	606	608	608	268	230	231
July Max	75th	cfs	955	956.5	956.5	397	334	329

July Min	25th	cfs	131	137.5	137.5	74.5	68.5	68.5
July Min	50th	cfs	201	202	202	98	87	89
July Min	75th	cfs	327	327.5	327.5	122.5	110.5	115.5
August Min	25th	cfs	93.5	95.5	95.5	61.5	52	53
August Min	50th	cfs	114	115	115	72	70	68
August Min	75th	cfs	140	140.5	140.5	88.5	79	79
September Min	25th	cfs	69.25	69	69	50	44.25	42.75
September Min	50th	cfs	84	85	85	62	57.5	56.5
September Min	75th	cfs	95.5	102.75	102.75	77.25	68	68.75
Octobr Min	25th	cfs	60	57.75	57.75	38.25	27.75	28.25
October Min	50th	cfs	77	77	77	51.5	40	39
3-day Min	75th	cfs	57.83	57.83	57.83	43.67	37.5	38.33
3-day Min	25th	cfs	39.33	39.33	39.33	30.83	16.5	16.5
3-day Min	50th	cfs	46.67	46.67	46.67	36.67	28	29.33
7-day Min	25th	cfs	41.71	41.71	41.71	32.5	18.5	18.57
7-day Min	50th	cfs	48.43	48.14	48.14	39.86	31.43	31.71
7-day Min	75th	cfs	60.21	60.14	60.14	46.64	39.43	39.86
30-day Min	25th	cfs	45.63	45.58	45.58	36.4	27.75	27.88
30-day Min	50th	cfs	52.77	52.77	52.77	43.67	36	36.2
30-day Min	75th	cfs	64.53	64.42	64.42	50.23	42	42.67

4.2.6 Saltado Creek

A stream gauge on Saltado Creek was used to support calibration and validation of the simulation model. Simulation results show a moderate degree of fidelity to observed data during peak flows at this location. Low flow observations are not available. The simulated hydrological regime for Saltado Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Saltado Creek of approximately 70 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. The reliability of simulation results for Saltado Creek is generally expected to be moderate.

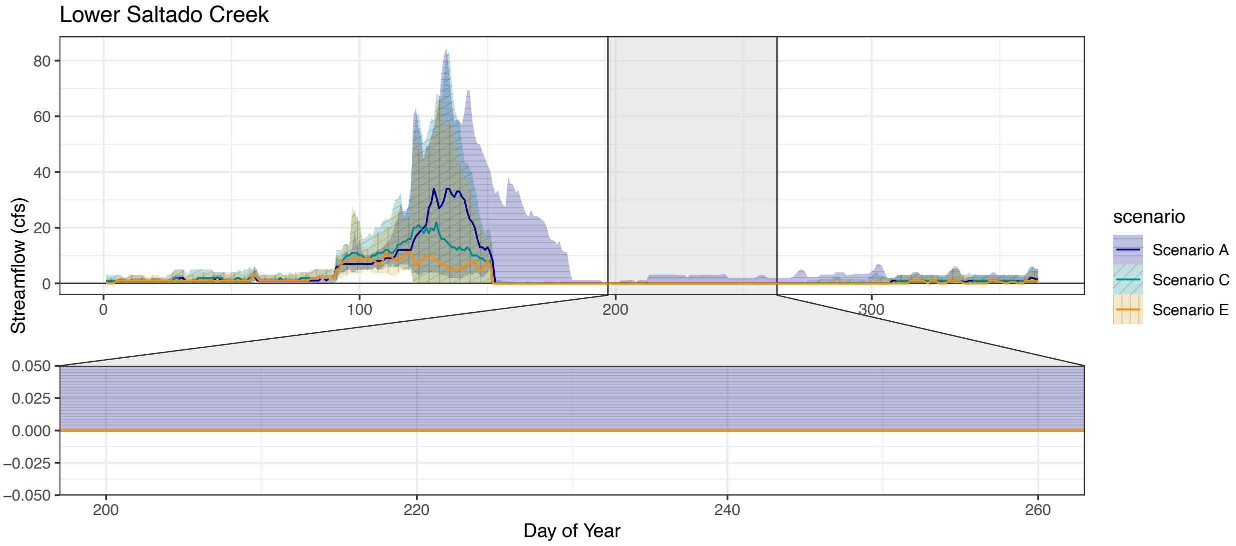

Figure 20. Hydrographs for lower Saltado Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 16. A selected set of streamflow metrics for lower Saltado Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	37.5	37.5	37.5	22.5	18	13.5
Annual Max	50th	cfs	50	50	50	36	26	27
Annual Max	75th	cfs	65.5	65.5	65.5	57	48.5	43.5
75pct Total Yield	25th	doy	138	137	138	132	132	129
75pct Total Yield	50th	doy	140	140	140	135	135	133
75pct Total Yield	75th	doy	155	155	155	139	138	136
April Max	25th	cfs	9	9	9	17.5	13	12
April Max	50th	cfs	14	14	14	20	21	20
April Max	75th	cfs	20.5	20.5	20.5	30	25	26.5
May Max	25th	cfs	37.5	37.5	37.5	9	4	0
May Max	50th	cfs	50	50	50	36	19	15
May Max	75th	cfs	65.5	65.5	65.5	57	48.5	43.5
June Max	25th	cfs	0	0	0	0	0	0
June Max	50th	cfs	0	0	0	0	0	0
June Max	75th	cfs	20.5	20.5	20.5	0	0	0
July Max	25th	cfs	0	0	0	0	0	0

July Max	50th	cfs	0	0	0	0	0	0
July Max	75th	cfs	0	0	0	0	0	0
July Min	25th	cfs	0	0	0	0	0	0
July Min	50th	cfs	0	0	0	0	0	0
July Min	75th	cfs	0	0	0	0	0	0
August Min	25th	cfs	0	0	0	0	0	0
August Min	50th	cfs	0	0	0	0	0	0
August Min	75th	cfs	0	0	0	0	0	0
September Min	25th	cfs	0	0	0	0	0	0
September Min	50th	cfs	0	0	0	0	0	0
September Min	75th	cfs	0	0	0	0	0	0
Octobr Min	25th	cfs	0	0	0	0	0	0
October Min	50th	cfs	0	0	0	0	0	0
3-day Min	75th	cfs	0	0	0	0	0	0
3-day Min	25th	cfs	0	0	0	0	0	0
3-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	25th	cfs	0	0	0	0	0	0
7-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	75th	cfs	0	0	0	0	0	0
30-day Min	25th	cfs	0	0	0	0	0	0
30-day Min	50th	cfs	0	0	0	0	0	0
30-day Min	75th	cfs	0	0	0	0	0	0

4.2.7 Beaver Creek

A stream gauge on Beaver Creek was used to support calibration and validation of the simulation model. Simulation results show a moderate degree of fidelity to observed data during low flows at this location but a low degree of fidelity at high flows. These discrepancies appear related to data quality issues identified when incorporating operations of the Lone Cone Ditch and Gurley Reservoir into the model. The simulated hydrological regime for Beaver Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Naturita Creek of approximately 70 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. The reliability of simulation results for Beaver Creek is expected to be moderate during low-flow periods and low during high-flow periods.

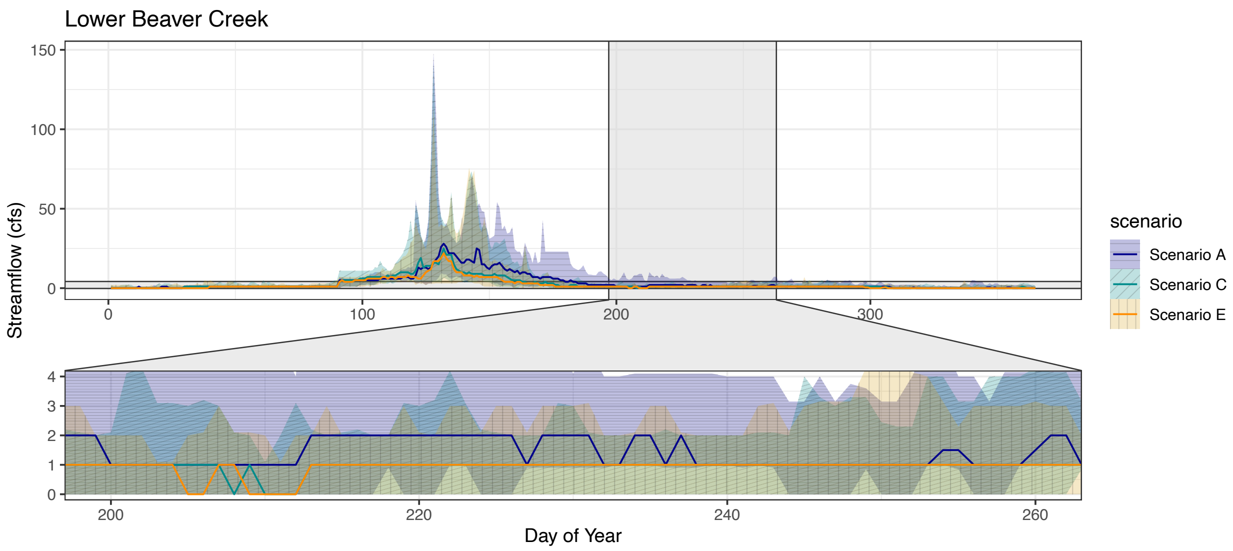

Figure 21. Hydrographs for lower Beaver Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 17. A selected set of streamflow metrics for Beaver Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	33	33	33	33.5	15.5	15.5
Annual Max	50th	cfs	44	44	44	47	34	34
Annual Max	75th	cfs	101	101	101	89	63	63
75pct Total Yield	25th	doy	158	158	158	152	150	150
75pct Total Yield	50th	doy	170	170	170	156	154	155
75pct Total Yield	75th	doy	176	176	176	160	162	162
April Max	25th	cfs	6	6	6	8	7	7
April Max	50th	cfs	8	8	8	13	8	8
April Max	75th	cfs	9	9	9	15.5	22	22
May Max	25th	cfs	32	32	32	27	15	15
May Max	50th	cfs	43	43	43	47	34	34
May Max	75th	cfs	101	101	101	89	63	63
June Max	25th	cfs	14.5	14.5	14.5	8	6	6
June Max	50th	cfs	26	26	26	12	9	9
June Max	75th	cfs	40.5	40.5	40.5	22.5	12.5	12.5
July Max	25th	cfs	3	3	3	2	2	2
July Max	50th	cfs	5	5	5	3	2	2

July Max	75th	cfs	10	10	10	4	3	3
July Min	25th	cfs	0	0	0	0	0	0
July Min	50th	cfs	0	0	0	0	0	0
July Min	75th	cfs	2	2	2	0	0	0
August Min	25th	cfs	1	1	1	0	0	0
August Min	50th	cfs	1	1	1	0	0	0
August Min	75th	cfs	1.5	1.5	1.5	1	1	1
September Min	25th	cfs	0	0	0	0	0	0
September Min	50th	cfs	1	1	1	1	0	0
September Min	75th	cfs	1	1	1	1	1	1
Octobr Min	25th	cfs	0	0	0	0	0	0
October Min	50th	cfs	0	0	0	0	0	0
3-day Min	75th	cfs	0	0	0	0	0	0
3-day Min	25th	cfs	0	0	0	0	0	0
3-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	25th	cfs	0	0	0	0	0	0
7-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	75th	cfs	0	0	0	0	0	0
30-day Min	25th	cfs	0	0	0	0	0	0
30-day Min	50th	cfs	0	0	0	0	0	0
30-day Min	75th	cfs	0.2	0.2	0.2	0.07	0	0

4.2.8 Naturita Creek

No stream gauges exist on Naturita Creek to validate the accuracy of simulation results. The simulated hydrological regime for Naturita Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. However, significant late fall peak flows reflect the sensitivity of this drainage to monsoonal weather patterns. The simulation model predicts 2-year annual peak flows in Naturita Creek of approximately 150 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. Some data quality problems were identified when incorporating reservoir operations into the model. The model’s handling of reservoir operations at the end of each month produces distinct (and likely inaccurate) steps in daily streamflow patterns. The reliability of simulation results for Naturita Creek is generally expected to be moderate to low.

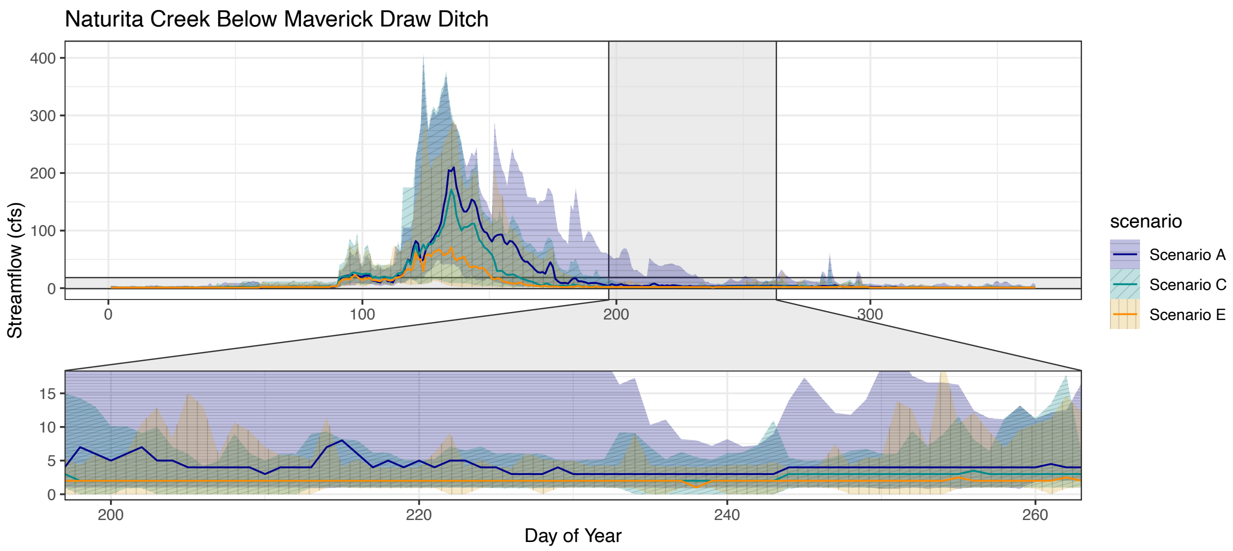

Figure 22. Hydrographs for lower Naturita Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 18. A selected set of streamflow metrics for Naturita Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	118.5	119.5	119.5	82	67.5	74
Annual Max	50th	cfs	260	256	256	171	116	95
Annual Max	75th	cfs	287.5	289	289	273	228	236
75pct Total Yield	25th	doy	150	151	151	144	145	146
75pct Total Yield	50th	doy	155	157	157	149	148	150
75pct Total Yield	75th	doy	167	172	172	153	152	154
April Max	25th	cfs	57	56.5	56.5	34	17.5	34
April Max	50th	cfs	81	82	82	67	49	61
April Max	75th	cfs	102.5	98.5	98.5	119	101	89
May Max	25th	cfs	118.5	119.5	119.5	80.5	65.5	51.5
May Max	50th	cfs	241	240	240	171	93	95
May Max	75th	cfs	271.5	278	278	273	228	233
June Max	25th	cfs	55.5	73.5	73.5	15	8.5	11
June Max	50th	cfs	128	123	123	35	18	19
June Max	75th	cfs	182.5	211.5	211.5	113	90.5	91.5
July Max	25th	cfs	8	8	8	4	2.5	3

July Max	50th	cfs	17	17	17	9	5	6
July Max	75th	cfs	83	87	87	17	9.5	10
July Min	25th	cfs	1	1	1	1	0	0.5
July Min	50th	cfs	3	3	3	2	1	1
July Min	75th	cfs	4	6	6	2	1	2
August Min	25th	cfs	1.5	1	1	1	0	0.5
August Min	50th	cfs	3	3	3	2	1	1
August Min	75th	cfs	3.5	3	3	2.5	1	2
September Min	25th	cfs	2	2	2	1	0	1
September Min	50th	cfs	3	3	3	2	1	1
September Min	75th	cfs	4	4	4	3	1.75	2
Octobr Min	25th	cfs	0	0	0	0	0	0
October Min	50th	cfs	1	1	1.5	1	1	1
3-day Min	75th	cfs	0.33	0.33	0.33	0	0	0
3-day Min	25th	cfs	0	0	0	0	0	0
3-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	25th	cfs	0	0	0	0	0	0
7-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	75th	cfs	0.64	0.64	0.64	0.29	0	0
30-day Min	25th	cfs	0.08	0.08	0.08	0.02	0	0
30-day Min	50th	cfs	0.67	0.67	0.67	0.37	0.1	0.1
30-day Min	75th	cfs	0.98	0.98	0.98	0.88	0.45	0.43

4.2.9 Tabeguache Creek

No stream gauges exist on Tabeguache Creek to validate the accuracy of simulation results. The simulated hydrological regime for Tabeguache Creek generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. The simulation model predicts 2-year annual peak flows in Naturita Creek of approximately 250 cfs. Water use and dry conditions in most years reduce flows below 1 cfs in the lower portions of the creek. Some data quality problems were identified when incorporating surface water ditch operations into the model. The reliability of simulation results for Tabeguache Creek is generally expected to be moderate to low.

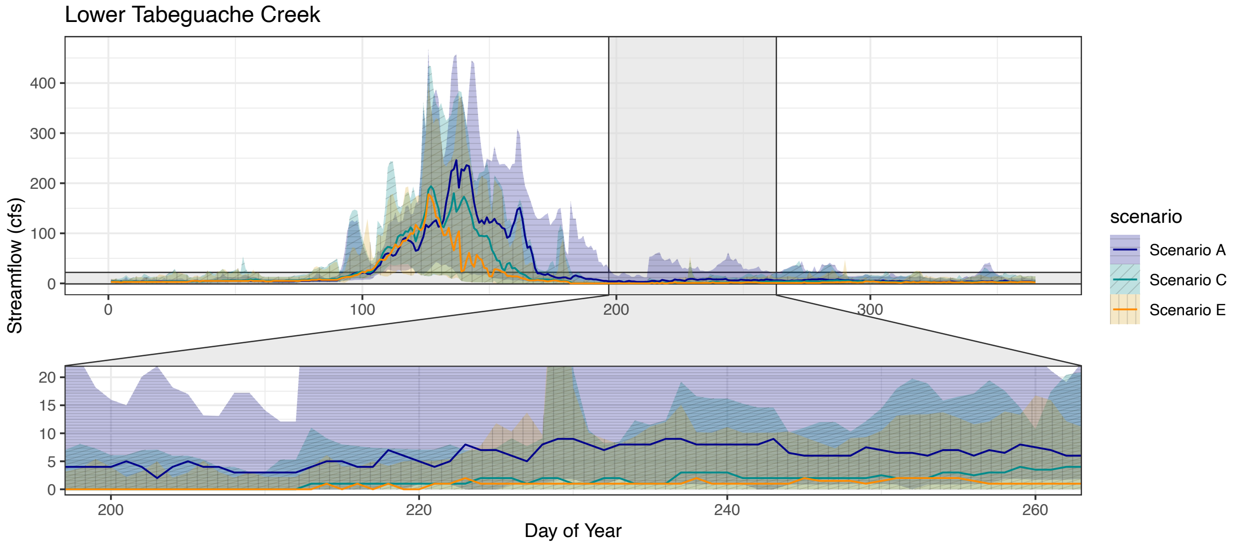

Figure 23. Hydrographs for lower Tabeguache Creek as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 19. A selected set of streamflow metrics for Tabeguache Creek evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	251	251	251	216.5	172.5	164
Annual Max	50th	cfs	346	346	346	306	277	292
Annual Max	75th	cfs	419.5	419.5	419.5	410	361.5	369
75pct Total Yield	25th	doy	152	152	152	140	137	136
75pct Total Yield	50th	doy	161	161	161	145	146	143
75pct Total Yield	75th	doy	168	168	168	150	150	148
April Max	25th	cfs	113.5	113.5	113.5	133	117	120.5
April Max	50th	cfs	126	126	126	155	141	143
April Max	75th	cfs	140	140	140	183	166.5	165.5
May Max	25th	cfs	251	251	251	216.5	172.5	161.5
May Max	50th	cfs	345	345	345	306	277	292
May Max	75th	cfs	419.5	419.5	419.5	410	361.5	369
June Max	25th	cfs	121	121	121	24	18	6.5
June Max	50th	cfs	195	195	195	78	48	32
June Max	75th	cfs	241	241	241	143	103	84.5
July Max	25th	cfs	1	1	1	0	0	0

July Max	50th	cfs	18	18	18	0	0	0
July Max	75th	cfs	94	94	94	4.5	4.5	0
July Min	25th	cfs	0	0	0	0	0	0
July Min	50th	cfs	2	2	2	0	0	0
July Min	75th	cfs	4	4	4	0.5	1	0
August Min	25th	cfs	1	1	1	0	0	0
August Min	50th	cfs	2	2	2	0	0	0
August Min	75th	cfs	7.5	7.5	7.5	1	1.5	1
September Min	25th	cfs	1.25	2	2	0	0	0
September Min	50th	cfs	3.5	3.5	3.5	1	1	0.5
September Min	75th	cfs	6	6	6	4	4	2.75
Octobr Min	25th	cfs	2	2	2	0	0	0
October Min	50th	cfs	4	4	4	1	1	1
3-day Min	75th	cfs	0.83	0.83	0.83	0	0	0
3-day Min	25th	cfs	0	0	0	0	0	0
3-day Min	50th	cfs	0	0	0	0	0	0
7-day Min	25th	cfs	0	0	0	0	0	0
7-day Min	50th	cfs	0.29	0.29	0.29	0	0	0
7-day Min	75th	cfs	1	1	1	0	0	0
30-day Min	25th	cfs	0.07	0.07	0.07	0	0	0
30-day Min	50th	cfs	1.27	1.27	1.27	0	0	0
30-day Min	75th	cfs	2.45	2.45	2.45	0	0	0

4.2.10 San Miguel River at Uravan

A stream gauge on the San Miguel River at Uravan supported calibration of the simulation model and provides a means for characterizing the reliability of simulation results on the mainstem San Miguel River. Simulation results show a high degree of fidelity to observed data at this location. The simulated hydrological regime for the lower San Miguel River generally reflects the dominance of the snowmelt driven hydrology of the San Miguel watershed. However, periods of peak streamflow tend to be longer at this location then at positions higher in the watershed. The simulation model predicts 2-year annual peak flows in the San Miguel River at Uravan of approximately 2000 cfs. Flows may dip to below 20 cfs in a 1-in-5 year drought. The reliability of simulation results for the San Miguel River at Uravan is expected to be high.

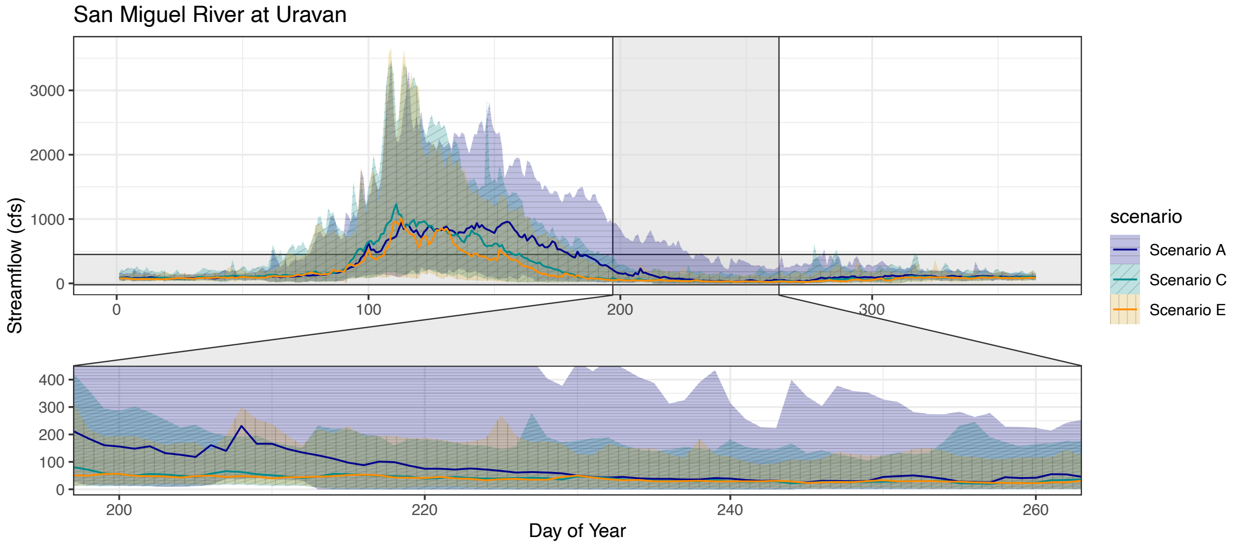

Figure 24. Hydrographs for the San Miguel River near Uravan as predicted by three different planning scenarios. Solid lines indicate mean daily flow values across the full simulation period, shaded areas indicate full range of daily flow values observed across the simulation period for a given scenario.

Table 20. A selected set of streamflow metrics for the San Miguel River at Uravan evaluated for each of the scenario planning models.

Metric	Percentile	Units	Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Annual Max	25th	cfs	1112	1095.5	1097	1189	1040	1059.5
Annual Max	50th	cfs	1922	1891	1893	1909	1723	1704
Annual Max	75th	cfs	2454.5	2487	2489.5	2548.5	2252	2070.5
75pct Total Yield	25th	doy	168	168	168	151.5	153	152.25
75pct Total Yield	50th	doy	172	172	172	159.5	159	162
75pct Total Yield	75th	doy	193	193	193	175.5	183	180.25
April Max	25th	cfs	866.5	836	838	859.5	862	844.5
April Max	50th	cfs	1601	1600	1602	1619	1660	1704
April Max	75th	cfs	2219.5	2220.5	2224	2548.5	2252	2070.5
May Max	25th	cfs	863	860.5	862	895.5	757	709.5
May Max	50th	cfs	1501	1498	1500	1242	1015	1101
May Max	75th	cfs	2326.5	2326.5	2328.5	1769	1648	1572
June Max	25th	cfs	665	648.5	652.5	229	113.5	126.5
June Max	50th	cfs	1040	1058	1062	599	573	621
June Max	75th	cfs	1718	1702.5	1705	1308.5	1003.5	948
July Max	25th	cfs	246	231	231	121	68	88

July Max	50th	cfs	589	622	627	201	165	173
July Max	75th	cfs	866	897	900	300.5	240.5	251
July Min	25th	cfs	40	48	48	15	13	17
July Min	50th	cfs	72	87	87	27	22	24
July Min	75th	cfs	218	224	225	51	40.5	42
August Min	25th	cfs	10	11	11	14.25	8	13
August Min	50th	cfs	24	24	24	22	16	21
August Min	75th	cfs	62	66	66	36.5	31	32
September Min	25th	cfs	6	7.25	7.25	5	6	7.75
September Min	50th	cfs	14.5	15	15	13	13	16.5
September Min	75th	cfs	42	42.25	42.5	35.5	31	27.25
Octobr Min	25th	cfs	14.25	15	15	9.25	10	9.25
October Min	50th	cfs	28	28	28	20	18	18
3-day Min	75th	cfs	23.33	24	24	19.17	14.83	18.5
3-day Min	25th	cfs	2.67	2.67	2.67	3	2.33	3.83
3-day Min	50th	cfs	6.33	8	8.33	10	7	10
7-day Min	25th	cfs	3.07	3.5	3.5	4	3.14	5
7-day Min	50th	cfs	8.29	11.14	11.14	11.71	8.14	11.14
7-day Min	75th	cfs	26.43	27.07	27.07	22.43	19.07	20.64
30-day Min	25th	cfs	5.58	6.83	6.98	7.22	6.05	10.22
30-day Min	50th	cfs	19.33	22.87	22.87	21.5	14.4	20.53
30-day Min	75th	cfs	47.73	49.83	49.98	32.75	24.35	25.83

5 Conclusions

Understanding the ability of the San Miguel River and its tributaries to meet both human and ecosystem needs lies in characterizing the range of possible and expected hydrological conditions throughout the watershed. Hydrological simulation results elucidated the convergence of climate, stream network structure, and patterns of water use that dictate the ability of local streams and rivers to meet the full array of existing uses in different year type and under different planning scenarios. Results produced by simulation modelling characterized the hydrological regime at locations throughout the watershed and provided foundational data sets for completing environmental and recreational needs assessments.

- Hydrological and water rights simulation modeling results produced for the san Miguel watershed reflect observed conditions with a high degree of accuracy on the mainstem San Miguel River.

- Data quality limitations, particularly historical records of reservoir operations and surface water diversions on tributaries to the San Miguel River, limited the success of model calibration in several drainages.

- Streamflows in much of the San Miguel watershed reflect natural conditions, particularly during winter and early summer months.

- Reservoir operations in the upper watershed alter streamflows on the South Fork San Miguel River in winter months.

- Several tributary streams in the Beaver Creek drainage are completely captured by surface water collection systems during most of the year.

- The segment of the San Miguel River below the Highline Canal is significantly affected by surface water diversions in the late summer months in most years.

- Changing climate may significantly reduce streamflows available to support irrigated agriculture, boating recreation, angling, and environmental needs on the San Miguel River by 2050.

All results produced by this assessment were combined with other data and interpretations to help local stakeholders understand how existing water management activities and potential changes to streamflow behavior as a function of population growth and climate change scenarios impact a variety of attributes (i.e. channel dynamics, riparian health, aquatic habitat, and recreational use opportunities).

6 References

[1] N. L. Poff *et al.*, “The Natural Flow Regime,” *BioScience*, vol. 47, no. 11, pp. 769–784, Dec. 1997.
[2] B. Johnson, M. Beardsley, and J. Doran, “FACStream Manual 1.0: Functional Assessment of Colorado Streams.,” 2016.
[3] *Colorado Decision Support Systems: State of Colorado Stream Simulation Model: Southwest Basin.* Colorado Division of Water Resources., 2015.
[4] *EflowStats*. United States Geological Survey.
[5] “Technical Update to the Colorado Water Plan,” Colorado Water Conservation Board, Volume 1., 2019.
[6] *Colorado Environmental Flow Tool*. Colorado Water Conservation Board.
[7] M. G. Ferrick and D. M. Murphy, “Investigation of River Ice Processes on the San Miguel River, Colorado.,” US Army Cold Regions Research and Engineering Laboratory, Hanover, NH.